Wave phenomena

Light

Qualitative and quantitative treatment of reflection in curved mirrors, refraction through lenses, refraction, total internal reflection and critical angle at a plane boundary.

Waves

Reflection and refraction at a plane boundary including phase and wave parameter changes if applicable, superposition of pulses, diffraction, 2-point source interference (qualitative), properties of electromagnetic waves.

Relationships:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad or \quad s_i s_o = f^2$$

$$m = \frac{d_i}{d_o} = \frac{h_i}{h_o} \quad or \quad m = \frac{f}{s_o} = \frac{s_i}{f}$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad \frac{n_1}{n_2} = \frac{v_2}{v_1} = \frac{\lambda_2}{\lambda_1}$$

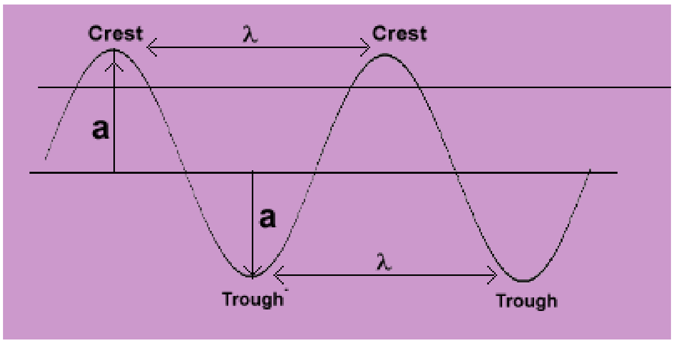
$$v = f\lambda \qquad f = \frac{1}{T} \quad v = \frac{d}{t}$$

All waves carry energy

- Electromagnetic waves:
  - Can travel through a vacuum
  - Maximum speed: **3×10^8ms^{-1}**
  - Radio, micro, infra-red, visible, ultra-violet, x rays, gamma

- Mechanical waves:
  - Water waves
  - waves of ropes/string/springs
  - sound waves **speed: 330ms^{-1}**
  - earthquakes

Useful quantities when measuring waves include wave speed (velocity), wavelength, frequency and amplitude.



The greater the amplitude of a wave then the more energy it is carrying.

Wave equation

v= f λ

All waves:

Reflect (Bounce off)
Refract (Change direction)
Diffract (Bend around)

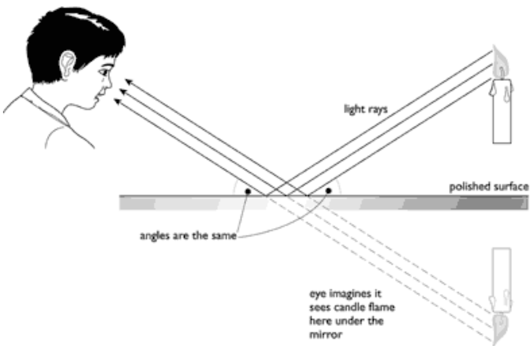
<u>Reflection of light:</u>

Law of reflection: i = r

Angle of incidence=angle of reflection

Plane mirrors

Lateral inversions the same size as the object. The image is the same distance behind the mirror as the object is in front of the mirror. The image is virtual (not real). The image is upright.

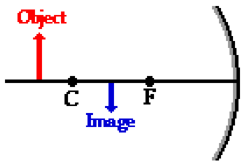


Concave Mirrors:

Using f, the focal length and C, the centre of curvature (sometimes called the radius):

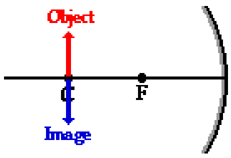
The object is located *beyond* C

The image will be an inverted image. The image is reduced in size. The image is real.



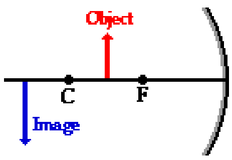
The object is located at C

The image will be inverted. The image size is equal to the object size. The image is real.



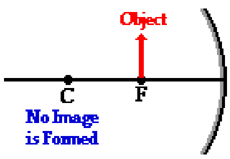
The object is located between C and F

The image will be inverted. The image is larger than the object. The image is real.



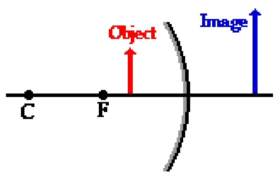
The object is located at F

When the object is located at the focal point, no image is formed.

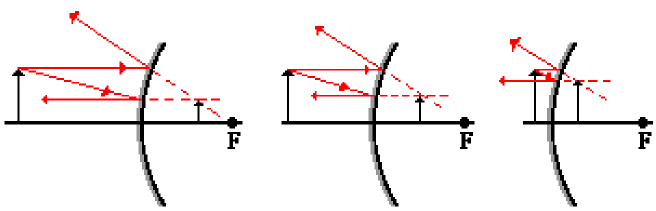


The object is located in front *of* F

The image will be an upright image. The image is magnified. The image is virtual. The image is behind the mirror.



Convex Mirrors:



Regardless of the position of the object:

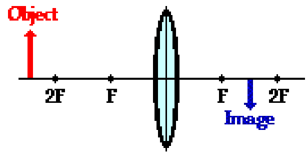
The image will be virtual. The image will be upright. The image will be reduced in size. The image is behind the mirror.

By calculation: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ Magnification: $m = \frac{d_i}{d_o} = \frac{h_i}{h_o}$

- If d_i is behind the mirror it is negative
- The image height, h_i for a virtual image is negative
- The focal length for a convex mirror is negative

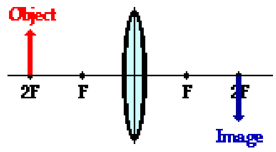
Convex Lenses:

The object is located *beyond* 2F



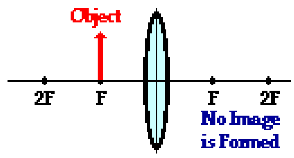
The image will be an **inverted image**. The image is **reduced in size**. The image is real.

The object is located at 2F



The image will be inverted. The image is real. The image size is equal to the object size.

The object is located between 2F and F

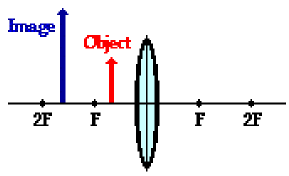


The image will be inverted. The image is larger than the object. The image is real.

The object is located at F

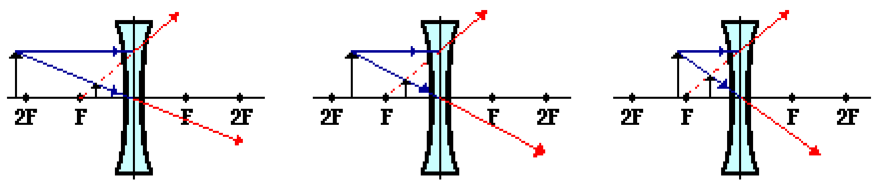
When the object is located at the focal point, no image is formed.

The object is located in front *of* F



The image will be an upright image. The image is magnified. The image is virtual. The image is located on the object's side of the lens.

Concave Lenses:



Regardless of the position of the object:

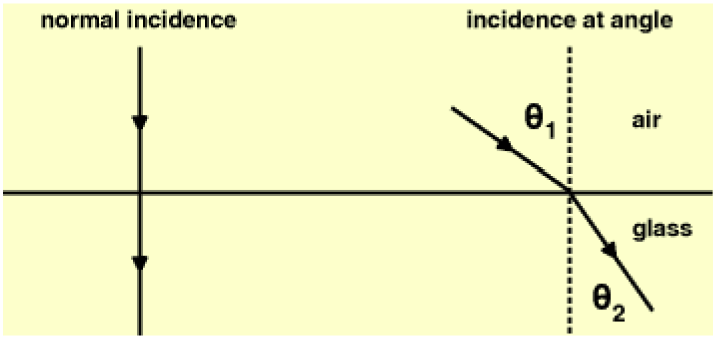
- The image will be virtual. The image will be upright. The image will be reduced in size. The image is located on the object's side of the lens

- By calculation: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ Magnification: $m = \frac{d_i}{d_o} = \frac{h_i}{h_o}$
- If d_i is the same side as the object it is negative
- The image height, h_i for a virtual image is negative
- The focal length for a concave lens is negative

Refraction:

When light travelling in one substance (called a medium) enters another substance at an angle other than perpendicular to the surface, the light changes direction. This is called **refraction**. This is due to the light changing speed as it enters the second medium.
When light travels into a medium of **greater** density it refracts **towards** the normal.
When light travels into a medium of **less** density it refracts **away** from the normal.

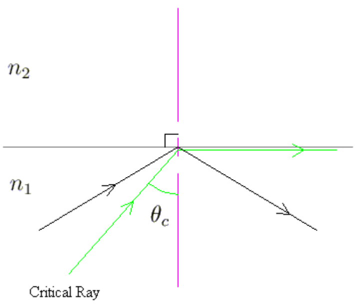
Snell's Law:



$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

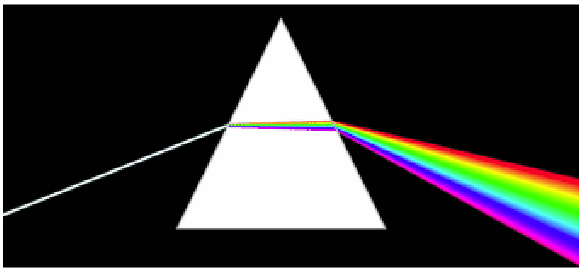
Total Internal Reflection:

When light travel from a certain medium to a less dense medium, a certain angle of incidence will produce an angle of refraction of 90°. This angle of incidence is called the **critical angle** for that material. If the angle of incidence is greater than the critical angle we get **Total Internal Reflection.**



Dispersion (refraction):

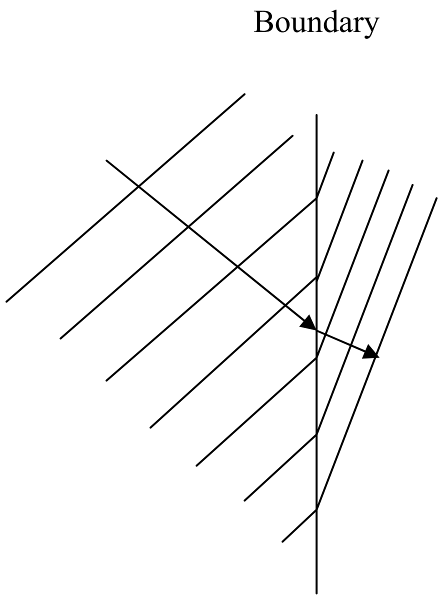
Dispersion is splitting up white light into its different colours.



$$\frac{n_1}{n_2} = \frac{v_2}{v_1} = \frac{\lambda_2}{\lambda_1}$$

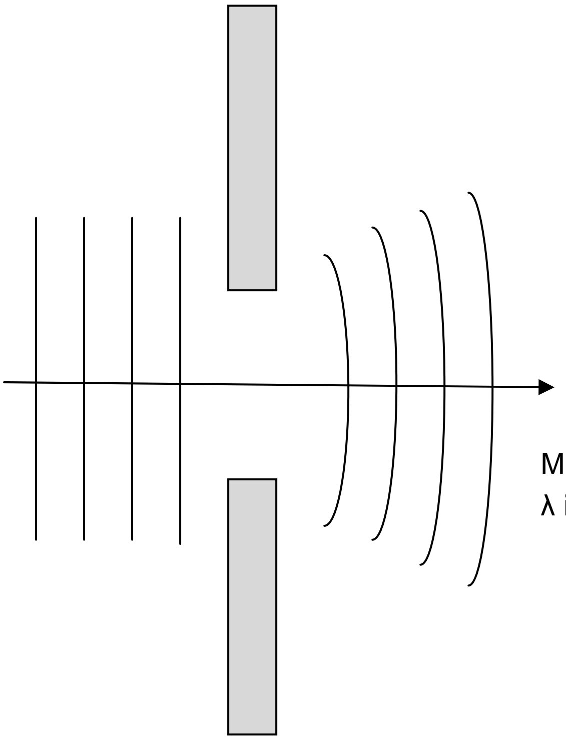
Because different wavelengths (colors) of light travel through a medium at different speeds, the amount of bending is different for different wavelengths. Violet is bent the most and red the least because violet light has a shorter wavelength, and short wavelengths travel more slowly through a medium than longer ones do.

Refraction of water wave (Transverse mechanical wave):



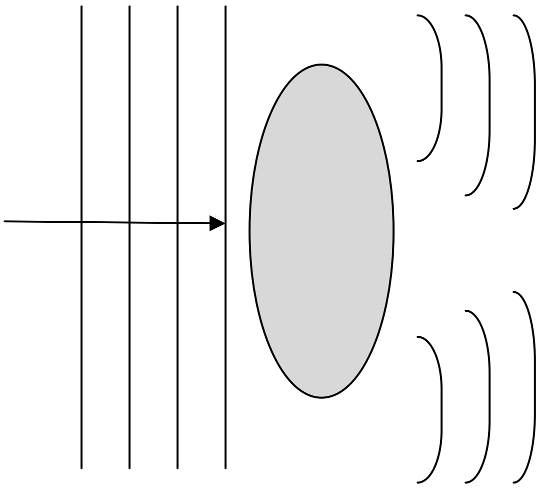
In water waves, shallow⟶ deep, wave length (λ) decrease, velocity (v) decrease, frequency (f) of the wave stays the same.

Diffraction of waves:



Maximum diffraction (spreading out) occurs when the λ is approximately equal to the size of the gap.

Diffraction of waves around a barrier:

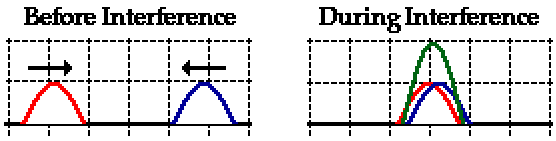


The longer the λ the greater the diffraction around a barrier.

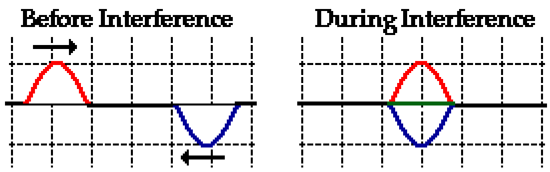
Interference:

Wave interference occurs when two waves meet while traveling along the same medium.

This type of interference is sometimes called constructive interference.

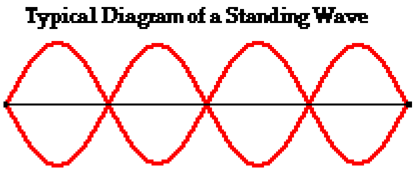


This type of interference is sometimes called constructive interference.



The **principle of superposition** states that when two waves interfere, the resulting displacement of the medium at any location is the algebraic sum of the displacements of the individual waves at that same location.

A **standing wave pattern** is a wave pattern where specific points along the medium appear to be standing still. This is a diagram of standing wave along a string where the wave is bouncing from left to right and then right to left etc.



The interference of two diffracted waves with the same frequency produces antinodes and nodes. The pattern is a standing wave pattern, with nodes (destructive interference) and antinodes (constructive interference) which are standing still. The antinodes (points where the waves always interfere constructively) are located along antinodal lines. The nodes occur along nodal lines.