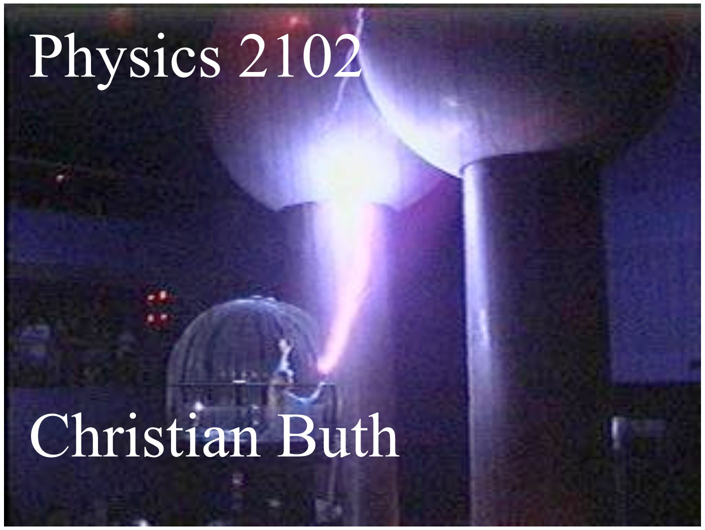
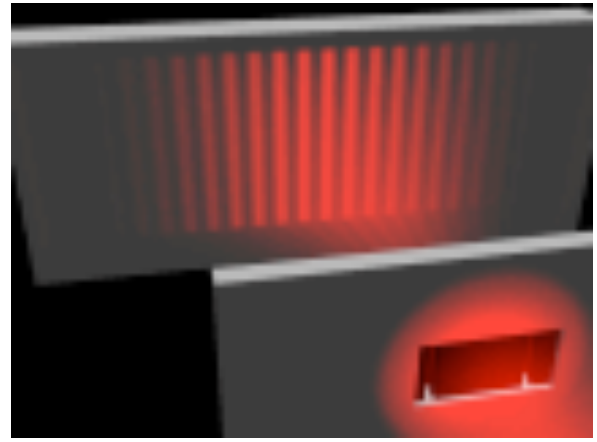
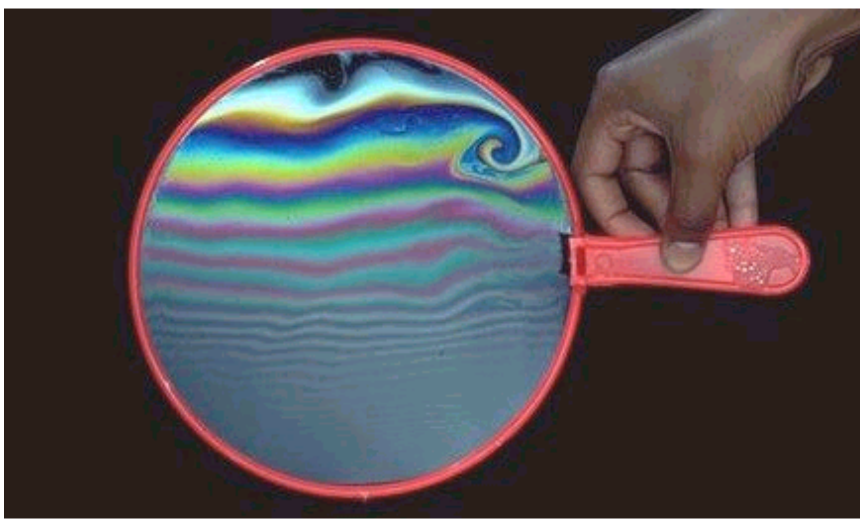


# Lecture 39

## Interference

## 04/24/2009



Christian Huygens

1629-1695

# Review

- Magnifying lens

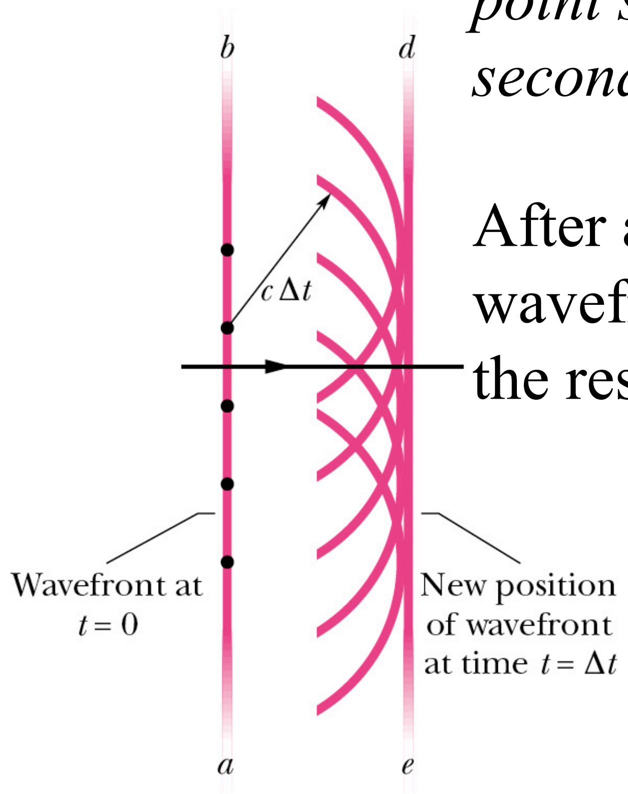
Simple Magnifier: $m_\theta \approx \dfrac{25\text{ cm}}{f}$

- Microscope and telescope combination of an **objective** and an **eyepiece**
- Magnification of microscope and telescope

$$M = m m_\theta = -\frac{s}{f_{ob}} \frac{25cm}{f_{ey}}$$

$$m = -\frac{f_{ob}}{f_{ey}}$$

# Wave Optics: Huygen’s Principle

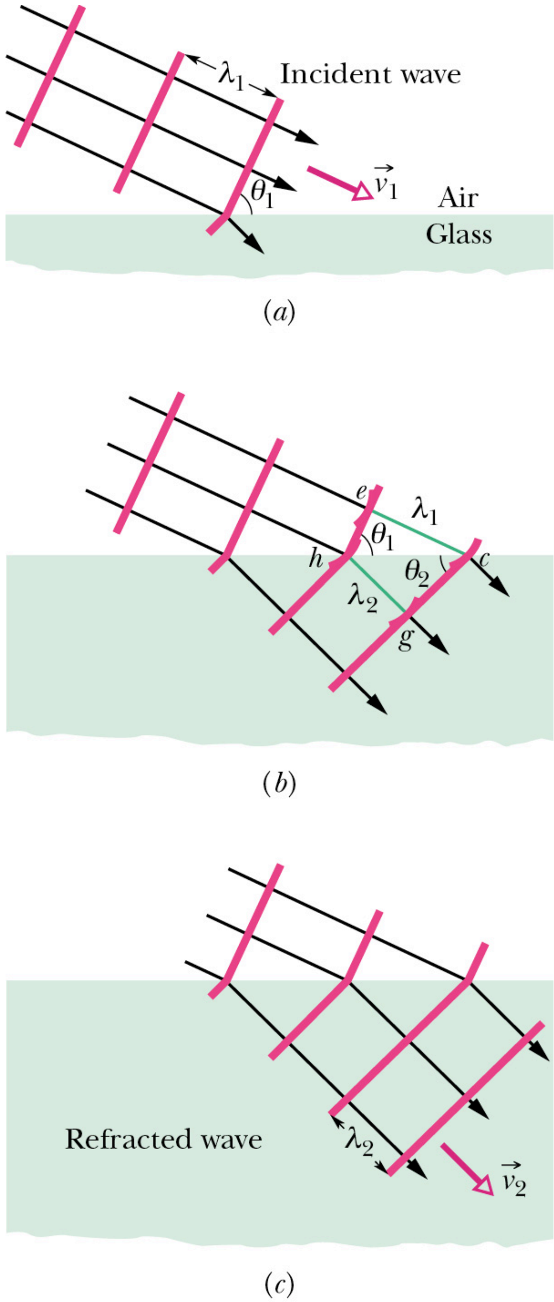



*All points in a wavefront serve as point sources of spherical secondary waves.*

After a time t, the new wavefront will be the tangent to all the resulting spherical waves.

Christian Huygens
1629-1695

# Reflection and Refraction Laws from Huygen's




The light travels more slowly in more dense media:
$v=c/n$ ($n$=index of refraction)

$$\sin\theta_1 = \frac{\lambda_1}{hc}, \quad \sin\theta_2 = \frac{\lambda_2}{hc} \quad \Rightarrow \frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

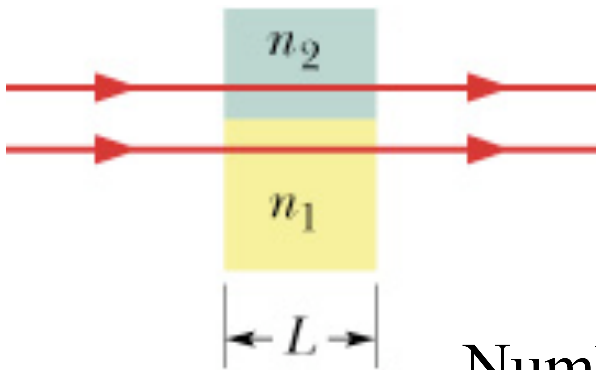
$$\boxed{\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}}$$

Snell's law!

Wavelength: $$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} \qquad \lambda_n = \lambda\frac{v_n}{c} = \frac{\lambda}{n}$$

Frequency: $$f_n = \frac{v_n}{\lambda_n} = \frac{c/n}{\lambda/n} = \frac{c}{\lambda} = f$$

# Wavelength and Index of Refraction




Since wavelengths in $n_1$ and $n_2$ are different, the two beams may no longer be in phase.

$$\text{Number of wavelengths in } n_1 : N_1 = \frac{L}{\lambda_{n1}} = \frac{L}{\lambda/n_1} = \frac{Ln_1}{\lambda}$$

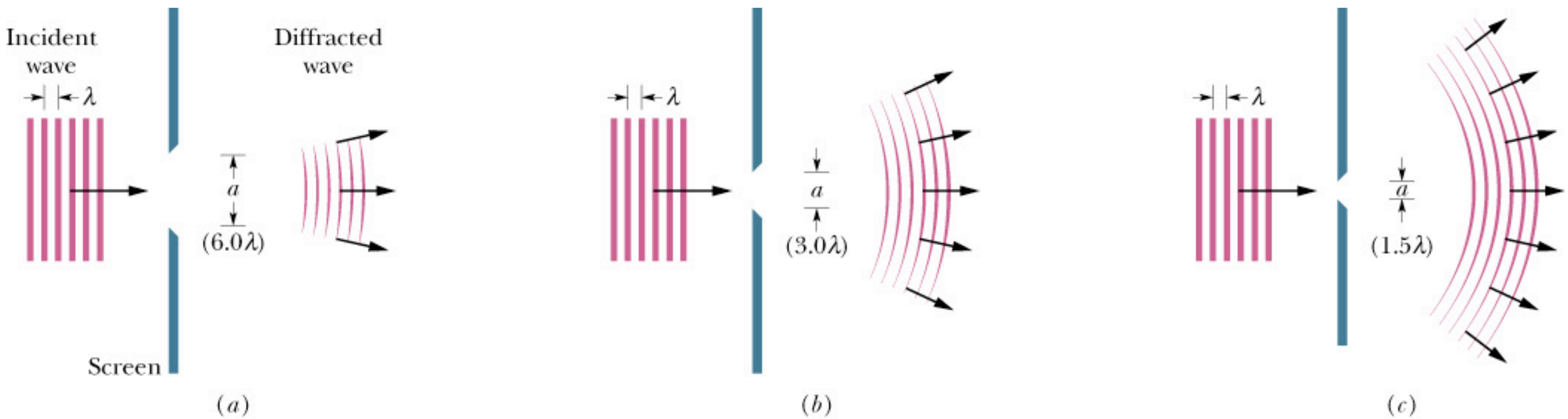
$$\text{Number of wavelengths in } n_2 : N_2 = \frac{L}{\lambda_{n2}} = \frac{L}{\lambda/n_2} = \frac{Ln_2}{\lambda}$$

$$\text{Assuming } n_2 > n_1 \text{:} \quad N_2 - N_1 = \frac{Ln_2}{\lambda} - \frac{Ln_1}{\lambda} = \frac{L}{\lambda}(n_2 - n_1)$$

$N_2 - N_1 = 1/2$ wavelength $\rightarrow$ destructive interference

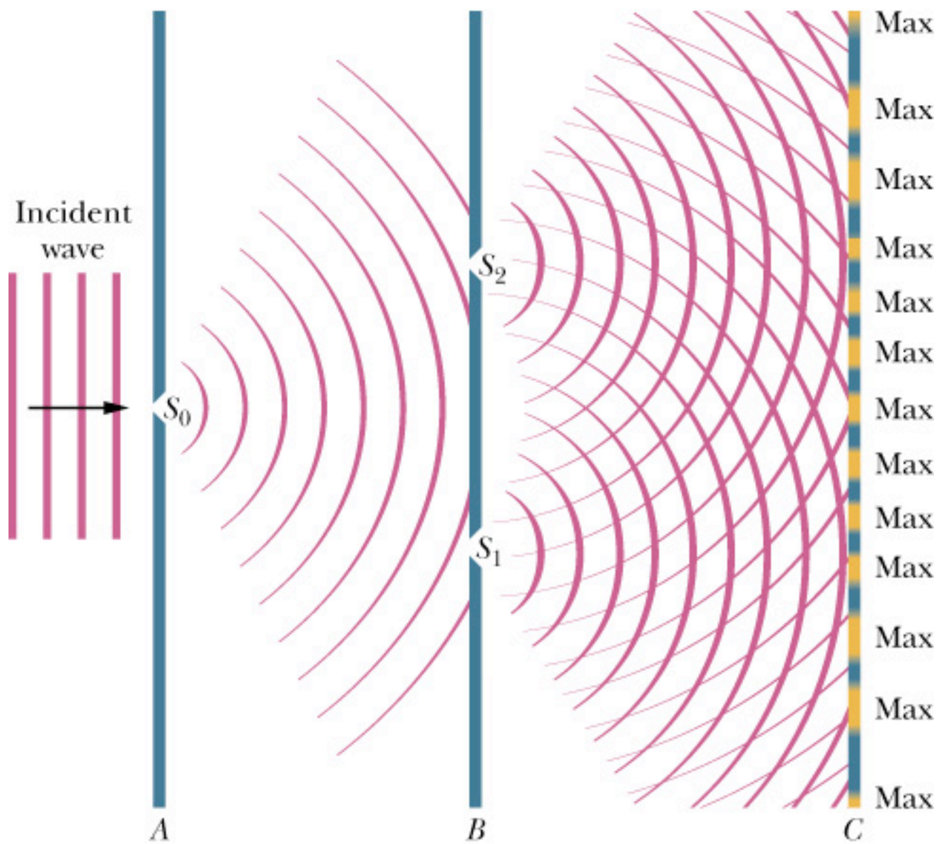
# Diffraction

For plane waves entering a single slit, the waves emerging from the slit start spreading out, **diffracting**



# Young's Double Slit Experiment

For waves entering two slits, the emerging waves **interfere** and form an interference (diffraction) pattern




Young experiment in 1801: **light is wave** phenomenon

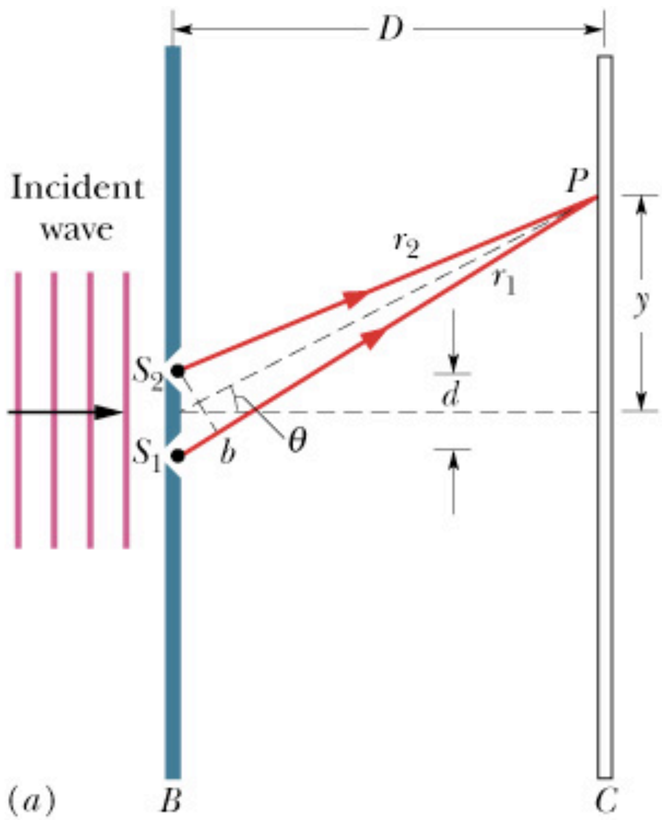
First plane wave through a small slit yields **coherent** spherical wave

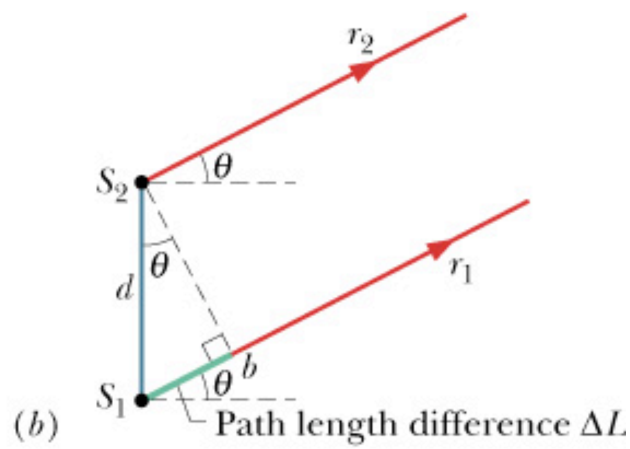
Then interposed **two slits**: interference of two spherical waves on a screen

# Locating Fringes

• **Phase difference** between two waves can change for paths of different lengths

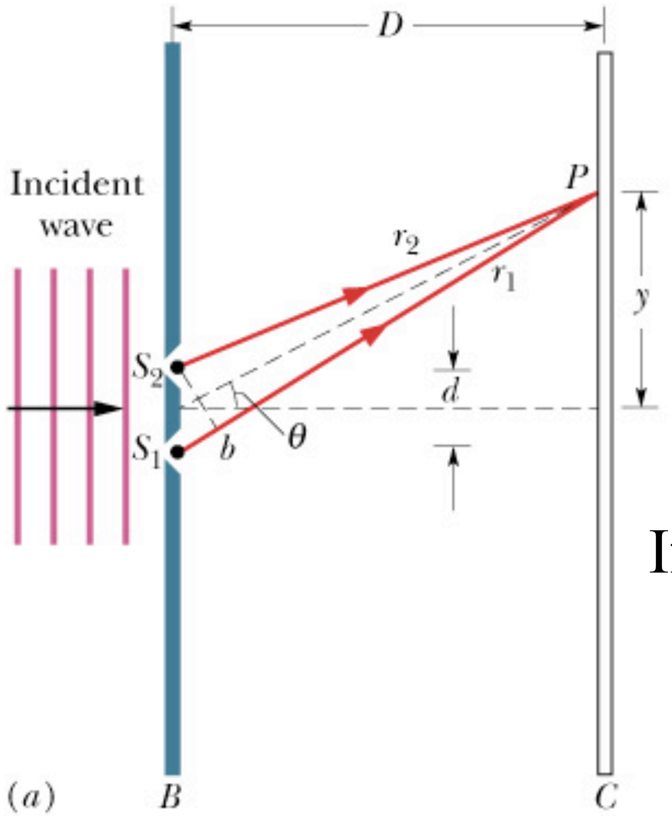
• Each point on the screen is determined by the **path length difference** $\Delta L$ of the rays reaching that point

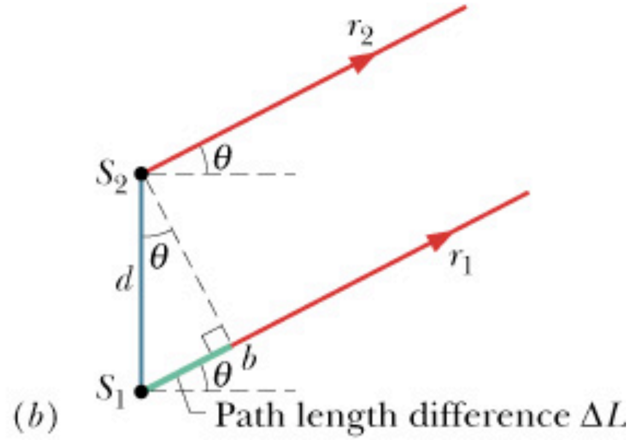



Path Length Difference: $\Delta L = d\sin\theta$

# Locating Fringes




$$\text{If } \Delta L = d\sin\theta = (\text{integer})(\lambda) \rightarrow \text{bright fringe}$$

Maxima-bright fringes:

$$d\sin\theta = m\lambda \quad \text{for } m = 0, 1, 2, \ldots$$

Minima-dark fringes: $d\sin\theta = \left(m + \tfrac{1}{2}\right)\lambda \quad \text{for } m = 0, 1, 2, \ldots$

$m = 2$ bright fringe at: $\theta = \sin^{-1}\left(\dfrac{2\lambda}{d}\right)$ $m = 1$ dark fringe at: $\theta = \sin^{-1}\left(\dfrac{1.5\lambda}{d}\right)$

# Summary 1

- **Huygen's principle**: All points in a wavefront serve as point sources of spherical secondary waves
- The frequency of light in a medium is the same as it is in vacuum

Index of Refraction: $n = \dfrac{c}{v}$

- Wavelength changes

$$\lambda_n = \lambda \frac{v_n}{c} = \frac{\lambda}{n}$$

# Summary 2

- **Diffraction** of light occurs at openings of the order of the wave length of the light
- **Double slit experiment**:

Maxima-bright fringes:

$$d\sin\theta = m\lambda \quad \text{for } m = 0,1,2,\ldots$$

Minima-dark fringes: $d\sin\theta = \left(m+\tfrac{1}{2}\right)\lambda \quad \text{for } m = 0,1,2,\ldots$