Phys102 Lecture 25

The Wave Nature of Light; Interference

Key Points

- Huygens' Principle
- Interference – Young's Double-Slit Experiment
- Intensity in the Double-Slit Interference Pattern

References

24-1,2,3,4,8.

The Wave Nature of Light

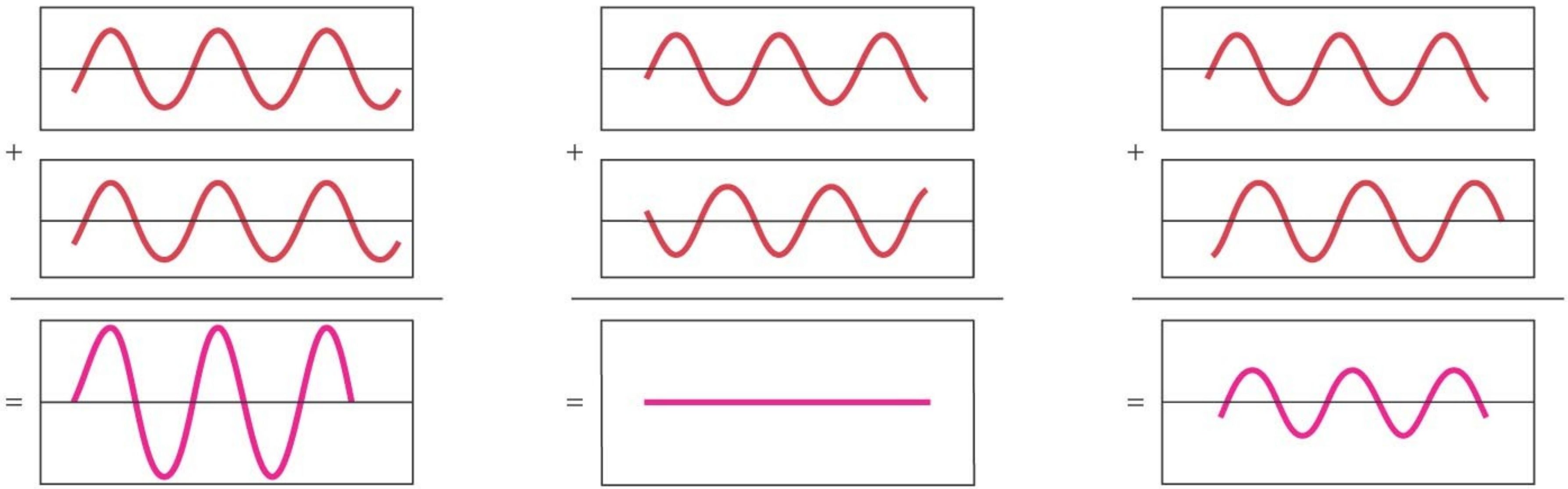
Wave Interference

$$E_1 = E_0 \cos(\omega t + \varphi_1)$$
$$E_2 = E_0 \cos(\omega t + \varphi_2)$$

Phase difference

$$\Delta\varphi = \varphi_2 - \varphi_1$$

These graphs show the interference of two waves. (a) Constructive interference; (b) Destructive interference; (c) Partially destructive interference.



(a) Constructive interference

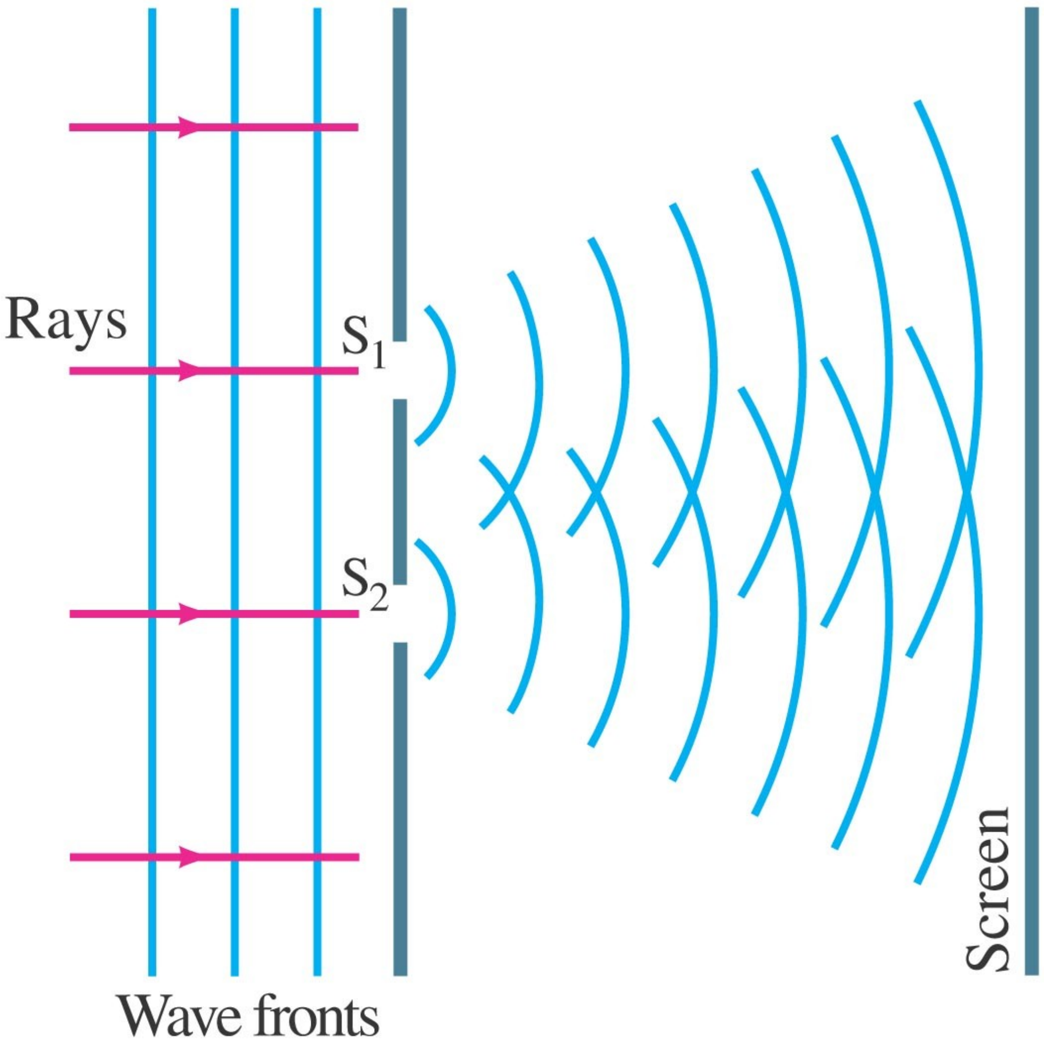
$$\Delta\varphi = 0, 2\pi, 4\pi, \ldots\ldots$$

(b) Destructive interference

$$\Delta\varphi = \pi, 3\pi, 5\pi, \ldots\ldots$$

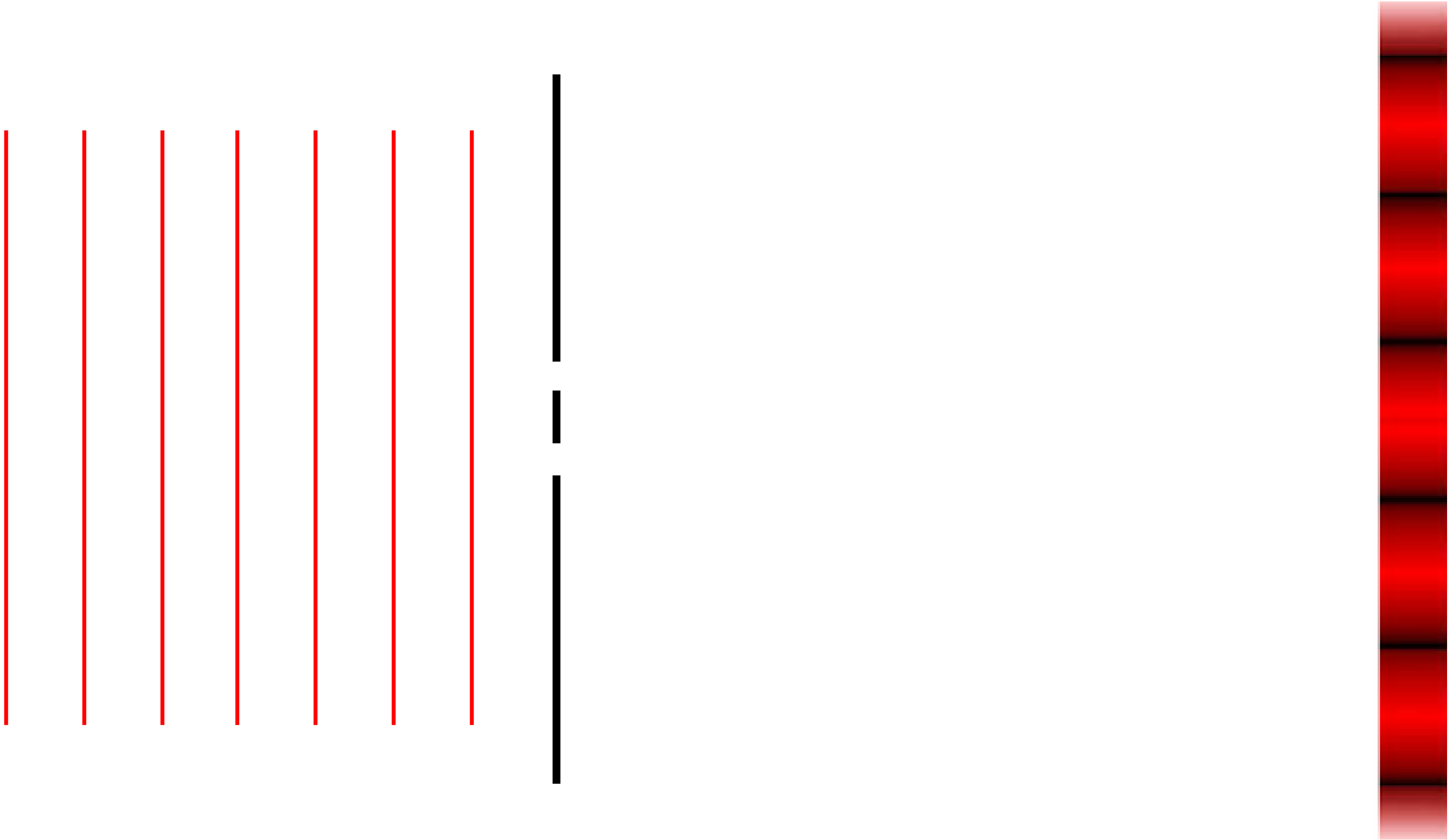
(c) Partially destructive interference

Interference – Young's Double-Slit Experiment



If light is a wave, there should be an interference pattern.

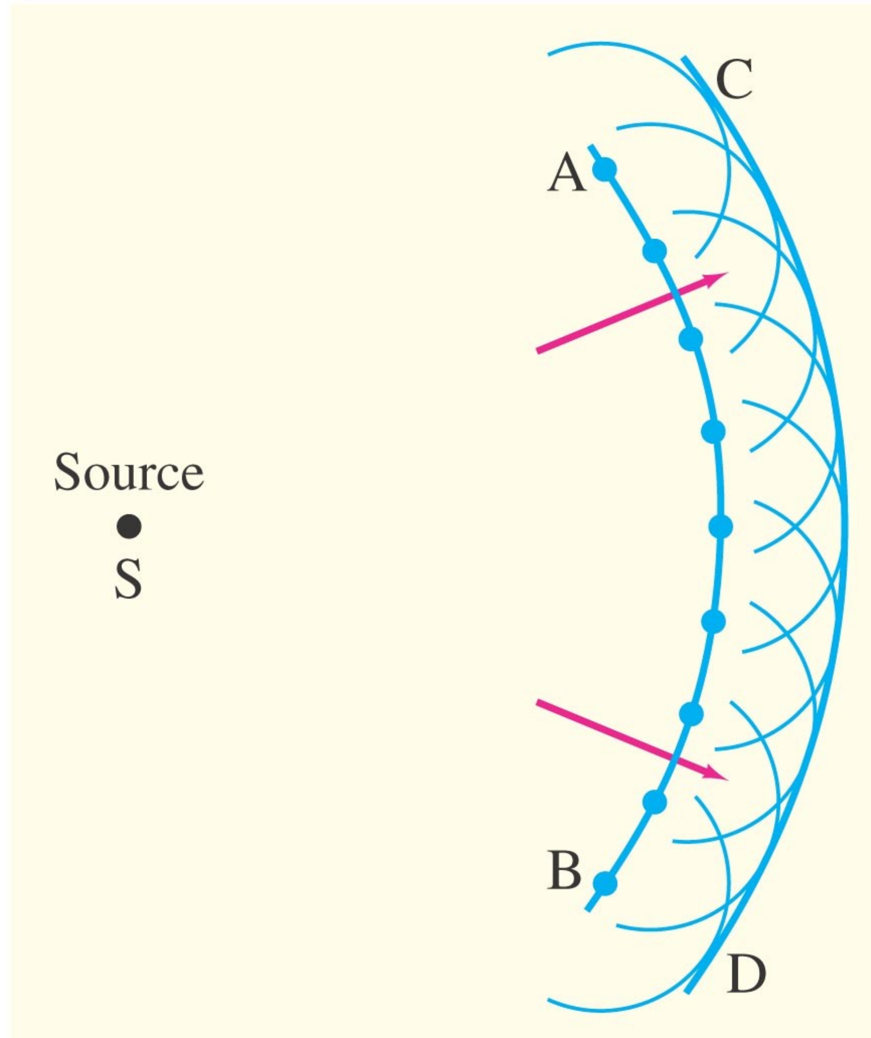
Interference – The Double Slit Experiment



Screen

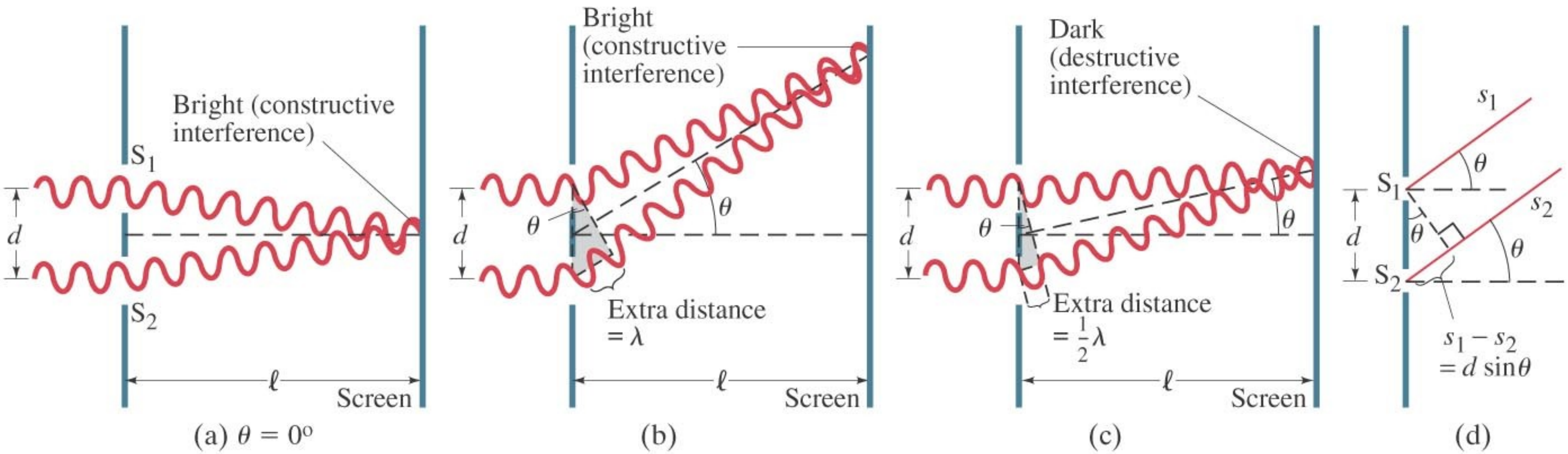
Huygens' Principle

Huygens' principle: every point on a wave front acts as a point source; the wave front as it develops is tangent to all the wavelets.



Young's Double-Slit Experiment

The interference occurs because each point on the screen is not the same distance from both slits. Depending on the path length difference, the wave can interfere constructively (bright spot) or destructively (dark spot).



Constructive interference: $$d \sin\theta = m\lambda, \quad m = 0,1,2,\ldots\ldots$$

Destructive interference: $$d \sin\theta = \left(m + \frac{1}{2}\right)\lambda, \quad m = 0,1,2,\ldots\ldots$$

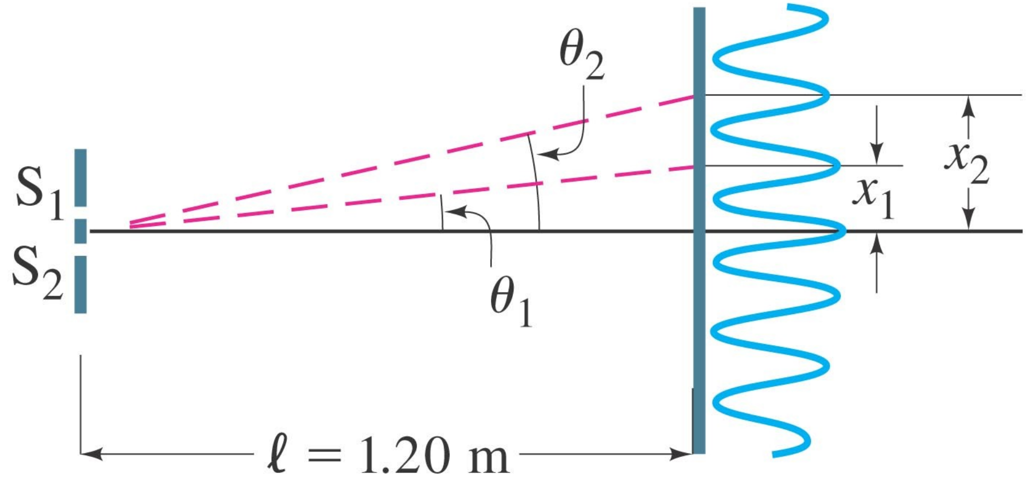
Example: Line spacing for double-slit interference.

A screen containing two slits 0.100 mm apart is 1.20 m from the viewing screen. Light of wavelength $\lambda = 500$ nm falls on the slits from a distant source. Approximately how far apart will adjacent bright interference fringes be on the screen?

$$d\sin\theta = m\lambda, \quad m = 0,1,2,\ldots\ldots$$

$$\frac{x}{l} = \tan\theta \approx \sin\theta \quad \text{for small } \theta$$

$$x \approx l\sin\theta = \frac{m\lambda l}{d} \qquad m = 0,1,2,\ldots$$



$$x_1 = \frac{\lambda l}{d}, \quad x_2 = \frac{2\lambda l}{d};$$

$$x_2 - x_1 = \frac{\lambda l}{d} = \frac{5.00\times10^{-7}\times1.20}{1.00\times10^{-4}} = 6.00\times10^{-3} m = 6.00\,mm$$

Conceptual Example: Changing the wavelength.

(a) i-clicker: What happens to the interference pattern in the previous example if the incident light (500 nm) is replaced by light of wavelength 700 nm?

A) The fringe spacing increases.

B) The fringe spacing decreases.

C) The fringe spacing remains the same.

b) i-clicker: What happens instead if the wavelength stays at 500 nm but the slits are moved farther apart?

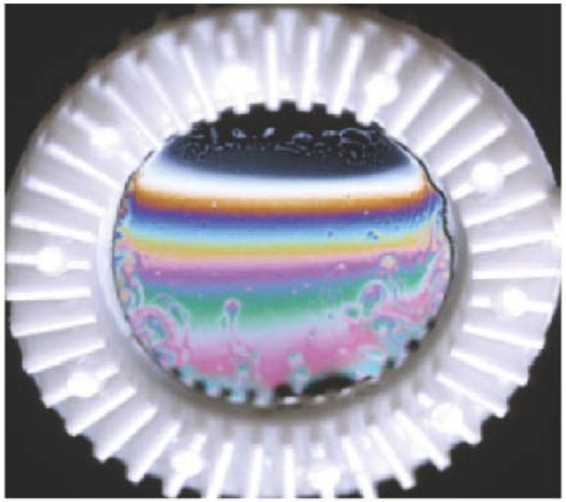
A) The fringe spacing increases.

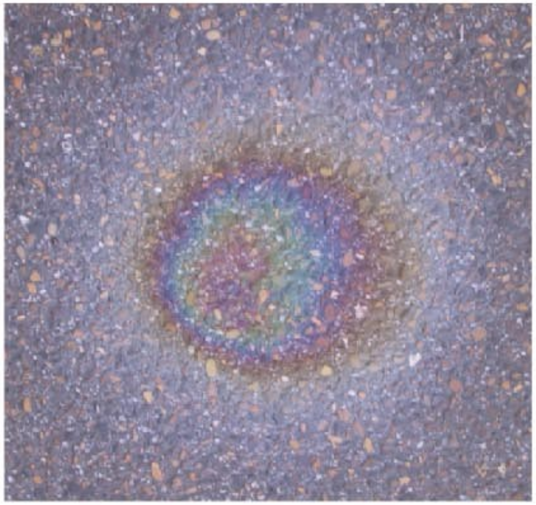
B) The fringe spacing decreases.

C) The fringe spacing remains the same.

Interference in Thin Films

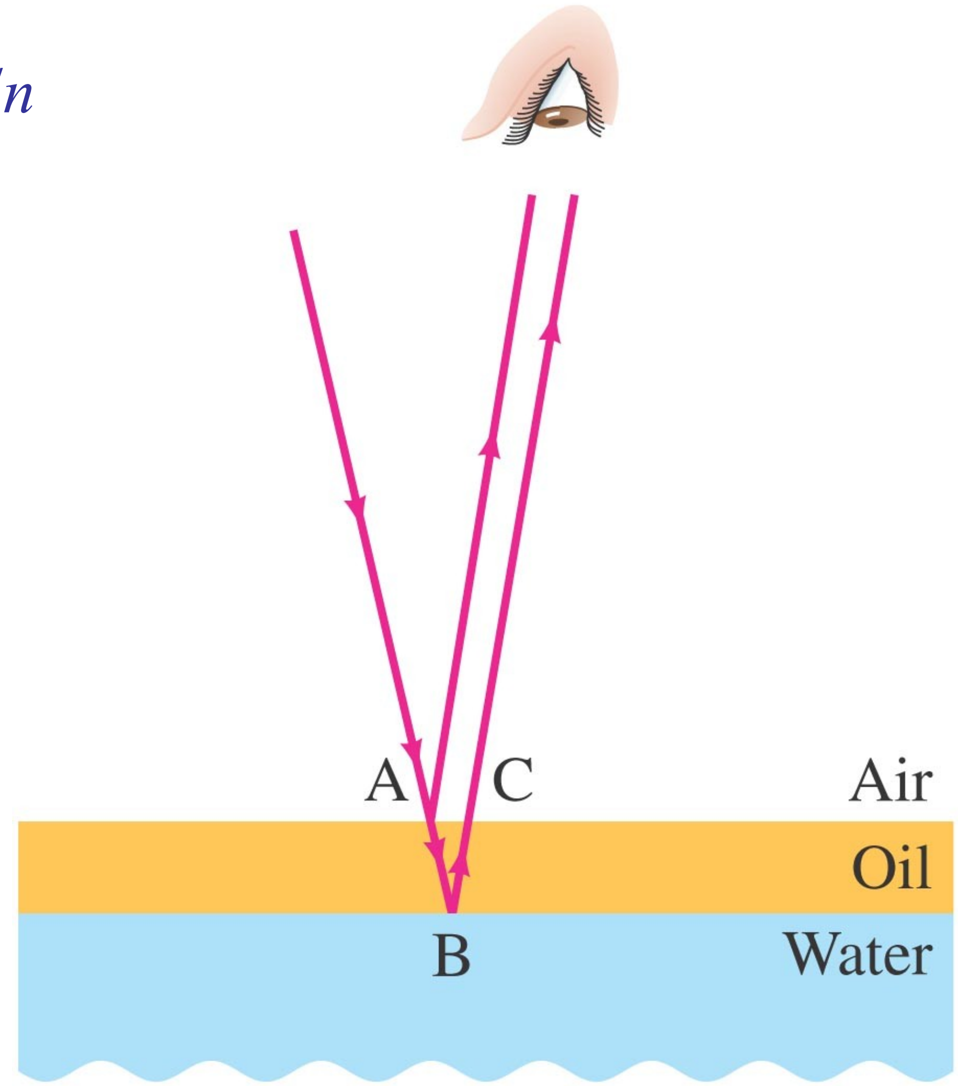
Another way path lengths can differ, and waves interfere, is if they travel through different media. If there is a very thin film of material – a few wavelengths thick – light will reflect from both the bottom and the top of the layer, causing interference. This can be seen in soap bubbles and oil slicks.





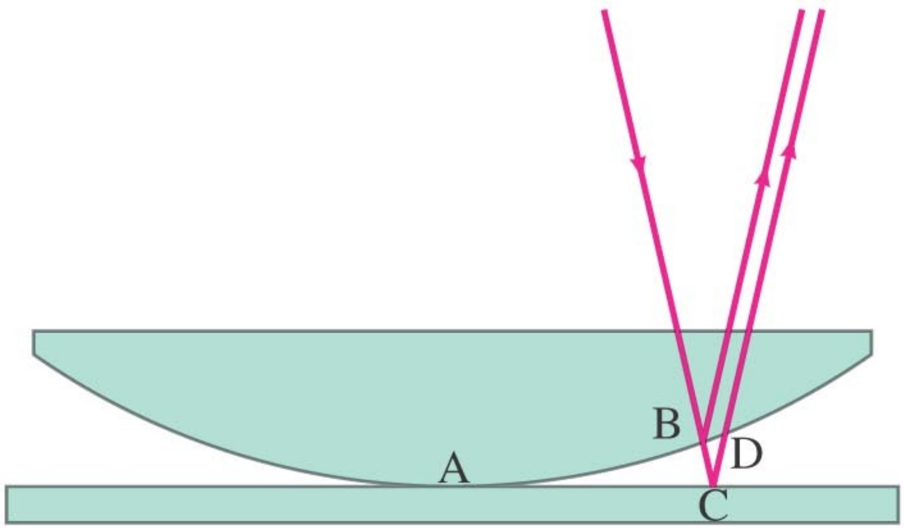
Interference in Thin Films

Wavelength in medium = λ/n

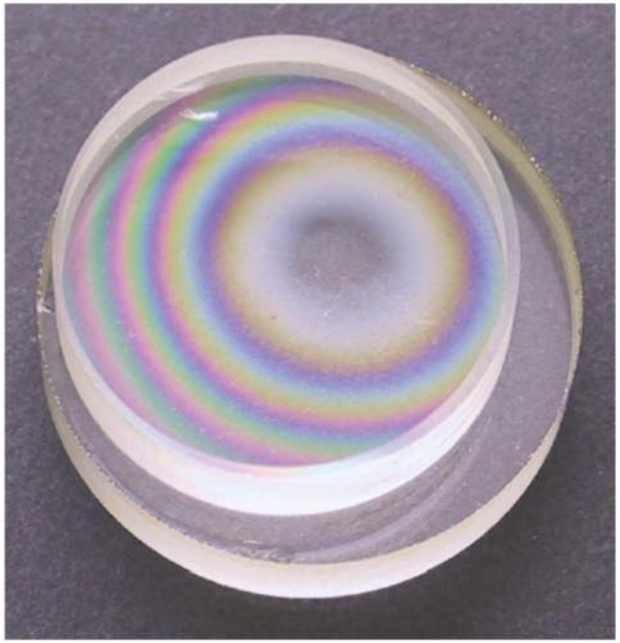


Interference in Thin Films

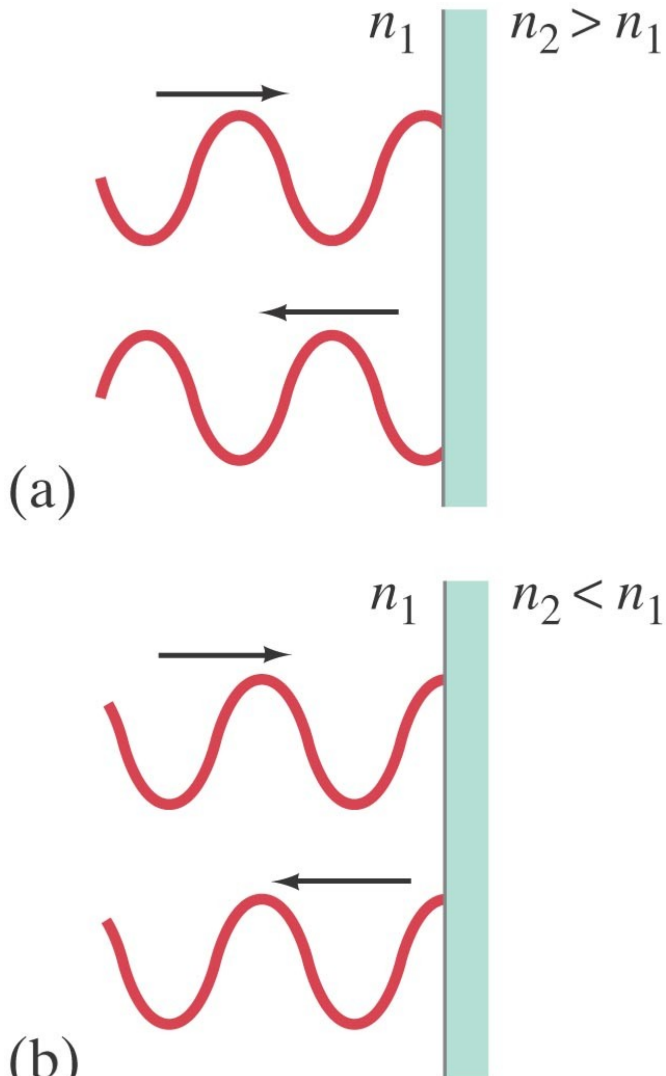
A similar effect takes place when a shallowly curved piece of glass is placed on a flat one. When viewed from above, concentric circles appear that are called Newton's rings.



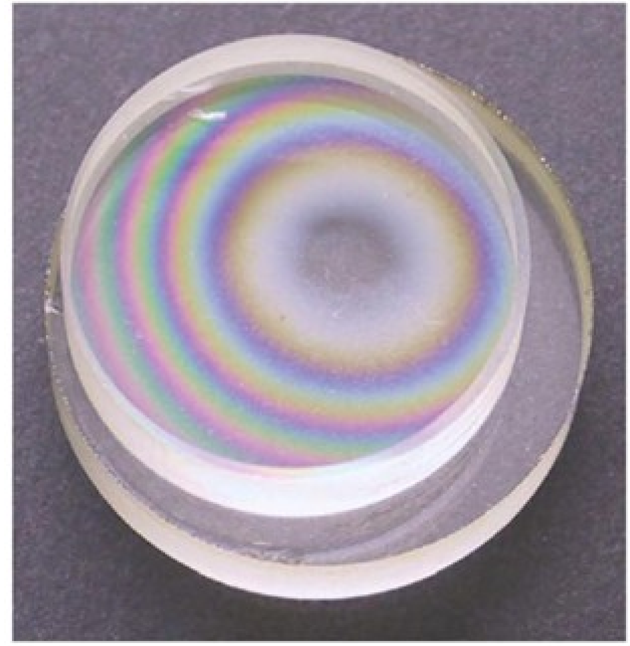
(a)

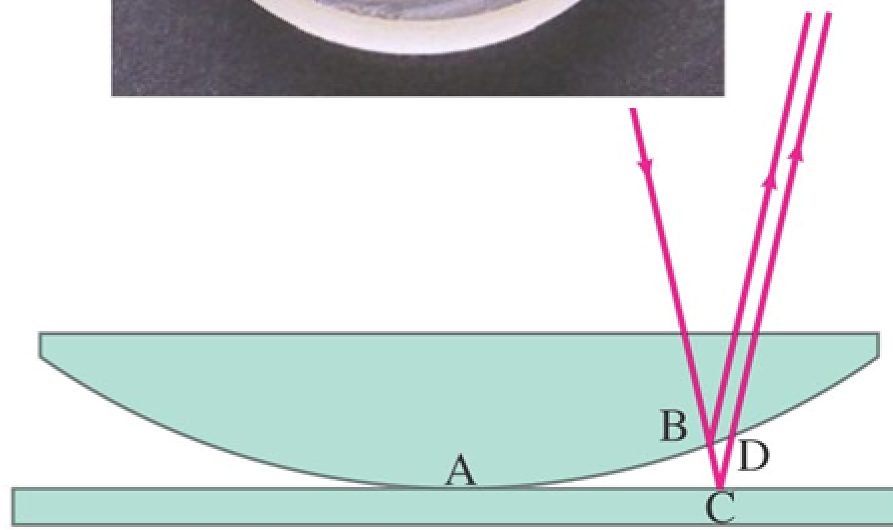


(b)



Copyright © 2008 Pearson Education, Inc.

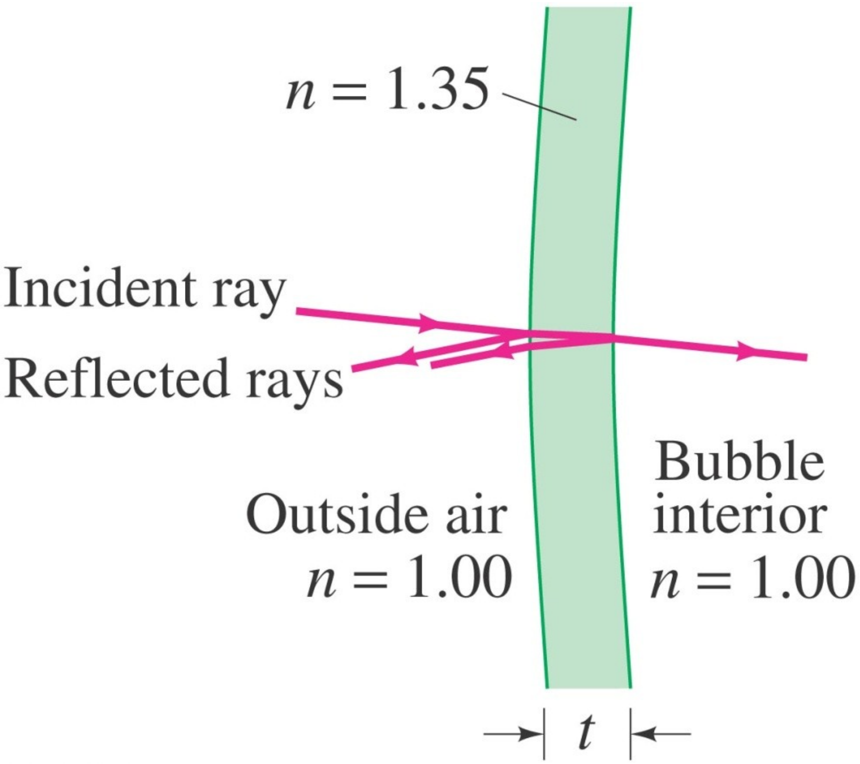




When $n_2 > n_1$, the phase changes by 180° ($\lambda/2$) upon reflection.

Example: Thickness of soap bubble skin.

A soap bubble appears green (λ = 540 nm) at the point on its front surface nearest the viewer. What is the smallest thickness the soap bubble film could have? Assume n = 1.35.



Compare the two reflected beams:

There is a 180° phase shift at the first surface. Then, constructive interference occurs when path difference is $\lambda/2$ rather than λ.

$$\text{smallest thickness t}: \quad 2t = \frac{\lambda}{2n}$$

$$t = \frac{\lambda}{4n} = \frac{540nm}{4 \times 1.35} = 100nm$$