Lecture 2-3: Optics - Interference

Optics by Ajoy Ghatak, 6E

Chapter 14, Two Beam Interference by division of wavefront
14.1 Introduction
14.4 Interference of Light waves
14.5 The interference pattern
14.6 The intensity distribution

Chapter 15: Interference by Division of Amplitude
15.1 Introduction
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Interference of waves

Colors of a humming bird’s feathers are not due to pigment.

It is due to the interference affect caused by structures in the feathers.

What is phase ?

for waves……

Phase is the position of a point in time on a cycle of a waveform. It is expressed in radians.

What is phase difference & path difference in waves ?

Phase difference and path difference are related as;

Phase difference, $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$; $\Delta x =$ path difference

What is wavefront?

A wavefront is a surface over which a light wave has a constant phase.

Converting wavefront from plane to speherical (2D view)

Plane wavefront (3D view)

Conditions to observe stationary interference pattern of light:

Interfering light waves should:

- have fixed phase relationship
- be monochromatic
- have equal or nearly equal amplitudes

How to achieve fixed phase relationship in light waves?

Division of wavefront

The coherent sources are obtained by dividing the wavefront, originating from a common source.

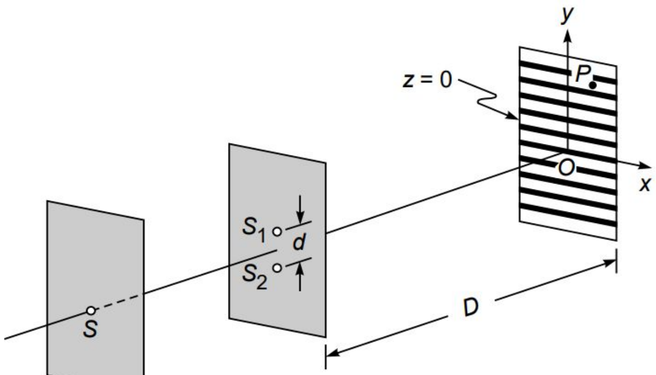
Examples:
Fresnel biprism, Fresnel mirrors, Lloyd's mirror, etc

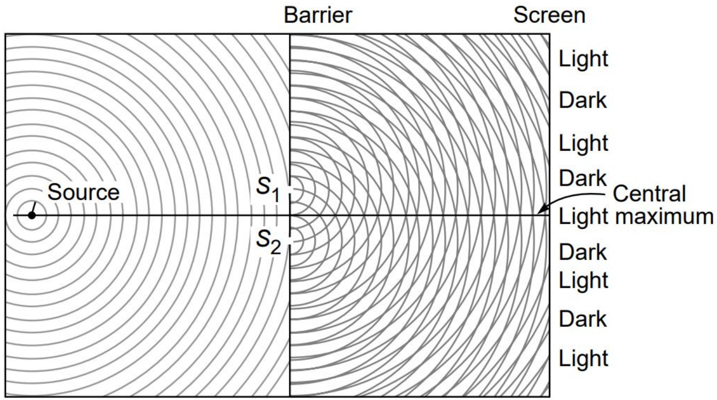
Division of amplitude

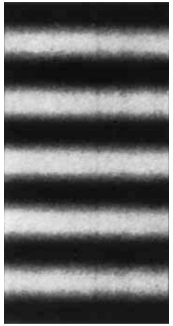
The amplitude of the incident beam is divided into two or more parts either by partial reflection or refraction.

Examples:
Michelson's interferometer, Interference in thin films, Newton's rings

Young's interference experiment







"light + light = dark"
"light + light = bright"

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Conditions for bright and dark fringes

Path difference between interfering waves:

$$S_2P - S_1P = n\lambda \qquad n = 0, 1, 2, \ldots$$

?

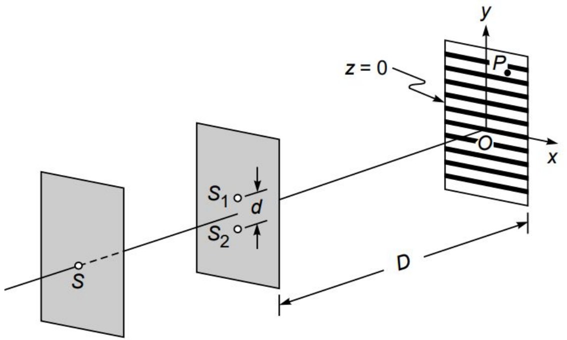
Path difference between interfering waves (by geometry) $S_2P - S_1P \approx \frac{y_n d}{D}$

Fringe position:

$$S_2P - S_1P = n\lambda \qquad n = 0, 1, 2, \ldots$$

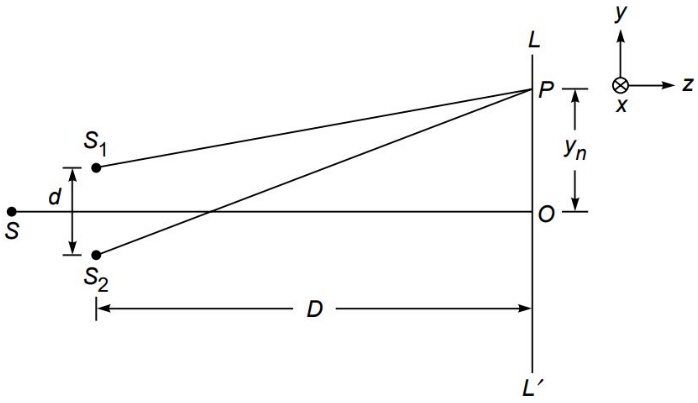
$$S_2P - S_1P \approx \frac{y_n d}{D}$$

$$y_n = \frac{n\lambda D}{d}$$



Fringe width:

$$\beta = y_{n+1} - y_n = \frac{(n+1)\lambda D}{d} - \frac{n\lambda D}{d} = \frac{\lambda D}{d}$$



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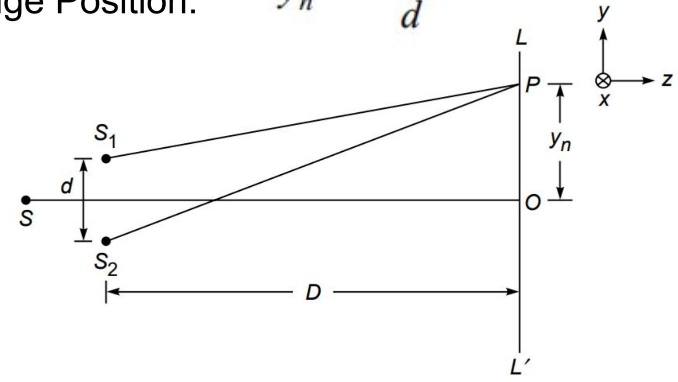
Question:

Hint:

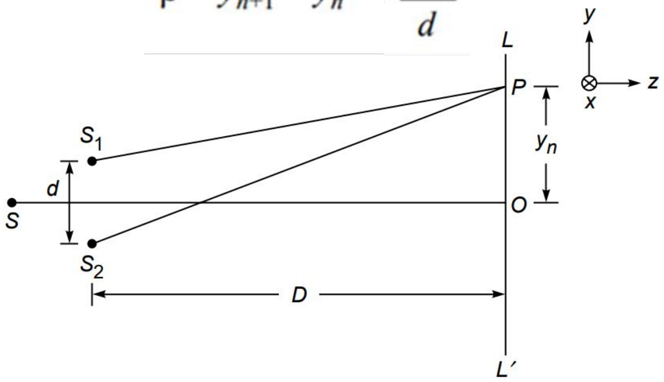
Fringe Position: $y_n = \dfrac{n\lambda D}{d}$



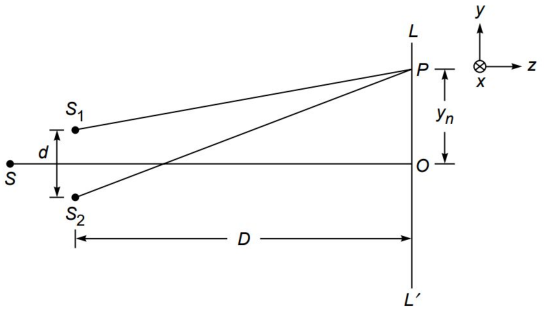
Question:

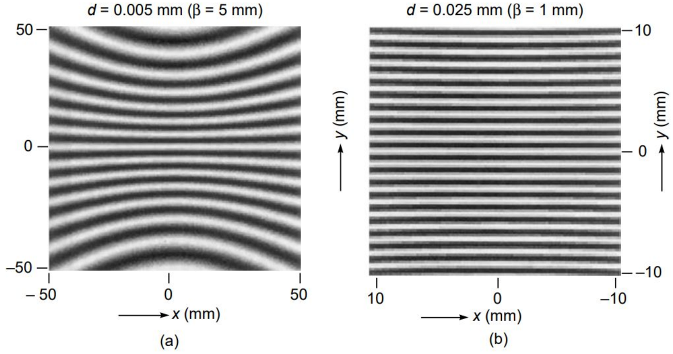
Hint:

Fringe width: $\beta = y_{n+1} - y_n = \dfrac{\lambda D}{d}$



Intensity distribution in Young's interference experiment





Computer-generated fringe pattern produced by two point sources S_1 and S_2 on the screen LL' (see Fig. 14.8); (a) and (b) correspond to d = 0.005 and 0.025 mm, respectively (both figures correspond to D = 5 cm and $\lambda = 5 \times 10^{-5}$ cm).

$$\mathbf{E}_1 = \hat{\mathbf{i}} E_{01} \cos\left(\frac{2\pi}{\lambda} S_1P - \omega t\right)$$

and **(25)**

$$\mathbf{E}_2 = \hat{\mathbf{i}} E_{02} \cos\left(\frac{2\pi}{\lambda} S_2P - \omega t\right)$$

where $\hat{\mathbf{i}}$ represents the unit vector along the direction of either of the electric fields. The resultant field is given by

$$\mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2$$

The intensity I is proportional to the square of the electric field and is given by

$$I = KE^2 \quad \textbf{(27)}$$

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\delta \quad \textbf{(30)}$$

where

$$\delta = \frac{2\pi}{\lambda}(S_2P - S_1P) \quad \textbf{(31)}$$

Light passing through glass

change

$$frequency = \frac{velocity}{wavelength}$$

No change

change

Reflection may cause phase change in waves

Reflected light experience:

- phase change of 180 degree (if reflected from a denser medium)
- No phase change (it reflected from rarer medium)

Refracted light experience:

- No phase change

Fig. 15.3 Thin film of air formed between two glass plates.

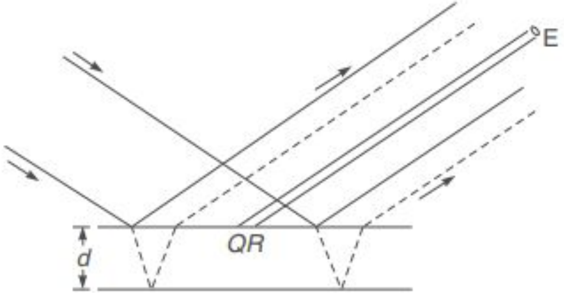


Fig. 15.4 The oblique incidence of a plane wave on a thin film. The solid and dashed lines denote the boundary of the wave reflected from the upper surface and from the lower surface of the film. The eye *E* receives the light reflected from the region *QR*.

Conditions for constructive and destructive:

$$\Delta = 2n_2 d \cos\theta' = m\lambda \qquad \text{minima} \qquad \textbf{(15.5a)}$$

$$= \left(m + \frac{1}{2}\right)\lambda \qquad \text{maxima} \qquad \textbf{(15.5b)}$$

Michelson Interferometer

Condition for destructive interference:

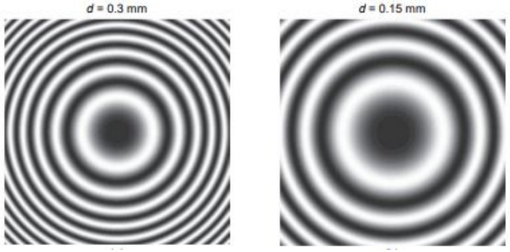
$$2d\cos\theta = m\lambda$$

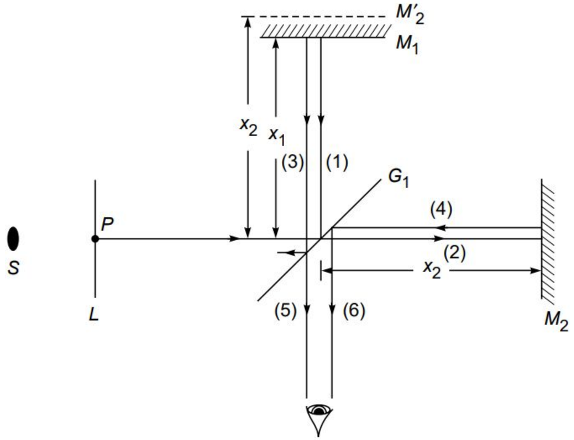
where $m = 0, 1, 2, 3, \ldots$ and

$$d = x_1 \sim x_2$$

Condition for constructive interference:

$$2d\cos\theta = \left(m + \tfrac{1}{2}\right)\lambda$$





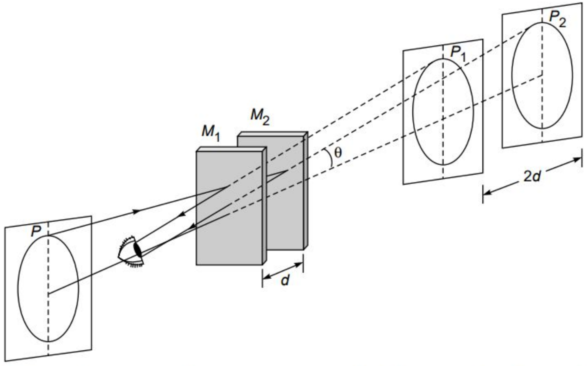


Fig. 15.35 A schematic of the formation of circular fringes (Adapted from Ref. 7).

Why fringes are circular

in Michelson Interferometer?

Simulation Experiment

On-axis interference

Off-axis interference

	Young's interference experiment	Michelson Interferometer
Interfernce type:	Division of wavefront	Division of amplitude
Condition for constructive interference:	Path difference between waves: $S_2P - S_1P = n\lambda \qquad n = 0, 1, 2, \ldots$	Path difference between waves: $2d\cos\theta = \left(m + \frac{1}{2}\right)\lambda$
Fringe type:	Linear	Can be circular or linear