Physics 122 – Class #8
Date: 9/11/14

Questions?
Announcements/reminders

MP HW03 and written HW03 are due next Tuesday, 16 September.

I-Clickers … X

Exam coming up. September, Thursday 25th.

Always check the class website to make sure of assignments and due dates.
(http://www.physics.nmt.edu/~saska/phys122.html)
Physics 122 – Class #8

Last class: Interference, diffraction, ...

Today: Wave Optics.

The spreading of the water is called diffraction.
WAVE OPTICS
Difraction & interference

The light spreads out behind the slit.

0.1-mm-wide slit in an opaque screen

Incident laser beam

Viewing screen

2.5 cm

2 m
Double-slit expt.

1. A plane wave is incident on the double slit.

2. Waves spread out behind each slit.

Top view of the double slit

3. The waves interfere in the region where they overlap.

4. Bright fringes occur where the antinodal lines intersect the viewing screen.

$m = 4$
$m = 3$
$m = 2$
$m = 1$
$m = 0$ Central maximum
$m = 1$
$m = 2$
$m = 3$
$m = 4$

bright fringes

dark fringes

interference pattern

Thomas Young 1801
Whether constructive or destructive IF, it will depend on the phase:

- in phase - constr.
- out of phase - destructive IF

\[ \Delta \phi = \frac{2\pi}{\lambda} \Delta \ell + \Delta \phi_0 \]
Double-slit expt.

In our case \( \Delta \phi_0 = 0 \)

\[ \Rightarrow \Delta \phi = \frac{2\pi}{\lambda} \Delta \Gamma \]

for \( \Delta \Gamma = m \lambda \) — constr. IF

\[ \Delta \Gamma = (m + \frac{1}{2}) \lambda \] — destr. IF

From the figure:

\[ \sin \Theta = \frac{\Delta \Gamma}{d} \approx \Theta \]

\[ \tan \Theta = \frac{y}{l} \approx \Theta \]

\( \frac{\Delta \Gamma}{d} = \frac{y}{l} \Rightarrow \) express \( y \)
Double-slit expt.

\[ y = L \frac{\Delta r}{d} \]

\[ y_m = \frac{L}{d} m \]

\[ y'_m = \frac{L}{d} (m + \frac{1}{2}) \lambda \]

\[ \theta = \sin \theta = \frac{\Delta r}{d} \quad \Rightarrow \quad \text{constructive} \]

\[ \theta_m = \frac{m \lambda}{d}, \quad m = 0, 1, 2, \ldots \]

\[ \theta_m = (m + \frac{1}{2}) \frac{\lambda}{d} \quad \text{destructive} \]
Double-slit expt.

\[ \Delta y = y_{m+1} - y_m = \frac{L \lambda}{d} (m+1) - \frac{L \lambda}{d} m = \frac{L \lambda}{d} \]

Spacing btw 2 neighbouring bright fringes.

\[ I \propto A^2 \]
\[ I = c A^2 \]

\[ I_i \rightarrow \text{intensity of each wave} \]

\[ A = 2 a \cos \left( \frac{\Delta \phi}{2} \right) \Rightarrow I = c A^2 \]
Double-slit expt.

\[ I = c 4a^2 \cos^2 \left( \frac{\Delta \phi}{2} \right) \]

Notice

\[ I_1 = ca^2 \]

\[ I = 4I_1 \cos^2 \left( \frac{\Delta \phi}{2} \right) \]

if we had \( N \) slits

\[ \Rightarrow I = N^2 I_1 \]
Double-slit expt.

Diffraction grating - \( N \) closely & equally spaced slits

\[
\Delta r_n = m \cdot \lambda \\
\Rightarrow \Delta r_{13} = 2 \Delta r_{12} \\
m = 0, 1, 2, \ldots
\]
Double-slit expt.

Angle of the bright fringes:

\[ \sin \theta_m = \frac{\Delta y}{d} = \frac{m \lambda}{d} \]

No small angle approx!

\[ \sin \theta_m = \left( m + \frac{1}{2} \right) \frac{\lambda}{d} \]

The positions of the fringes:

Bright: \[ y_m = L \tan \theta_m \]

\[ \tan \theta_m = \frac{y}{L} \]

\[ m = 0, 1, 2, \ldots \]

m = order of diffraction
Double-slit expt.
A laboratory experiment produces a double-slit interference pattern on a screen. If the screen is moved farther away from the slits, the fringes will be

A. Closer together.
B. In the same positions.
C. Farther apart.
D. Fuzzy and out of focus.
Diffraction Grating
Diffraction Grating
Diffraction Grating
Diffraction Grating
A reflection grating can be made by cutting parallel grooves in a mirror surface. These can be very precise, for scientific use, or mass produced in plastic.
EXAMPLE 22.3  Measuring wavelengths emitted by sodium atoms

VISUALIZE  This is the situation shown in the figure. The two fringes are very close together, so we expect the wavelengths to be only slightly different. No other yellow fringes are mentioned, so we will assume these two fringes are the first-order diffraction \((m = 1)\).
Example 22.3 continues...

Assume \( m = 1 \)

\[
y_m = \frac{\lambda_m L}{d}
\]

\[
y_1' = \frac{\lambda_1' L}{d} \quad \Rightarrow \quad \lambda_1' = \frac{y_1' d}{L} = 728.8 \text{ nm}
\]

\[
y_1 = \frac{\lambda_1 L}{d} \quad \Rightarrow \quad \lambda_1 = \frac{y_1 d}{L} = 730.06 \text{ nm}
\]

\[
d = \frac{1 \text{ mm}}{1000} = 10^{-6} \text{ m}
\]

\[
\sin \theta = \frac{y_1}{d}, \quad \sin \theta' = \frac{y_1'}{d}
\]
Single-slit diffraction

- Viewing screen
- Secondary maxima
- Central maximum
- Single slit of width $a$
- Distance $L$
- Incident light of wavelength $\lambda$
Each point on the wave front is paired with another point distance $a/2$ away.

These wavelets all meet on the screen at angle $\theta$. Wavelet 2 travels distance $\Delta r_{12} = (a/2) \sin \theta$ farther than wavelet 1.
Circular aperture diffraction
Example 22.4
Example 22.4

**Example 22.4** Diffraction of a laser through a slit

Light from a helium-neon laser ($\lambda = 633$ nm) passes through a narrow slit and is seen on a screen 2.0 m behind the slit. The first minimum in the diffraction pattern is 1.2 cm from the central maximum. How wide is the slit?

**Model** A narrow slit produces a single-slit diffraction pattern. A displacement of only 1.2 cm in a distance of 200 cm means that angle $\theta_1$ is certainly a small angle.
Ray vs Wave Model of Light
Acoustical interferometer
Acoustical interferometer
Acoustical interferometer
Interferometers
Interferometers
Interferometers

1. The wave is divided at this point.

2. The returning waves recombine at this point.

3. The detector measures the superposition of the two waves that have traveled different paths.

Mirror $M_1$

Source

Beam splitter

$L_1$

$L_2$

Adjustment screw

Mirror $M_2$
Interferometers
Interferometers
Interferometers