1. Review of Huygen’s principle, Chap 33.7, and 36.1, and
2. Diffraction Chap 36.1-5, 7, and
3. Review of Interference, Chap 35.1-5
Huygen’s Construction for a Plane Wave

- At $t = 0$, the wave front is indicated by the plane AA’
- The points are representative sources for the wavelets
- After the wavelets have moved a distance $c\Delta t$, a new plane BB’ can be drawn tangent to the wavefronts
Huygen’s Construction for a Spherical Wave

- The inner arc represents part of the spherical wave
- The points are representative points where wavelets are propagated
- The new wavefront is tangent at each point to the wavelet
Huygen’s Principle and the Law of Reflection

• The Law of Reflection can be derived from Huygen’s Principle
• AA’ is a wave front of incident light
• The reflected wave front is CD
Huygen’s Principle and the Law of Reflection

- Triangle ADC is congruent to triangle AA’C
- Angles $\theta_1 = \theta_1'$
- This is the Law of Reflection
Huygen’s Principle and the Law of Refraction

- In time $\Delta t$, ray 1 moves from A to B and ray 2 moves from A’ to C
- From triangles AA’C and ACB, all the ratios in the Law of Refraction can be found
  - $n_1 \sin \theta_1 = n_2 \sin \theta_2$
Single Slit Interference? Yes—Diffraction!
Diffraction: Interference of light from within just one slit

When $\frac{D}{2} \sin \theta = \frac{\lambda}{2}$ rays 1 and 1' will interfere destructively.

Rays 2 and 2' also start $D/2$ apart and have the same path length difference.

Condition for every ray originating in top half of slit to interfere destructively with the corresponding ray originating in bottom half.

$1^{st}$ minimum at $\sin \theta = \frac{\lambda}{D}$
Diffraction: Interference of light from within just one slit

When \( \frac{D}{4} \sin \theta = \frac{\lambda}{2} \) rays 1 and 1’ will interfere destructively.

Rays 2 and 2’ also start \( D/4 \) apart and have the same path length difference.

Condition for every ray originating in top half of slit to interfere destructively with the corresponding ray originating in bottom half. 2\textsuperscript{nd} minimum at \( \sin \theta = 2\lambda/D \)
**diffraction**

36.8 Using phasor diagrams to find the amplitude of the $\vec{E}$ field in single-slit diffraction. Each phasor represents the $\vec{E}$ field from a single strip within the slit.

(a) Strips within slit

(b) At the center of the diffraction pattern (point $O$), the phasors from all strips within the slit are in phase.

36.9 (a) Intensity versus angle in single-slit diffraction. The values of $m$ label intensity minima given by Eq. (36.8). Most of the wave power goes into the central intensity peak (between the $m = 1$ and $m = -1$ intensity minima). (b) These
(c) Phasor diagram at a point slightly off the center of the pattern; $\beta =$ total phase difference between the first and last phasors.

$$E_P = E_0 \frac{\sin(\beta/2)}{\beta/2}$$

$$I = I_0 \left[ \frac{\sin(\beta/2)}{\beta/2} \right]^2$$

(d) As in (c), but in the limit that the slit is subdivided into infinitely many strips

$$\beta = \frac{2\pi}{\lambda} a \sin \theta$$

$$I = I_0 \left( \frac{\sin[\pi a (\sin \theta)/\lambda]}{\pi a (\sin \theta)/\lambda} \right)^2$$
Diffraction pattern width

(a) $a = \lambda$

If the slit width is equal to or narrower than the wavelength, only one broad maximum forms.

(b) $a = 5\lambda$

The wider the slit (or the shorter the wavelength), the narrower and sharper is the central peak.

(c) $a = 8\lambda$
Maxima and minima will be a series of bright and dark rings on screen.

First diffraction minimum is at

\[
\sin \theta = 1.22 \frac{\lambda}{D}
\]
Intensity from Circular Aperture

$I \propto \sin^2 \left( \frac{\lambda}{D} \right)$

First diffraction minima

$1.22 \frac{\lambda}{D}$
These objects are *just* resolved. Two objects are just resolved when the maximum from one is at the minimum of the other.
Resolving Power

Two objects are just resolved when the maximum from one is at the minimum of the other.

To see objects distinctly, need

\[ \theta \geq \theta_{\text{min}} \]

\[ \sin \theta_{\text{min}} \approx \theta_{\text{min}} = 1.22 \frac{\lambda}{D} \]

This is why cameras with bigger apertures are “better”
Resolving Power Question

\[ \sin \theta_{\text{min}} \approx \theta_{\text{min}} = 1.22 \frac{\lambda}{D} \]

How does the maximum resolving power of your eye change when the brightness of the room is decreased.

1) Increases  
2) Constant  
3) Decreases

When the light is low, your pupil dilates (D can increase by factor of 10!)
Diffraction Summary

Condition for halves of slit to destructively interfere

\[ \sin(\theta) = \frac{\lambda}{D} \]

Condition for quarters of slit to destructively interfere

\[ \sin(\theta) = 2 \frac{\lambda}{D} \]

Condition for sixths of slit to destructively interfere

\[ \sin(\theta) = 3 \frac{\lambda}{D} \]

\[ D \sin \theta = m \lambda \quad (m=1, 2, 3, \ldots) \]

THIS FORMULA LOCATES MINIMA!!

Narrower slit => broader pattern
Interference

Young’s Double Slit Experiment
2-slit interference

Huygen’s Principle: each point on the wave front is a point source

Diffraction: These sources interfere

Light can bend around corners (like sound)
Multiple Slit Interference
(Diffraction Grating)

For many slits, maxima are still at

\[ \sin \theta = m \frac{\lambda}{d} \]

Region between maxima gets suppressed more and more as no. of slits increases.
2-slit interference plus diffraction

36.12 Finding the intensity pattern for two slits of finite width.

(a) Single-slit diffraction pattern for a slit width $a$

(b) Two-slit interference pattern for narrow slits whose separation $d$ is four times the width of the slit in (a)

(c) Calculated intensity pattern for two slits of width $a$ and separation $d = 4a$, including both interference and diffraction effects
36.16 A portion of a transmission diffraction grating. The separation between the centers of adjacent slits is $d$. 

![Diagram of a diffraction grating](image)
Interference from 8 slits

36.14 Phasor diagrams for light passing through eight narrow slits. Intensity maxima occur when the phase difference $\phi = 0, 2\pi, 4\pi, \ldots$. Between the maxima at $\phi = 0$ and $\phi = 2\pi$ are seven minima, corresponding to $\phi = \pi/4, \pi/2, 3\pi/4, \pi, 5\pi/4, 3\pi/2,$ and $7\pi/4$. Can you draw phasor diagrams for the other minima?

(a) Phasor diagram for $\phi = \pi$

(b) Phasor diagram for $\phi = \pi/4$

(c) Phasor diagram for $\phi = \pi/2$
Intensity patterns for 2, 8, and 16 slits

(a) $N = 2$: two slits produce one minimum between adjacent maxima.

(b) $N = 8$: eight slits produce taller, narrower maxima in the same locations, separated by seven minima.

(c) $N = 16$: with 16 slits, the maxima are even taller and narrower, with more intervening minima.
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