8. What class of interference is obtained here?

*Ans.* Division of wavefront class.

9. Why is it necessary to use a narrow source here?

*Ans.* A broad source is equivalant to a large number of sources lying side by side. Each pair of such sources gives rise to its own pattern of fringes. The overlapping of a number of such patterns results in general illumination.

10. Why do you get coloured fringes with white light?

*Ans.* Fringe width is a function of wavelength $\lambda$. Smaller is the value of $\lambda$ closer is the fringes. As a result fringes become coloured.

11. Are the fringes in this experiment localised or non-localised?

*Ans.* Non-localise.

[Also see the Oral Questions of Expt. 5.2.]

## 5.4 Determination of the radius of curvature of the lower surface of a plano-convex lens by using Newton's ring apparatus :

• **Apparatus :** Newton's ring apparatus consists of a plano-convex lens $L$ whose convex surface (having large radius of curvature) is placed in contact with a plane glass plate $G$ (Fig. 5.4-1). This lens-plate combination is enclosed in a cylindrical case provided with three levelling screws. The inside of the case is painted black while the top of the case is open and is provided with a screw cap by which suitable pressure can be uniformly applied on the rim of the lens.

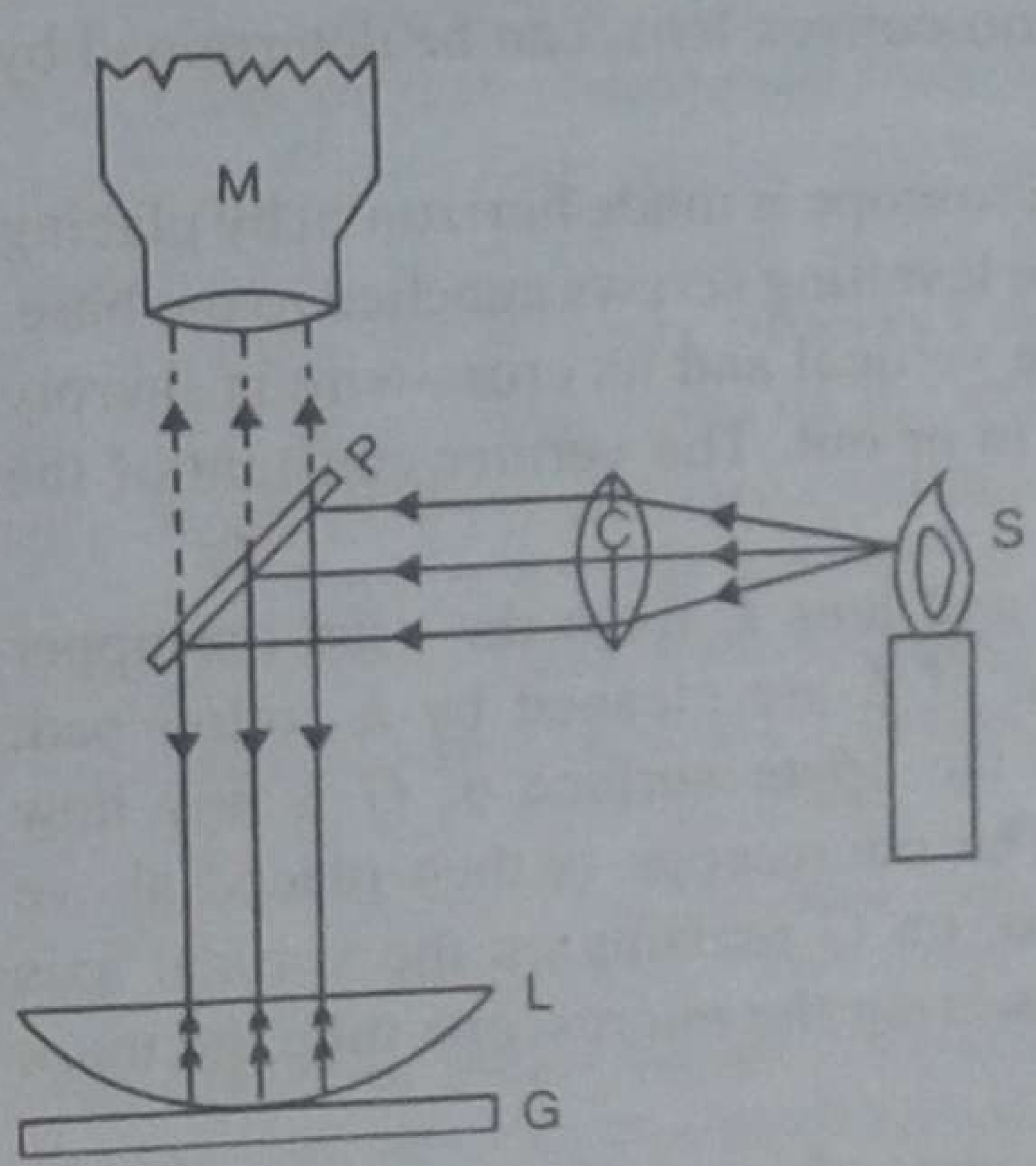


Fig. 5.4-1

A plane-parallel glass plate $P$ is kept above the top of the case by making an angle of 45° with the vertical. Light from a monochromatic source $S$ is made parallel by a convex lens $C$ and is made to fall on the glass plate $P$ at an angle of 45°. These rays will be reflected downwards and will fall normally on the air-film, enclosed between the glass plate $G$ and the convex surface of the plano-convex lens $L$. Newton's rings can be viewed by a low power microscope $M$ from above.

• **Theory :** When a parallel beam of monochromatic light of wavelength $\lambda$ is made incident on the wedge-shaped film of air enclosed between a glass plate $G$ and the convex surface of a plano-convex lens $L$ of long focal length each incident ray on the air-film will give rise to two reflected rays by reflection from the front and back surfaces of the air-film (Fig. 5.4-2). These two reflected rays will interfere (for they are coherent) and will produce alternate bright and dark concentric rings, having darkness at the common centre.

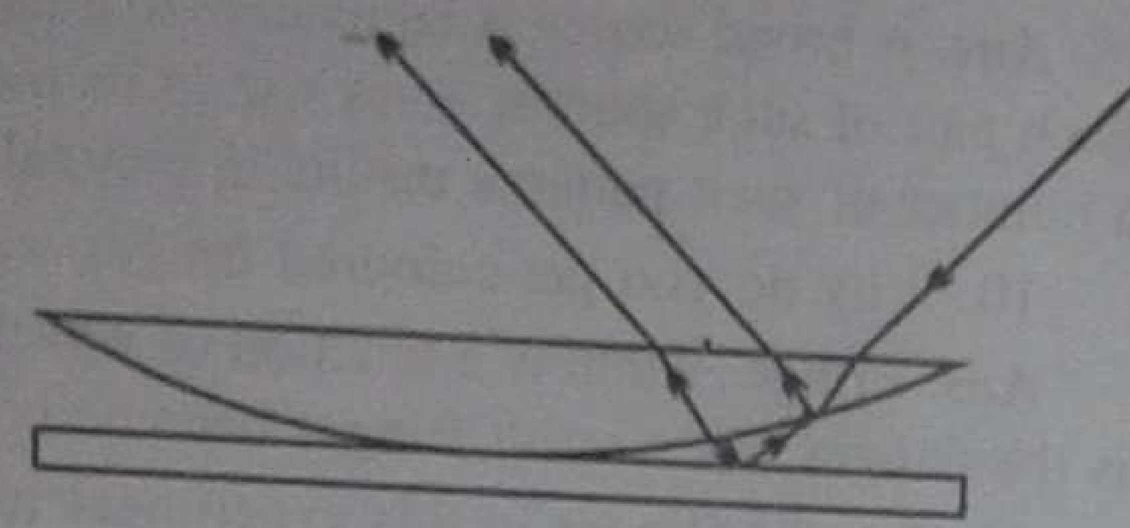

Fig. 5.4-2

If $D_n$ and $D_{n+s}$ be the diameters of $n$-th and $(n+s)$-th bright or dark rings then the wavelength $\lambda$ of the incident monochromatic light (incident almost normally) is given by,

$$\lambda = \frac{D^2_{n+s} - D^2_n}{4Rs} \quad \text{... (5.4-1)}$$

By measuring the diameters $D_n$ and $D_{n+s}$ of $n$-th and $(n+s)$-th bright or dark rings and by knowing the wavelength $\lambda$ of the light employed the radius of curvature $R$ of the convex surface of plano-convex lens, can be determined by using this relation.

- **Procedure :** (*i*) The base of the microscope is made horizontal by placing a spirit level on the base and adjusting the levelling screws attached to the base. The axis of the microscope tube is made vertical and its cross-wire is sharply focussed by moving the focussing lens in or out. The vernier constant of the horizontal scale is determined.

(*ii*) Taking away the glass plate $G$ and lens $L$ from the case the upper surface of $G$ and lower convex surface of $L$ are cleaned by a cotton pad, moistened with alcohol. The centre of the upper surface of $G$ is any how marked and inserted within the case. The microscope is then placed above the plate $P$ in such a way that this mark on $G$ remains on the vertical axis of the microscope tube. By raising or lowering the microscope tube the mark on $G$ is focussed.

(*iii*) The lens $L$ is now placed on the glass plate so that its convex surface may remain in contact with the marked point on $G$. By applying the screw cap at the mouth of the case a suitable pressure is applied. The sodium flame (which may be the usual sodium vapour lamp) is placed at the focus of the convex lens $C$. The parallel rays from the lens $C$, after being reflected from the plate $P$, are made incident on the air-film (enclosed between $L$ and $G$) normally. This time, on looking through the microscope alternate bright and dark rings will be seen. The microscope tube is then slowly adjusted until the rings are focussed as distinctly as possible.



(*iv*) The glass plate $P$ is then adjusted by rotating it about a horizontal axis until a large number of uniformly illuminated rings are seen. Then the position of the flame $S$ with respect to the lens $C$ is adjusted until a large number of rings are visible through the microscope.

(*v*) The case containing the lens-plate combination is slightly adjusted until the point of intersection of the cross-wire coincides with the centre of the central dark ring and one of the cross-wires becomes perpendicular to the line of movement of the microscope and also tangential to the bright or dark rings.

(*vi*) Counting from the first clear ring, which may be called as $p$-th ring (as the first few rings are indistinct, it is difficult to know the order number of the first clear ring), the microscope is shifted towards the left until one of its cross-wires becomes tangential to the remotest distinctly observed bright or dark ring. The ring number (counted from the first clear ring which was called as the $p$-th ring) of this ring is noted, as well as the position of the microscope is noted from the horizontal scale and vernier. The microscope is then displaced towards right and the same line of the cross-wires is made tangential to the next lower numbered ring. (If you get a large number of rings then readings may be taken for every third or fifth ring.) The readings of the horizontal scale and vernier are again noted. This process of recording the ring number and the vernier readings of the horizontal scale is continued from one ring to the next, until we arrive through the centre to the extreme distinctly observed ring on the right whose order number is the same as was first noted on the extreme left. When tabulating the positions of the microscope, the two readings for the opposite ends of each ring are entered opposite to one another in a single row.

(*vii*) Another set of observations may be taken by starting from the extreme right-end and ending in the extreme left-end of the same remotest distinctly observed ring as was employed in the former set. The difference of the two microscope readings corresponding to the two ends (one in the left and another in the right) of each ring will be give the diameter of that ring. Thus from two sets of observations (one starting from left and another starting from right), we get two values of the diameter of each ring. The mean of these two values will give the diameter of the ring.

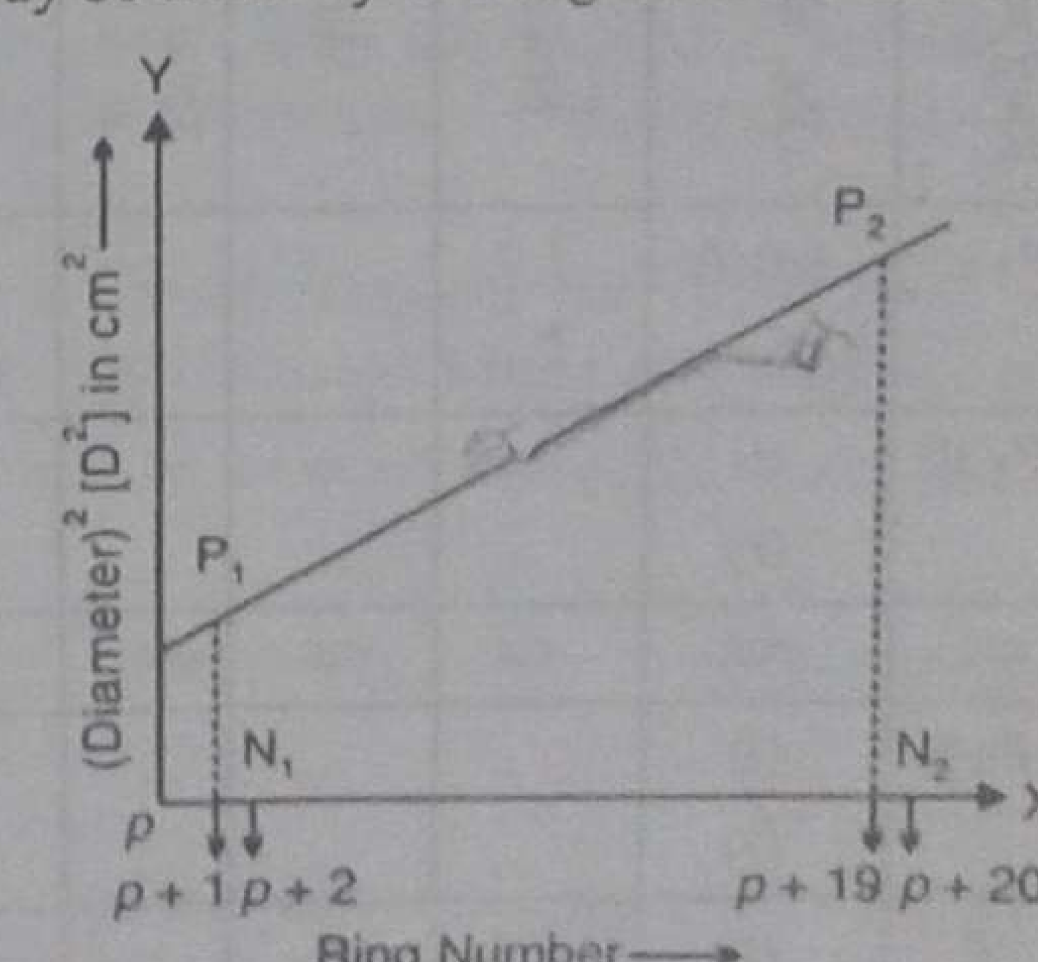


Fig. 5.4-3

*(viii)* If a curve be drawn with the square of the diameter ($D^2$) of a ring as ordinate and the corresponding ring number as abscissa then the graph would be a straight line as shown in the Fig. 5.4-3. Two points $P_1$ and $P_2$ are taken on this graph as far apart as possible. The ordinate of $P_2$ is $P_2N_2 = D^2_{n+s}$ (say) while the ordinate of $P_1$ is $P_1N_1 = D^2_n$ (say). $N_1N_2 = s$ = difference of ring numbers. Hence the slope of this straight line is $m = \dfrac{P_2N_2 - P_1N_1}{N_1N_2}$ or, $m = \dfrac{D^2_{n+s} - D^2_n}{s}$. Finding $P_2N_2$, $P_1N_1$ and $N_1N_2$ from the graph, the value of the radius of curvature is given by $R = m/4\lambda$.

- **Experimental data :**

(A) *Vernier constant of the microscope employed :*
[See examples of Art. 2.1.]

(B) *Determination of the diameter (D) of rings :*

**TABLE I**

[Specific values of $s$ are given for illustration only]

| Ring number | Obs. started from | Reading of microscope for the | | | | | | Diameter $D = (R_1 \sim R_2)$ | Mean $D$ in cm |
|---|---|---|---|---|---|---|---|---|---|
| | | (*a*) left-end of the ring | | | (*b*) right-end of the ring | | | | |
| | | Scale ($S$) in cm | Vernier (*v.r.*) | Total reading in cm $R_1 = S + v.r. \times v.c.$ | Scale ($S$) in cm | Vernier (*v.r.*) | Total reading in cm $R_2 = S + v.r. \times v.c.$ | | |
| $P+35$ | left($l$) | $\downarrow l$... | ... | ... | ... $\uparrow l$ | ... | ... | ... | ... |
| | right ($r$) | $\uparrow r$... | ... | ... | $\downarrow r$... | ... | ... | ... | |
| $P+30$ | ($l$) | ... | ... | ... | ... | ... | ... | ... | ... |
| | ($r$) | ... | ... | ... | ... | ... | ... | ... | |
| etc. | etc. | etc. | etc. | etc. | etc. | etc. | etc. | etc. | etc. |
| $P+5$ | ($l$) | ... | ... | ... | ... | ... | ... | ... | ... |
| | ($r$) | ... | ... | ... | ... | ... | ... | ... | |
| $P$ | ($l$) | $\downarrow l$... | ... | ... | ... $\uparrow l$ | ... | ... | ... | ... |
| | ($r$) | $\uparrow r$... | ... | ... | $\downarrow r$... | ... | ... | ... | |



N.B. [In the first set, when Obs. started from left $\downarrow l$ readings (*a*) were taken first and then the readings (*b*), while in the second set, when Obs. started from right $\downarrow r$ readings (*b*) were taken first and then the readings (*a*)].

(C) *Data for drawing graph :*

**TABLE II**

| Ring number | $p$ | $p+5$ | $p+10$ | ... | $p+35$ |
|---|---|---|---|---|---|
| $D^2$ in cm$^2$ | ... | ... | ... | ... | ... |

(D) *Determination of R from graph :*

**TABLE III**

[Wavelength of given light = $\lambda$ = ... cm]

| $P_1N_1 = D^2_n$ in cm$^2$ | $P_2N_2 = D^2_{n+s}$ in cm$^2$ | $N_1N_2 = s$ | $R = \dfrac{D^2_{n+s} - D^2_n}{4s\lambda}$ cm |
|---|---|---|---|
| ... | ... | ... | ... |

- **Precautions and Discussions :** *(i)* As the first few rings are indistinct, it is very difficult to ascertain the exact ring number of the first clearest ring.

*(ii)* In this arrangement, the rings (which are formed in the air-film lying in the space between the lens and the glass plate) are seen after refraction through the lens and the error due to this is very small if the lens employed is thin.

*(iii)* When the rings are visible in the microscope, it may sometimes be necessary to shift the lens to and fro and across to get bright and clear bands.

*(iv)* The central indistinct rings should be avoided while taking readings.

- **Maximum percentage error :**

$$R = \frac{D^2_{n+s} - D^2_n}{4\lambda s}$$

$$\left(\frac{\delta R}{R}\right)_{max} = \frac{\delta(D^2_{n+s} - D^2_n)}{D^2_{n+s} - D^2_n} = \frac{2D_{n+s}\,\delta D + 2D_n\,\delta D}{D^2_{n+s} - D^2_n} = \frac{2\delta D}{D_{n+s} - D_n}$$

11. What type of fringes do you get here?

*Ans.* Fringes of equal width.

12. Are the rings equi-spaced?

*Ans.* No, the rings get closer with the increase in diameters.

13. Can you measure the wavelength of light by this experiment?

*Ans.* Yes. If the radius of curvature is known then measuring the diameter of the rings $\lambda$ can be determined.

14. Can the radius of curvature be measured by a spherometer?

*Ans.* The radius of curvature of the lens used here is very large so the elevation of the central screw of the spherometer will be small causing large error in measurement.

15. Is light energy destroyed in the dark regions?

*Ans.* No. There is only a redistribution of energy.

## 5.4(a) Determination of the wavelength of a monochromatic light by Newton's ring method :

- **Apparatus** : [See Expt. 5.4.]
- **Theory** : [Write the theory of Expt. 5.4 upto the equation (5.4-1) and then add the following.]

The radius of curvature $R$ of the convex surface of the plano-convex lens can be measured by a spherometer using the formula,

$$R = \frac{d^2}{6h} + \frac{h}{2} \qquad \text{... (5.4-2)}$$

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

By measuring the diameters $D_n$ and $D_{n+s}$ of $n$-th and $(n+s)$-th bright or dark rings and finding $R$ from equation (5.4-2), the wavelength $\lambda$ can be determined by using the relation (5.4-1).

- **Procedure** : (*i*)–(*vii*) Same as in Expt. 5.4.

(*viii*) By removing the screw cap, the lens $L$ is taken out and the radius of curvature ($R$) of the lower convex surface of the lens $L$ is measured by an accurate spherometer (See Art. 2.5 on spherometer).

Usually the radius of curvature of the lens used in this experiment is very large and the elevation '$h$' of the central screw of spherometer is small, causing much error in the measurement. In such a situation '$R$' can be first measured by using a light of known $\lambda$ (as in Expt. 5.4) and then this '$R$' can be used to find unknown $\lambda$. '$R$' can also be measured by **Boy's method.**

- **Experimental data :**

(A) & (B) : Same as in Expt. 5.4.

(C) *Measurement of the radius of curvature (R) of the lower convex surface of the lens :*

[Calculate least count, measure distance between legs and make a spherometer chart as in Art. 2.5]

(D) Same as item (C) in Expt. 5.4.

(E) *Determination of $\lambda$ from graph :*

[Make the TABLE III of Expt. 5.4, where in the last column write $\lambda = \dfrac{D_{n+s}^2 - D_n^2}{4R \cdot s}$ in cm ]

- **Precautions and Discussions :** (*i*)–(*v*) Same as in Expt. 5.4.

(*vi*) Greatest source of error is in the measurement of $R$. As the radius of curvature of the convex surface of plano-convex lens is very large, '$h$' is small and the spherometer method of finding it is not accurate. The better method of finding $R$ is to employ a light of known $\lambda$ and then to use this $R$ to find unknown $\lambda$.

- **Maximum percentage error :**

$$\lambda = \frac{D_{n+s}^2 - D_n^2}{4Rs}$$

$$\left(\frac{\delta\lambda}{\lambda}\right)_{max} = \frac{\delta R}{R} + \frac{2(D_{n+s} + D_n)\delta D}{D_{n+s}^2 - D_n^2} = \frac{\delta R}{R} + \frac{2\delta D}{D_{n+s} - D_n}$$

where $R = \dfrac{d^2}{6h} + h/2$

$$\simeq \frac{d^2}{6h} \qquad [\because h \text{ is small}]$$

$$\therefore \left(\frac{\delta R}{R}\right)_{max} = 2\frac{\delta d}{d} + \frac{\delta h}{h}$$

Now using, $\delta D = 2 \times$ v.c. of microscope

$\delta d = 0.1$ cm (1 div. of metre scale)

$\delta h = 2 \times$ l.c. of spherometer

and a typical set of experimental data we can calculate $\left(\dfrac{\delta\lambda}{\lambda}\right)_{max} \times 100\%$.