LIQUID LENS - REFRACTIVE INDEX OF LIQUID

Aim

To determine the refractive index of the given liquid by forming a liquid lens of a plano concave nature.

Apparatus

The given liquid, a convex lens preferably of small focal length (say 10cm, 15cm or 20cm), a plane mirror, a retort stand, a pointer, ink filler and mercury.

Theory

According to lens makers formula the focal length of a lens is given by

$$\frac{1}{f_1} = (\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \text{..........(1)}$$

where f_1 - Focal length of the lens

μ_g - Refractive index of the material of the lens

R_1 - Radius of curvature of first face of the lens

R_2 -Radius of curvature of second face of the lens. When the convex lens is placed on a plane mirror on which some drops of liquid is spilled, a plano concave liquid lens is formed in between the convex lens and the plane mirror as shown in figure.

Let f_2 be the focal length of the liquid lens, radius of curvature of the plane surface $R_1 = \infty$, radius of curvature of the second surface R_2 = -R (which is the same as the radius of curvature of the surface of the convex lens which is in contact with the liquid). Using eq(1), we get

$$\frac{1}{f_2} = (\mu_l - 1)\frac{1}{R}$$

$$\therefore \quad \mu_1 = 1 + \frac{R}{f_2}$$

Knowing R and f. H, can be calculated.

To find f

The focal length of the liquid lens f_2 can be calculated by measuring focal length of the convex lens f_1 and the focal length of the combination F. (liquid lens and convex lens).Using the law of combination of lenses, when lenses are put in contact we have

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

We get $$f_2 = \frac{Ff_1}{f_1 - F} \quad \text{.......(3)}$$

To find R

To find the radius of curvature R, we may use mercury as a reflector and get the radius of curvature directly by the Boy's method.

When the convex lens is floated on mercury the lower surface of lens acts as a reflector. Suppose an object is placed at 0. A light ray OA starting from 0 gets refracted into the glass at the first surface and strikes the bottom surface along AB. To form the image on the object itself the rays retrace their path after reflection from the bottom surface. This could be possible only when light ray AB falls normally on the bottom surface. Thus, AB should appear to come from the centre of curvature C, of the second surface. This implies that due to refraction at the first surface, a virtual image 0 is formed at C. Here $v_2 = -R$ let $u=-d$ using thin lens formula, we have

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$-\frac{1}{R} + \frac{1}{d} = \frac{1}{f}$$

Observations and calculations

Focal length of the convex lens (f_1)

Trial No.	Distance of the pointer from the top of the lens f_1' (cm)	Distance of the pointer from the plane mirror f_1'' (cm)	Mean $f_1 = \frac{f_1' + f_1''}{2}$ (cm)
1			
2			
3			
4			

Mean f_1 = ... cm

Focal length of the combination (F)

Trial No.	Distance of the pointer from the top of the lens F′ (cm)	Distance of the pointer from the plane mirror F″ (cm)	Mean F $F = \frac{F' + F''}{2}$ (cm)
1			
2			
3			
4			

Mean F = ... cm

Radius of curvature of liquid lens (R)

Trial No.	Distance of the pointer from the top surface of the lens d′ (cm)	Distance of the pointer from the surface of mercury d″ (cm)	Mean d $= \frac{d' + d''}{2}$ (cm)
1			
2			
3			

Mean d = ... cm

Radius of curvature of the liquid lens, R = $\frac{f_1 d}{f_1 - d}$ =................. cm

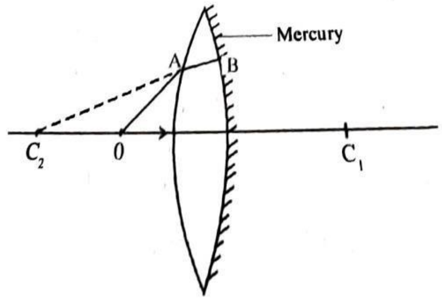
Focal length of the liquid lens $f_2 = \frac{F f_1}{f_1 - F}$ = ... cm

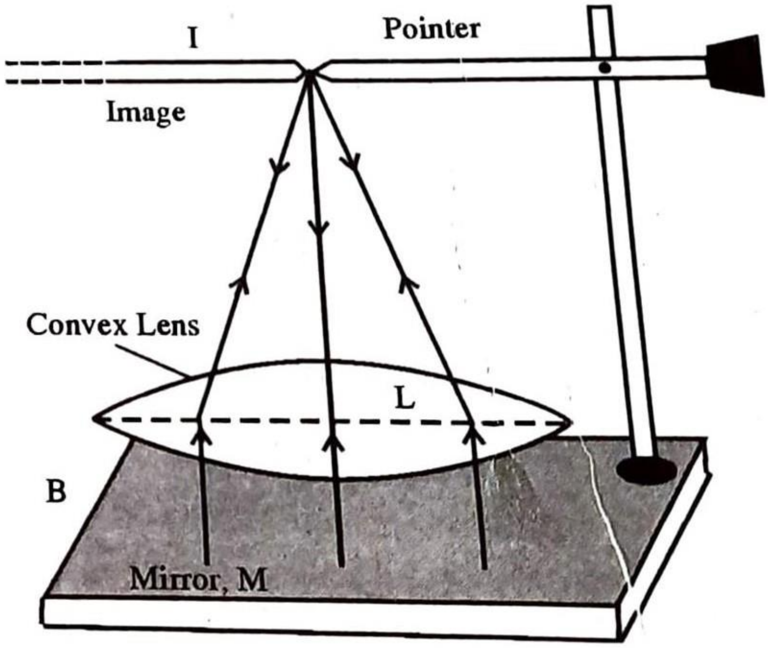
Refractive index of the liquid,μ_l = 1+ $\frac{R}{f_2}$ = ... cm

$$-\frac{1}{R} = \frac{1}{f} - \frac{1}{d} = \frac{d-r}{fd}$$

Or $\quad R = \frac{fd}{f-d}$ ……(4)

This is the Boy’s formula for determining the radius of curvature.





Procedure

The focal length of the convex lens f, is first determined by the parallax method. For this a plane mirror M is kept horizontally on the base of the retort stand. The given convex lens is kept on the plane mirror. The pointer is fixed horizontally on the vertical stand of the retort above the convex lens. Looking into the convex lens from vertically above an inverted image of the pointer can be seen in the convex lens. Adjust the pointer (raise or lower) so that the image size is of the same size as that of the object. The tip of the virtual image seen can be made to coincide with the tip of the real object. By looking the object and the image, gently move your head to and fro, if the pointer and the image appears to move as a single object the adjustment is over. If not slightly adjust the height of the pointer till the above mentioned two criteria are satisfied. This happens when the distance from the centre of the lens to the distance of the pointer will be the focal length. Then the distances of the tip of the pointer to the top surface of the lens and to the mirror surface with the lens removed are measured as fand f. The average of these two gives the focal length f, of the convex lens. The adjustment is repeated three or four times and the average value obtained .

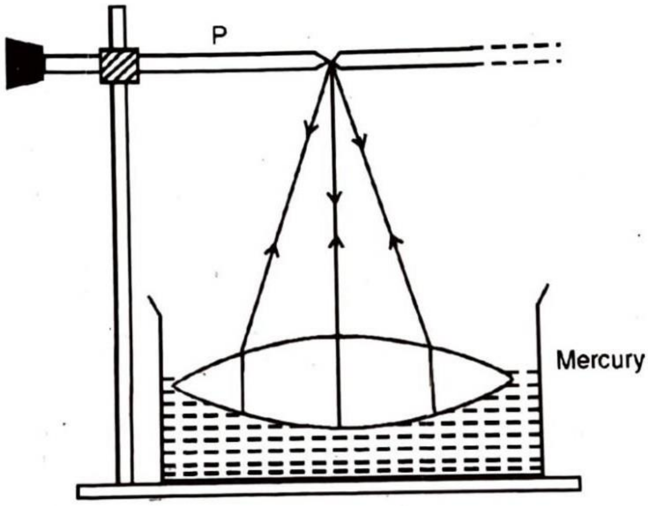
Experimental determination of f_2

For this, the lens is removed and a few drops of given liquid is dropped over the plane mirror using ink filler. Then the convex lens is placed carefully over the liquid. Now we have a combination of lenses. A convex glass lens and a plano concave liquid lens. The focal length of this combination F can be determined as before. Using eq (3), f_2 can be calculated.

Experimental determination of R- Boys method

Now the given mercury is taken in a china dish. The given lens is then floated in the dish of mercury. It should be reminded that the surface whose radius of curvature is to be found out to be kept in contact with the mercury surface. The height of the pointer is lowered to make the image tip coincide with the pointer without parallax. Measure the distances of the pointer from the surface of mercury and top of the lens. Average of this gives d. Repeat the experiment three or four times and take the average of d. Using eqn (4), radius of curvature R can be calculated.

By using f_2 and R, the refractive index of the liquid u, can be calculated using the formula $\mu_l = 1+ \frac{R}{f_2}$ (see eqn)



Result

The refractive index of the given liquid =……………

References

- Experimental Physics – I, For First, Second, Third and Fourth Semester, BSc Degree Programme, Dr.P.Sethumadhavan, Prof. K.C. Abraham, Prof .Sunil John, **Manjusha Publications**
- https://youtu.be/7FLFWQYkCWE?si=ZmP22gYLGKm-q2a-