Chapter- 10

Nature of Propagation of Light

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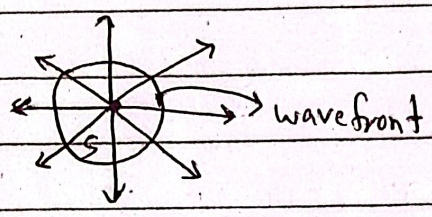
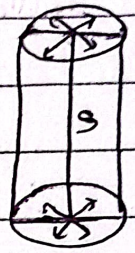
Wavefront

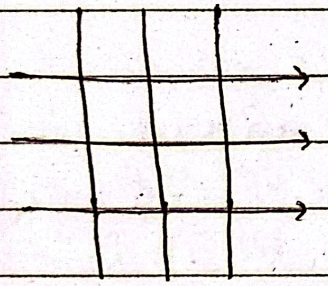
It is the locus of all adjacent points which are equidistant from the source of light and are vibrating in the same phase.



Spherical wavefront



cylindrical wavefront



Plane wavefront

Ray of light

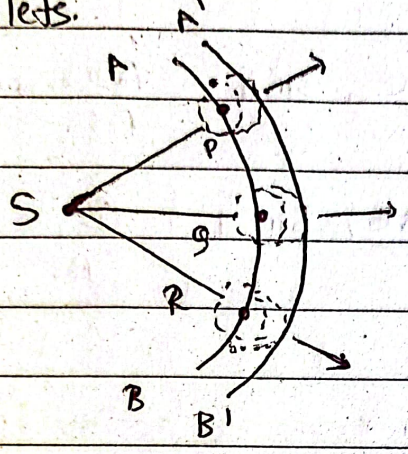
An arrow drawn perpendicular to the wavefront in a ~~distraction~~ direction of propagation of wave is called ray of light. It ~~includes the path~~ indicates the path along which the light travels.

Huygen's Principle

Statement: (i) Each point on the primary wavefronts act as a ~~source~~ source of new disturbance called secondary wavelets.

ii) The secondary wavelets spread out in all directions with the speed of light as source does.

iii. The forward envelope of the secondary wavelets at any ~~point~~ instant gives the shape of new wavefronts i.e. the new wavefront is found by constructing a surface tangent to the secondary wavelets.



Laws of Reflection on the basis of Huygen's Theory:

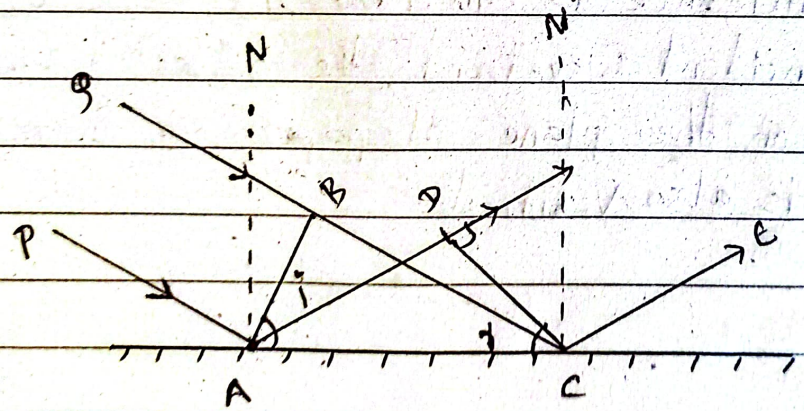


fig: Laws of reflection on the basis of Huygen's theory

Let us consider a plane wavefront, AS incident on reflecting surface making angle i with reflecting surface. Let P and Q are two rays perpendicular to wavefront AS. When the ray Q reaches the reflecting surface the ray P is reflected along AD such that BC = AD. The tangent connecting points C and D gives the

reflected ~~wavefront~~ wavefront which makes angle r with the reflecting surface.

Now,

from the figure:

In right angled ΔADC, $\sin r = \frac{AD}{AC}$ or, $AD = AC \sin r$ — ①

In right angled ΔABC, $\sin i = \frac{BC}{AC}$ or, $BC = AC \sin i$ — ②

As, $BC = AD$

i.e. $AC \sin i = AC \sin r$

or, $\sin i = \sin r$

$\therefore i = r$

i.e angle of incidence is equal to the angle of reflection.

In figure the incident wavefront, the reflected wavefront and normal all lie on the plane of paper. So, ~~second~~ second law of reflection is also verified.

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Laws of Reflection on the basis of Huygen's Principle:

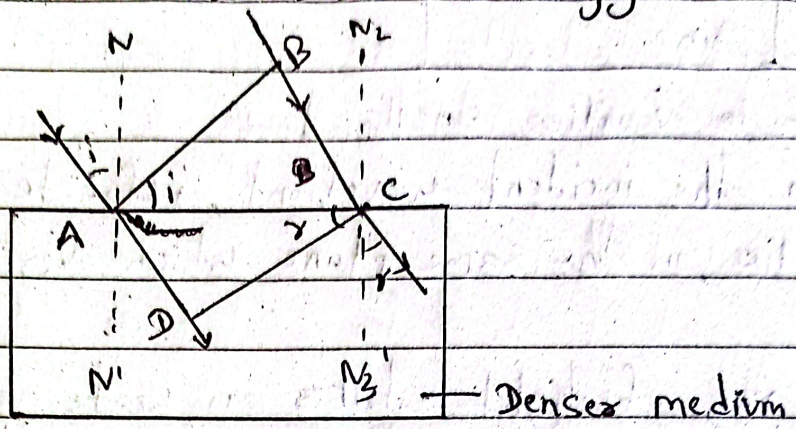

Fig: Refraction of wave

Let AB is incident wavefront on which two rays are drawn perpendicular at points A and B. N_2N_1 is normal at point A, i is angle of incidence. Let v_1 is velocity of light in rarer medium and v_2 is velocity of light in denser medium. When the ray at B reaches the interface at C, the ray at A would have refracted and reached point D as shown in figure. The refracted wavefront is denoted by CD. N_2N_3 is normal at point C and r is angle of refraction.

In triangle ABC,

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

In Δ ACD, $\sin r = \frac{AD}{AC}$ ——(II)

Dividing (I) by (II)

$$\frac{\sin i}{\sin r} = \frac{BC}{AC} \times \frac{AC}{AD} = \frac{v_1 \times t}{v_2 \times t}$$ {t is the time taken}

or $$\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$$

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or, $\boxed{\frac{\sin i}{\sin r} = \mu}$

This ~~is~~ verifies snell's law.

Also, the incident wavefront, refracted wavefront and the normal all lie on the same plane which verifies 2nd law of refraction.

Q. A ray of light strikes on water glass interface at 60° with glass surface. find the angle of refraction ~~in~~ in glass.
(Absolute R.I of water = 1.33, Absolute R.I of glass = 1.5)

Solution:

Given, Absolute R.I of water $({}_a\mu_w) = 1.33$

Absolute R.I of glass $({}_a\mu_g) = 1.5$

Angle of incident $(\angle i) = 60°$

Angle of refraction $(\angle r) = ?$

We know,

$$\frac{\sin i}{\sin r} = {}_w\mu_g$$

$$\text{or, } \frac{\sin i}{\sin r} = {}_a\mu_g \times {}_g\mu_w \times {}_w\mu_a \times {}_a\mu_g$$

$$\text{or } \frac{\sin i}{\sin r} = \frac{{}_a\mu_g}{{}_a\mu_w}$$

$$\text{or } \frac{\sin 60}{\sin r} = \frac{1.5}{1.33}$$

$$\text{or, } \sin r = \sin 60 \times \frac{1}{1.127}$$

$$\text{or } r = \sin^{-1}(0.97) \quad \sin^{-1}($$

$$\text{or, } \frac{\sqrt{3}}{2} \times \frac{1.33}{1.5} = \sin r$$

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$$\text{or } \gamma = \sin^{-1}\left(\frac{\sqrt{3} \times 1.33}{2 \times 1.5}\right)$$

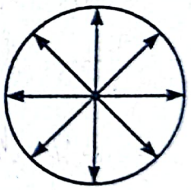
$$\therefore \gamma = 50.16^{\circ}$$

Old Course

Short Answer Questions

3. 2076 GIE Set A Q.No. 4b Differentiate between a plane wave front and a spherical wave front.

A wavefront is the continuous locus of vibrating particles of the medium which are in the same state of vibration or phase. If a point source in an isotropic medium (i.e. a medium in which the waves travel with the same speed in all directions) is sending out waves in three dimensions, the wavefronts are spheres centered on the source as shown in Fig. (i), such a wavefront is called a spherical wavefront. At a large distance from a source of any kind, the wavefront will appear plane as shown in Fig. (ii), such a wavefront is called plane wavefront.

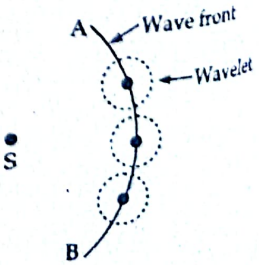


(i)

(ii)

4. 2076 GIE Set B Q.No. 4a What are meant by wave front and wavelets? [2]

Wavefront at any instant is defined as the locus of the particles of the medium vibrating in the same phase. Every point on the wavefront acts a source of a disturbance; these disturbances from the points are called wavelets. Each point on a wave surface can act like a new source of smaller spherical waves which are called wavelets. The wavelets may originate from the primary as well as secondary source of light. Wavefronts are the envelope of these wavelets.



[2]

5. 2076 Set B Q.No. 4a State Huygen's principle. Does it apply to sound wave in air?

Please refer to 2080 Set P Q.No. 15 or

6. 2076 Set C Q.No. 4a | 2075 Set A Q.No. 4a | 2075 Set B Q.No. 4a | 2074 Supp Q.No. 4a | 2072 Set C Q.No. 4a | 2070 Set C Q.No. 4 b | 2056 Q.No. 2 c **Differentiate wave front and wavelet.** [2]

Please refer to 2076 GIE Set B Q.No. 4a

7. 2074 Set A Q.No. 4a | 2072 Set E Q.No. 4a **Explain with proper sketch, the differences between wavefronts and wavelets.** [2]

Please refer to 2076 GIE Set B Q.No. 4a

8. 2073 Set D Q.No. 4a **What is the difference between wavefront and wavelets in the explanation of Huygen's wave theory?** [2]

Please refer to 2076 GIE Set B Q.No. 4a

9. 2072 Set E Q.No. 4a **Explain with proper sketch, the differences between wavefronts and wavelets.** [2]

Please refer to 2076 GIE Set B Q.No. 4a

10. 2071 Supp Q.No. 4a **If light travels from one medium to another, its velocity changes? Is it due to change in frequency or wavelength? Explain.** [2]

The velocity of light is given by $v = \lambda \times f$, where λ is wavelength of light in that medium & f is frequency. Since, frequency is fundamental or empirical parameter of a wave & it does not change with medium. So, the velocity of light wave changes on changing wavelength when light passes from one medium to another medium.

11. 2070 Supp. (Set B) Q.No. 4 a **A normally incident wavefront does not deviate, when it travels from one medium to another. Explain.** [2]

According to Snell's law of refraction, the refractive index of a medium is given by, $\mu = \frac{\sin i}{\sin r}$, where i is incident angle and r is refracted angle. For normal incidence, $i = 0$, then $r = 0$ as $\mu \neq 0$, the minimum value of μ is 1 but never is equal to 0. So, a normally incident wavefront does not deviate, when it travels from one medium to another.

12. 2069 Supp Set B Q.No. 4 b **Can Snell's law be verified from wave theory? Explain with figure only.** [2]

Yes, snell's law can be verified from wave theory.

From right angled triangle APP',

$\sin i = \frac{PP'}{AP'} = \frac{ct}{AP'}$;

c = vel. of light in air

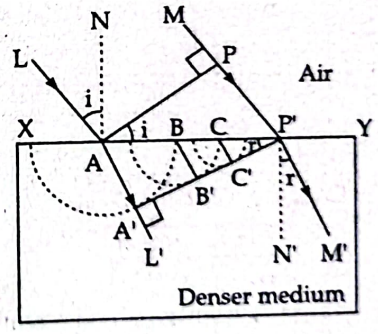
From right angled triangle AA'P',

$\sin r = \frac{AA'}{AP'} = \frac{vt}{AP'}$;

v = vel. of light in denser medium

Now, $\frac{\sin i}{\sin r} = \frac{ct}{vt} = \frac{c}{v} = \mu$

$\therefore \mu = \frac{\sin i}{\sin r}$ which is Snell's law.



13. 2069 (Set A) Old Q.No. 2g | 2068 Q.No. 4 b **What is wavefront?** [2]

Wavefront is the locus of all vibrating particles which are in same phase. The shape of wavefront is different according to the nature and distance from the source of light.

14. 2067 Q.No. 4b **What is Huygens's principle?** [2]

Please refer to 202080 Set P Q.No. 15 or

15. 2067 Old Q.No. 2c **When monochromatic light incidents on a surface, the reflected and refracted wave will have same frequency, why?** [2]

When monochromatic light incidents on a surface, the reflected and refracted wave will have same frequency because frequency of a wave is empirical parameter and does not change with reflection and refraction.

16. 2063 Q.No. 2 c **Which parameter of light does not change on refraction?** [2]

During the refraction of light, velocity and wavelength of light wave are changed but frequency is not changed because frequency is fundamental parameter of light wave. It is the characteristics of the source that produce the wave.

Long Answer Questions

17. 2078 Set C Q.No. 8a State Huygen's principle and use it to verify laws of reflection on the basis of wave theory. [4]

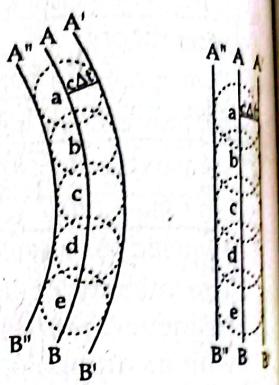
Please refer to 2080 Set P Q.No. 15 OR

18. 2077 Set D Q.No. 2d State and explain Huygen's construction and use it to verify laws of refraction. [4]

Huygen's principle: Huygens principle is a geometrical construction of a wavefront which is used to determine the position of wavefront at a later time from its position at any instant. The principle is based on the following assumptions:

a. Each point on the primary (given) wavefront acts as a source of secondary wavelets, the light waves sending out from secondary sources travel in all direction with the speed of light.

b. The new position of the wavefront at any instant is given by the forward envelope of the secondary wavelets at that instant.



Refraction on basis of wave theory: Let XY be a plane surface separating air form a denser medium and AP be a plane wavefront just incident on it. The lines LA and MP which are perpendicular to the incident wavefront AP, represent incident rays. If AN is normal to the surface at A, then ∠LAN = i is the angle of incidence as shown in figure. Again the wavefront arrives at point A first of all and will arrive at points B, C,... later in time but in this order.

Therefore, different points on the surface XY will become source of secondary wavelets at different instants of time. When the disturbance from point P on incident wavefront has reached point P' on the surface, the secondary wavelets from point A on the surface will have acquired a radius, say equal to AA' and those from points B, C ... equal to BB', CC'... respectively. The refracted wavefront will be the tangent plane A'P' touching all the secondary spherical wavelets. The lines A'L' and P'M perpendicular to the refracted wavefront A'P' are refracted rays. If P'N' is normal to the surface of separation at point P', then ∠N'P'M' = r is the angle of refraction.

Let c be velocity of light in air and v, the velocity in denser medium. As the distance PP' in air and the distance AA' in denser medium are covered by the light in same time, therefore

$$\frac{PP'}{AA'} = \frac{c \times t}{v \times t} = \frac{c}{v} \quad \ldots(i)$$

As the angle between two lines is same as the angle between their perpendiculars, therefore,

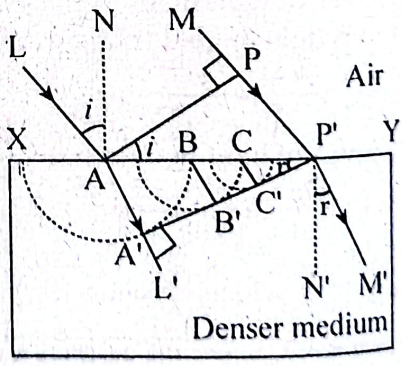
∠PAP' = i and ∠AP'A' = r

From right angled triangle APP',

$$\sin i = \frac{PP'}{AP'}$$

And from right angled triangle AA'P',

$$\sin r = \frac{AA'}{AP'}$$



$$\therefore \mu = \frac{\sin i}{\sin r} = \frac{PP'}{AP'} \cdot \frac{AP'}{AA'}$$

$$\frac{\sin i}{\sin r} = \frac{PP'}{AA'} \quad \ldots(ii)$$

From equation (i) and (ii), we have

$$\frac{\sin i}{\sin r} = \frac{c}{v} = \mu$$ which is Snell's law.

Here, $\frac{c}{v} = \mu$, a constant and is called the refractive index of denser medium with respect to rarer medium.

∴ Thus, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for the given pair of media.

Further, it can be proved that the incident ray (LA), the normal (AN) and the refracted ray (AA'L) all lie in the same plane. This proves another law of refraction.

Hence, the laws of refraction are proved on the basis of wave theory.

19. 2076 GIE Set A Q.No. 8a Explain laws of reflection of light on the basis of wave theory. [4]

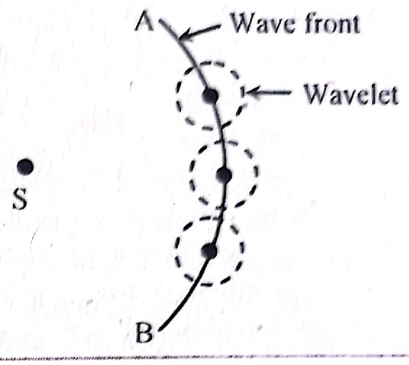
Please refer to 2080 Set P Q.No. 15 OR

20. 2076 Set C Q.No. 8a 2072 Set D Q.No. 8a **State and explain Huygen's principle and use it to verify laws of reflection on the basis of wave theory.** [4]

Please refer to 2080 Set P Q.No. 15 OR

21. 2075 GIE Q.No. 8a **What is meant by wave front? Verify Snell's law on the basis of wave theory.** [4]

Wave Front: Wavefront at any instant is defined as the locus of the particles of the medium vibrating in the same phase. Every point on the wavefront acts a source of a disturbance; these disturbances from the points are called wavelets. Each point on a wave surface can act like a new source of smaller spherical waves which are called wavelets. The wavelets may originate from the primary as well as secondary source of light. Wavefronts are the envelope of these wavelets.



Refraction on basis of wave theory: Please refer to 2077 Set D Q.No. 2d