Engineering Optics

Lecture 9

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by

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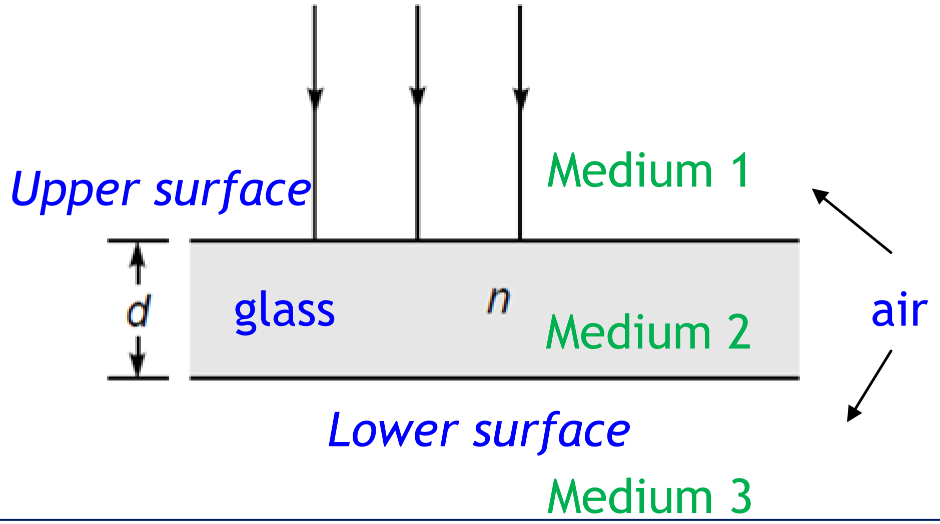
Amplitude-Splitting (normal incidence)



Earlier

$(r_1 - r_2)$ or $S_2P\text{-}S_1P = m\,\lambda$ **Maxima**

$=(m+\frac{1}{2})\lambda$ **Minima**

$$2nd = m\lambda \qquad \text{destructive interference} \qquad \textbf{(1a)}$$

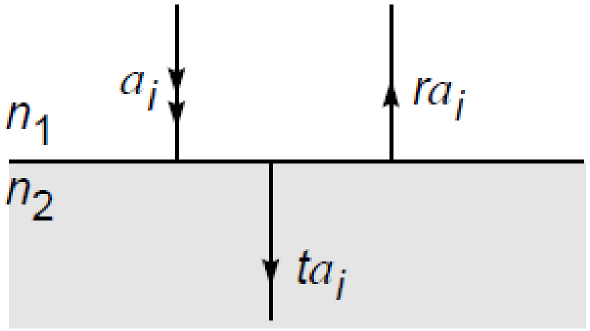
$$= \left(m+\tfrac{1}{2}\right)\lambda \qquad \text{constructive interference} \qquad \textbf{(1b)}$$

where $m = 0, 1, 2, \ldots$ and λ represents the free space wavelength.

Now

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta$$

Optics, by Hecht; Ghatak



amplitudes of the reflected and the transmitted beams are a_r and a_t, respectively.

$$a_r = \frac{n_1 - n_2}{n_1 + n_2} a_i$$

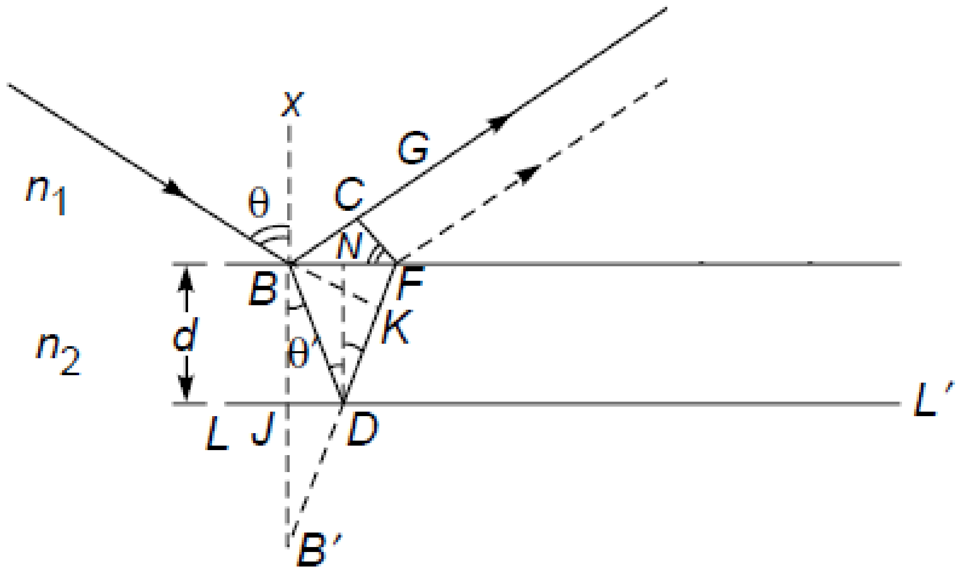
$$a_t = \frac{2n_1}{n_1 + n_2} a_i$$

$\boxed{\text{when } n_2 > n_1}$ a_r becomes –ve → Π phase difference

When $n_2 < n_1$ → a_r is +ve → no phase difference

Optics, Ghatak

Oblique incidence



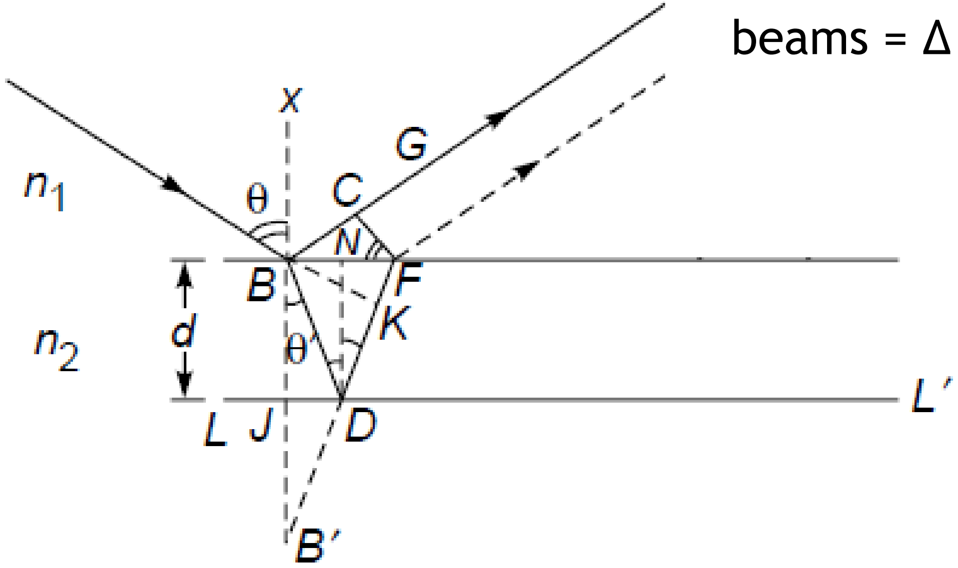
Path diff. = ??

Conditions for Maxima and minima ?

Optics, Ghatak

*https://thefactfactor.com/tag/reflection-at-boundary-of-rarer-medium/

Oblique incidence



Pathlength difference between two interfering beams = Δ

$$\Delta = n_2(BD + DF) - n_1 BC$$

Reference→ Optics book, Ghatak: 15.3 'The cosine law'

$$\Delta = 2n_2 d \cos\theta' = m\lambda \qquad \text{minima}$$

$$= \left(m + \tfrac{1}{2}\right)\lambda \qquad \text{maxima}$$

Optics, Ghatak

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Problem1:

The yellow line from a sodium discharge lamp has a vacuum wavelength of 5895.923Å. Suppose such light falls at 30° on the surface of a film of soybean oil ($n = 1.4729$) suspended (within a wire frame) in air.

What minimum thickness should the film have in some region if that area is to strongly reflect the light?

Answer:

Incident angle $\theta_i = 30°$

$[i = incident, t = transmitted\ waves]$

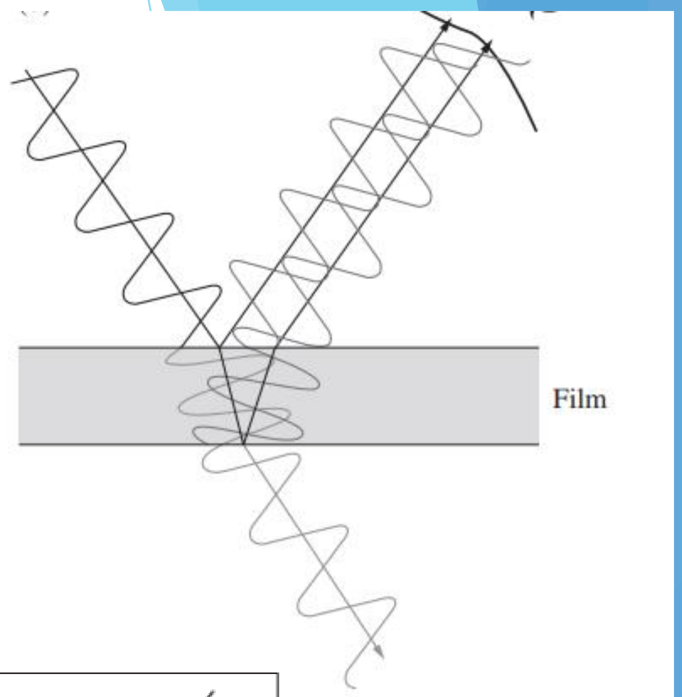
$n_t = 1.4729, n_i = 1.0$

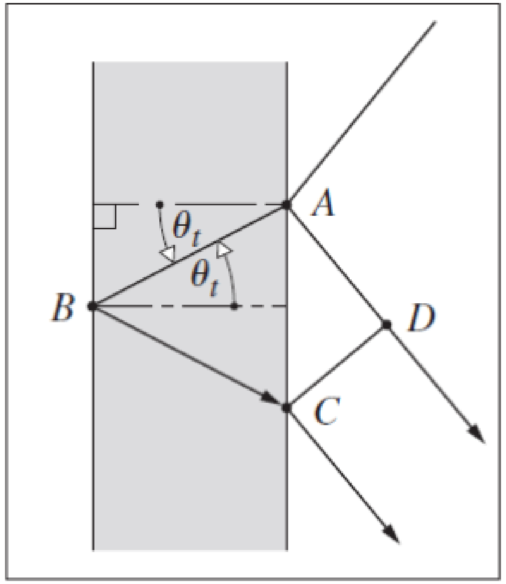
From Snell's law $n_i sin\theta_i = n_t sin\theta_t$

$$sin\theta_t = \frac{n_i sin\theta_i}{n_t}$$

$$sin\theta_t = \frac{sin30.00°}{1.4729} = 0.3395$$

$$\theta_t = 19.844°$$





For a reflected maxima to obtain,

$2n_t d cos\theta_t = \left(m + \frac{1}{2}\right)\lambda$ [remember the usual interference conditions change for reflection by denser media]

$m = 0$ to obtain minimum thickness

Thickness d is,

$$d = \frac{\lambda}{4n_t cos\theta_t}$$

$$d = \frac{5895.923 \times 10^{-10}\ m}{4 \times 1.4729 \times cos19°} = 106.4 \text{ nm}$$

Various fringes

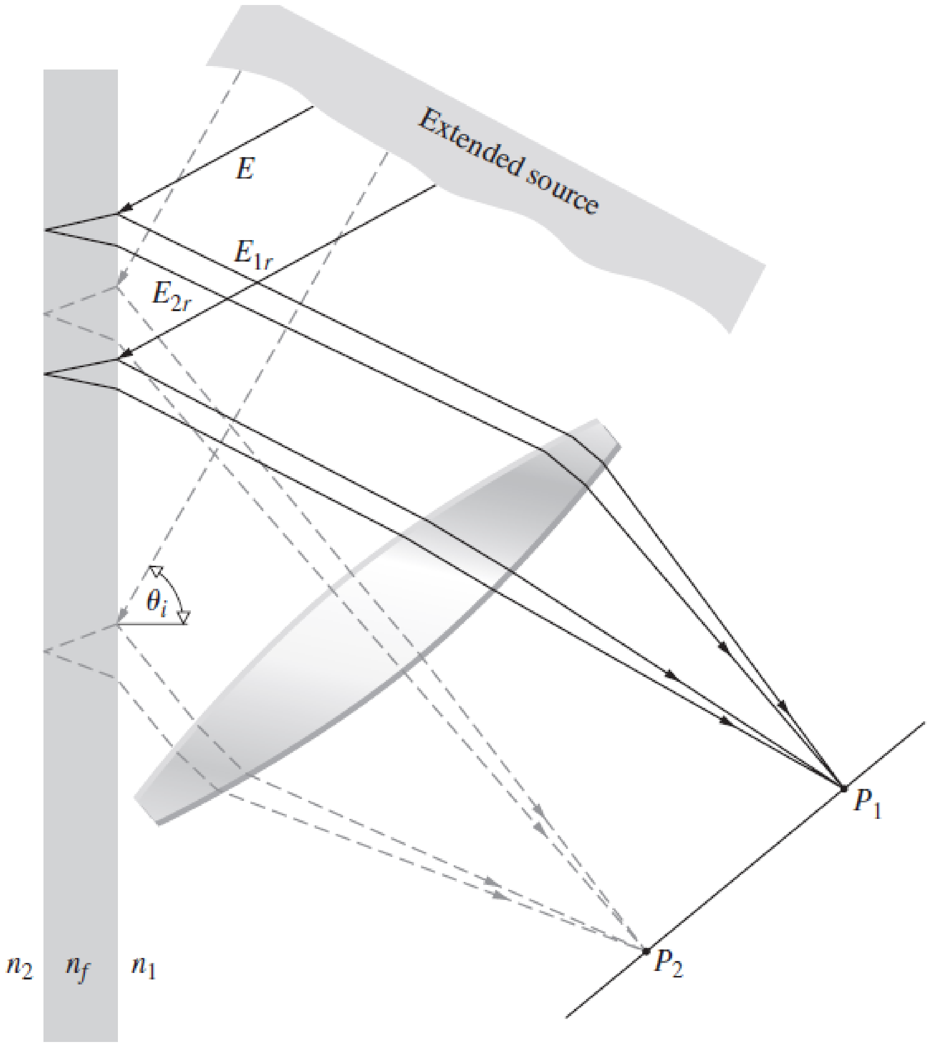


Figure 9.31 All rays inclined at the same angle arrive at the same point.

Fringes of equal inclination

→ **Haidinger fringes**

Fringes of equal thickness

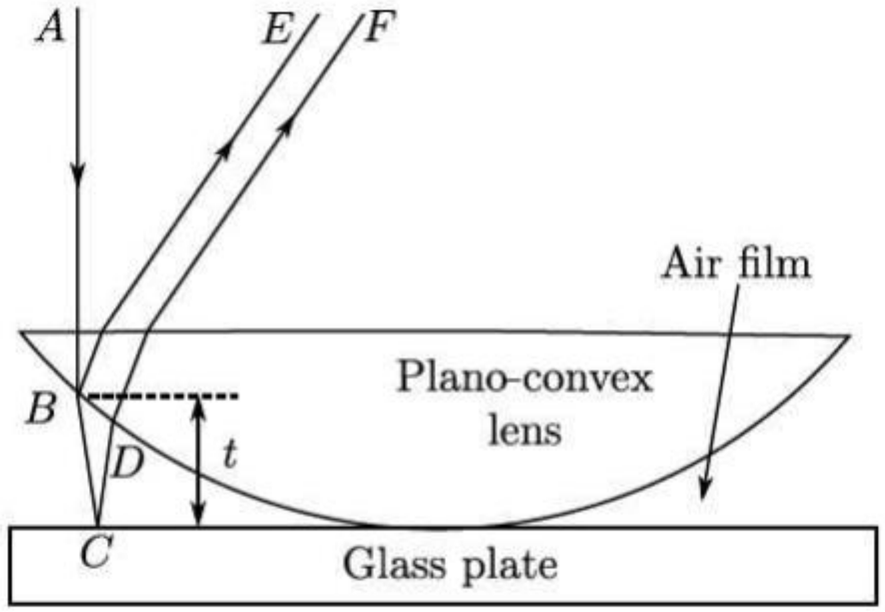
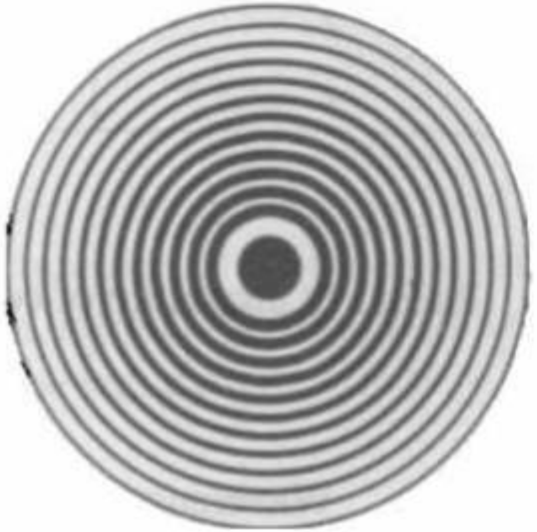


Figure 6.2: Schematic diagram of the light rays

Name?



Fringes of equal thickness

https://aashish157.github.io/Physics-Lab-Website/rings.html

Optics, Hecht; Ghatak

Fringes of equal thickness

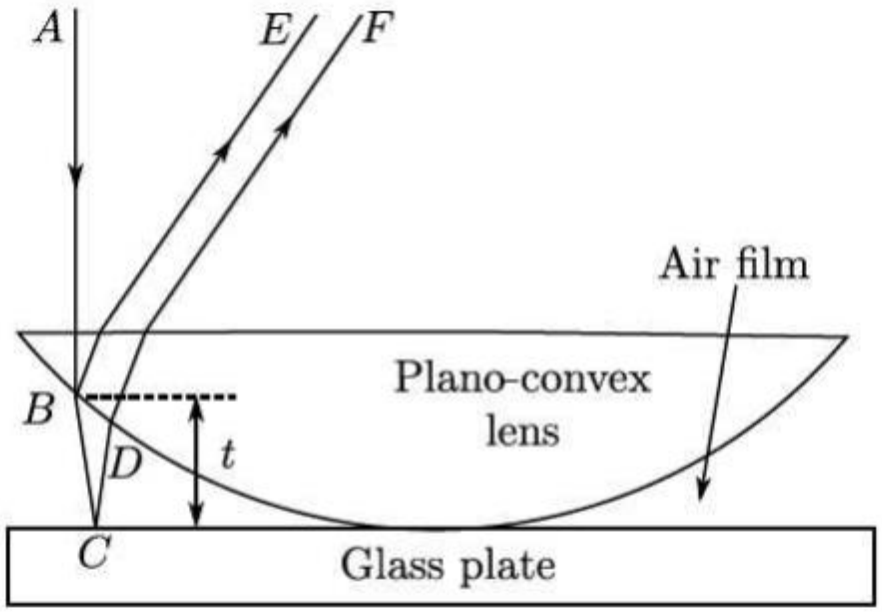
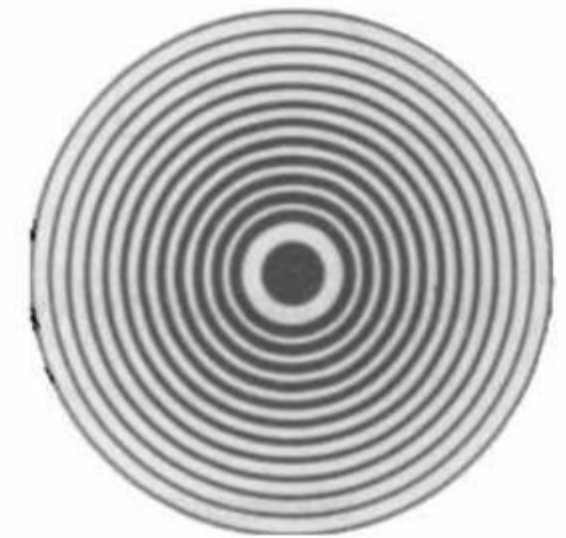


Figure 6.2: Schematic diagram of the light rays



Thus, whenever the thickness of the air film satisfies the condition

$$2nt = \left(m + \tfrac{1}{2}\right)\lambda \qquad m = 0, 1, 2, \ldots$$

we will have maxima. Similarly the condition

$$2nt = m\lambda$$

will correspond to minima.

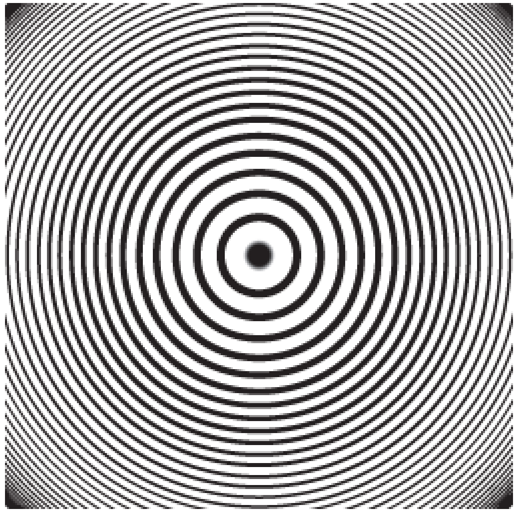
Fringes of equal thickness

Newton's Ring

Q: why is the center dark?

https://aashish157.github.io/Physics-Lab-Website/rings.html

Optics, Hecht; Ghatak



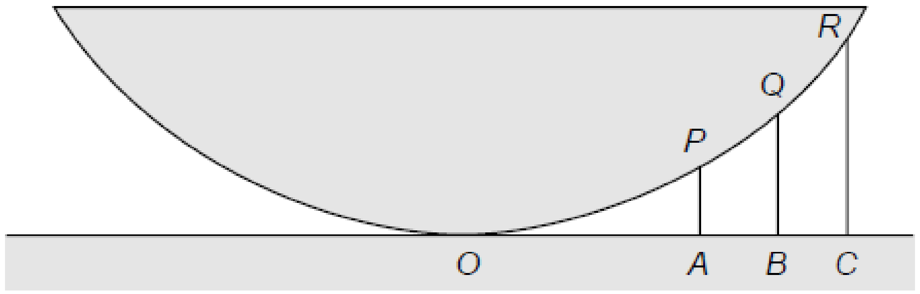
radius of the mth dark ring is

$$r_m^2 \approx m\lambda R$$

where $m = 0, 1, 2, \ldots$, and the central dark circle (in reflected light) corresponds to $m = 0$. Then the first dark ring arises for $m = 1$, the second for $m = 2$, and so forth.

a bright ring whose radius will be

$$\sqrt{m + \tfrac{1}{2}}\,\lambda R.$$

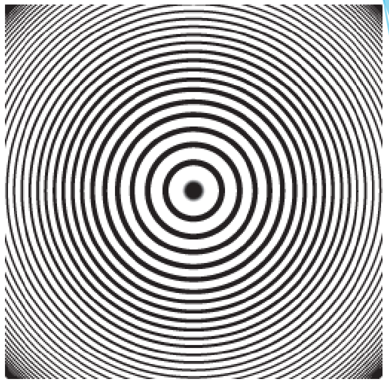


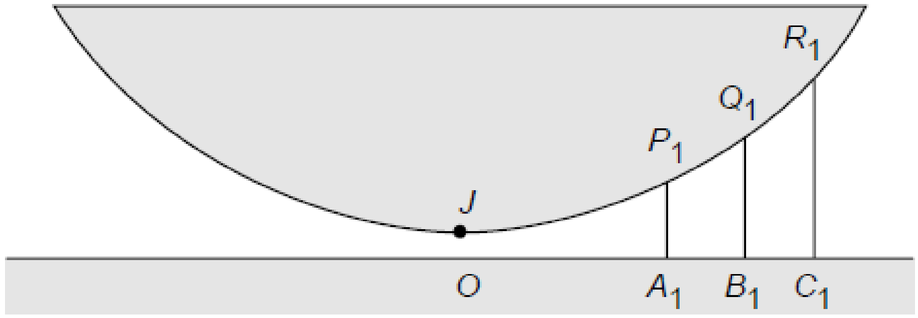
(a)

$PA = \lambda/2$

$QB = \lambda$

$RC = 3\lambda/2$





(b)

$JO = \lambda/4$

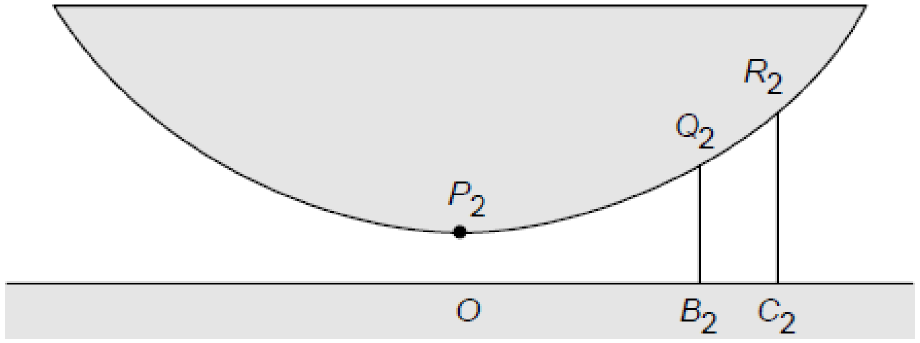
$P_1A_1 = \lambda/2$

$Q_1B_1 = \lambda$

$R_1C_1 = 3\lambda/2$

Q: What happens to the fringes?

Q: If distance by which the lens is lifted is given to you, can you guess the number of fringes collapsed?



(c)

$P_2O = \lambda/2$

$Q_2B_2 = Q_1B_1 = QB = \lambda$

$R_2C_2 = R_1C_1 = RC = 3\lambda/2$

Thus, whenever the thickness of the air film satisfies the condition

$$2nt = \left(m + \tfrac{1}{2}\right)\lambda \qquad m = 0, 1, 2, \ldots$$

we will have maxima. Similarly the condition

$$2nt = m\lambda$$

will correspond to minima.

Problem-1

Consider the formation of Newton's rings by monochromatic light of $\lambda = 6.4 \times 10^{-5}$ cm. Assume the point of contact to be perfect. Now slowly raise the lens vertically above the plate. As the lens moves gradually away from the plate, discuss the ring pattern as seen through the microscope. Assume the radius of the convex surface to be 100 cm.

Solution: Since the point of contact is perfect, the central spot will be dark, the first dark ring will form at P where $PA = \lambda/2$, and the radius of this ring OA will be $\sqrt{\lambda R}$ (= 0.080 cm); see Fig. 15.32(a). Similarly, the radius of the second dark ring will be $OB = \sqrt{2\lambda R}$ (= 0.113 cm). If we now raise the lens by $\lambda/4$ (= 1.6×10^{-5} cm), then $2t$ corresponding to the central spot would be $\lambda/2$ and instead of the dark spot at the center we will now have a bright spot. The radii of the first and the second dark rings will be

$$OA_1 = \left(\frac{1}{2}\lambda R\right)^{1/2} = 0.0566 \text{ cm}$$

and

$$OB_1 = \left(\frac{3}{2}\lambda R\right)^{1/2} = 0.098 \text{ cm}$$

respectively [see Fig. 15.32(b)]. If the lens is further moved by $\lambda/4$ (see Fig. 15.32(c)], then the first dark ring collapses to the center and the central spot will be dark. The ring which was originally at Q now shifts to Q_2; similarly the ring at R [Fig. 15.32(a)] collapses to R_2 [Fig. 15.32(c)].

Thus, as the lens is moved upward, the rings collapse to the center. Hence if we can measure the distance by which the lens is moved upward and also count the number of dark spots that have collapsed to the center, we can determine the wavelength. For example, in the present case, if the lens is moved by 6.4×10^{-3} cm, 200 rings will collapse to the center. If one carries out this experiment, it will be observed that the 200th dark ring will slowly converge to the center, and when the lens has moved by exactly 6.4×10^{-3} cm, it has exactly come to the center.

Thank You