Reflection

i = angle of incidence
r = angle of reflection

i = r
Reflection from a mirror

O = object      I = image

- reflected rays seem to come from I
- Point I is located behind the mirror at a distance $h$ equal to the distance between O and the mirror
- Point O and point I are on a line perpendicular to the plane of the mirror

The image is *virtual*, not real
is it you in the mirror?
no! it’s a virtual you

real you

virtual you

mirror
Refraction: Snell’s law

- \( \frac{\sin \vartheta_{\text{air}}}{\sin \vartheta_{\text{water}}} = \frac{n_{\text{water}}}{n_{\text{air}}} = \text{constant} \)
- \( n \) is the index of refraction
- \( n \) depends on the density of the medium

\( \vartheta_{\text{air}} \): angle of incidence

\( \vartheta_{\text{medium}} \): angle of refraction
Refraction: Snell’s law

\[
\frac{\sin \theta_{\text{air}}}{\sin \theta_{\text{water}}} = \text{constant}
\]

- \(\theta_{\text{air}} = \) angle of incidence
- \(\theta_{\text{medium}} = \) angle of refraction

\(\sin \theta_{\text{air}} \) and \(\sin \theta_{\text{water}}\) are shown in the diagram.
Refraction: total internal reflection
Refraction: examples

- Apparent position
- Real bottom of stick

- Apparent position of the fish
- Real position of the fish

$n = 1.33$
Refraction: examples
Refraction: non parallel surfaces

Prism

Double prism

Region in which the rays cross each other - converge

Lens
converging lenses

Lens formula: \( \frac{1}{o} + \frac{1}{i} = \frac{1}{f} \)

\( f > 0 \)

converging lens, \( o = \infty \)
- real image in focal point
- \( M = \frac{i}{\infty} = 0 \)

converging lens, \( o > f \)
- real inverted image
- \( M = \frac{i}{o} > 0 \) M>1 or M<1

converging lens, \( o < f \)
- virtual upright image
- \( M = \frac{i}{o} > 1 \)
**diverging lenses**

**Lens formula**  \[
\frac{1}{o} + \frac{1}{i} = \frac{1}{f} \quad f < 0
\]

- **diverging lens, \( o = \infty \)**
  - virtual image in focal point
  - \( M = \frac{i}{\infty} = 0 \)

- **diverging lens, \( o > f \)**
  - virtual upright image
  - \( M = \frac{i}{o} < 1 \)

- **diverging lens, \( o < f \)**
  - virtual upright image
  - \( M = \frac{i}{o} < 1 \)