Date 10-02-2022

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"Newton's Rings"

Objective:- To determine wavelength of monochromatic sodium light with the help of Newton's rings arrangement.

Apparatus:- A plano convex lens of large radius of curvature, a plane glass plate, sodium lamp, 45° inclined glass plate arrangement, a traveling microscope, reading lens, a lamp and a spherometer.

Theory:- The newton's rings experiment shows the interference of light waves reflected from the surfaces of a thin film of variable thickness. The two interfering beams are coherent because they are derived from same light ray. The gap between glass plate and curved surface of lens can be considered as a thin wedge shaped air film. The experiment produces ring shaped pattern.

A horizontal beam of monochromatic light falls on a glass plate inclined at 45°. The glass plate partially reflects the part of incident light towards the lens. The light beam incident on lens is further reflected partially from curved surface of lens and partially transmitted towards glass plate.

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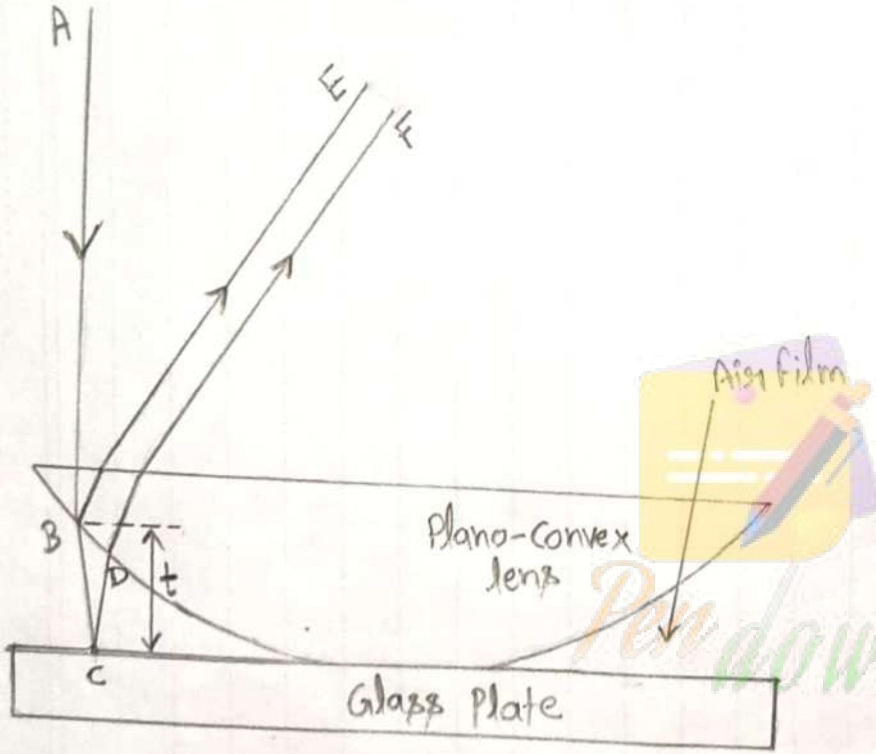
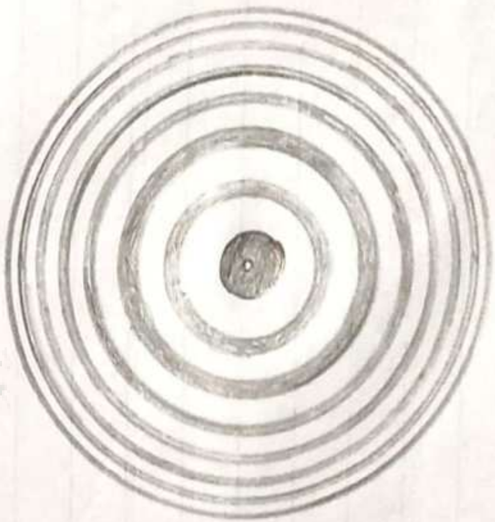
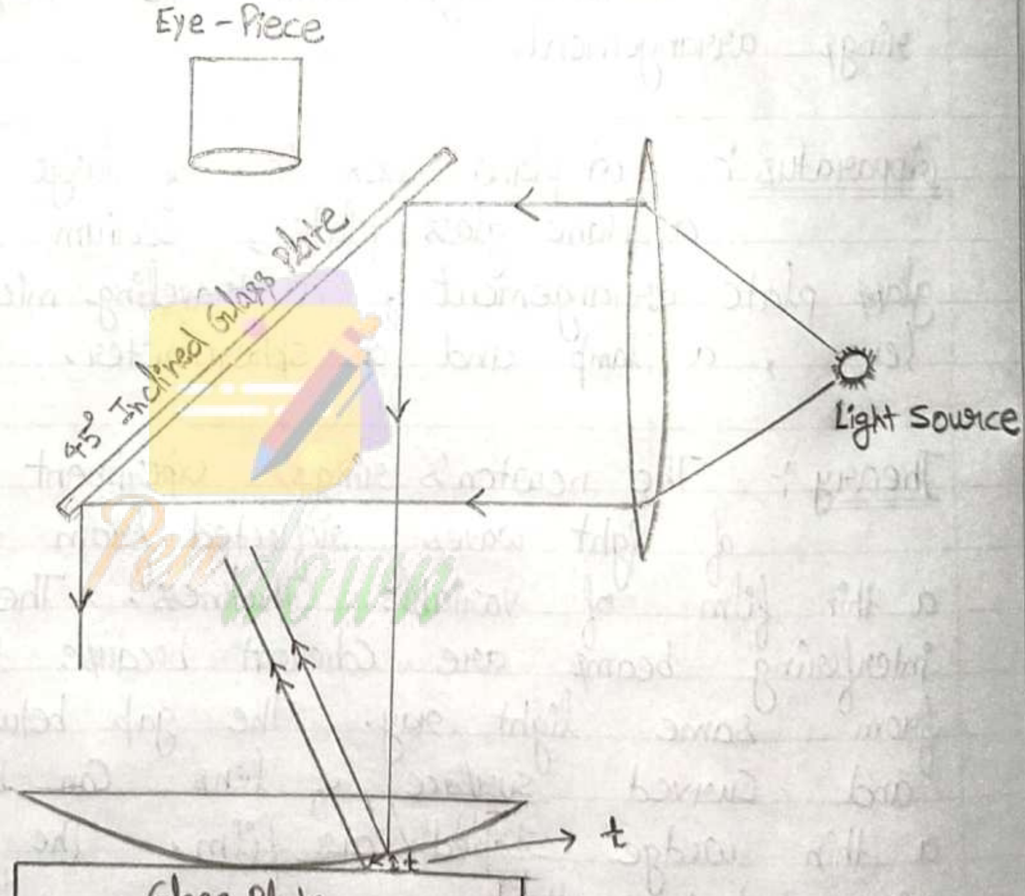


☐ Schematic Diagram of light rays in Newton's Ring



☐ Newton's ring



Schematic for Newton's ring arrangement.

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The light incident on glass plate again partially reflected is further reflected from the thin film and then observed from the microscope placed on the top. The dark and bright circular concentric fringes are seen due to interference.

The phase difference between beams reflected from a point r distance away from the centre can be calculated as follow:

$$\text{Phase difference} = \frac{2\pi}{\lambda}\left(\text{additional path travelled by one of the beam.}\right) + \pi$$

$$\simeq \frac{2\pi}{\lambda}(2t) + \pi$$

$$= \frac{4\pi}{\lambda}\left(R - \sqrt{(R^2 - r^2)}\right) + \pi$$

$$= \frac{4\pi R}{\lambda}\left(1 - \left(1 - \frac{r^2}{2R^2}\right)\right) + \pi \quad \text{(by binomial theorem.)}$$

$$= \frac{2\pi r^2}{\lambda R} + \pi$$

Here phase difference due to reflection is taken π.
In order to get bright rings, we must have constructive interference i.e. phase difference between two reflected beam must be $0, \pm 2\pi, \pm 4\pi$ ..... , $\pm 2n\pi$.

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For n-th bright / dark ring, we have

For Bright ring

$$2\pi n = \frac{2\pi r_n^2}{\lambda R} + \pi$$

Therefore $r_n^2 = \left(n - \frac{1}{2}\right)\lambda R$

$$\boxed{\lambda = \frac{D_{n+p}^2 - D_n^2}{4PR}}$$

For Dark ring

$$(2n+1)\pi = \frac{2\pi r_n^2}{\lambda R} + \pi$$

Therefore $r_n^2 = 2n\lambda R$

$$\boxed{\lambda = \frac{D_{n+p}^2 - D_n^2}{4PR}}$$

where $\boxed{D_n = 2r_n}$

Procedure :-

- Switch on the source light
- Determine the Least Count of the travelling microscope.
- Clean the glass plate and the lens surface and place the curved surface of the lens over the glass plate and below the 45° inclined glass plate.
- Move the microscope in vertical direction to focus the Ramsden's eye piece of the microscope on its cross wire. Set the cross ~~at~~ wire at the central dark ring.

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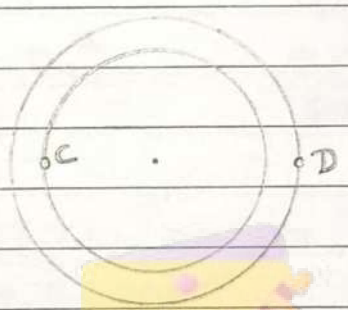
- In order to calculate diameter of a ring with inner and outer boundry, we measure the seperation between C and D i.e. outer boundry on one side and inner boundry on the other side.



- Now rotate slowly the knob in reverse direction and record observations.

Observations :-

Value of one main scale division of travelling microscope = 0.1cm

Total number of divisions on vernier scale = n = 100

Least Count of microscope = $\frac{0.1}{100}$ cm = 0.001cm

Let value of P = 4

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★ Determination of $D_{n+p}^2 - D_n^2$:- (P=4)

order of the ring (n)	Reading for the inner surface of left side of the ring.			Reading for the outer surface of right side of the ring			Diameter $\lvert x_l - x_r \rvert$ (cm)	D_n^2 (cm^2)	$D_{n+p}^2 - D_n^2$ $(cm)^2$	Mean $(cm)^2$
	Main scale (cm)	vernier scale (cm)	Total (x_l) (cm)	Main scale (cm)	vernier scale (cm)	Total (x_r) (cm)				
20	0.3	0.024	0.324	-0.3	-0.026	-0.326	0.650	0.4225	$D_{20}^2 - D_{16}^2 = 0.093$	
18	0.3	0.011	0.311	-0.3	-0.009	-0.309	0.620	0.3844	$D_{18}^2 - D_{14}^2 = 0.109$	
16	0.2	0.081	0.281	-0.2	-0.093	-0.293	0.574	0.3295	$D_{16}^2 - D_{12}^2 = 0.103$	
14	0.2	0.060	0.260	-0.2	-0.068	-0.268	0.528	0.2788	$D_{14}^2 - D_{10}^2 = 0.089$	0.0983
12	0.2	0.038	0.238	-0.2	-0.038	-0.238	0.476	0.2266	$D_{12}^2 - D_8^2 = 0.098$	
10	0.2	0.016	0.216	-0.2	-0.019	-0.219	0.435	0.1892	$D_{10}^2 - D_6^2 = 0.098$	
08	0.1	0.078	0.178	-0.1	-0.081	-0.181	0.359	0.1289		
06	0.1	0.049	0.149	-0.1	-0.053	-0.153	0.302	0.0912		

★ Radius of Curvature (R) = 100.0075 cm

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Calculations :-

we have, $R = 100.0075 cm$

$D_{n+p}^2 - D_n^2 = 0.0983 \; cm^2$

$p = 4$

then

$$\lambda = \frac{D_{n+p}^2 - D_n^2}{4PR} = \frac{0.0983}{4 \times 4 \times 100.0075} \; cm$$

$$\lambda = 6.143 \times 10^{-5} \; cm = 6.143 \times 10^{-7} \; m$$

or $\boxed{\lambda = 614.3 \; nm}$

Method II :- From Graph, slope of line $= 4\lambda R$

$$\text{slope of line} = \frac{AB}{BC} = \frac{0.423 - 0.135}{20 - 8} = 0.024$$

$$\text{slope of line} = \frac{MN}{PN} = \frac{0.330 - 0.225}{16 - 12} = 0.026$$

Taking Mean of both slopes, we get

slope of line $= 0.025$.

Now $0.025 = 4\lambda(100.0075)$

$\lambda = 6.249 \times 10^{-5} \; cm$

or

$\boxed{\lambda = 624.9 \; nm}$

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Result :- The wavelength of sodium light is 614.3 nm

Precautions :- ① The microscope should be parallel to the edge of the glass plate.

② If you place the cross wire tangential to the outer side of a ring on one side of the central spot then the cross wire should be placed tangential to the inner side of the same numbered ring on the other side of central spot.

③ The travelling microscope should move only in one direction.

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