Diffraction, Geometrical Optics, Huygens Principle, Refracting Media, Laws of Reflection + Refraction, Fermat's Principle

Geometrical optics: light like particles, $\uparrow$am! straight lines that get reflected, refracted.

Diffraction: wave properties matter.

How to tell?

1. Dimensions $\gg \lambda$

2. Huygens Principle:
   All points on a wavefront can be considered as point sources for the production of spherical secondary wavelets. After time $t$ the new position of a wavefront is the surface tangent to these secondary wavelets.

Figures 8, 17, 2 from RTHK4.

Key: $\gg \lambda$, mention Kirchhoff
Refracting Media

\[ n = \frac{c}{\nu} \]

\[ n = \text{index of refraction} \]

\[ \nu \approx \sqrt{\frac{\varepsilon}{\mu}} \]

Causes reflection/refraction.

\[ \nu = \nu' / \lambda \]

\( \nu \) stays same.

\( \lambda \) changes.

\( n = 1 \) (vacuum/air)

\( c = \lambda_0 \nu \)

match boundary conditions

\( n = 1.33 \)

\( \lambda = \frac{c}{\nu} \cdot \frac{1}{n} \)

\( \lambda = \frac{\lambda_0}{n} \)

a reflected wave!
Law of reflection...
\[ \theta_i = \theta_i' \]

Law of refraction:
\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]

**Proof by Fermat’s Principle:**
*Time is either max or min*

\[ L = \sqrt{a^2 + x^2} + \sqrt{b^2 + (a-x)^2} \]

\[ \sin \theta_1 = \frac{x}{\sqrt{a^2 + x^2}} = \frac{d-x}{\sqrt{b^2 + (d-x)^2}} = \sin \theta_2 \]
It takes the path that minimizes the time it takes to go from point A to point B.

Snell's law: \( n_1 \sin \theta_1 = n_2 \sin \theta_2 \).

A view of Snell's law

Integrate to propagate.

Another view of Snell's law

Plane wave

Spherical wave

Meaning:

E

\( \frac{dE}{dx} \)

UCSB

Physics 25

Nelson
Plane mirrors

Virtual means: rays never actually touch or pass through the image (really)

Reversal: Left $\Leftrightarrow$ Right

Actually, in/out got reversed can rotate

$y \leftarrow \text{"total flip"}$
Corved Mirror

Reason from flat,

concave

convex

special ray

coneave
convex

image

bocyte

bounce off
midpoint
(unchanged)

looking at special ray
+ congruent triangles,

lateral mag

\[ \frac{-i}{o} = m \]
Something special about concave... ray can go out parallel...

\[ f < 0 \] for that ray

\[ \frac{1}{-\infty} = 0 \]

\[ f = \frac{R}{2} \]

\[ \frac{1}{0} + \frac{1}{i} = \frac{1}{f} = \frac{2}{R} \]

\[ \frac{1}{f} \to 0, \quad \frac{1}{i} = -\frac{1}{0} \]

Virtual image \( i = -0 < 0 \)

Real image \( i > 0 \)

\( f = -\frac{R}{2} \)
1) calc: \( \frac{1}{f} + \frac{1}{0} = -\frac{1}{5} \)

\[
\frac{1}{i} = -\frac{1}{5} - \frac{1}{8} = -\frac{8 - 5}{40} = -\frac{13}{40}
\]

\( i = -\frac{40}{13} \approx -3.08 \text{ cm} = -3.08 \text{ cm} \)

2) \( m = \frac{-i}{0} = -\frac{-3.08}{5} = 0.615 \)

Spherical Refracting Surfaces

\[
\frac{n_1}{0} + \frac{n_2}{i} = \frac{(n_2 - n_1)}{r}
\]

\( r > 0 \) shown.
Thin lens \( \frac{1}{o} + \frac{1}{i} = \frac{(n-1)}{r_1} \),

\( r_2 < 0 \),

\( r_1 > 0 \),

but \( o' = -i < 0 \)

\( \frac{1}{o'} + \frac{1}{i'} = \frac{(1-n)}{r_2} \),

\( -t = \frac{n}{i'} \).