Huygens's principle
&
Wavefronts

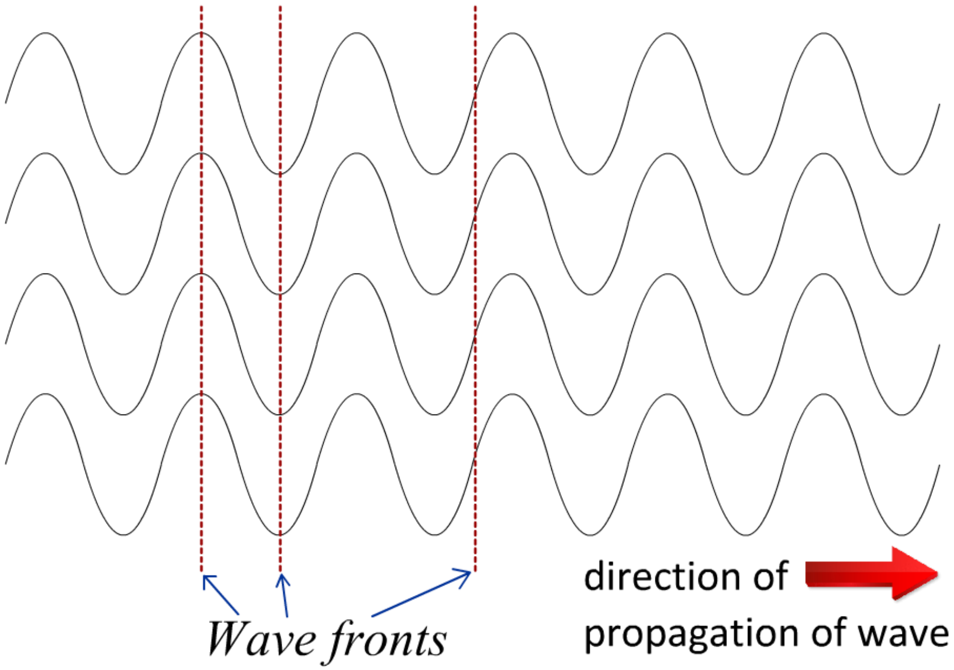
Note : This PPT will NOT help you learn physics concepts. It is intended only as a quick revision of formulas, definitions, theorems and concepts before examinations. No physics can be learnt just by watching a few videos or going through a few slides of PPT.

V Vijaykiran
M.Sc., B.Ed., NET
SIGMA Physics Resource Centre
http://www.sigmaprc.in

Wavefront

A wavefront is defined as a surface of constant phase.
A wavefront is defined as the locus of all points which are in phase.

- Speed at which the wavefront moves forward is called as the speed of the wave
- Energy transfer due to the wave takes place in a direction perpendicular to the wavefront.

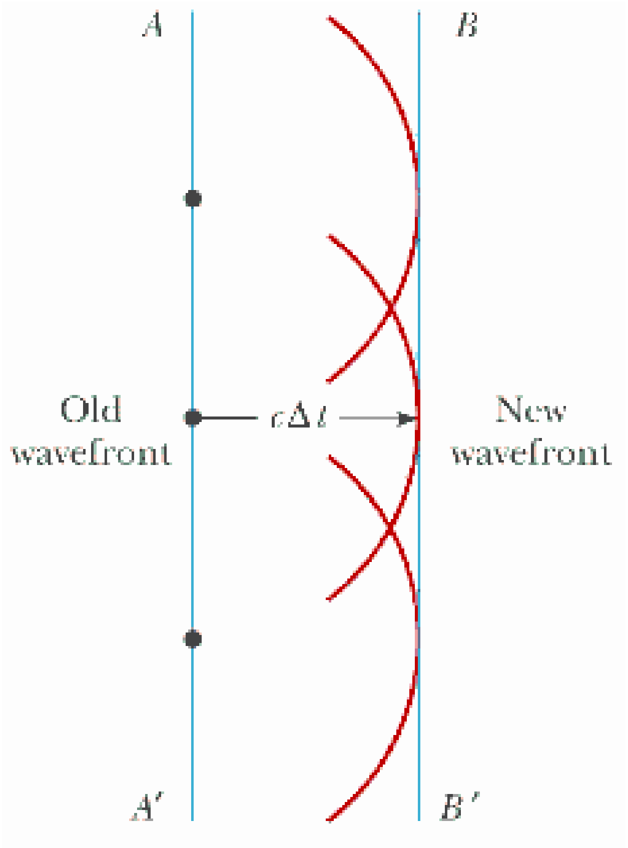


Huygens's principle

Each point of a wavefront acts as a source of secondary disturbance and wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are called as secondary wavelets and a common tangent drawn to all these spheres gives us the new wavefront.

From each point on a wavefront, arcs of radius equal to the distance travelled by light in a certain interval of time, can be drawn. All these arcs represent points which are in phase. When we join these arcs we get a new secondary wavefront.

This process can be repeated to obtain other secondary wavefronts as light propagates in space.



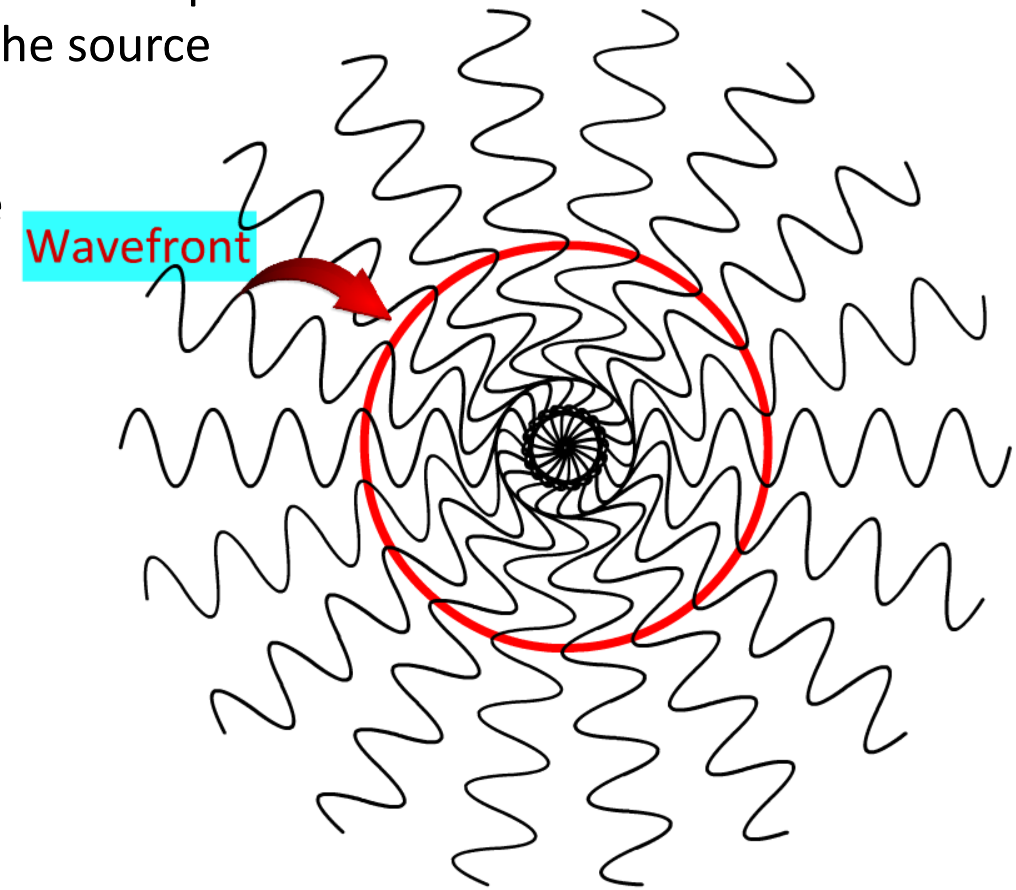
(a)

Kinds of wavefronts (based on the source)

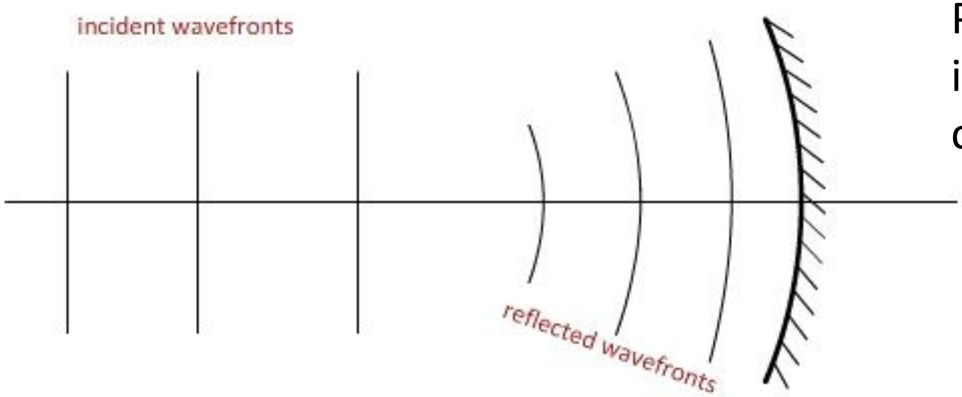
A thin linear source of light produces coaxial cylindrical wavefronts with the source at the axis.

A planar source of light produces plane wavefronts parallel to the plane of the source

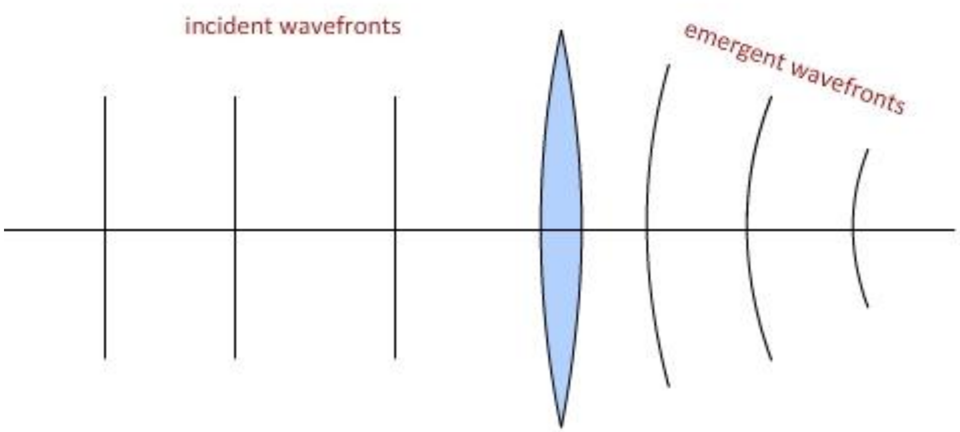
A point source produces spherical wavefronts with the centre at the source.



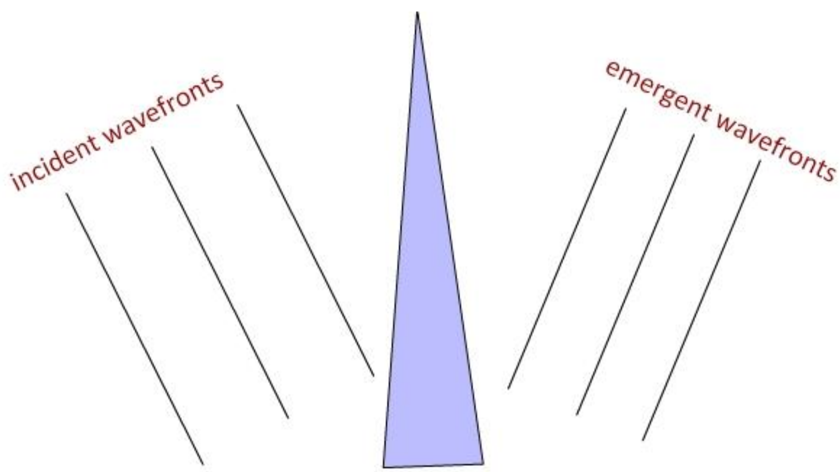
Wavefronts for different phenomena



Plane wavefronts represent a parallel beam of incident light. Concave wavefronts represent a convergent beam of reflected light.



Plane wavefronts represent a parallel beam of incident light. Concave wavefronts represent a convergent beam of emergent light.



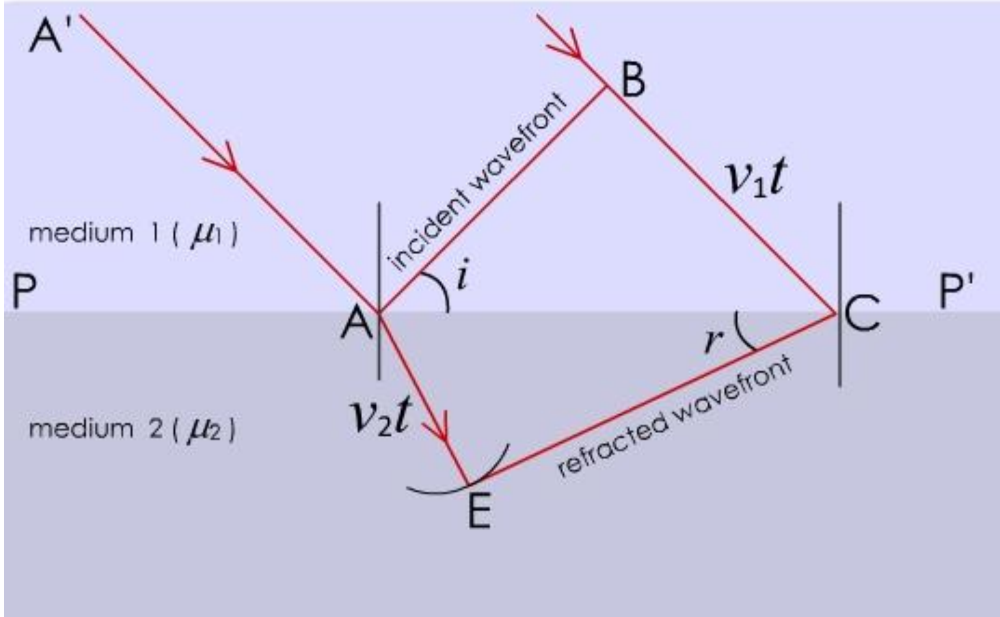
One set of plane wavefronts represent a parallel beam of incident light and the other set of plane wavefronts represent a parallel beam of emergent light.

Refraction of light from rarer to denser medium (using Huygens's principle)

Consider two media of refractive indices μ_1 and μ_2 as shown in the diagram. PP' represents the interface of the two media.

Consider a beam of light propagating from rarer medium (μ_1) to the denser medium (μ_2).

Let AB be the plane wavefront incident on the interface. Angle of incidence (i) is also the angle made by incident wavefront w.r.t. the plane of interface of the media.



Let t be the time taken for the incident wavefront to travel from B to C.
If the same interval of time (t) distance covered by refracted wave from A is obtained by (using Huygens's principle) drawing arcs of radius v_2t from the point A. Joining C to the arc at E we get the plane that represents the refracted wavefront.

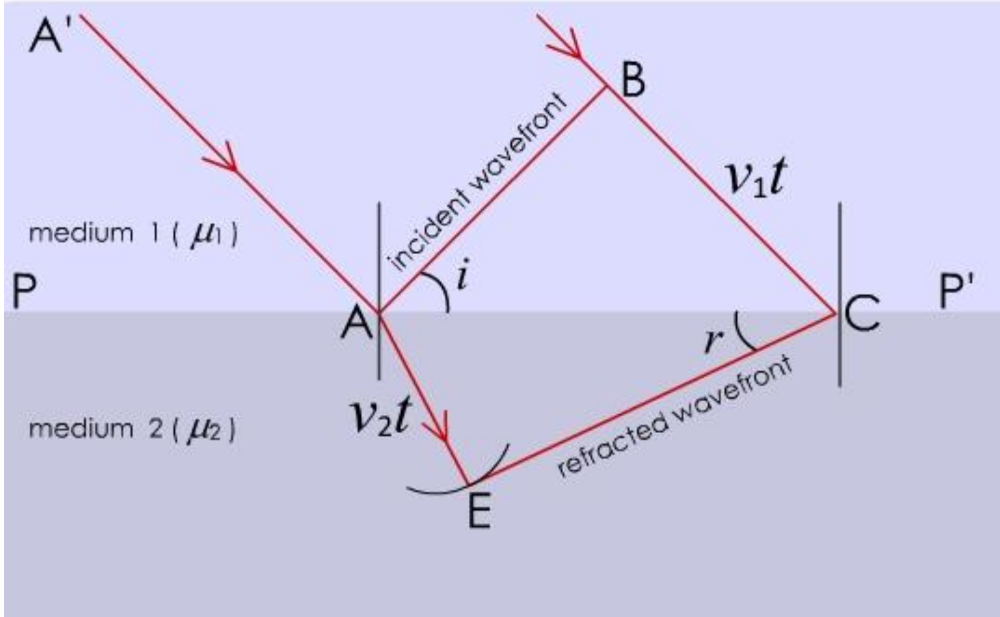
Refraction of light (using Huygens's principle)

From triangle ABC $\sin(i) = \dfrac{BC}{AC}$

$$\Rightarrow AC = \frac{BC}{\sin(i)} \quad \text{i}$$

From triangle AEC $\sin(r) = \dfrac{AE}{AC}$

$$\Rightarrow AC = \frac{AE}{\sin(r)} \quad \text{ii}$$



Comparing equations (i) & (ii)

$$\frac{BC}{\sin(i)} = \frac{AE}{\sin(r)}$$

$$\frac{BC}{AE} = \frac{\sin(i)}{\sin(r)}$$

Using $s = v \times t$ we get

$$\frac{v_1 t}{v_2 t} = \frac{\sin(i)}{\sin(r)}$$

$$\frac{v_1}{v_2} = \frac{\sin(i)}{\sin(r)}$$

Using $\mu = v_o / v$ we get

$$\frac{\mu_2}{\mu_1} = \frac{\sin(i)}{\sin(r)}$$

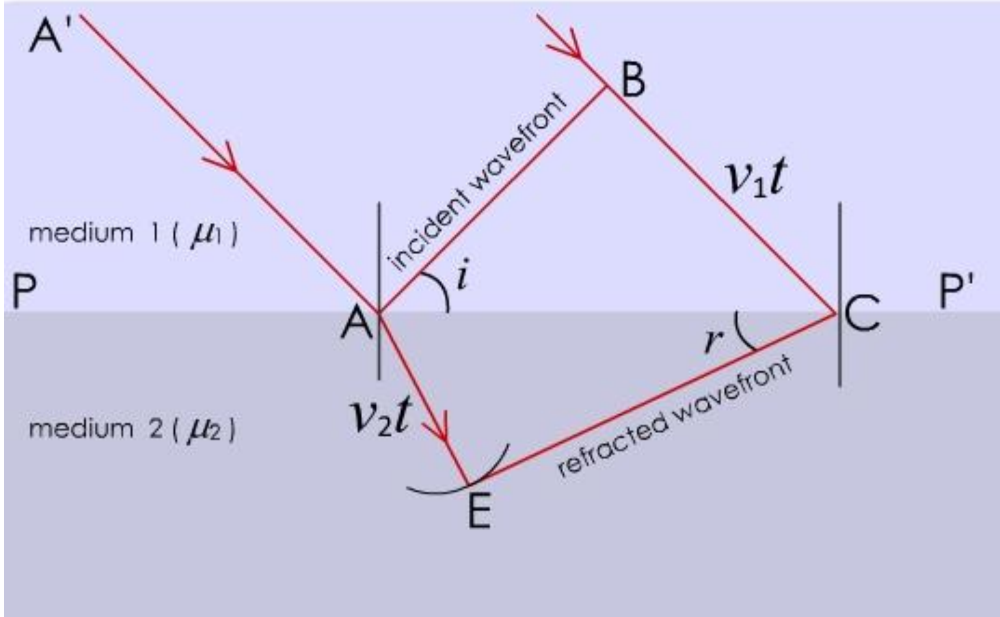
$$\boxed{\mu_1 \sin(i) = \mu_2 \sin(r)}$$

Refraction of light from denser to rarer medium (using Huygens's principle)

Consider two media of refractive indices μ_1 and μ_2 as shown in the diagram. PP' represents the interface of the two media.

Consider a beam of light propagating from denser medium (μ_1) to the rarer medium (μ_2).

Let AB be the plane wavefront incident on the interface. Angle of incidence (i) is also the angle made by incident wavefront w.r.t. the plane of interface of the media.



Let t be the time taken for the incident wavefront to travel from B to C.
If the same interval of time (t) distance covered by refracted wave from A is obtained by (using Huygens's principle) drawing arcs of radius $v_2 t$ from the point A. Joining C to the arc at E we get the plane that represents the refracted wavefront.

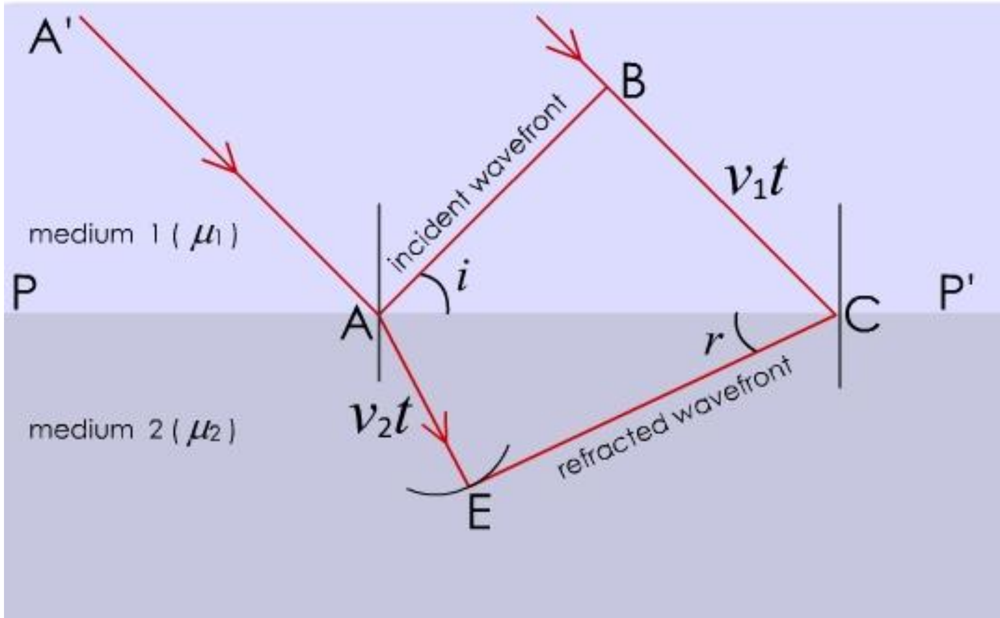
Refraction of light (using Huygens's principle)

From triangle ABC $\sin(i) = \dfrac{BC}{AC}$

$$\Rightarrow AC = \frac{BC}{\sin(i)} \quad \text{--- i}$$

From triangle AEC $\sin(r) = \dfrac{AE}{AC}$

$$\Rightarrow AC = \frac{AE}{\sin(r)} \quad \text{--- ii}$$



Comparing equations (i) & (ii)

$$\frac{BC}{\sin(i)} = \frac{AE}{\sin(r)}$$

$$\frac{BC}{AE} = \frac{\sin(i)}{\sin(r)}$$

Using $s = v \times t$ we get

$$\frac{v_1 t}{v_2 t} = \frac{\sin(i)}{\sin(r)}$$

$$\frac{v_1}{v_2} = \frac{\sin(i)}{\sin(r)}$$

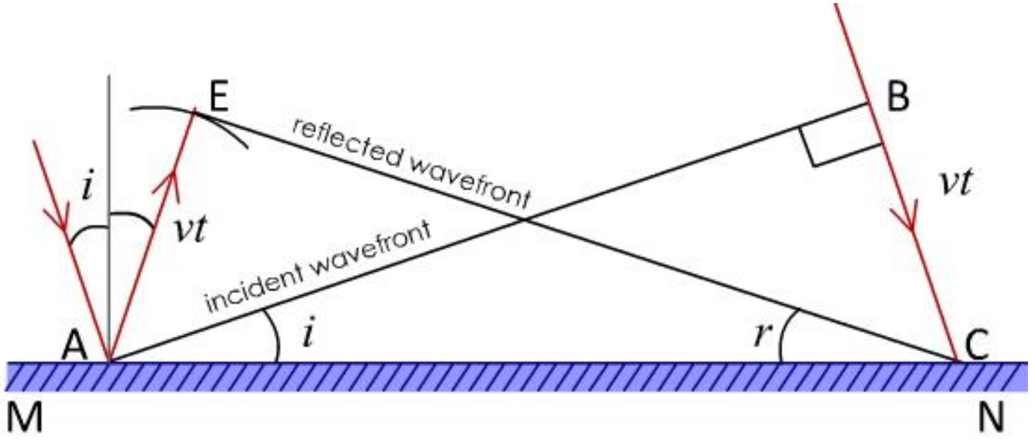
Using $\mu = v_o / v$ we get

$$\frac{\mu_2}{\mu_1} = \frac{\sin(i)}{\sin(r)}$$

$$\boxed{\mu_1 \sin(i) = \mu_2 \sin(r)}$$

Reflection of light (using Huygens's principle)

Consider a plane wavefront AB incident on a reflecting surface MN as shown in the figure.
Let v be velocity of the wave (or the wavefront). If t is the time taken for the wave to propagate from B to C then BC = vt.

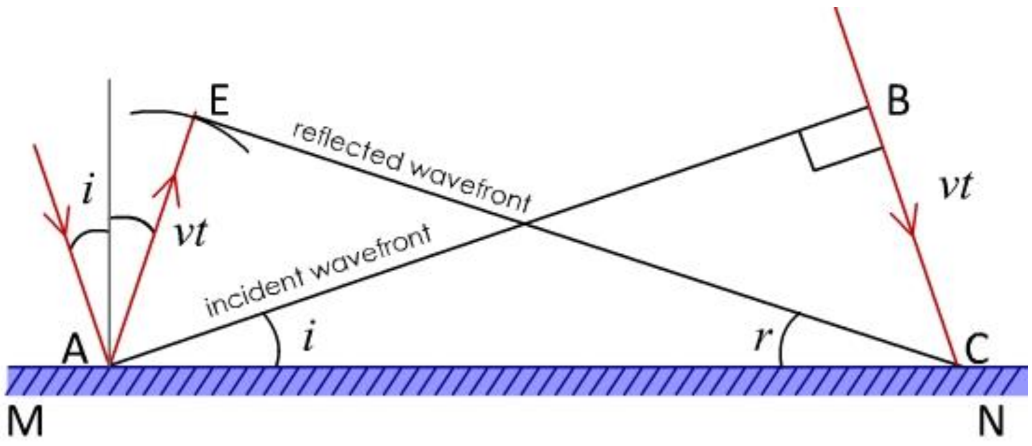


Distance travelled by the reflected wave at point A, in the same interval of time is AE. Using Huygens construction, we draw an arc of length vt, with A as the centre. A tangent drawn to this arc from the point C represents the reflected wavefront.

Refraction of light (using Huygens's principle)

From Δ ABC $\quad \sin(i) = \dfrac{BC}{AC}$

$$\Rightarrow AC = \frac{BC}{\sin(i)} \quad \text{— i}$$



From Δ AEC $\quad \sin(r) = \dfrac{AE}{AC}$

$$\Rightarrow AC = \frac{AE}{\sin(r)} \quad \text{— ii}$$

Comparing equations (i) & (ii)

$$\frac{BC}{\sin(i)} = \frac{AE}{\sin(r)}$$

$$\frac{BC}{AE} = \frac{\sin(i)}{\sin(r)}$$

Using $\quad s = v \text{ x } t \quad$ we get

$$\frac{vt}{vt} = \frac{\sin(i)}{\sin(r)}$$

$$\frac{\sin(i)}{\sin(r)} = 1$$

$$\sin(i) = \sin(r)$$

$$\boxed{i = r}$$