WAVE OPTICS

Nature of Light

Definition and properties of wave-front

Huygens' Principle

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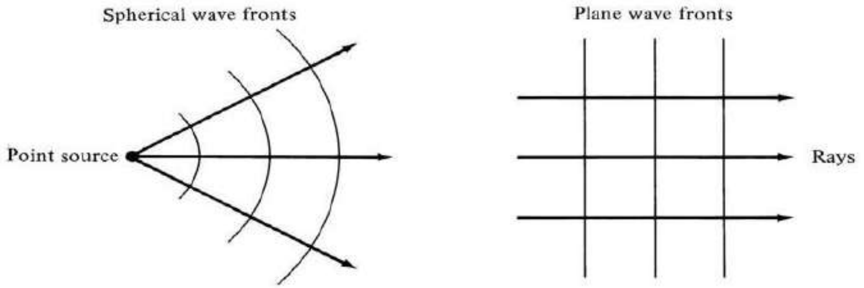
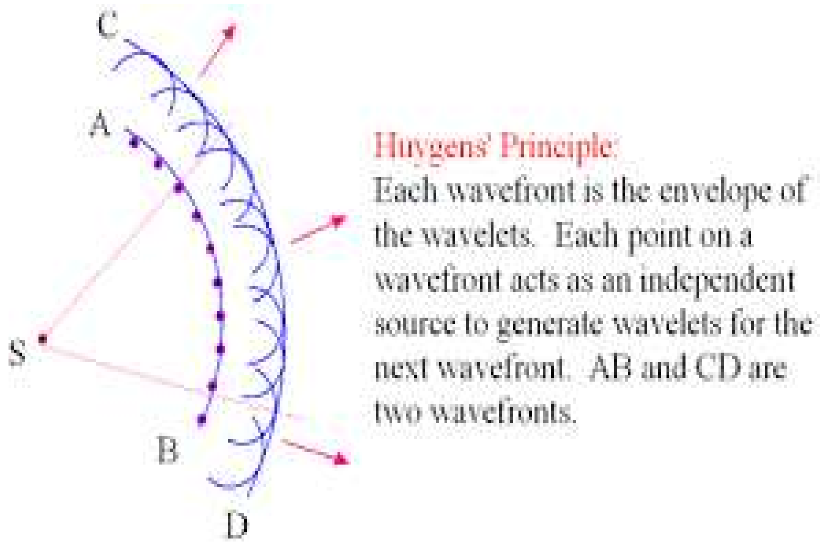
WAVE & WAVEFRONT

- Any physical entity which varies both in space and time is said to constitute a wave.
- $\psi = f(x, t)$
- $\psi(x, t) = f(x - vt)$ General form of one dimensional wave propagating along the positive x-direction.
- $\frac{\partial^2 \psi}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 \psi}{\partial t^2}$ Differential wave equation
- Superposition principle: $\psi = c_1 f_1(x - vt) + c_2 f_2(x + vt)$
- Wavefront: A wavefront is a surface upon which the phase of the disturbance is the same at any given instant of time.

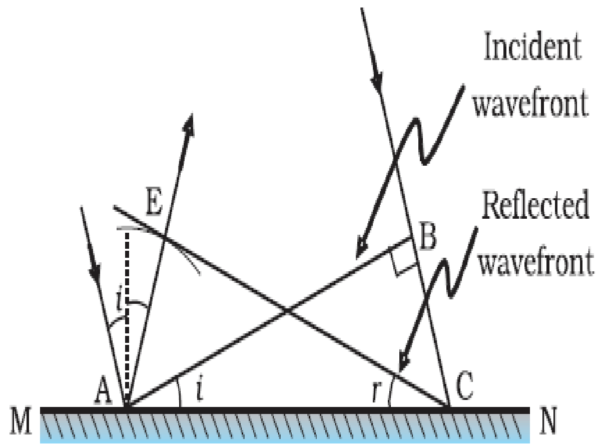


HUYGENS' PRINCIPLE

- In a homogeneous and isotropic medium every point of a primary wavefront serves as the source of spherical secondary wavelets that travel with a speed and frequency equal to those of primary wave. The wavefront at some later instant of time is the envelope of theses wavelets.



LAWS OF REFLECTION FROM THE WAVE THEORY



Reflection of a plane wave AB by the reflecting surface MN. AB and CE represent incident and reflected wavefronts.

These incident wavefront is carrying two points, point A and point B, so we can say that from point B to point C light is travelling a distance. If ' v ' represents the speed of the wave in the medium and if ' r ' represents the time taken by the wavefront from the point B to C then the distance

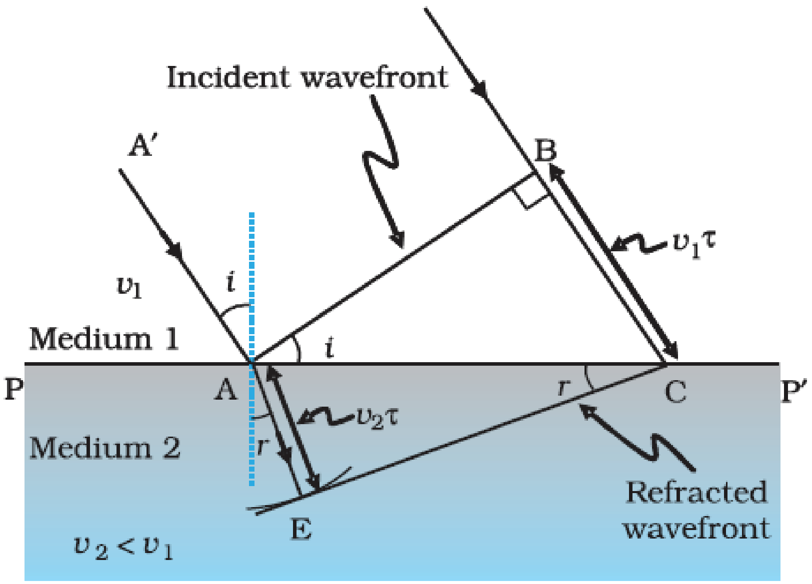
$$BC = vr$$

In order the construct the reflected wavefront we draw a sphere of radius vr from the point A. Let CE represent the tangent plane drawn from the point C to this sphere. So,

$$AE = BC = vr$$

If we now consider the triangles EAC and BAC we will find that they are congruent and therefore, the angles ' i ' and 'r ' would be equal. This is the law of reflection.

LAWS OF REFRACTION FROM THE WAVE THEORY

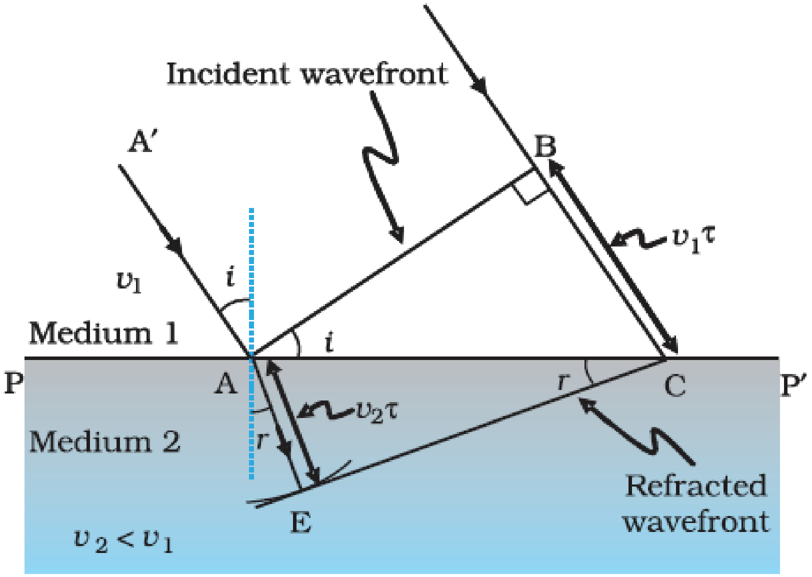


A plane wave AB is incident at an angle i on the surface PP′ separating medium 1 and medium 2. The plane wave undergoes refraction and CE represents the refracted wavefront. The figure corresponds to $v_2 < v_1$ so that the refracted waves bends towards the normal.

We know that when a light travels from one transparent medium to another transparent medium its path changes. So the laws of refraction state that the angle of incidence is the angle between the incident ray and the normal and the angle of refraction is the angle between the refracted ray and the normal.

The incident ray, reflected ray and the normal, to the interface of any two given mediums all lie in the same plane. We also know that the ratio of the sine of the angle of incidence and sine of the angle of refraction is constant.

LAWS OF REFRACTION FROM THE WAVE THEORY



A plane wave AB is incident at an angle *i* on the surface PP′ separating medium 1 and medium 2. The plane wave undergoes refraction and CE represents the refracted wavefront. The figure corresponds to $v_2 < v_1$ so that the refracted waves bends towards the normal.

We can see a ray of light is incident on this surface and another ray which is parallel to this ray is also incident on this surface. As these rays are incident from the surface, so we call it incident ray.

Let PP' represent the medium 1 and medium 2. The speed of the light in this medium is represented by v_1 and v_2. If we draw a perpendicular from point 'A' to this ray of light, Point A, and point B will have a line joining them and this is called as wavefront and this wavefront is incident on the surface.

If ' r ' represents the time taken by the wavefront from the point B to C then the distance,

$$\mathbf{BC = v_1 r}$$

So to determine the shape of the refracted wavefront, we draw a sphere of radius v_2r from the point A in the second medium. Let CE represent a tangent plane drawn from the point C on to the sphere. Then, AE = v_2r, and CE would represent the refracted wavefront. If we now consider the triangles ABC and AEC, we readily obtain

$$\sin i = \frac{BC}{AC} = \frac{v_1 r}{AC}$$

$$\sin r = \frac{AE}{AC} = \frac{v_2 r}{AC}$$

where' i ' and ' r ' are the angles of incidence and refraction, respectively. Substituting the values of v_1 and v_2 in terms of we get the Snell's Law,

$n_1 \sin i = n_2 \sin r$