Experiment - 15 : Refractive index of a glass slab using a travelling microscope

Real and Apparent Thickness of a Glass Slab

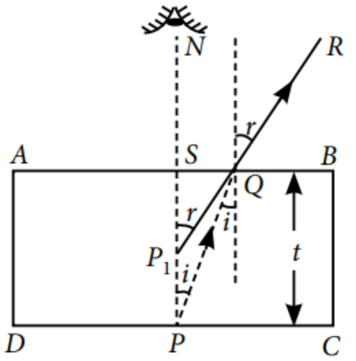
Diagram shows a section ABCD of a glass slab taken by a horizontal plane. The slab has thickness t.

Description: P is a point marked at the bottom of the slab. A ray of light PQ from P is incident at the top at the point Q at an angle of incidence i and refracts along QR at an angle r. It appears to come from P_1.

P_1 is the virtual image of real object P formed on normal PSN.

PS is the real thickness of the slab.

P_1S is the apparent thickness of the slab.



Calculation

In ΔSPQ, ∠SPQ = i (being alternate angle of i)

$$\sin i = \frac{SQ}{PQ}$$

In ΔSP1Q, ∠SP1Q = r (being corresponding angle of r)

$$\therefore \quad \sin r = \frac{SQ}{P_1Q}$$

From Snell's law, for light going from glass to air

$$_g\mu_a = \frac{\sin i}{\sin r} = \frac{SQ/PQ}{SQ/P_1Q} = \frac{P_1Q}{PQ}$$

$$_o\rho\ _a\mu_g = \frac{1}{_g\mu_a} = \frac{PQ}{P_1Q}$$

For a ray received normally along PSN, Q is very close to S.

Then $PQ = PS$ and $P_1Q = P_1S$

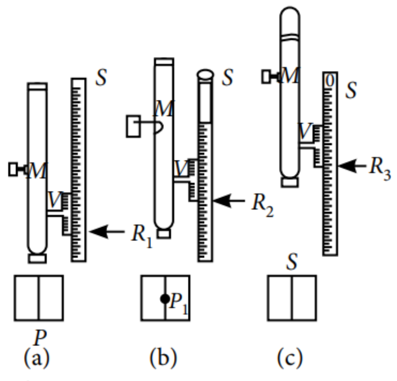
$$\text{and } {}_a\mu_g = \frac{PS}{P_1S} = \frac{\text{Real thickness}}{\text{Apparent thickness}}$$

$${}_a\mu_g = \frac{\text{Real thickness of slab}}{\text{Apparent thickness of slab}}$$

To determine refractive index of a glass slab, using a travelling microscope, the required apparatus is three glass slabs of different thickness but same material, a travelling microscope, lycopodium powder.

A Short Description of Travelling Microscope

It is a compound microscope fitted vertically on a vertical scale. It can be moved up and down, carrying a vernier scale moving along the main scale. In any position, the reading is taken by combining main scale and vernier scale reading.



We mark a cross (P) on a board and measure its distance as shown in fig. (a) with the travelling microscope. Then the glass-slab is placed over the cross. Now, the cross appears at (P_1) and its distance is measured using the travelling microscope.

Finally, we put some lycopodium powder(S) on top of the slab and measure its distance using the travelling microscope.

PS = Real Thickness of slab and

P_1S = Apparent thickness of slab

Thus refractive index can be found as

$$\mu = \frac{\text{Real thickness of slab}}{\text{Apparent thickness of slab}} = \frac{PS}{P_1S}.$$

MCQs Corner

Experiment – 15

66. A bird in air looks at a fish vertically below it and inside water; h_1 is the height of the bird above the surface of water and h_2, the depth of the fish below the surface of water. If refractive index of water with respect to air be μ, then the distance of the fish observed by the bird is

(a) $h_1 + h_2$ (b) $h_1 + h_2/\mu$ (c) $\mu h_1 + h_2$ (d) $\mu h_1 + \mu h_2$

67. To determine refractive index of glass slab using a travelling microscope, minimum number of readings required are

(a) Two (b) Four (c) Three (d) Five

68. An experiment is performed to find the refractive index of glass using a travelling microscope. In this experiment distances are measured by

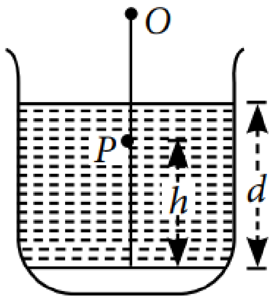
(a) a screw gauge provided on the microscope

(b) a vernier scale provided on the microscope

(c) a standard laboratory scale

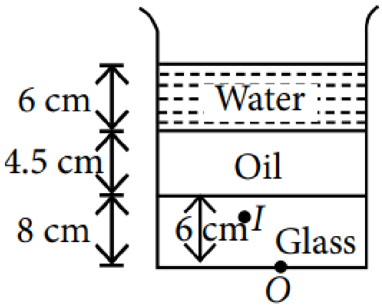
(d) a meter scale provided on the microscope.

69. A plane mirror is placed at the bottom of a tank containing a liquid of refractive index μ. P is a small object at a height h above the mirror. An observer O, vertically above P, outside the liquid sees P and its image in the mirror. The apparent distance between these two will be



(a) $2\mu/h$ (b) $2h/\mu$ (c) $2h/(\mu - 1)$ (d) $h[1 + (1/\mu)]$

70. A vessel contains a slab of glass 8 cm thick and refractive index 1.6. Over the slab, the vessel is filled by oil of refractive index μ upto a height 4.5 cm and also by another liquid i.e., water of refractive index 4/3 upto a height 6 cm as shown in figure. An observer looking down from above, observes that, a mark at the bottom of the glass slab appears to be raised upto position 6 cm from the bottom of the slab. The refractive index of oil (μ) is



(a) 1.5 (b) 2.5 (c) 0.5 (d) 1.2

71. Monochromatic light of wavelength λ_1 travelling in a medium of refractive index n_1 enters a denser medium of refractive index n_2. The wavelength in the second medium is

(a) $\lambda_1\left(\frac{n_1}{n_2}\right)$ (b) $\lambda_1\left(\frac{n_2}{n_1}\right)$

(c) $\frac{\lambda_1(n_2-n_1)}{n_2}$ (d) $\frac{\lambda_1(n_2-n_1)}{n_1}$

Answer Key

66. (b) 67. (c) 68. (b) 69. (b) 70. (a) 71. (a)

Hints & Explanation

66. **(b) :** Apparent position of fish as seen by bird is $= h_1 + \left(\frac{h_2}{\mu}\right)$.

67. **(c)**

68. **(b) :** A travelling microscope moves horizontally on a main scale provided with a vernier scale, provided with the microscope.

69. **(b) :** The image of P will be formed at a distance h below the mirror. Apparent depth of $P = x_1 = \frac{(d-h)}{\mu}$

Apparent depth of the image of $P = x_2 = \frac{(d+h)}{\mu}$

Apparent distance between P and its image $= x_2 - x_1 = \frac{2h}{\mu}$.

70. **(a) :** The total shift (OI) is given by

OI = shift due to glass + shift due to oil + shift due to water

$$\therefore\ 6 = 8\left(1-\frac{1}{1.6}\right)+4.5\left(1-\frac{1}{\mu}\right)+6\left(1-\frac{1}{\frac{4}{3}}\right)$$

or $\quad 6 = \frac{8\times 0.6}{1.6}+\left(4.5-\frac{4.5}{\mu}\right)+\frac{6\times 1}{4}$

or $\quad \frac{4.5}{\mu} = 3 + 4.5 + 1.5 - 6 = 3$ or $\mu = \frac{4.5}{3} = 1.5.$

71. **(a) :** $\lambda_a = \frac{c}{\upsilon}$ or $\lambda_m = \frac{v}{\upsilon} = \frac{c}{\mu_m \upsilon}$

$\therefore\ \lambda_1 = \frac{c}{n_1\upsilon}$ and $\lambda_2 = \frac{c}{n_2\upsilon}$

or $\lambda_1 n_1 = \lambda_2 n_2$ and $\lambda_2 = \lambda_1\left(\frac{n_1}{n_2}\right)$