Indian National Physics Olympiad (INPhO)-2026

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION
Tata Institute of Fundamental Research
V. N. Purav Marg, Mankhurd, Mumbai, 400 088

Question Paper

Date: 01 February 2026
Time: **09:00-12:00 (3 hours)** Maximum Marks: **75**

Instructions **Roll Number:** ☐☐☐☐ - ☐☐☐☐ - ☐☐☐☐

1. This booklet consists of 21 pages and total of 6 questions. Write roll number at the top wherever asked.
2. Booklet to write the answers is provided separately. Instructions to write the answers are on the Answer Booklet.
3. Non-programmable scientific calculators are allowed. Mobile phones **cannot** be used as calculators.
4. Take as many data points as possible for the analysis.
5. **Please submit the Answer Sheet at the end of the examination.** You may retain the Question Paper.
6. Except for writing your roll number, no rough work or scribbling is allowed on the question paper.

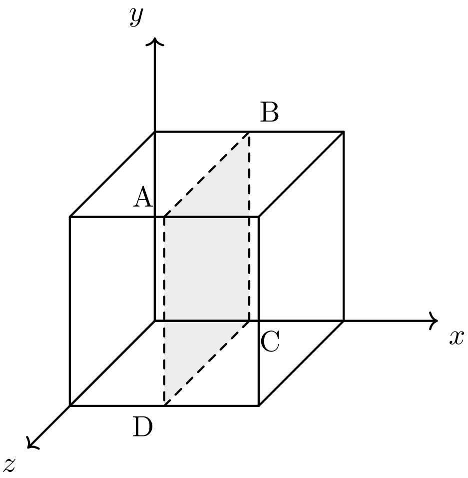
Table of Constants

Speed of light in vacuum	c	3.00×10^{8} m·s^{-1}
Magnitude of electron charge	e	1.60×10^{-19} C
Avogadro's number	N_A	6.022×10^{23} mol^{-1}
Acceleration due to gravity	g	9.81 m·s^{-2}
Universal Gas Constant	R	8.31 J· K^{-1}·mol^{-1}
	R	0.0821 l·atm·mol^{-1}·K^{-1}
Boltzmann constant	k_B	1.3806×10^{-23} J·K^{-1}
Permeability constant	μ_0	$4\pi \times 10^{-7}$ H·m^{-1}
One Atmospheric pressure	atm	1.013×10^{5} Pa

Question Number	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
Maximum Marks	12	12	11	10	18	12	**75**

Please note that alternate/equivalent methods and different ways of expressing final solutions may exist. A correct method will be suitably awarded.

1. **[12 marks] Find the flaw**
Consider a non-conducting, charged, thin cubical shell with a uniform surface charge density. Consider the plane ABCD, which vertically and symmetrically divides the cubical shell (see figure). Six students independently solved for the electric field on the plane ABCD and presented six different answers, shown below in Figs. (a) to (f), each approximately depicting the electric field lines in the ABCD plane (the field line arrows are not shown). Consider each of the six answers, and for each, give



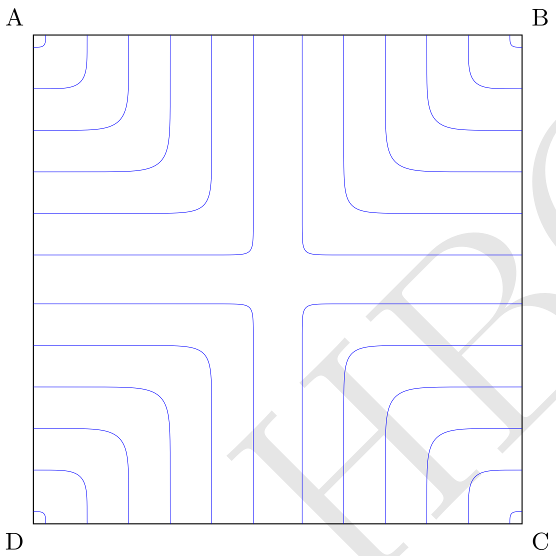
- at least one reason (based on a physics argument), explaining why it is incorrect

OR

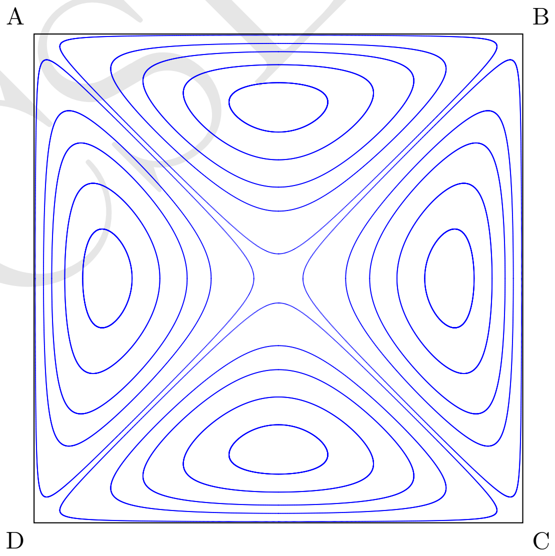
- at least two reasons why it **could be** correct.

Note that you are not required to obtain the correct depiction of the electric field or to provide a detailed derivation in this question.

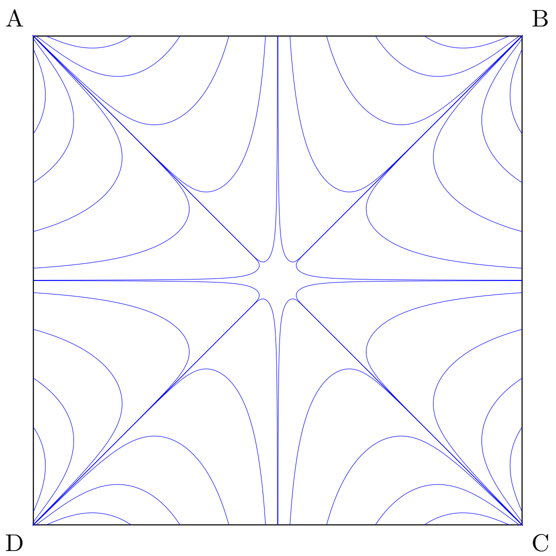
In none of the figures, adjacent field lines touch or intersect each other, although they may appear to do so in Fig. (c) and Fig. (e), where they are very close. In Fig. (d), the diagram indicates that no field is present. In Fig. (f), $\otimes$ denotes a field directed along the $-x$ axis, and $\odot$ denotes a field directed along $+x$ axis.



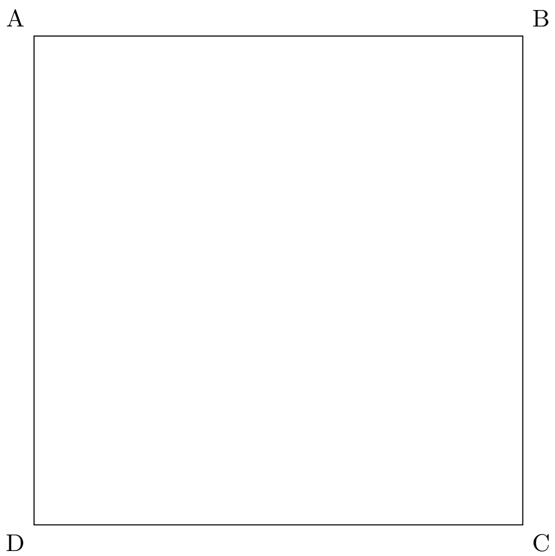
(a)



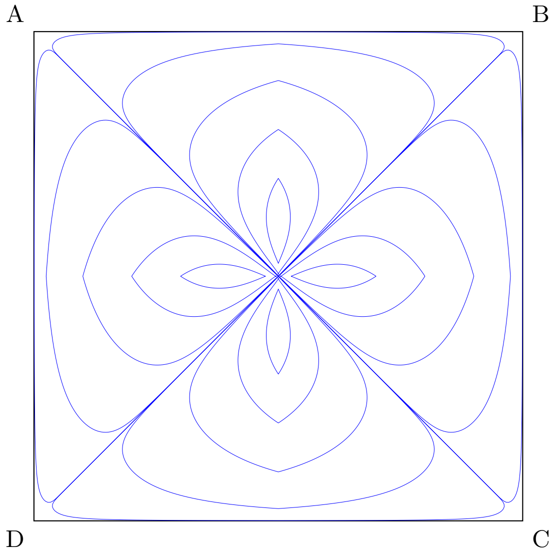
(b)



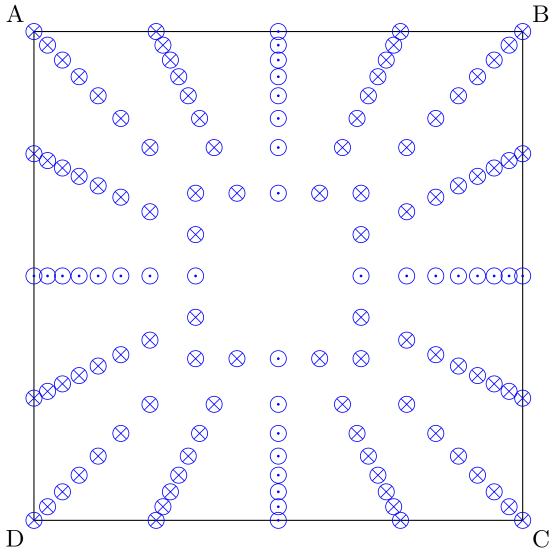
(c)



(d)



(e)



(f)

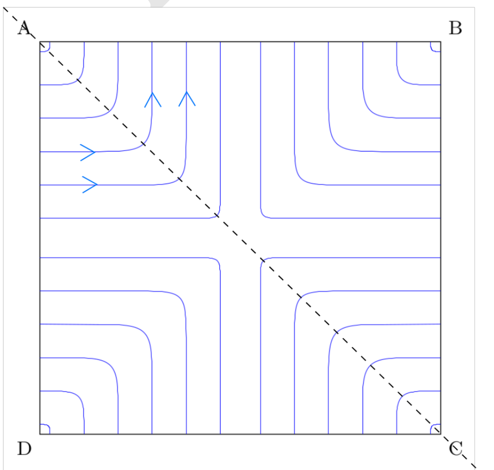
Solution: A key thing to take into account in the given problem is that all the charge is uniformly distributed over the surface of the cube, and there are no other charges inside (or outside the cube).

Some arguments for why each option is clearly incorrect or may be correct are given below. Most of these are based on symmetry arguments (all faces of the cube are identical, and therefore, reflections of the cube surfaces about planes passing through its centre and either parallel to its faces, or passing through diagonally opposite vertices must not alter the electric field at all).

Other valid arguments may be possible and will be evaluated according to their merit.

(a) **Incorrect**

The electric field pattern does not remain unchanged under reflection about a diagonal mirror line in the plane. This can be seen by assigning a direction to the field lines as drawn (see figure). Under reflection along the dashed line, the direction of the electric field reverses, whereas symmetry requires the field to be invariant. Choosing the opposite direction for the field lines leads to the same contradiction. Hence, this option is incorrect.



(a)

(b) **Incorrect**

(a) Electric field lines cannot form closed loops. Since the curves shown form closed loops, this diagram cannot represent an electrostatic field.

(b) Very near the centre of a face, the electric field is dominated by the nearby uniformly charged face. A uniformly charged finite flat surface produces an electric field normal to the surface in the middle region. In this diagram, the electric field is shown to be parallel to the edges near the face centre, which is physically incorrect. Hence, this option is incorrect.

(c) **May be correct**

This pattern may be correct, based on the following two arguments, and in the absence of an obviously incorrect feature.

(a) This pattern respects all mirror symmetries of the cube (irrespective of the direction of arrows placed on each line), and the electric field lies entirely within the symmetry plane. Also, by symmetry, the electric field at the centre of the cube must vanish, which is correctly depicted.

(b) Near the centres of the faces, the electric field is dominated by the nearby uniformly charged face and is therefore approximately normal to the face. Away from the face centres, the relative contributions from different faces change, leading to a smooth bending of the field lines.

(d) **Incorrect.**

Unlike a conducting shell, there is no mechanism that can make the electric field vanish everywhere inside. A uniformly charged non-conducting cubical shell does not allow charge rearrangement on the surface. In particular, near an edge of the cube there is positive surface charge in its immediate neighbourhood, which must produce a nonzero electric field in the interior. Hence the claim $\vec{E} = 0$ everywhere inside is incorrect.

(e) **Incorrect**

(a) Several field lines converge at the centre, implying the presence of a charge there. Since the interior contains no charge, this pattern is impossible.

(b) The field lines seem to form closed loops, which is not possible with static charges.

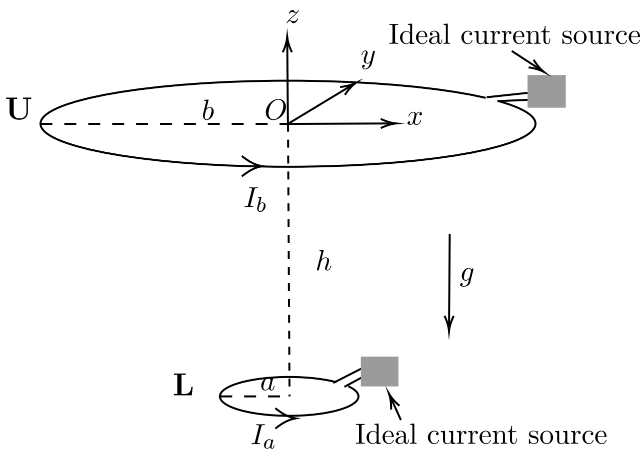
(c) Near the edges of the cube the electric field should be dominated by the nearby positive surface charge and hence be approximately normal to the surface. In this figure, the field lines are shown parallel to the edges, which is physically incorrect.

(f) **Incorrect**

If, on the plane, the electric field points inwards or outwards, the symmetry is lost. Hence, this option is incorrect as well.

2. **[12 marks] Current affairs**

Consider two coaxial conducting circular loops: a lower loop L of radius a and an upper loop U of radius b (see figure). The planes of the loops are parallel and separated by a distance h. The loop U is held fixed in the x-y plane, while the loop L is free to move vertically.
Each loop is connected to an ideal current source that maintains a constant current I_a in loop L and I_b in loop U. Assume $a \ll b$, so that the magnetic field produced by the loop U may be treated as uniform over the entire area of the loop L. Let g be the acceleration due to gravity. The system is initially in static equilibrium under gravity.



The loop L is then displaced very slowly by an external agent toward the loop U through a distance dh, while the currents in both loops are maintained constant by ideal power supplies.

During this process, let the change in the gravitational potential energy of the loop L be dU_g, and the change in the energy stored in the magnetic field be dU_m. For the same process, let the extra work done by the power supplies connected to the lower and upper loops be dW_L and dW_U, respectively.

Express each of dU_g, dU_m, dW_U, and dW_L in terms of I_a, I_b, the geometrical parameters (a, b, h, dh), and any relevant constants, if they are non-zero.

Solution:

Since the system is initially in static equilibrium under gravity, the upward magnetic force F_L on the lower loop L balances its weight. When the lower loop is displaced slowly upward by a distance dh, the change in its gravitational potential energy is

$$dU_g = mg\,dh = F_\mathrm{L}\,dh, \tag{2.1}$$

The lower loop L may be treated as a magnetic dipole with moment

$$\vec{m}_\mathrm{L} = I_a(\pi a^2)\,\hat{z}. \tag{2.2}$$

The axial magnetic field due to U at a distance h is

$$B_\mathrm{U}(h) = \frac{\mu_0 I_b b^2}{2(b^2+h^2)^{3/2}}. \tag{2.3}$$

The force on L due to B_U is

$$F_{L,z} = \frac{d}{dz}(\vec{m}_\mathrm{L}\cdot\vec{B}_\mathrm{U}) \tag{2.4}$$

$$F_{L,z=-h} = \frac{3\pi}{2}\,\mu_0 I_a I_b \frac{a^2 b^2 h}{(b^2+h^2)^{5/2}}. \tag{2.5}$$

Substituting Eq. (2.5) into Eq. (2.1) yields

$$\boxed{dU_g = \frac{3\pi}{2}\,\mu_0 I_a I_b \frac{a^2 b^2 h}{(b^2+h^2)^{5/2}}\,dh} \tag{2.6}$$

The magnetic flux through L due to U is

$$\Phi_\mathrm{L} = \pi a^2 B_\mathrm{U}(h) = \frac{\mu_0 \pi a^2 b^2}{2(b^2+h^2)^{3/2}}\,I_b \tag{2.7}$$

The induced emf in L is

$$e_{\mathrm{L}} = -\frac{d\Phi_{\mathrm{L}}}{dt} \tag{2.8}$$

and the incremental work supplied by L's power source to maintain current I_a is

$$|dW_{\mathrm{L}}| = e_{\mathrm{L}} I_a \, dt \tag{2.9}$$

Using Eq. (2.7),

$$\boxed{dW_{\mathrm{L}} = \frac{3\pi}{2}\,\mu_0 I_a I_b \frac{a^2 b^2 h}{(b^2+h^2)^{5/2}}\,dh} \tag{2.10}$$

Equation (2.7) can be written in terms of mutual inductance M as

$$\Phi_{\mathrm{L}} = M I_b, \qquad M = \frac{\mu_0 \pi a^2 b^2}{2(b^2+h^2)^{3/2}}. \tag{2.11}$$

Using Eq. (2.8),

$$e_{\mathrm{L}} = -I_b \frac{dM}{dt}, \tag{2.12}$$

As the separation changes slowly by dh,

$$dM = -\frac{3\mu_0 \pi a^2 b^2 h}{2(b^2+h^2)^{5/2}}\,dh. \tag{2.13}$$

The flux through the upper loop due to the lower loop is $\Phi_{\mathrm{U}} = M I_a$, so an analogous calculation gives

$$\boxed{|dW_{\mathrm{U}}| = \frac{3\pi}{2}\,\mu_0 I_a I_b \frac{a^2 b^2 h}{(b^2+h^2)^{5/2}}\,dh} \tag{2.14}$$

The magnetic energy stored in the two-loop system is

$$U = \frac{1}{2} L_{\mathrm{L}} I_a^2 + \frac{1}{2} L_{\mathrm{U}} I_b^2 + M I_a I_b. \tag{2.15}$$

Since the currents are constant, the change in magnetic field energy arises solely from the change in M:

$$dU_m = I_a I_b \, dM. \tag{2.16}$$

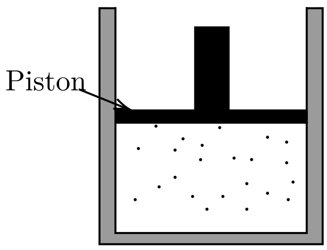
Using Eq. (2.13),

$$\boxed{dU_m = \frac{3\pi}{2}\,\mu_0 I_a I_b \frac{a^2 b^2 h}{(b^2+h^2)^{5/2}}\,dh} \tag{2.17}$$

$$\boxed{dU_g = dW_{\mathrm{L}} = dW_{\mathrm{U}} = dU_m = \frac{3\pi}{2}\,\mu_0 I_a I_b \frac{a^2 b^2 h}{(b^2+h^2)^{5/2}}\,dh} \tag{2.18}$$

3. **Slow, smooth, and sudden**

A vertical insulated cylinder fitted with a frictionless, movable, thermally conducting massless piston contains air at pressure $p_0 = 1$ atm, volume $V_i = 3.0$ L, and temperature $T_0 = 300$ K. Assume the gas is ideal with a ratio of specific heats $\gamma = 1.4$. The system is initially in equilibrium with its surroundings at temperature T_0 and pressure p_0. The piston is then moved so that the gas is compressed to a final volume $V_f = 2.0$ L.



This compression is performed in three different ways:

(a) [**3 marks**] The piston is moved slowly, so that the compression remains quasistatic and the gas stays in thermal equilibrium with the surroundings throughout (isothermal process). Calculate the total heat exchanged Q_a in the process.

Solution:
For a quasistatic isothermal (reversible) compression of an ideal gas,

$$\Delta U = 0 \quad \Rightarrow \quad Q_{\text{a}} = -W,$$

where W is the work done on the gas.

$$W = \int_{V_i}^{V_f} -p\,dV = nRT_0 \ln \frac{V_i}{V_f}.$$

Using $nR = \dfrac{p_0 V_i}{T_0}$ we get

$$\boxed{Q_a = p_0 V_i \ln \frac{V_i}{V_f}}.$$

Given: $p_0 = 1$ atm $= 1.013 \times 10^5$ Pa, $V_i = 3.0$ L $= 3.0 \times 10^{-3}$ m^3, $V_f = 2.0$ L $= 2.0 \times 10^{-3}$ m^3, $T_0 = 300$ K.

$$\boxed{Q_a = 1.23 \times 10^2 \text{ J (heat transferred to surroundings)}}$$

(b) [**3 marks**] The piston is moved quickly but smoothly, so that during compression heat exchange with the surroundings is negligible (adiabatic and reversible). After compression, the gas is allowed to exchange heat with the surroundings without any change in volume, and it returns to the equilibrium temperature T_0. Calculate the total heat exchanged Q_b in the process.

Solution:
For a reversible adiabatic compression of an ideal gas,

$$Q_{\text{sys}} = 0, \qquad T_2 = T_0 \left(\frac{V_i}{V_f}\right)^{\gamma-1}.$$

When the gas later cools back to T_0, the heat released equals the drop in internal energy:

$$Q_b = nC_V(T_2 - T_0) = \frac{p_0 V_i}{\gamma - 1}\left[\left(\frac{V_i}{V_f}\right)^{\gamma-1} - 1\right].$$

Given: $p_0 = 1.013 \times 10^5$ Pa, $V_i = 3.0 \times 10^{-3}$ m^3, $V_f = 2.0 \times 10^{-3}$ m^3, $\gamma = 1.4$.

$$\boxed{Q_b = 1.34 \times 10^2 \text{ J (heat transferred to surroundings)}}$$

(c) [**5 marks**] The piston is moved suddenly, producing a rapid, irreversible adiabatic compression.

After compression, the gas reached a temperature T_c. The gas is now left to exchange heat with the surroundings without further change in the volume, and eventually returns to its equilibrium temperature T_0. Calculate T_c and the total heat exchanged Q_c in the process.

Solution: When the mass is dropped suddenly, the compression is adiabatic and irreversible. Let the pressure be P_c when the temperature is T_c. During the fast motion, no heat is exchanged ($Q_{\text{sys}} = 0$). The work done on the gas is $W{=}p_c(V_i - V_f)$. The increase in internal energy equals this work:

$$nC_V(T_c - T_0) = p_c(V_i - V_f), \quad C_V = \frac{R}{\gamma - 1}.$$

Also,

$$\frac{P_0V_0}{T_0} = \frac{P_cV_f}{T_c}$$

Substituting $nR = \frac{p_cV_f}{T_c}$,

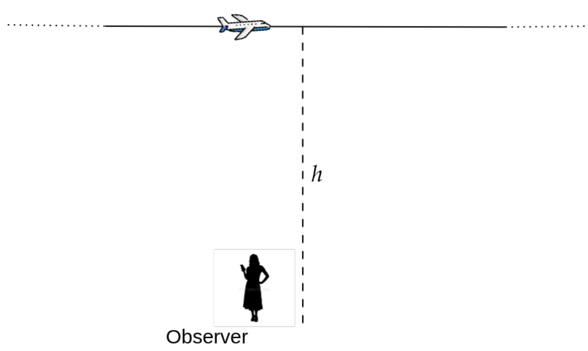
$$\boxed{T_c = \frac{T_0V_f}{V_f - (V_i - V_f)(\gamma - 1)} = 375 \text{ K}}$$

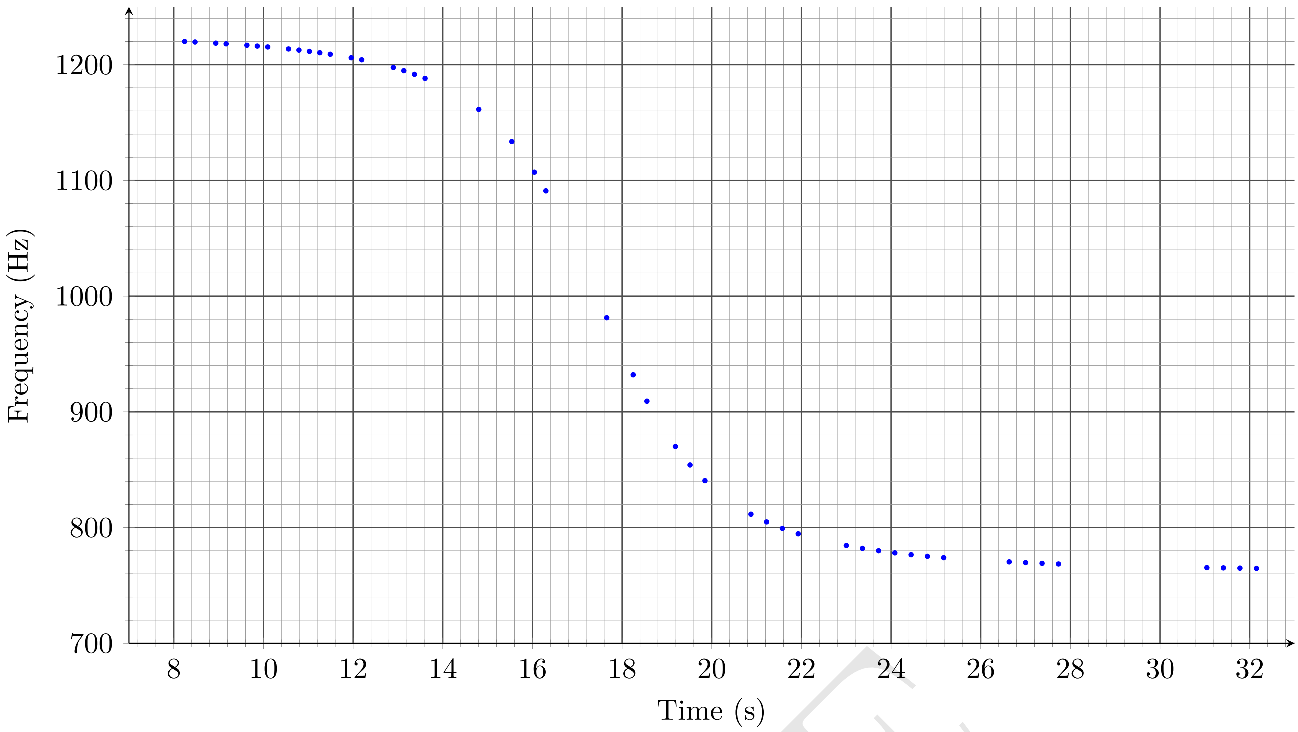
After the compression, the gas cools back to T_0, releasing

$$\boxed{Q_c = nC_V(T_c - T_0) = \frac{P_0V_i}{(\gamma - 1)}\frac{(T_c - T_0)}{T_0} = 1.89 \times 10^2 \text{J}}.$$

4. **A Curve You Can Hear**

An aeroplane flies along a horizontal path, emitting sound at a constant frequency f_0. A stationary observer with a detector on the ground directly beneath the flight path records the sound frequency as the plane passes overhead, which is plotted below. The speed of sound in the medium is $c_s = 340\,\text{m s}^{-1}$.



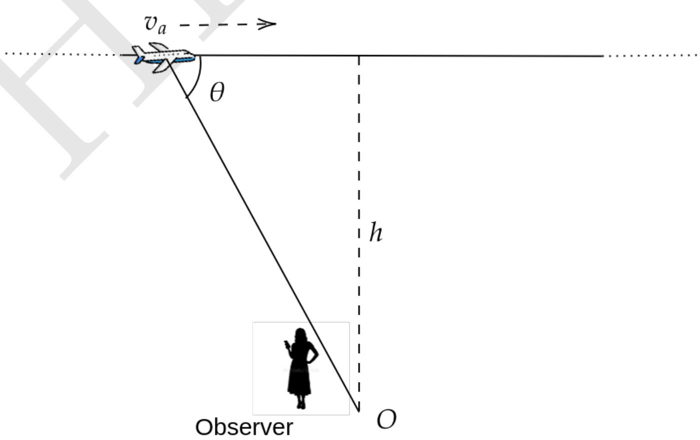


(a) **[5 marks]** Your task is to measure the speed of the aeroplane, v, from the graph. Express v in terms of quantities measurable from the graph, and define/mark these quantities on the graph reproduced in the Summary Answersheet. Calculate the value of v.

Solution: Let θ be the angle between the path of the aeroplane and the line joining the aeroplane and the observer. Using the Doppler formula, the expression for the apparent frequency when the observer is at rest is given by

$$f' = f_0 \frac{c_s}{c_s \mp v\cos\theta},$$

where c_s is the speed of sound. The negative and positive signs correspond to the source moving towards and away from the observer, respectively.



When the aeroplane is far away, $\cos\theta \approx 1$. Hence, there will be no significant variation in the frequency heard by the observer. This occurs at $t < 10\,\text{s}$ and $t > 28\,\text{s}$ in the given graph.

A significant change occurs only when $\cos\theta$ varies (from 12-24 s). Let the frequencies shown in the graph be f'_l and f'_r when the aeroplane is at the extreme left and right, respectively, where $\cos\theta \approx 1$. Then,

$$f' = f_0 \frac{c_s}{c_s \mp v},$$

where the + and − signs give f'_r and f'_l, respectively.
The ratio of the two frequencies is

$$\frac{f'_l}{f'_r} = \frac{c_s + v}{c_s - v}.$$

Rearranging, we obtain

$$v = c_s \frac{f'_l - f'_r}{f'_l + f'_r}.$$

From the graph,

$$f'_l \approx 1220\,\text{Hz}, \quad f'_r \approx 760\,\text{Hz},$$

which gives $\boxed{v \approx 79\,\text{m/s}}$.
Accepted range of $v = 75\text{-}80\,\text{m/s}$.

(b) **[5 marks]** Find the height h of the plane's flight path.

Solution: The frequency of the sound emitted by the engine is

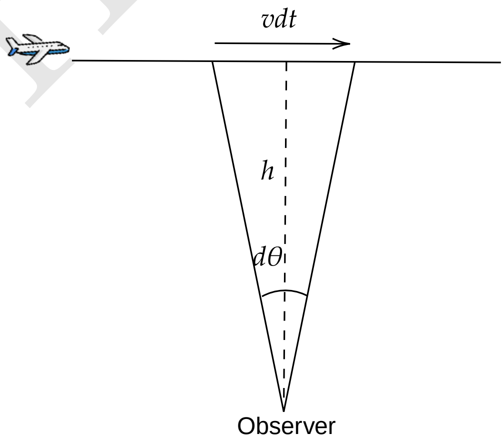
$$f_0 = \frac{f'_l(c - v)}{c} \approx 937\,\text{Hz}.$$

From the Doppler formula, this frequency is heard at $\theta = 90°$. Let t be the observation time and t' be the source emission time. Time t' will include the time delay due to finite distance between the observer and the aeroplane.

$$\frac{df'}{dt'} = f_0 \frac{cv\sin\theta}{(c - v\cos\theta)^2}\frac{d\theta}{dt}.$$

At $\theta = 90°$, $dt' = dt$. From the geometry shown below,

$$\frac{d\theta}{dt} = \frac{v}{h}.$$

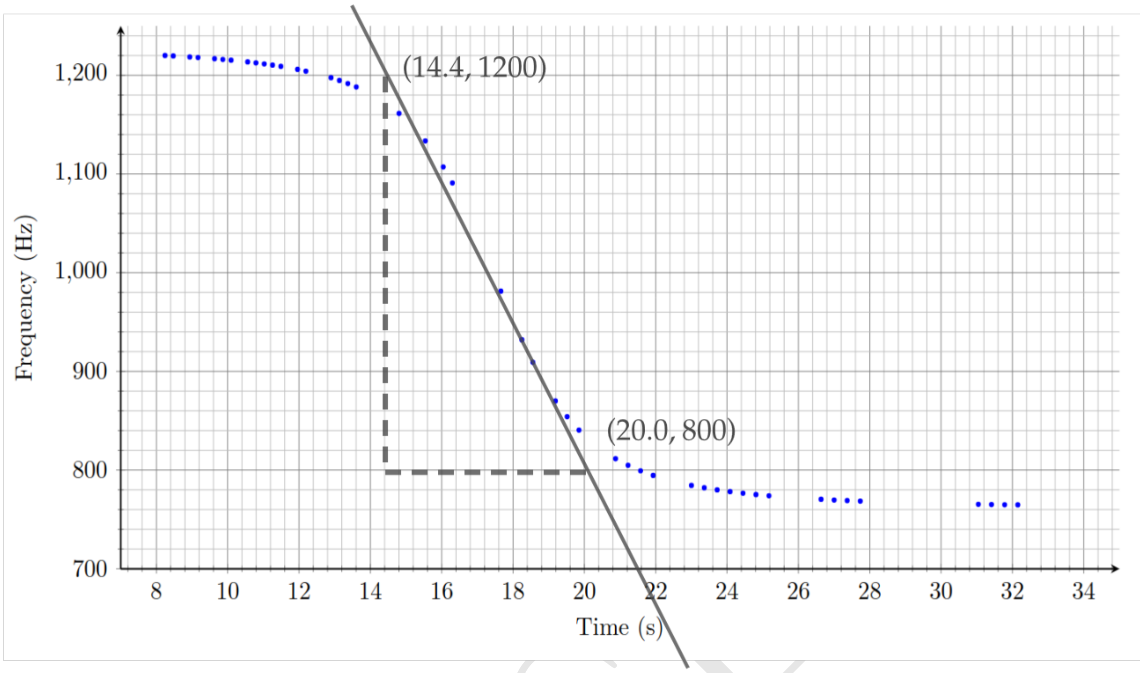


Thus,

$$\left.\frac{df'}{dt}\right|_{\theta=90°} = f_0 \frac{cv}{c^2}\frac{v}{h},$$

$$\Rightarrow \quad h = \frac{f_0 v^2}{c \left.\frac{df'}{dt}\right|_{\theta=90°}}.$$

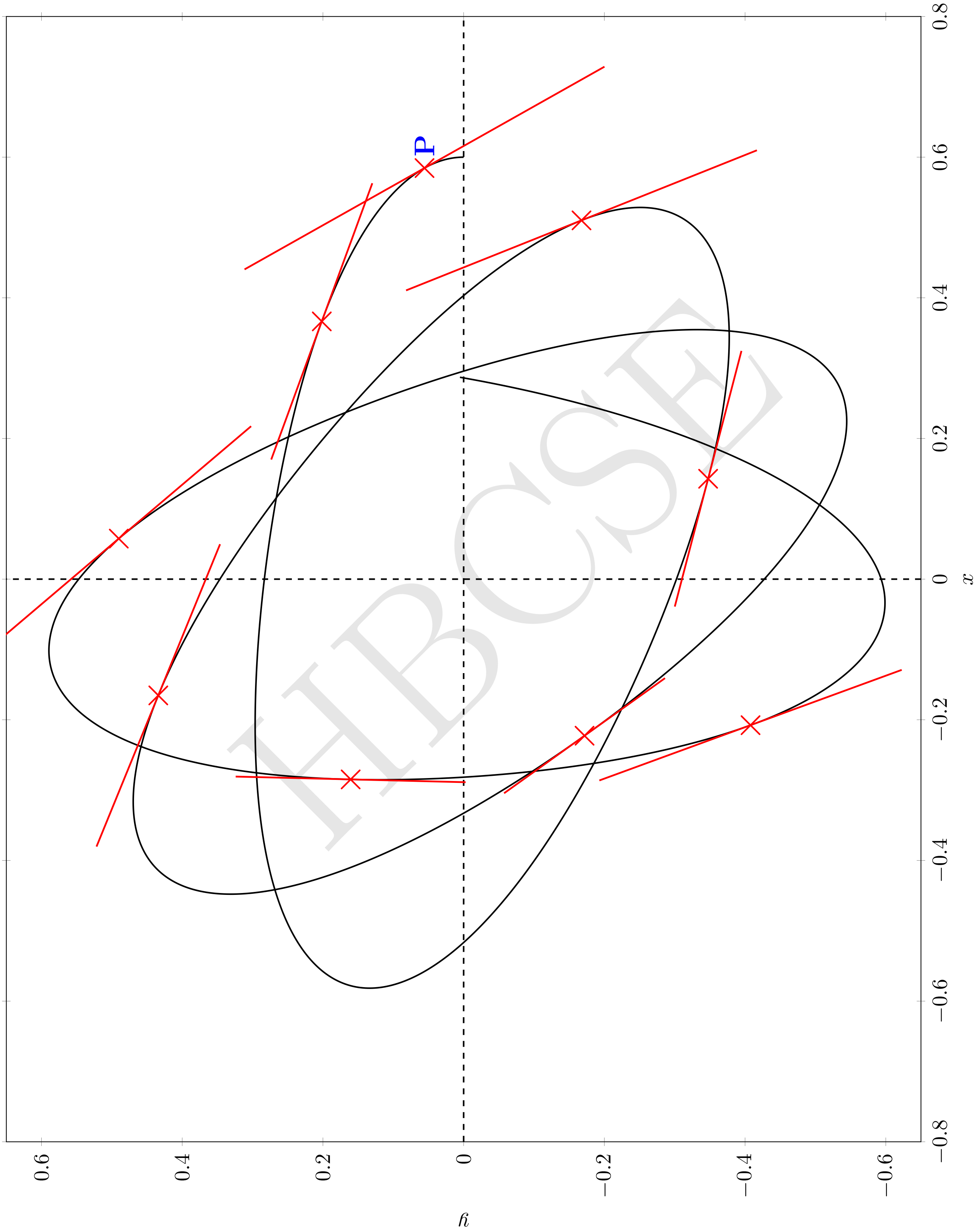
From the graph, the frequency near $t \approx 18\,\mathrm{s}$ is approximately 940 Hz. A tangent drawn at this point gives the slope.



The slope at $\theta = 90^\circ$ is approximately -71.4, which gives $\boxed{h \approx 247\,\mathrm{m}}$. Depending on the slope calculated, an accepted range of h is 185-250 m.

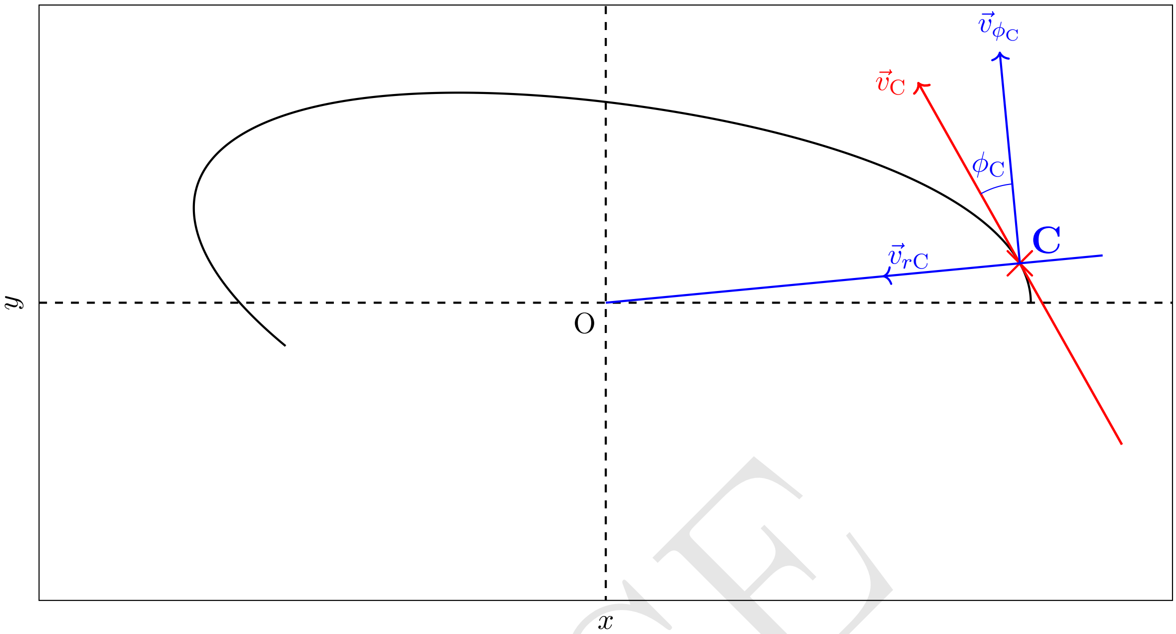
5. **From Kepler's archive**

A short note found in Kepler's archive describes a curious central-force problem. The note states that the radial potential has the form $U(r) = kr^n$, where $k > 0$ is a dimensional constant, n is a positive integer, and r is the distance from a fixed origin. Kepler also recorded the particle's precise trajectory by listing its x-y coordinates in its plane of motion (see the figure below). His sketch includes several short tangent segments drawn at selected points, marked by $\times$.



The coordinates x and y are given in arbitrary units. Kepler's notes indicate that at point P, the kinetic energy is exactly one quarter of the total mechanical energy. He further noted that the exponent n could be determined by performing calculations based on the graph and by constructing a linear plot. Unfortunately, the remainder of the manuscript explaining this method has been lost.

To understand what Kepler did, we define a few variables below. The figure below shows the trajectory of a particle moving under a central force.



Consider a fixed point C on the trajectory (shown by ×), located at a distance r_C from the origin O. At point C, let the speed of the particle be v_C, and let the radial and tangential components of its velocity be v_{rC} and $v_{\phi C}$, respectively ($\vec{v}_{\phi_C}$ is $\perp$ to $\vec{v}_{r_C}$).

The angle between $\vec{v}_{\phi_C}$ and the velocity vector $\vec{v}_C$ is denoted by ϕ_C.

At an arbitrary point on the trajectory, the particle is at a distance r from the origin, its speed is v, and the corresponding angle between $\vec{v}$ and its tangential component $\vec{v}_\phi$ is ϕ.

(a) [**5 marks**] The speed v at an arbitrary point can be written in terms of the speed at point C as $v = \alpha v_C$. Express α in terms of r_C, r, ϕ_C, and ϕ.

Solution: From the given trajectory,

$$v_r = v_\phi \tan\phi$$
$$v_\phi = v\cos\phi$$

In central forces, the angular momentum l is conserved.

$$l = rmv_\phi = \text{constant}$$

Using conservation of momentum at point C and any arbitrary point, we get

$$rv_\phi = r_C v_{\phi C}$$
$$rv\cos\phi = r_C v_C \cos\phi_P$$
$$v = v_C \frac{r_C\cos\phi_P}{r\cos\phi}$$
$$v = \alpha v_C$$

where

$$\boxed{\alpha = \frac{r_C\cos\phi_C}{r\cos\phi}}.$$

(b) **[13 marks]** Two versions of Kepler's diagram are given in the answer sheet: one with tangents drawn and one without. You may use either or both figures as needed.

Use these to devise a method to find the value of n. Perform all relevant analyses using the figures provided on the answer sheet. Finally, use the graph paper at the end of the answer sheet for plotting a linear graph to determine n, and report any necessary data tables in the detailed answersheet.

Solution: From the previous part

$$v = \alpha v_{\mathrm{P}}.$$

It is given that kinetic energy at point P is 1/4th of the total energy E.

$$\frac{1}{2} m v_{\mathrm{P}}^2 = \frac{E}{4}$$

$$2 m v_{\mathrm{P}}^2 = E = k r^n + \frac{1}{2} m v^2$$

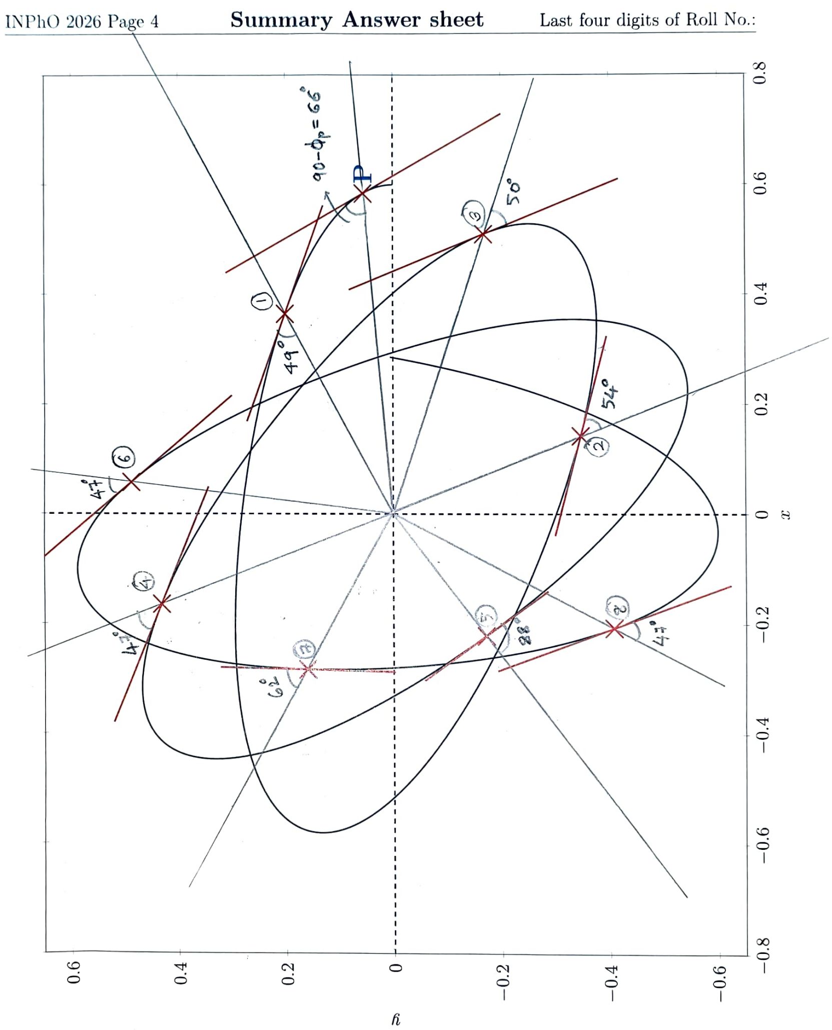
$$4 m v_{\mathrm{P}}^2 = 2 k r^n + m \alpha^2 v_{\mathrm{P}}^2$$

$$m v_{\mathrm{P}}^2 \left(4 - \alpha^2\right) = 2 k r^n$$

Taking log log of both the sides and rearranging

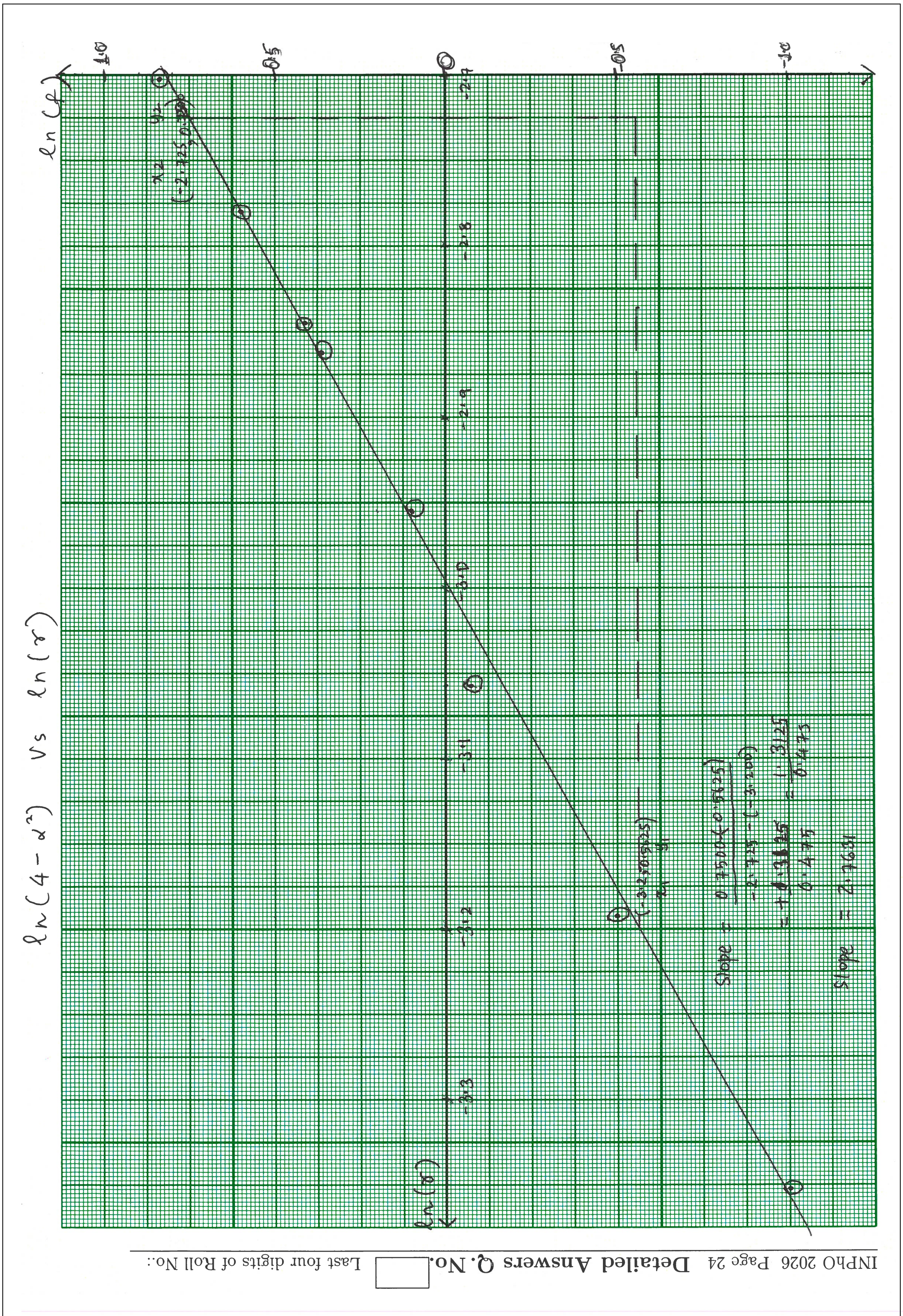
$$\boxed{\ln\left(4 - \alpha^2\right) = n \ln r + \ln \frac{2k}{m v_{\mathrm{P}}^2}}$$

The slope of graph plotted between $\ln\left(4 - \alpha^2\right)$ vs $\ln r$ can be used to calculate the value of n. The trajectory of the particle is given in the figure, the tangents are drawn at some points. We measure r and ϕ at those points using a ruler and protractor. Also measure $r_{\mathrm{C}}, \phi_{\mathrm{C}}$. We use these values to calculate α for each × on the trajectory. In the figure on the next page, the angles measured are $90° - \phi$. The final data is tabulated on the next page.



Solution:

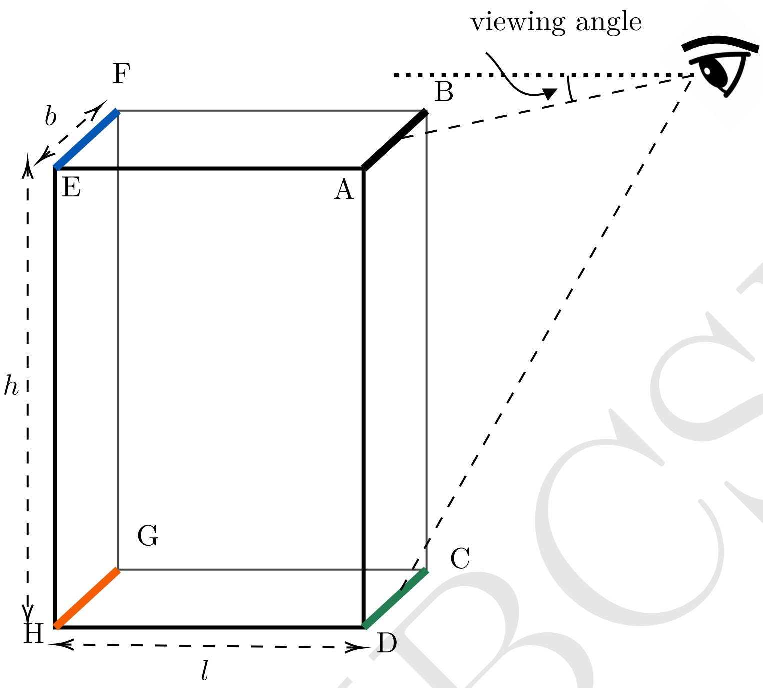
Sr.No	r (in arbitrary units)	ϕ(in degrees)	ln(r)	ln($4-\alpha^2$)
1	5.2	41	-2.957	0.107
2	4.7	36	-3.058	-0.079
3	6.7	40	-2.703	0.838
4	5.8	43	-2.847	0.424
5	3.5	2	-3.352	-1.008
6	6.2	43	-2.781	0.608
7	4.1	28	-3.194	-0.5
8	5.7	43	-2.865	0.365
P	7.3	24		



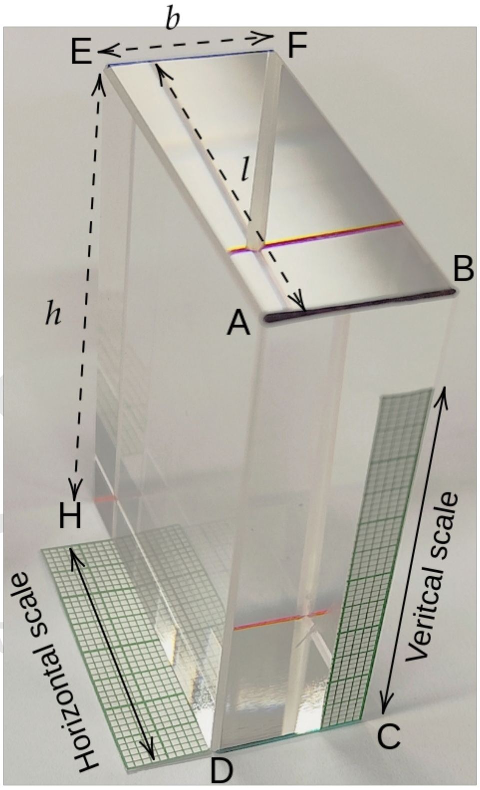
The slope of the graph is 2.76. so the value of $\boxed{n \text{ is } 3}$.

We rule out $n = 2$ case, since for that, the trajectory will be an ellipse.

6. **Perspective matters**
Consider a glass slab (ABCDHGFE) of dimensions ($l \times b \times h$). The slab is placed on its base (CDHG), and viewed at different viewing angles with the vertical face (ABCD) facing the observer (see Fig. (a)). The edges of the glass slab are coloured as shown in Fig. (a). A piece of graph paper is placed next to the base (CDHG). Another piece of graph paper is pasted on the vertical face (ABCD) of the slab (see Fig. (b)). The least count of both the pasted graph papers is 1 mm.



(a)

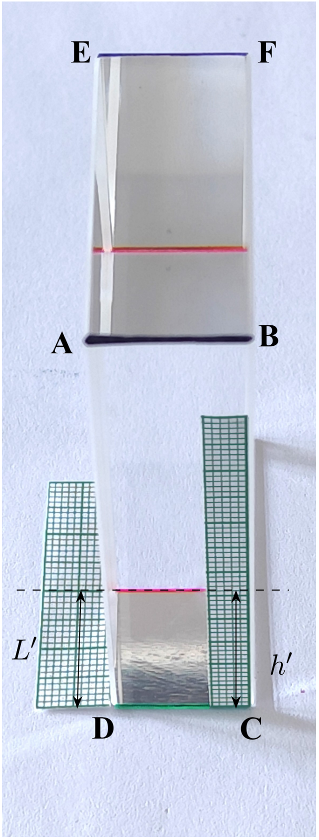


(b)

The task is to determine the refractive index μ_g of the glass slab from a series of photographs of the slab taken from different viewing angles (by lowering the eye position) shown in Figs. (i) to (vi) on the next page. The viewing angle decreases progressively from Figs. (i) to (vi). Take the refractive index of air μ_a to be 1.00. In this exercise, focus your attention on the red line visible through the vertical face (ABCD) only.

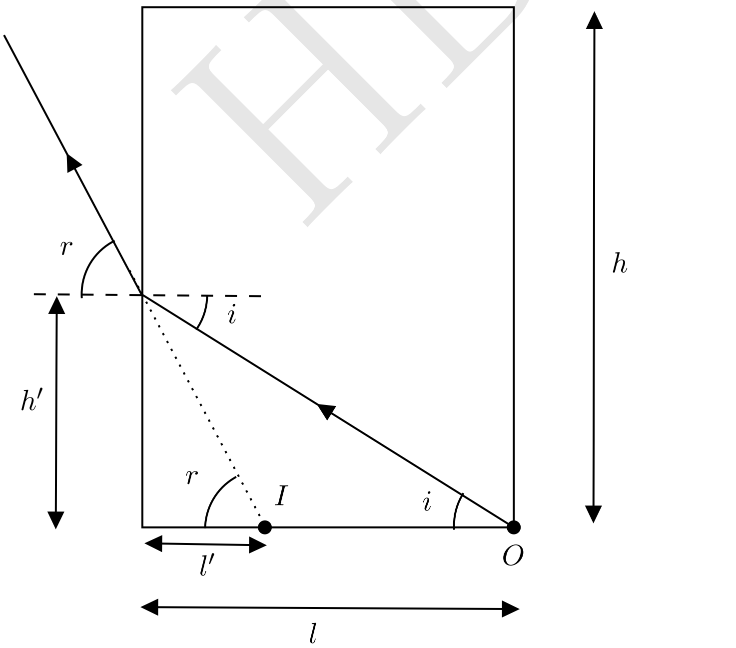
(a) [**2 marks**] Mark and state the measurable quantities in the photo given in the summary answer sheet, that can be used in subsequent parts for measuring the refractive index of the slab.

> **Solution:** When viewed through the slab an edge GH is seen in the lower half of face ABCD. This allows to measure two distances l', and h' which can be used to measure the refractive index as follows. Extend the image of the edge GH seen in the face ABCD. Note the positions where this dashed line coincides with the horizontal and vertical scales. The distance from the front edge of the glass slab to the dashed line on the horizontal scale is denoted by l', and the distance from the bottom of the glass slab to the dashed line on the vertical scale is denoted by h'.



(b) **[4 marks]** Draw a ray diagram showing these measured quantities, and the relevant given dimensions of the slab. Derive an expression for the refractive index μ_g of the glass slab in terms of the measured quantities that you have decided to use.

Solution: The side view of the image is shown below.



Using Snell's law

$$\mu_g \sin i = \mu_a \sin r$$

$$\mu_g \frac{h'}{\sqrt{h'^2 + l^2}} = 1.\frac{h'}{\sqrt{h'^2 + l'^2}}$$

$$\boxed{\mu_g = \sqrt{\frac{h'^2 + l^2}{h'^2 + l'^2}}}$$

(c) **[6 marks]** Calculate the value of μ_g, by plotting a linear graph. Report your datatable in the detailed answersheet.

Solution: The refractive index is given by

$$\mu_g = \sqrt{\frac{h'^2 + l^2}{h'^2 + l'^2}}$$

Rearranging the above equation, we get

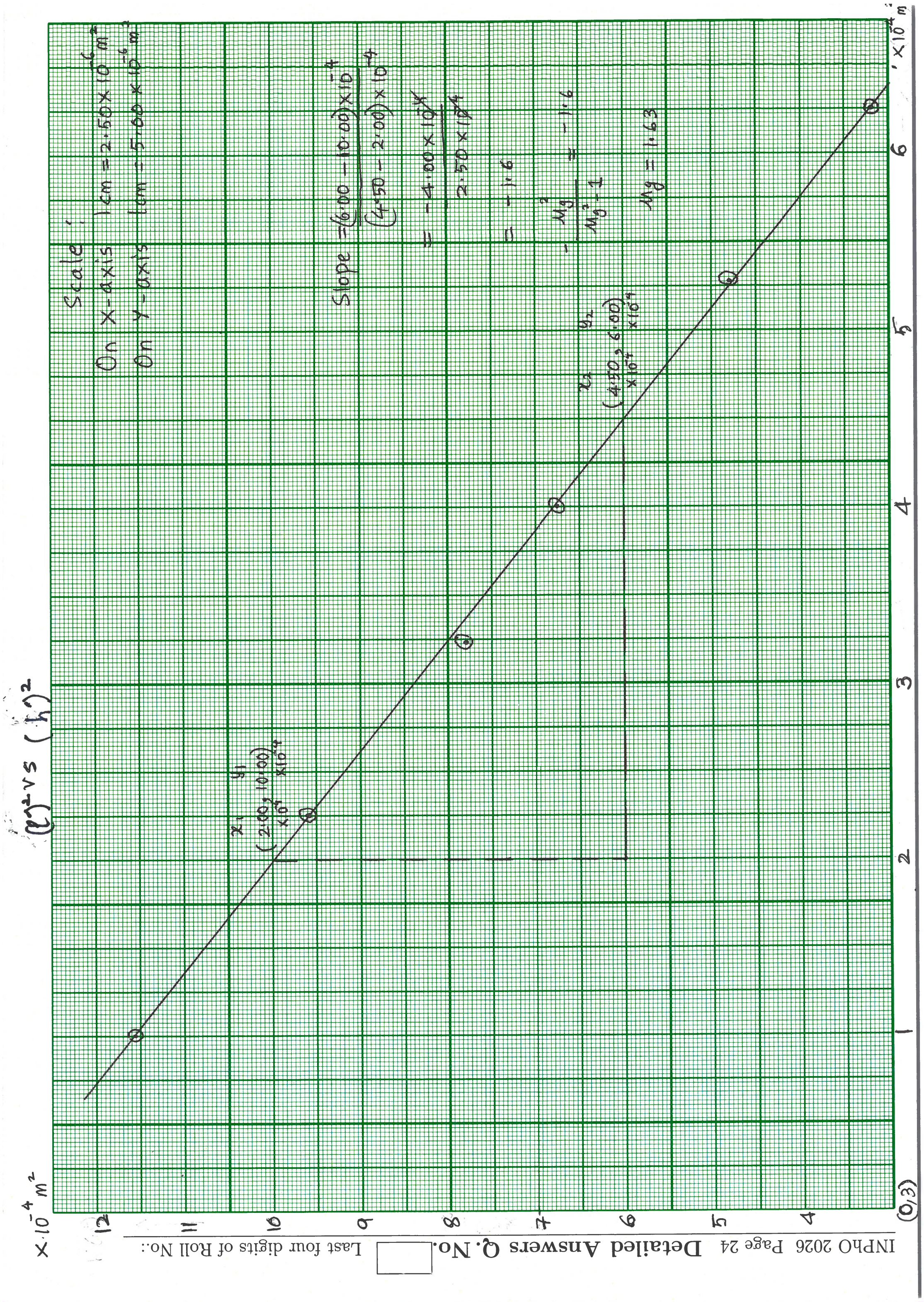
$$\boxed{h'^2 = -\frac{\mu_g^2}{(\mu_g^2 - 1)} l'^2 + \frac{l^2}{(\mu_g^2 - 1)}}$$

The data from the six figures can be tabulated as follows

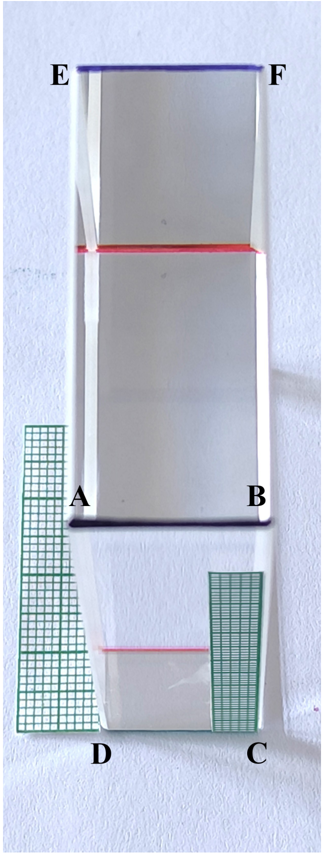
Sr. No.	h'(cm)	l'(cm)	$h'^2(\times 10^{-4})$	$l'^2(\times 10^{-4})$
1	3.4	1	11.56	1.00
2	3.1	1.5	9.61	2.25
3	2.8	1.8	7.84	3.24
4	2.6	2	6.76	4.00
5	2.2	2.3	4.84	5.29
6	1.8	2.5	3.24	6.25

The slope of the graph of h'^2 vs l'^2 will give the refractive index.

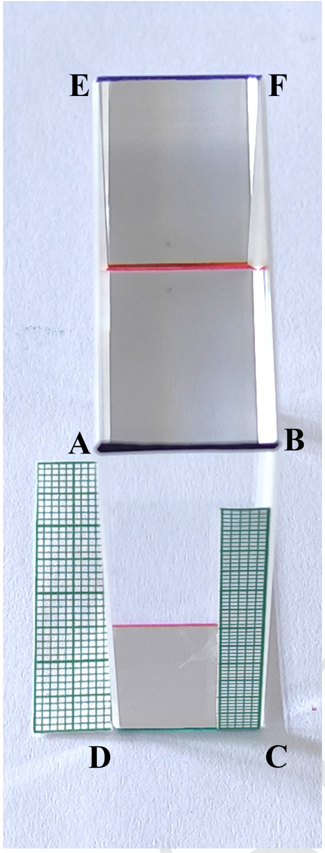
Solution:



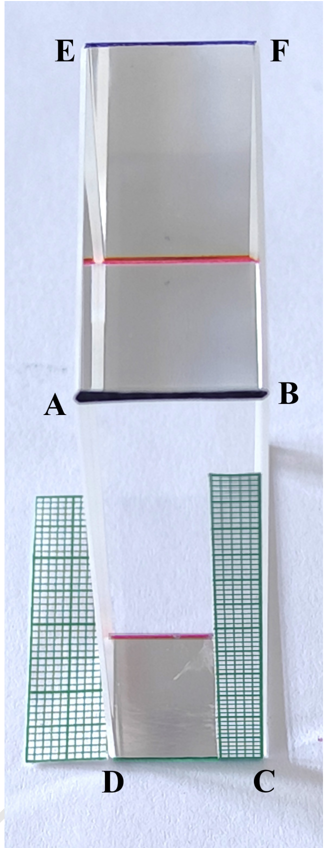
The slope of the graph is -1.60. The refractive index of the glass slab is 1.63.
An accepted range of μ is 1.60-1.70.



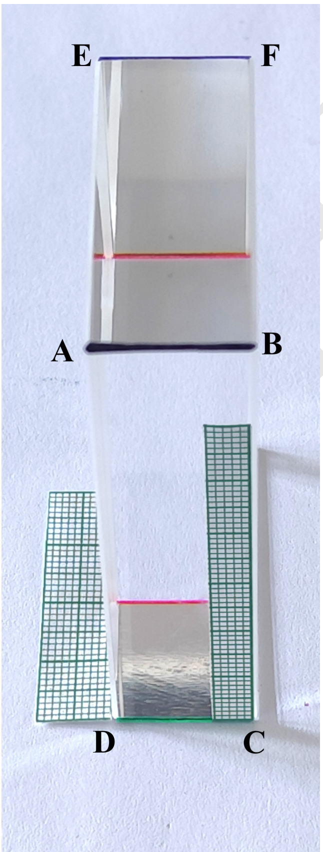
(i)



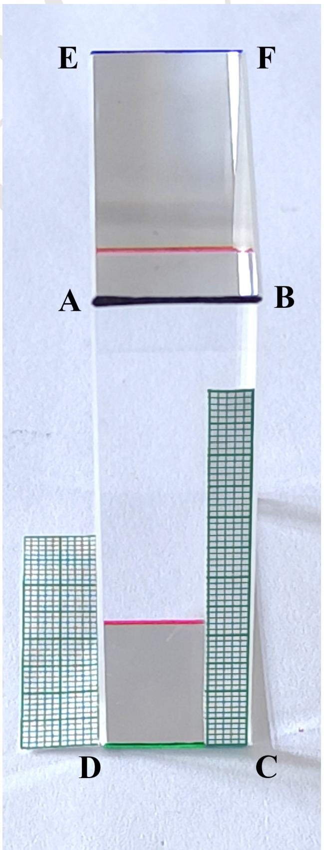
(ii)



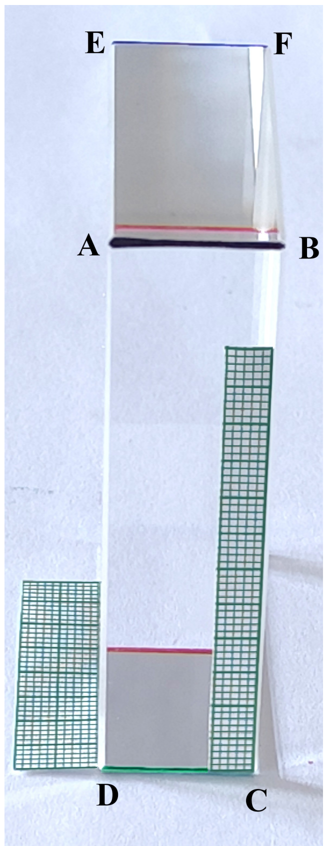
(iii)



(iv)



(v)



(vi)

****** END OF THE QUESTION PAPER ******