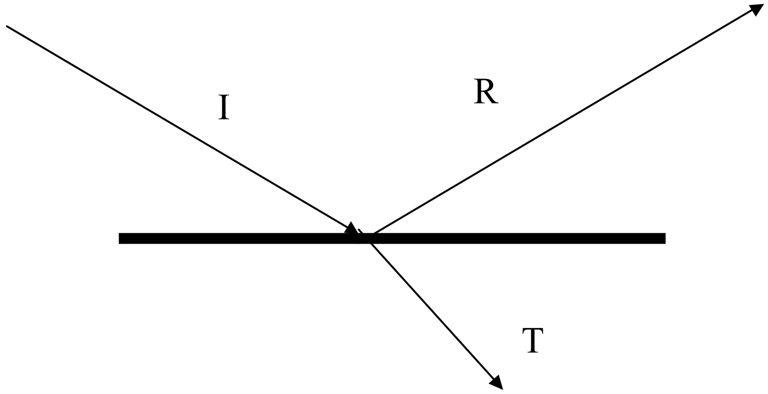
WAVES (cont'd)

WHAT WAVES DO:

- GENERALLY TRAVEL IN STRAIGHT LINES
- REFLECTION
- REFRACTION
- DIFFRACTION
- INTERFERENCE

REFLECTION AND REFRACTION

Reflection and reflection occur whenever a wave hits a boundary between media that have different properties (specifically, the wave has different speeds on either side of the boundary).



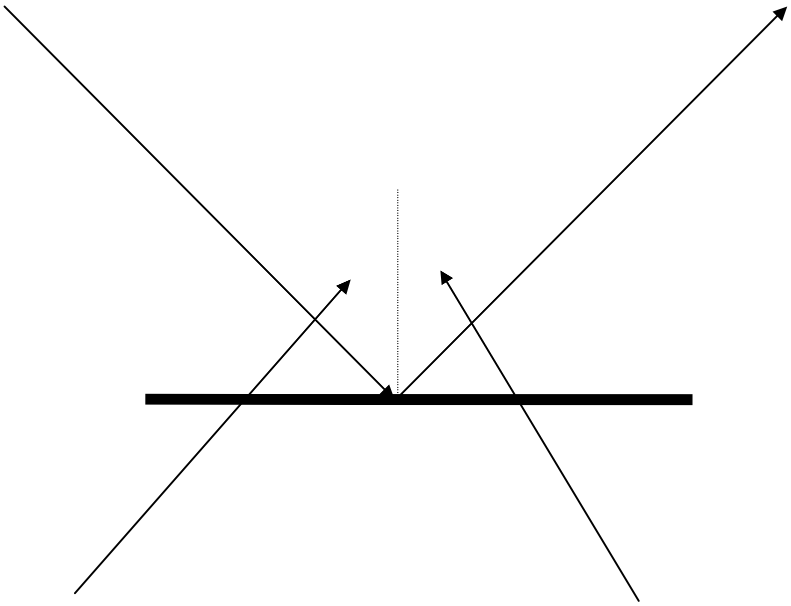
By conservation of energy, R+T=I.

Both reflection and transmission always occur, although the ratio between R and T depends on many factors (such as the speeds of the wave, and the angle of incidence). *Fresnel's equations* give the ratio between R and T.

In general, the shallower the incidence, the greater the reflection.

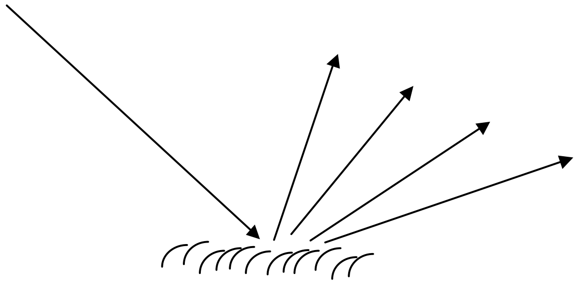
The transmitted wave has to travel through the second medium: if this absorbs the wave ("opaque") , then the wave will not appear to be transmitted. However this does not mean that the wave is completely reflected (R=I) .

REFLECTION



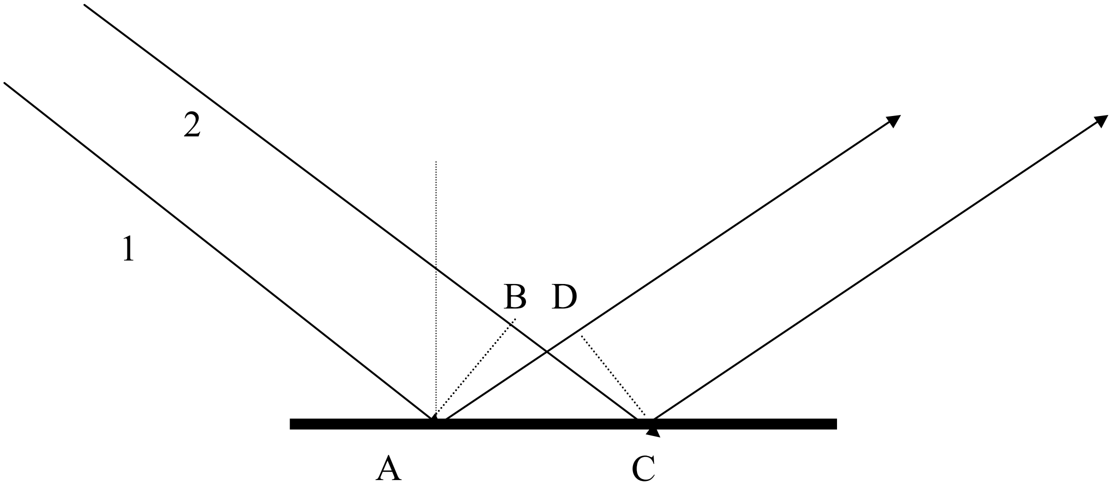
angle of incidence = angle of reflection

(specular reflection)



diffuse reflection

Explanation of reflection



Suppose A and B are two corresponding points on the *wavefront* of a plane wave. Note that AB is perpendicular to both rays 1 and 2.

Thus, when ray 1 is at A, ray 2 is at B

When ray 2 reaches the mirror at C, ray 1 has reached point D.

Since both rays travel at the same speed, BC=AD.

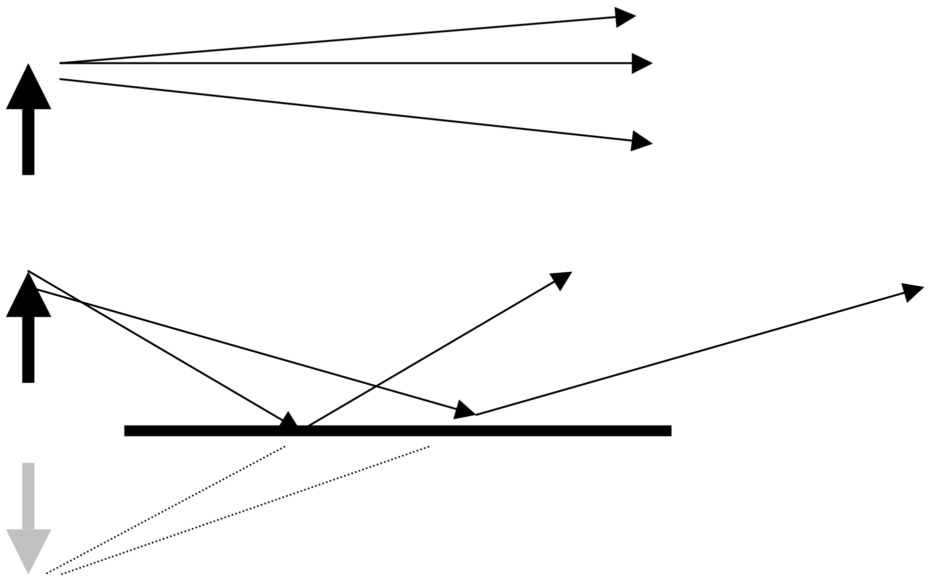
From the congruency of triangles ABC and ADC, the law of reflection follows.

IMAGE FORMING

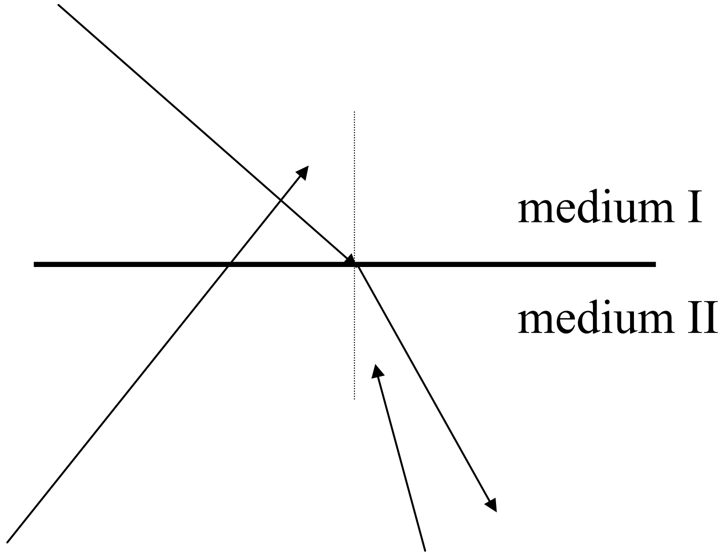
Since specular reflection maps each incident ray into a unique reflected ray, the topographic relationship between rays is maintained.

Thus the reflected rays appear to be coming from an "object" – called an image – that is behind the mirror.

If the reflecting surface is curved, the image may be distorted but is topologically equivalent to the object.



REFRACTION



angle of incidence > angle of refraction (I less dense than II)

angle of incidence < angle of refraction (I more dense than II)

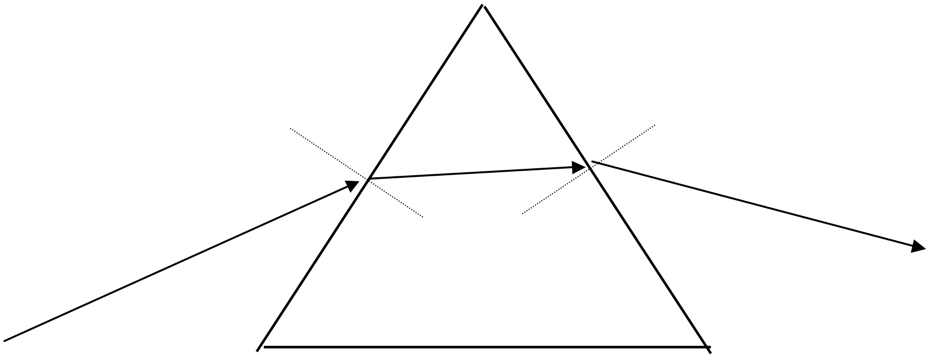
Snell's Law:

$$\frac{\sin i}{\sin r} = n \qquad \text{(refractive index of medium II)}$$

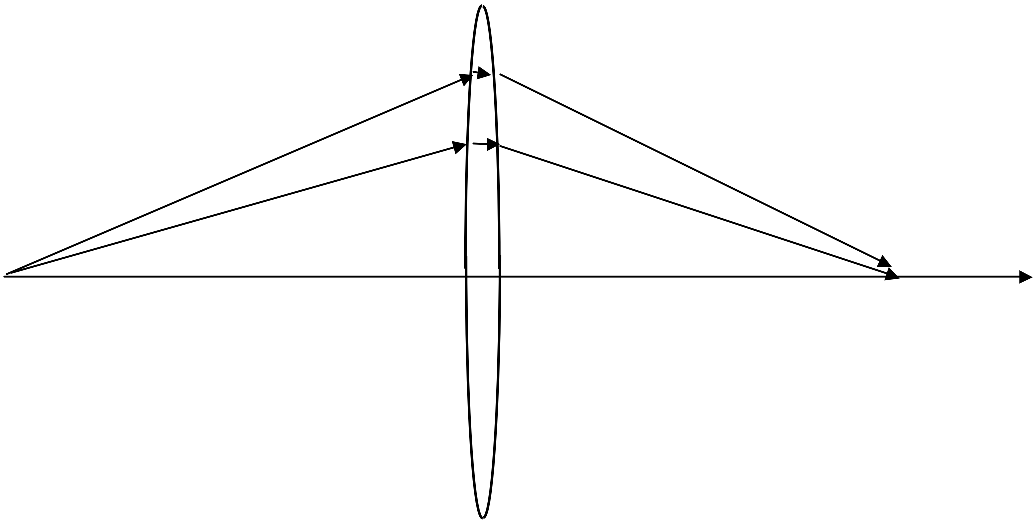
Refraction is also image-forming.

Path of rays through:

- prism

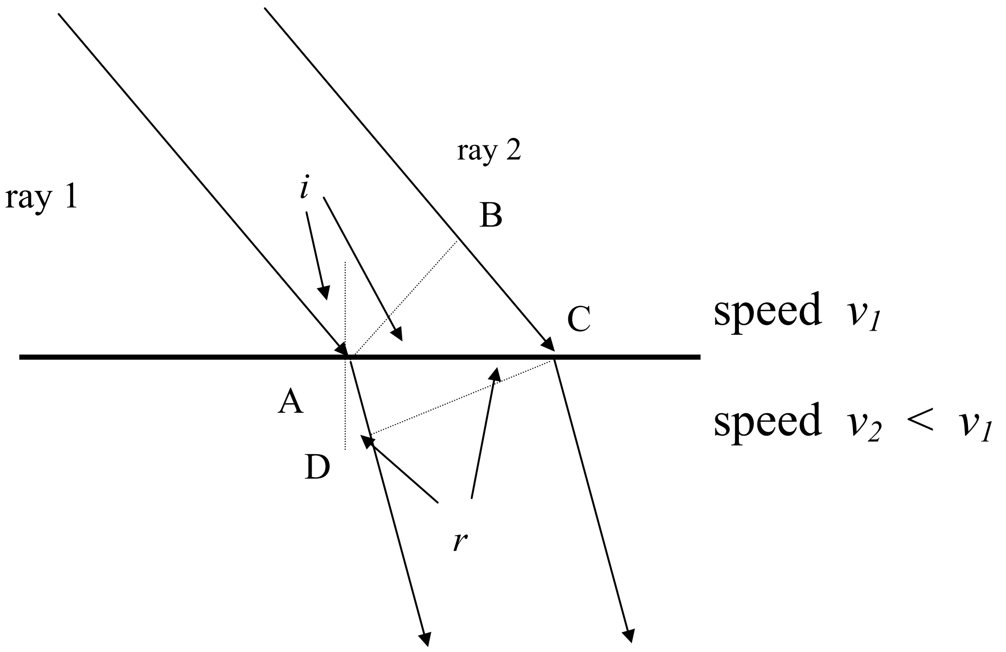


- lens



Explanation of refraction

Waves travel in different media at different speeds



When ray 1 is at A, ray 2 is at B

When ray 2 reaches C , ray A has travelled a *shorter* distance (AD < BC if $v_2 < v_1$)

$$\frac{BC}{AD} = \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = n$$

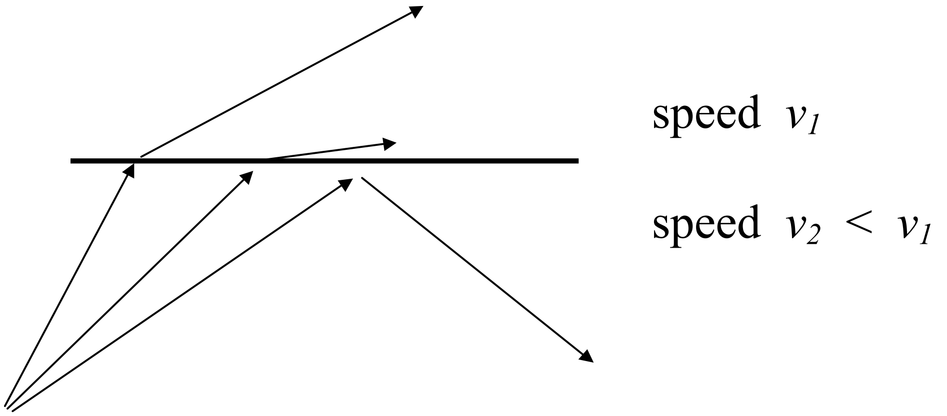
The critical angle

Suppose a ray exits from a dense medium into a less dense medium ($v_1 < v_2$)

Then the refractive index is less than 1 and the angle of refraction is greater than the angle of incidence

In fact, it is possible to have angles of incidence such that $\sin r > 1$.

In this case, refraction does not occur and the wave is reflected back inside the "dense" medium.



It is easy to show that this happens when $\sin i = v_2/v_1$

Newton’s explanation of refraction

Isaac Newton believed that light consisted of a stream of particles, not waves.

When a particle (such as a billiard ball) hits a solid object at an angle, the component of velocity parallel to the object is unchanged. If the object repels the particles of light, then conservation of energy requires that the component of velocity perpendicular to the object is reversed.

Refraction can be explained by having the surface repel the particles more in the denser medium than in the less dense medium. Thus the component of velocity perpendicular to the surface in the denser medium is increased. resulting in the smaller angle of refraction as observed. Note that this explanation results in the velocity of the particles being *greater* in the denser medium.

This theory was finally only refuted by direct measurements of the speed of light in water, which was found to be less than that in a vacuum.

Dispersion

The refractive index of a material is not a constant but depends (among other things) on the frequency of the waves passing through it.

The speed of waves in a material is thus not a constant but a function of the frequency.

Optically, we see different frequencies as different colours. When light passes through a a suitably shaped dispersive material, different colours emerge at different angles. This may be either

- desired (eg: in diamonds)

or

- undesired (eg: in camera or telescope lenses).

Dispersion is a major limiting factor in data transfer rates through optical fibre because if different frequencies travel at different speeds and thus arrive at their destination at different times, the data may be corrupted.