combined with a high power convex lens (low focal length) so that the combination is a converging one.

12. Can you do with a convex lens of any focal length?

Ans. For reasons see Q.11.

13. Why don't you employ $(u-v)$ method for finding f?

Ans. For in that case, we require the thickness of the combination of lenses as well as the index corrections both for u and v. Here we require only one index correction for D and the thickness of the lens is not required.

14. Do you get real or virtual image in this experiment?

Ans. Real image.

15. Define refractive index ; does its value depend on the colour of light?

Ans. If i and r are respectively the angles of incidence and refraction of a ray of light of wavelength λ, then $\frac{\sin i}{\sin r} = \mu$ (constant) which is known as the refractive index of refracting medium with respect to the incident medium. Yes, $\mu_v > \mu_r$ i.e., μ increase as the wavelength of light decreases.

16. What relation does the velocity of light bear to the refractive index?

Ans. If V_0 and V are the velocities of light in the incident and refracting media, then $\mu = V_0/V$.

17. Can you perform the experiment by using a concave lens alone?

Ans. No ; for this lens cannot produce any real image.

18. What is parallax and how would you avoid it?

Ans. If the two objects are not coincident, then the movement of eye will cause a relative displacement between the two objects. This is parallax. When there is no relative displacement between the two objects with the movement of eye, then parallax is avoided [see Art. 5.1].

19. See oral questions 1—5 on spherometer, Art. 2.5.

5.1(b) Determination of the refractive index of a liquid by using a plane mirror and a convex lens :

• **Theory :** If a double convex lens C of focal length f_1 is placed over a few drops of liquid placed on a plane mirror, then a plano-concave liquid lens of focal length f_2 is formed between the lower surface of the convex lens and the plane mirror (Fig. 5.1-2). If F be the focal length of the combination (which is behaving as a convex lens), then we have

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

$$\text{or,}\quad f_2 = -\frac{Ff_1}{F - f_1} \qquad \text{... (5.1-11)}$$

Finding f_1 and F experimentally by coincidence method, and putting their values in the relation (5.1-11) we can calculate f_2. Again, the focal length f_2 of the plano-concave liquid lens is given by

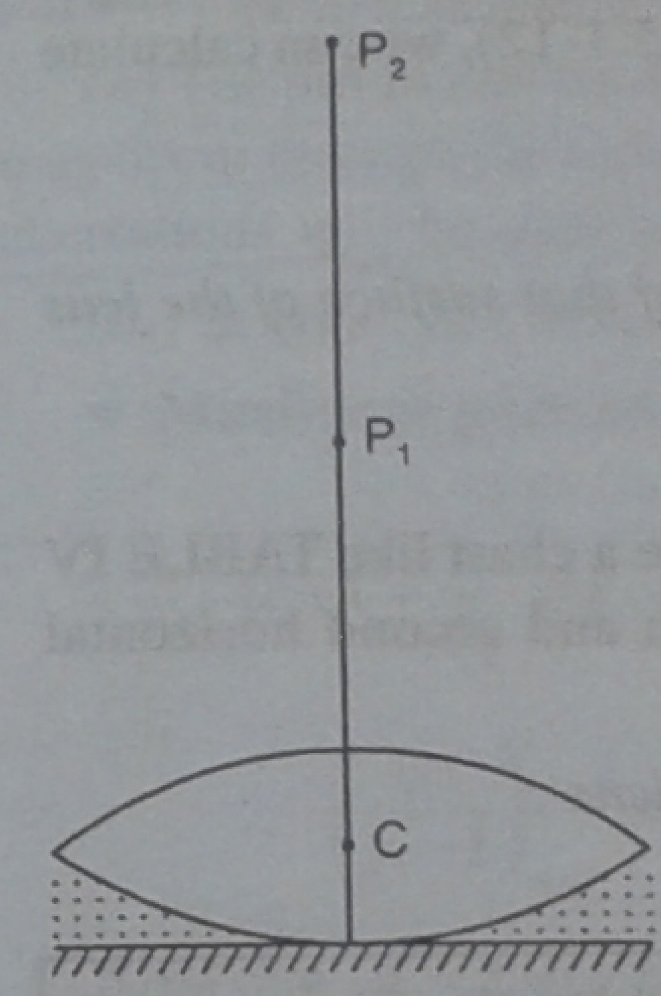

Fig. 5.1-2

$$\frac{1}{f_2} = (\mu - 1)\left(\frac{1}{r} - \frac{1}{r'}\right) = (\mu - 1)\frac{1}{r} \; [\because r' = \infty]$$

$$\text{or,}\quad \mu = 1 + \frac{r}{f_2} \qquad \text{... (5.1-12)}$$

where r is the radius of curvature of the lower surface of the convex lens. The value of r can be measured by a spherometer, using the formula

$$r = \frac{d^2}{6h} + \frac{h}{2} \qquad \text{... (5.1-13)}$$

where d is the mean distance between any two consecutive legs of the spherometer and h is the displacement of the screw tip when it touches consecutively the lower surface of the lens and a plane surface.

Thus knowing f_2 and r and putting their numerical values in Eq. (5.1-12) we can calculate μ, the refractive index of the liquid.

• **Apparatus :** A vertical stand with a pin, plane mirror, convex lens, etc.

• **Procedure :** (*i*) The radius of curvature of one surface of the convex lens (which is somehow kept marked) is determined by a spherometer. Thus we get r (see Art. 2.5 on spherometer).

(*ii*) The convex lens C is then placed on a plane mirror M (Fig. 5.1-2) so that its particular surface, whose radius of curvature was measured, may touch the mirror. A horizontal pointer is moved vertically up and down along the axis of the lens until there is no parallax between the tip of the pin and its own real image. Thus the pin is at the first principal focus P_1 of the lens. The heights h_1 and h_2 of the pin from the upper surface of the lens and the mirror are mesured and the mean of h_1 and h_2 gives the focal length f_1 of the convex lens alone. This is repeated three times and the mean of these three values gives f_1.

(*iii*) A few drops of liquid are now placed on the plane mirror and the surface of the lens, which was originally in contact with the mirror, is now placed over the liquid. The mean of the three values of the focal length F of the combination is then determined exactly in the same way as in (*ii*). This time the pointer and its real image will coincide at P_2 (Fig. 5.1-2) which is the first focus of the combination.

(*iv*) By putting the mean *numerical values* of F and f_1 in (5.1-11), we get f_2. Then by putting the numerical values of r and f_2 in (5.1-12), we can calculate μ.

- **Experimental data :**

(A) *Determination of the radius of curvature (r) of that surface of the lens which is in contact with the mirror :*

TABLE I

[Calculate the least count of spherometer and make a chart like TABLE IV of Expt. 5.1(a) excepting the second vertical column and second horizontal row]

(B) *Determination of focal length (f_1) of convex lens :*

TABLE II

No. of obs.	Height of pin (P_1) in cm from the upper surface of		Focal length $f_1 = \frac{h_1+h_2}{2}$ cm	Mean f_1, in cm
	lens (h_1)	mirror (h_2)		
1.	...	...	...	
2.	...	...	...	...
3.	...	...	...	

(C) *Determination of focal length (F) of the combined lens :*

TABLE III

No. of obs.	Height of pin (P_1) in cm from the upper surface of		Focal length $F = \frac{h_1'+h_2'}{2}$ cm	Mean F in cm
	lens (h_1')	mirror (h_2')		
1.	...	...	...	
2.	...	...	...	...
3.	...	...	...	

- **Calculations and Result :**

$$r = \frac{d^2}{6h} + \frac{h}{2} = \ldots, \qquad |f_2| = \frac{Ff_1}{F - f_1} = \ldots, \qquad \mu = 1 + \frac{r}{|f_2|} = \ldots$$

- **Precautions and Discussions :** (*i*) To find the coincidene of the object pin with its real inverted image, parallax should be carefully avoided.

(*ii*) The pin should be moved along the axis of the lens so that the refraction may occur through the central part of the lens by which spherical and chromatic aberrations will be avoided.

(*iii*) & (*iv*) : See Precautions (*vii*) & (*viii*) of Expt 5.1(a).

- **Maximum percentage error :**

$$\mu - 1 = \frac{r}{f_2} = r \cdot \frac{F - f_1}{F \cdot f_1} \text{ (numerically)}$$

$$\therefore \left(\frac{\delta\mu}{\mu - 1}\right)_{max} = \frac{\delta r}{r} + \frac{\delta F}{F} + \frac{\delta f_1}{f_1} + \frac{\delta F + \delta f_1}{F - f_1}$$

Now $\delta f = \delta f_1 = 1$ div. of metre scale, δr can be calculated as in Expt. 5.1(a). Therefore, using a typical set of observed data, it is possible to calculate the error $(\delta\mu)_{max}$ and hence the maximum percentage error $\left(\frac{\delta\mu}{\mu}\right)_{max} \times 100\%$.

☐ Oral Questions and Answers ☐

1. What is the nature of the liquid lens?

Ans. It is a plano-concave lens.

2. Do you consider the focal length of the liquid concave lens greater or smaller than that of the convex lens?

Ans. Greater (or smaller diverging power) otherwise the combination cannot behave as a convex lens.

3. Can you measure refractive index of any value by this method?

Ans. No, when the refractive index of the liquid is such that the focal lengths f_2 and f_1 of the liquid concave lens and the given convex lens respectively are equal, the combination is no longer a lens and the method fails. If an equi-convex lens of refractive index μ (= 1.5) be taken, then its focal length f_1 is equal to the radius r of its surfaces.

The maximum refractive index of liquid is $\mu = 1 + \frac{r}{f_2} = \ldots = 2$ (for $f_2 = f_1 = r$).