Huygens Principle

1 Mark Questions

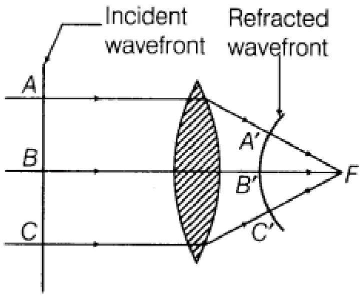
1.When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a decrease in the energy carried by the light wave? Justify your answer.[All India 2010]

Ans.speed decreases due to decrease of wavelength of wave but energy carried by the light wave depends on the amplitude of electric field vector

2.What type of wave front will emerge from a
(i)point source
(ii)distant light source? [Delhi 2009]

Ans.(i)When source of light is a point source, the wavefront is spherical.
(ii) At very large distances from the source, a portio of spherical or cylindrical waver at appears to be plane.

3.Draw a diagram to show refraction of a plane wave front incident on a convex lens and hence draw the refracted wave front. [Delhi 2009]
Ans.The refraction of a plane wavefront is shown in the figure below



(1)

4.Differentiate between a ray and a wave front.[Delhi 2009]
Ans. Ray A ray always remains perpendicular to the wave front and directed along the direction of propagation of wave.
Wave front The locus of all those particles which are vibrating in the same phase at any instant is called wave front.

5.Draw the wave front coming out from a convex lens, when a point source of light is placed at its focus. [Foreign 2009]
Ans.The wavelength in the given condition is shown in figure below

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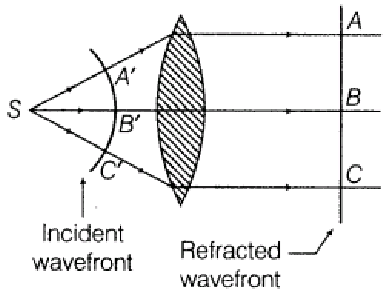
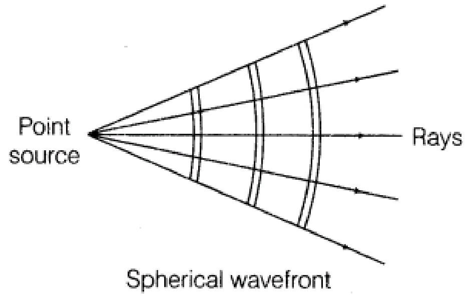


(1)

6.Sketch the shape of wave front emerging from a point source of light and also mark the rays. [Foreign 2009]
Ans.

When source of light is a point source, then wavefront is spherical.



(1)

7.Define a wave front. [Foreign 2009]
Ans.When light is emitted from a source, then the particles present around it begins to vibrate.

The locus of all such particles which are vibrating in the same phase is termed as wave front.

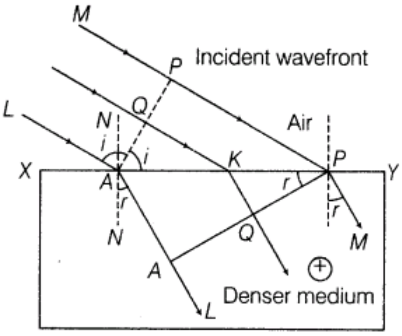
3 Marks Questions

8.Define a wavefront. Use Huygens' geometrical construction to show the propagation of plane wave front from a rarer medium (1) to a denser medium (2) undergoing refraction, hence derive Snell's law of refraction. [Foreign 2012]

Ans.When light is emitted from a source, then the particles present around it beginsto vibrate.

The locus of all such particles which are vibrating in the same phase is termed as wave front.

Consider any point Q on the incident wavefront.



(1)

Suppose when disturbance from point P on incident wavefront reaches point P' on the refracted wavefront, the disturbance from point Q reaches the point Q' on the refracting surface XY. Since, $A'Q'P'$ represents the refracted wavefront, the time taken by light to travel from a point on incident wavefront to the corresponding point on refracted wavefront should always be the same. Now, time taken by light to go from Q to Q' will be

$$t = \frac{QK}{c} + \frac{kQ'}{v} \quad \text{...(i)}$$

(where, c and v are the velocities of light in two mediums)

In right angled ΔAQK, $\angle QAK = i$

$$\therefore \quad QK = AK \sin i \quad \text{...(ii)}$$

In right angled $\Delta P'Q'K$, $\angle Q'P'K = r$,

$$KQ' = KP' \sin r \quad \text{...(iii)}$$

Substituting Eqs. (ii) and (iii) in Eq. (i), we get

$$t = \frac{AK \sin i}{c} + \frac{KP' \sin r}{v}$$

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The rays from different points on the incident wavefront will take the same time to reach the corresponding points on the refracted wavefront, i.e. given by Eq. (iv) is independent of AK. It will happen so, if

$$\frac{\sin i}{c} - \sin\frac{r}{v} = 0 \Rightarrow \frac{\sin i}{\sin r} = \frac{c}{v}$$

However, $\frac{c}{v} = n$

9.(i) Use Huygens' geometrical construction to show the behaviour of a plane wave front,

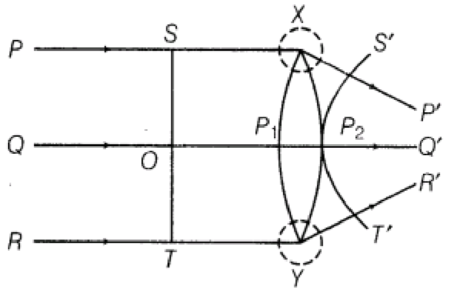
(a)passing through a biconvex lens

(b)reflected by a concave mirror,

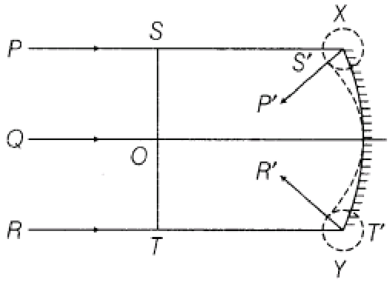
(ii) When monochromatic light is incident on a surface separating two media, why does the refracted light have the same frequency as that of the incident light? [Foreign 2012]

Ans.

(*i*) (*a*) **Behaviour of a converging lens**



(*b*) **Behaviour of a concave mirror**

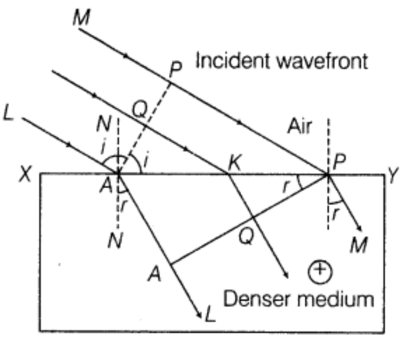


(ii)The frequency and time period of an electromagnetic wave depends only on the source which produces it. The frequency is independent of the medium through which it travels. But the speed and wavelength depends on the medium through which the wave travels. Because of this, the frequency and time period of sound wave do not change due to change in medium

10.Using Huygens' geometrical construction of wave front, show how a plane wave g^is reflected from a surface. Hence, verify laws of reflection. [All India 2011]

Ans.When light is emitted from a source, then the particles present around it beginsto vibrate. The locus of all such particles which are vibrating in the same phase is termed as wave front.

Consider any point Q on the incident wavefront.



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Suppose when disturbance from point P on incident wavefront reaches point P' on the refracted wavefront, the disturbance from point Q reaches the point Q' on the refracting surface XY. Since, $A'Q'P'$ represents the refracted wavefront, the time taken by light to travel from a point on incident wavefront to the corresponding point on refracted wavefront should always be the same. Now, time taken by light to go from Q to Q' will be

$$t = \frac{QK}{c} + \frac{kQ'}{v} \quad \text{...(i)}$$

(where, c and v are the velocities of light in two mediums)

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The rays from different points on the incident wavefront will take the same time to reach the corresponding points on the refracted wavefront, i.e. given by Eq. (iv) is independent of AK. It will happen so, if

$$\frac{\sin i}{c} - \sin\frac{r}{v} = 0 \Rightarrow \frac{\sin i}{\sin r} = \frac{c}{v}$$

However, $\frac{c}{v} = n$

11.Use Huygens' principle to verify the laws of refraction. [Delhi 2011]

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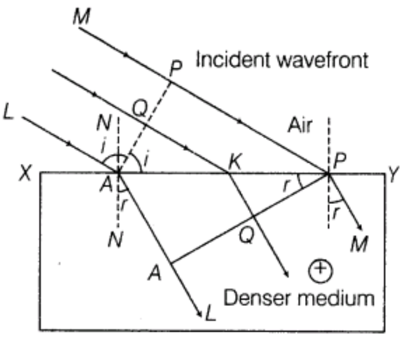

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However, $\frac{c}{v} = n$

12.Using Huygens' principle, draw a diagram showing how a plane wave gets refracted, when it is incident on the surface separating a rarer medium from a denser medium. Hence, verify Snell's laws of refraction. [All India 2011]

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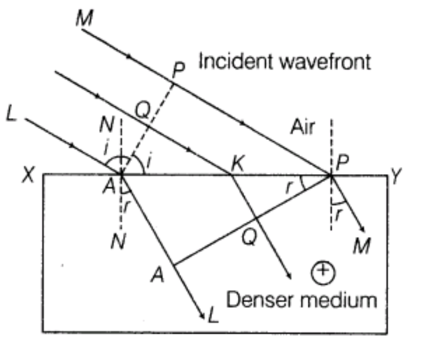

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However, $\frac{c}{v} = n$

13.How is a wave front defined? Using Huygens' construction, draw a figure showing the propagation of a plane wave refracting at a plane surface separating two media. Hence, verify Snell's law of refraction. [Delhi 2008]

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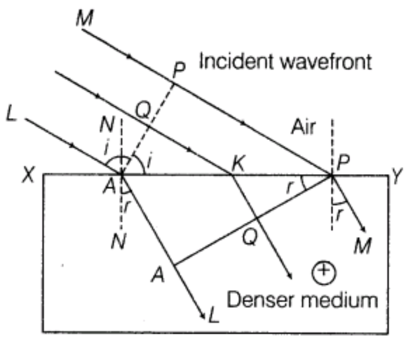

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5 Marks Questions

14.(i) Use Huygens' geometrical construction to show how a plane wave front at t = 0 propagates and produces a wave front at a later time.

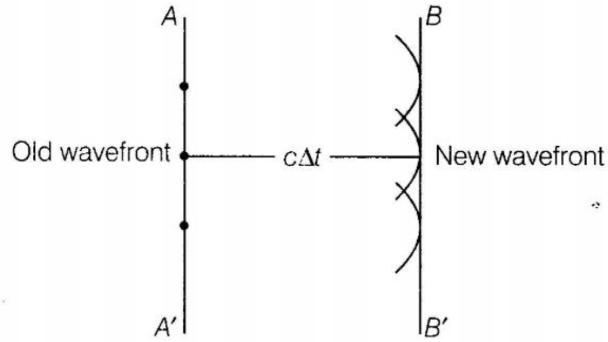
(ii) Verify, using Huygens' principle, Snell's law of refraction of a plane wave propagating from a denser to a rarer medium.

(iii)When monochromatic light is incident on a surface separation two media, the reflected and refracted light both have the same frequency. Explain why?[Delhi 2013 C]

Ans.

(*i*) Consider a plane wave moving through free space as shown in figure. At $t = 0$, the wavefront is indicated by the plane labelled AA'. According to Huygens' principle, each point on this wavefront is considered a point source.

For clearity, only three point sources on AA' are as shown in figure below.



With these sources for the wavelets, we draw circular arcs, each of radius $c\,\Delta t$, where c is the speed of light in vacuum and Δt is some time interval during which the wave propagates. The surface drawn target to these wavelets is the plane BB', which is the wavefront at a later time and is parallel to AA'. **(1)**

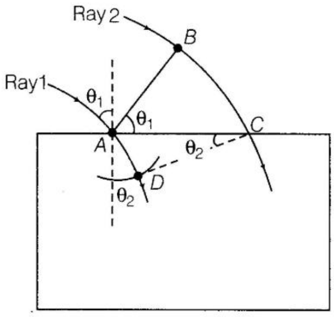
(*ii*) Consider ray 1 strikes the surface and the subsequent time interval ray 2 strikes the surface as shown in the given figure. During the time interval, the wave at A sends out a Huygens' wavelet (the light brown are passing through D) and the light refracts into the material, making an angle θ_2 with the normal to the surface.

In the same time interval, the wave at B sends out a Huygens' wavelet (the light brown are passing through C) and the light continues to propagate in the same direction. The radius of the wavelet from A is $AD = v_2 \Delta t$, where v_2 is the wave speed in the second medium. The radius of the wavelet from B is $BC = v_1 \Delta t$, where v_1 is the wave speed in the original medium.

From ΔS, ABC and ADC, we find that

$$\sin\theta_1 = \frac{BC}{AC} = \frac{v_1 \Delta t}{AC} \quad \text{...(i)}$$

and $$\sin\theta_2 = \frac{AD}{AC} = \frac{v_2 \Delta t}{AC} \quad \text{...(ii)}$$



On dividing the Eq.(i) by the Eq.(ii), we get

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}$$

We know that, $v_1 = \frac{c}{n_1}$ and $v_2 = \frac{c}{n_2}$

Therefore, $\frac{\sin\theta_1}{\sin\theta_2} = \frac{c / n_1}{c / n_2} = \frac{n_2}{n_1}$

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

Which is Snell's law of refraction. **(2)**

(iii) The reflection and refraction phenomenon occur due to interaction of corpuscles of incident light and the atoms of matter on receiving light energy, the atoms are forced to oscillate about their mean positions with the same frequency as incident light. According to Maxwell's classical theory, the frequency of light emitted by a charged oscillator is same as its frequency of oscillation. Thus, the frequency of reflected and refracted light is same as the incident frequency.

15.State Huygens' principle. Using. this principle draw a diagram to show how a plane wavefront incident at the interface of the two media gets refracted when it propagates from a rarer to a denser medium. Hence, verify Snell's law of refraction. [Delhi 2013]
Ans.Huygens' Principle

- Each point on the primary wavefront acts as a source of secondary wavelets, sending out disturbance in all directions in a similar manner as the original source of light does,

(I)

- The new position of the wavefront at any instant (called secondary wavefront) is the envelope of the secondary wavelets at that instant.

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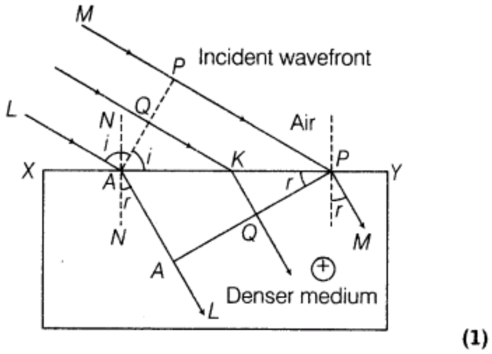
Consider any point Q on the incident wavefront.



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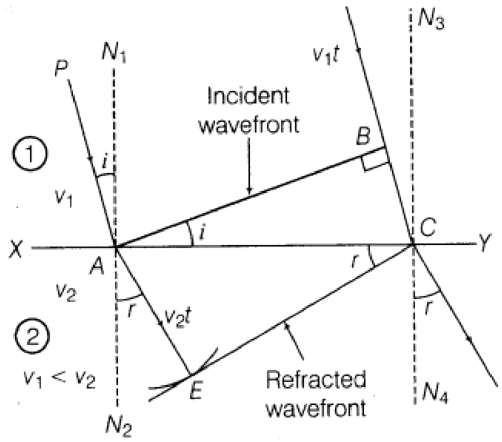
However, $\quad \frac{c}{v} = n$

16.(i) A plane wavefront approaches a plane surface separating two media. If medium 1 is optically denser and medium 2 is optically rarer, using Huygens' principle, explain and show how a refracted wavefront is constructed?

(ii)Verify Snell's law.

(iii)When a light wave travels from a rarer to a denser medium, the speed decreases. Does it imply reduction in its energy? Explain.[Foreign 2011]

Ans.(i) Let a plane wavefront AB is incident at the interface XY separating two media such that medium 1 is optically denser than medium 2. Let time t is taken by the wave to reach from B to C



then, $BC = v_1 t$ ...(i)

where, v_1 is the velocity of light in medium 1. In the duration of time t, the secondary wavelets emitted from point A gets spread over a hemisphere of radius,

$$AE = v_2 t \quad \text{...(ii)}$$

in the medium 2 and $v_2 > v_1$.

The tangent plane CE from C over this hemisphere of radius $v_2 t$ will be the new refracted wavefront of AB.

It is the evidence that angle of refraction r is greater than angle of incidence i.

By geometry,

$$\angle N_2AE = \angle ECA = r$$

(angle of refraction)

Also, $\angle PAN_1 = \angle BAC = i$

(angle of incidence) **(2)**

(*ii*) Now, in ΔABC,

$$\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC} \quad \text{...(iii)}$$

(from Eq. (i))

$$\text{In } \Delta AEC, \sin r = \frac{AE}{AC} = \frac{v_2\, t}{AC} \quad \text{...(iv)}$$

(from Eq. (ii))

$$\text{Now, } \frac{\sin i}{\sin r} = \frac{\frac{v_1 t}{AC}}{\frac{v_2 t}{AC}}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \text{constant}$$

$$= {}_1\mu_2$$

where, ${}_1\mu_2$ = refractive index of second medium w.r.t. first medium. **(2)**

Hence, Snell's law of refraction is verified.

(*iii*) No, energy carried by the wave does not depend on its speed instead, it depends on the amplitude of wave. **(1)**