Refraction of Light at Plane Surfaces

Improve your learning

Q. 1. Why is it difficult to shoot a fish swimming in water? (AS1)

Answer : Due to the phenomenon of refraction the depth of pond appears to rise upwards. Hence, we cannot estimate the actual depth of fish in water and when we shoot the fish it appears to be raised therefore it becomes difficult to shoot the fish swimming in water. The figure below illustrates the phenomenon.

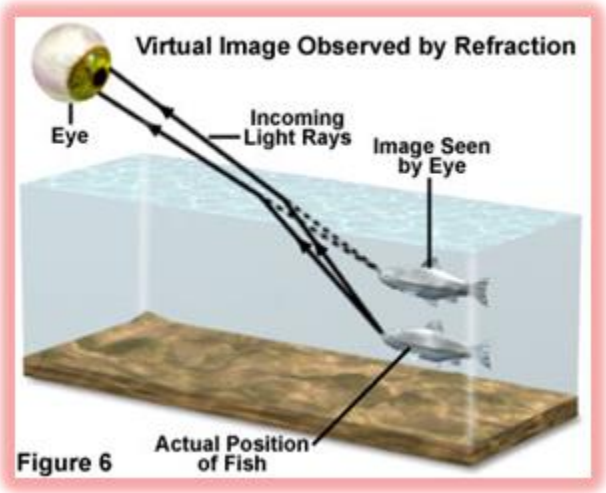


Figure 6

Q. 2. The speed of the light in a diamond is 1,24,000 km/s. Find the refractive index of diamond if the speed of light in air 3.00,000 km/s. is (AS I)

Answer :

$$\text{Refractive index of diamond (n)} = \frac{\text{Speed of light in air}}{\text{speed of lightin diamond}}$$

Given;

Speed of light in air = 3.00,000 km/s.

Speed of light in diamond = 1,24,000 km/s.

$$\Rightarrow n = \frac{3.00,000}{1,24,000}$$

⇒ n = 2.42

Hence refractive index of diamond is 2.42.

Q. 3. Refractive index of glass relative to water is 9/8. What is the refractive index of water relative to glass? (AS1)

Answer :

$$\text{Refractive index of water relative to glass} = \frac{1}{\text{Refractive index of glass relative to water}}$$

$$\Rightarrow \text{Refractive index of water relative to glass} = \frac{1}{\frac{9}{8}}$$

$$\Rightarrow \text{Refractive index of water relative to glass} = \frac{8}{9}$$

$$\text{Refractive index of water relative to glass is} = \frac{8}{9}$$

Q. 4. The absolute refractive index of water is 4/3. What is the critical angle?(AS1)

Answer : Given;

Absolute refractive index of water (n) = $\frac{4}{3}$

By Snell's Law critical angle(c) is given by = $\sin^{-1} 1/n$ (sin inverse of $\frac{1}{\text{refractive index}}$)

$$\Rightarrow c = \sin^{-1} \frac{1}{\frac{4}{3}}$$

$$\Rightarrow c = \sin^{-1} 3/4$$

$\therefore c = 48.5^{o}$. (y looking in sine table).

Hence the critical angle is $\sin^{-1}\frac{1}{\frac{4}{3}}$ or 48.5^{o}.

Q. 5. Determine the refractive index of benzene if the critical angels 42°. (AS1)

Answer : Given;

Critical angle (c) = 42^{o} .

By Snell's Law;

$$\text{Refractive index}(n) = \frac{1}{\sin c}$$

$$\Rightarrow n = \frac{1}{\sin 42}$$

$$\Rightarrow n = \frac{1}{0.6691} = 1.51 \text{ (By looking in sine table } \sin 42 = 0.6691).$$

Hence refractive index of benzene is 1.51

Q. 6. Explain the formation of mirage? (AS1)

Answer : <u>Definition:</u> Mirage is the optical illusion; the water appears at the distance but when we go there we don't find any water. It occurs due to Total Internal Reflection.

<u>Formation:</u>

1. During hot summer days air just above road is very hot and air at higher altitudes is cold.

2. It means that temperature decreases with height. As a result density of air increases with height.

3. We know that refractive index of air increases with density. Thus refractive index of air increases with height.

4. So cooler air has higher refractive index than the hotter air just above the road.

5. Therefore light travels faster through thinner hot air than dense cold air.

6. When light from tree passes through the medium just above ground whose refractive index decreases towards ground it suffers total internal reflection and takes the curved path.

7. This appears as the ray is reflected from the ground. Hence we feel illusion of water being present on the road.

8. The inverted virtual image seen by observer is called as the mirage.

The figure below depicts the formation.

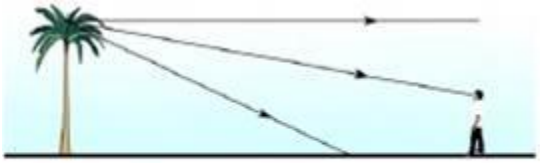


fig-9(b): The paths of light rays when there is no change in density of air

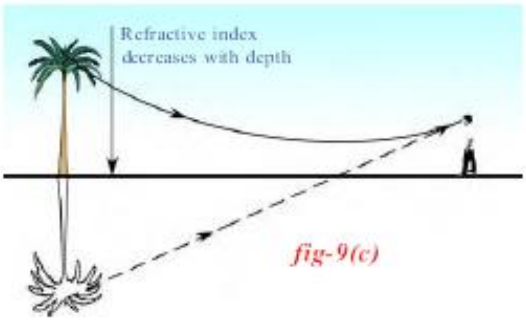
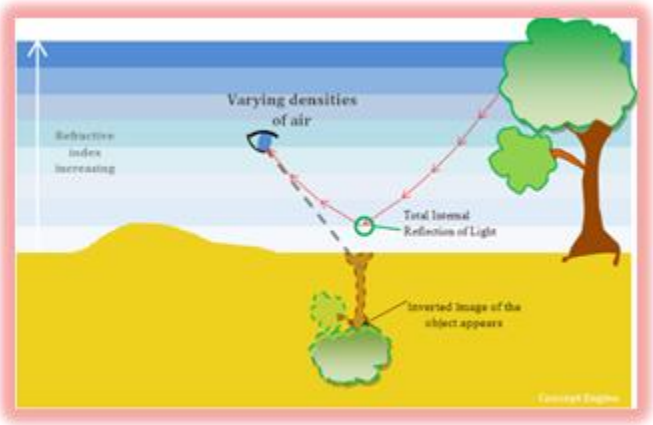


fig-9(c)



Q. 7. How do you verify experimentally that sin i/sin r is a constant? (AS1)

Answer : <u>Aim:</u> To obtain the relation between angle of incidence and angle of refraction.

<u>Materials Required:</u> A plank, white chart paper, protector, semicircular glass disc, pencil, laser light.

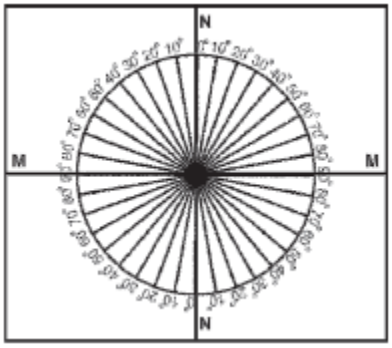
<u>Procedure:</u>

1. Take a wooden plank covered with white chart paper and draw two perpendicular lines passing through center as shown in figure.

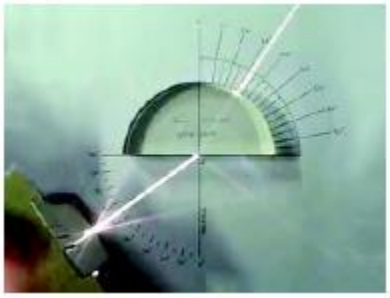
2. Mark one line as NN which is perpendicular to the other line MM. Let O be the point of intersection of both lines.

3. Take protector and place it along NN and then mark the angles from 0^o to 90^o on both sides of NN as shown in figure.

4. Now place the semicircular glass disc such that the diameter coincides with the MM and center coincides with the O.



5. Send the laser light along line which makes an angle of 20^{o} with NN. Measure its corresponding angle of refraction.



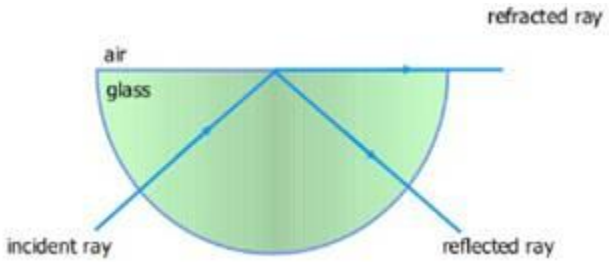
6. Repeat the procedure for 30^{o}, 40^{o}, 50^{o} and 60^{o}.

Observation: If we calculate the ratio of the sine of angle of incidence and sine of angle of reflection than it will come out to be constant.

Result: Ratio of sine of angle of incidence and angle of refraction is constant.

Q. 8. xplain the phenomenon of total internal reflection with one or two activities. (AS1)

Answer : When the angle of incidence is greater than the particular angle (called as critical angle) than the ray of light instead of refracting gets reflected into denser medium at the interface. This phenomenon is called as the total internal reflection.



Conditions Of Total internal Reflection: Total internal reflection takes place when both of the following two conditions are met:

• The light is in the denser medium and approaching the less dense medium.

• The angle of incidence is greater than the so-called critical angle.

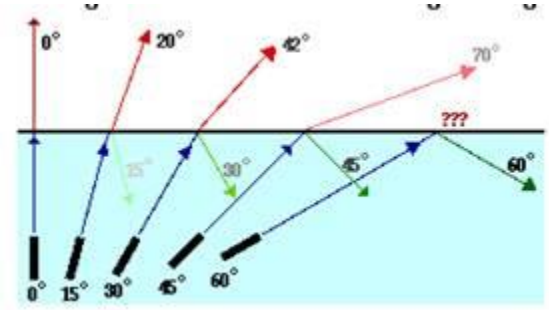
Activity 1:

1. Place the semicircular disc in such a way that diameter coincides with the interface and centre coincides with the center of the interface.

2. Now send the light along the curved side of the disc and. Start with angle of incidence 0^o .

3. Send the laser along the angles 5^o, 10^o, 15^o,… and measure the angle of refraction.

Observation: We will observe that at certain angle of incidence the refracted ray does not come out but gazes the interface. This angle of incidence is called as the critical angle. Figure below depicts the same.



Q. 9. How do you verify experimentally that the angle of refraction is more than angle of incidence when light rays travel from denser to rarer medium. (AS1)

Answer : Aim: Verify that the angle of refraction is more than angle of incidence when light rays travel from denser to rarer medium.

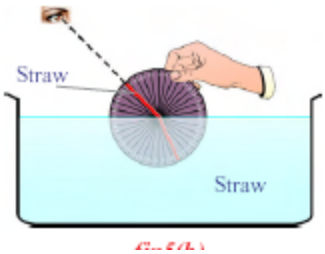
Procedure:

1. Take a metal disc and mark angle along its edges using protractor as shown in the figure.

2. Arrange two straws at center of disc such that they can be rotated freely about center of disc.

3. Adjust one of the straw to make the angle of 10^o and immerse half of the disc vertically into the water verify that straw is at 10^o inside the water.

4. From the top of the vessel view the straw as shown in the figure.



5. Adjust straw until both straw are in single straight line.

6. Take disc out of water and we will observe that two straws are not in straight line.

7. Measure the angle between the normal and second straw and note it.

8. Repeat for various angles and find their corresponding angle of refraction.

Observation: we will note that angle of refraction(r) is more than angle of incidence (i).

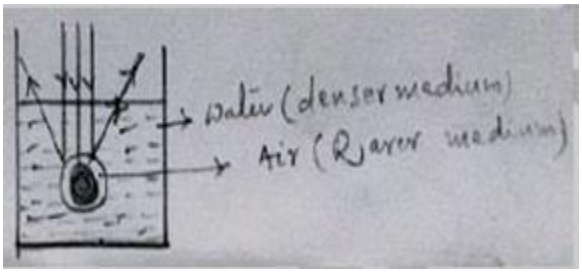
Conclusion: When the light travels from denser (water) to rarer (air) medium it bends away from the normal.

Q. 10. Take a blight metal ball and make it black with soot in a candle flame. Immerse it in water. How does it appear and why? (Make hypothesis mid do the above experiment). (A52)

Answer : When the bright metal ball is made black with soot in candle flame the air enters the space between the soot and metal ball.

• Light passes from the denser medium (water) to the rarer medium (air).

• When the angle of incidence exceeds the critical angle, the total internal reflection takes place.



• The ball appears to be shining due to total internal reflection.

Q. 11. Take a glass vessel and pour some glycerine into it and then power water upto the brim. Take a quartz glass rod. Keep it in the vessel. Observe the glass rod from the sides of the glass vessel.

• What changes do you notice?
• What could be the reasons for these changes? (AS2)

Answer : When the glass rod is put in liquid than the part of the glass rod that is in glycerin will disappear as shown in figure below.

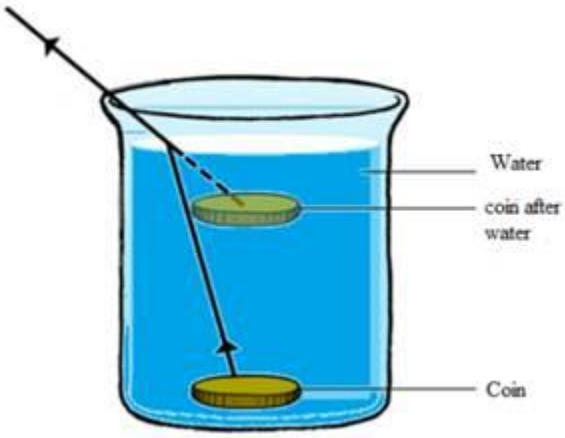
This happens because both glass rod and glycerin has almost same refractive index (1.47 and 1.5). Thus when the refractive index is same the speed of light is same in both the medium thus no bending of light takes place. Hence no refraction takes place and the glass rod disappears.

Q. 12. Do activity-7again. How can you find critical angle of water? Explain your steps briefly. (AS3)

Answer : 1. Take the cylindrical transparent vessel and put the coin at the bottom of the vessel.

2. Now pour some water in vessel until we get some image of coin on the water surface.

3. The coin is visible only when we pour the water into the vessel. This is because of total internal reflection. The figure below depicts the same.



We know that

$$\text{sinc} = \frac{1}{\text{refractive index}}$$

$$\Rightarrow \text{sinc} = \frac{1}{1.33} = 0.7518$$

$\because$ refractive index of water is 1.33.

$$\Rightarrow c = \sin^{-1} 0.7518.$$

$c = 48.7^{o}$.

Hence critical angle of water is 48.7^{o}.

Q. 13. Collect the values of refractive index of the following media. (AS4)

Water, coconut oil, flint glass, crown glass, diamond. benzene and hydrogen gas.

Answer :

1. Water = 1.33

2. Coconut oil = 1.445

3. Flint glass = 1.62

4. Crown glass = 1.52

5. Diamond = 2.42

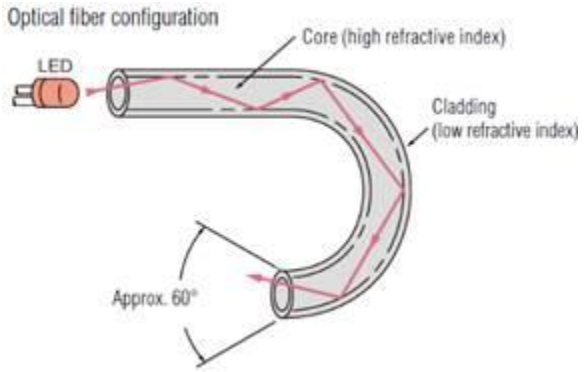
6. Benzene = 1.50

7. Hydrogen gas = 1.000132

Q. 14. Coiled information a working of optical fibers. Prepare a report about various uses of optical rubles in our daily life. (AS4)

Answer : Optical fiber an optical fiber is a very thin fiber made up of glass or plastic having diameter about a micrometer (10^{-6} m). A bunch of such fibers form a light pipe.

Working Total internal reflection is the basic principle behind the working of the optical fibers. Because of the small radius of the fiber, light going into it makes a nearly Glancing incidence on the wall. The angle of incidence is greater than the Critical angle and hence total internal reflection takes place. The light is thus transmitted along the fiber. The figure below depicts the working of optical fibers..



Use of Optical fibers

1. Optical fibers are used in the medical equipment such as endoscope to observe deep parts of the body.

2. Optical fibers are used as sensors in industry to measure temperature and pressure.

3. They are used in telephones lines and internet cables for transmission.

Q. 15 A. Take a thin thermal sheet. Cut it in circular discs of different radii like 2cm, 3cm, 4cm, 4.5cm. 5cm etc ad mark centers with sketch pen. Now take needles of length nearly firm. Pin a needle to each disc at its centre vertically. Take water in a large opaque tray and place the disc with 2cm radius in such a way that the raw& is inside the water ac shown in fig Q15. Now try to view the free end (head) of the needle from surface of the water.

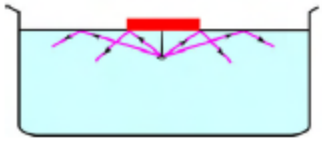


fig-Q15

• Are you able to see the head of the needle?

Answer : Yes, I am able to see the head of the needle.

Q. 15 B. Take a thin thermal sheet. Cut it in circular discs of different radii like 2cm, 3cm, 4cm, 4.5cm. 5cm etc ad mark centers with sketch pen. Now take needles of length nearly firm. Pin a needle to each disc at its centre vertically. Take water in a large opaque tray and place the disc with 2cm radius in such a way that the raw& is inside the water ac shown in fig Q15. Now try to view the free end (head) of the needle from surface of the water.

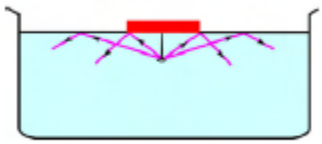


fig-Q15

• At what maximum radius of disc, were you not able to see the free end of the needle?

Answer : At radius 6 cm of disc I am not able to see the free end of the needle.

Q. 15 C. Take a thin thermal sheet. Cut it in circular discs of different radii like 2cm, 3cm, 4cm, 4.5cm. 5cm etc ad mark centers with sketch pen. Now take needles of length nearly firm. Pin a needle to each disc at its centre vertically. Take water in a large opaque tray and place the disc with 2cm radius in such a way that the raw& is inside the water ac shown in fig Q15. Now try to view the free end (head) of the needle from surface of the water.

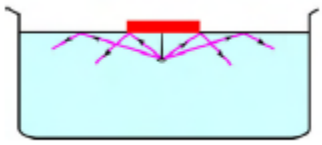


fig-Q15

• Why were you not able to view the head of the nail fix certain radii of the discs?

Answer : Because the light rays coming from the head of the nail for the certain radius undergoes the total internal reflection when they are incident on the surface of the water.

Q. 15 D. Take a thin thermal sheet. Cut it in circular discs of different radii like 2cm, 3cm, 4cm, 4.5cm. 5cm etc ad mark centers with sketch pen. Now take

needles of length nearly firm. Pin a needle to each disc at its centre vertically. Take water in a large opaque tray and place the disc with 2cm radius in such a way that the raw& is inside the water ac shown in fig Q15. Now try to view the free end (head) of the needle from surface of the water.

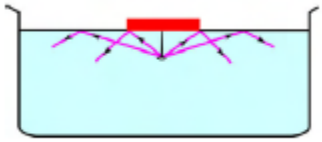


fig-Q15

• Does this activity help you to limit he ethical age of the medium (water)?

Answer : Yes, we can find the critical angle of the water by applying the Snell's law at the water and air interface.

$$\text{sinc} = \frac{1}{\text{refractive index of water}}$$

Refractive index of water = $\frac{4}{3}$

$$\Rightarrow \text{sinc} = \frac{1}{\frac{4}{3}}$$

$$\Rightarrow \text{sinc} = \frac{3}{4}$$

$$\Rightarrow c = \sin^{-1} 3/4$$

$\Rightarrow c = 49^{o}$.

Hence critical angle of the water is 49^{o}.

Q. 15 E. Take a thin thermal sheet. Cut it in circular discs of different radii like 2cm, 3cm, 4cm, 4.5cm. 5cm etc ad mark centers with sketch pen. Now take needles of length nearly firm. Pin a needle to each disc at its centre vertically. Take water in a large opaque tray and place the disc with 2cm radius in such a way that the raw& is inside the water ac shown in fig Q15. Now try to view the free end (head) of the needle from surface of the water.

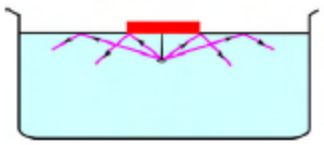
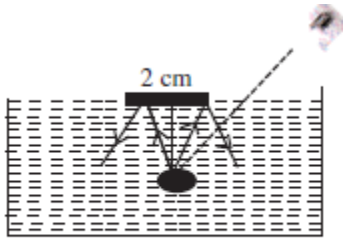


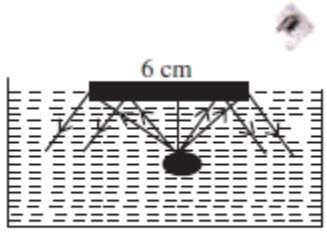
fig-Q15

• Draw a diagram to show the passage of light ray from the head of the nail in different situations. (AS4)

Answer :



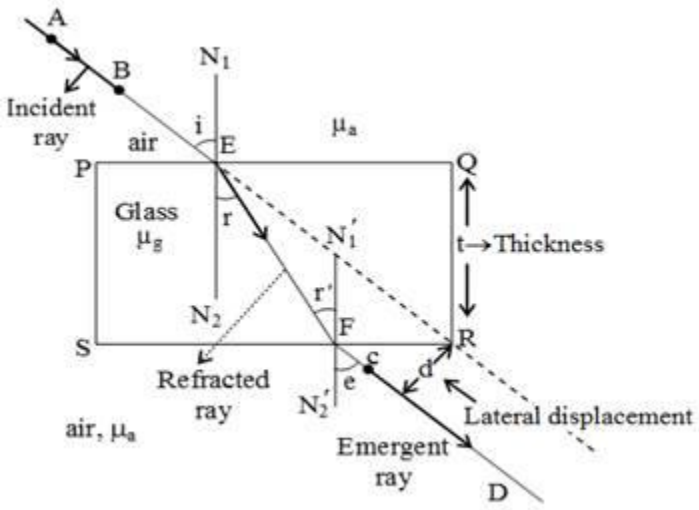
Head of the needle is visible



Head of the needle is not visible

Q. 16. Explain the refraction of light through a glass slab with a neat ray diagram. (AS5)

Answer : Consider the rectangular slab as shown in figure.



AE = incident ray;

I = Angle if incidence;

R = Angle of refraction;

• On entering the glass slab the light ray bends towards the normal and travels along EF.

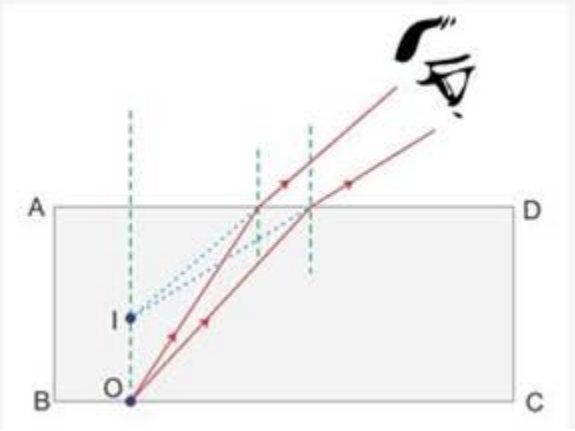
• The refracted ray EF is incident on the face SR at angle of incidence r'.

• The emergent ray FD bends away from normal at angle of refraction e.

• The emergent ray FD is parallel to the incident ray AE but it has been laterally displaced with respect to incident ray.

Q. 17. Place an object on the table. Look at the object through the transparent glass slab. You will observe that it will appear closer to you. Draw a ray diagram to show the passage of light ray in this situation. (AS5)

Answer : When the object is looked through the transparent glass the object seems to rise or appears closer to us because of refraction. The Ray diagram is shown in the figure.



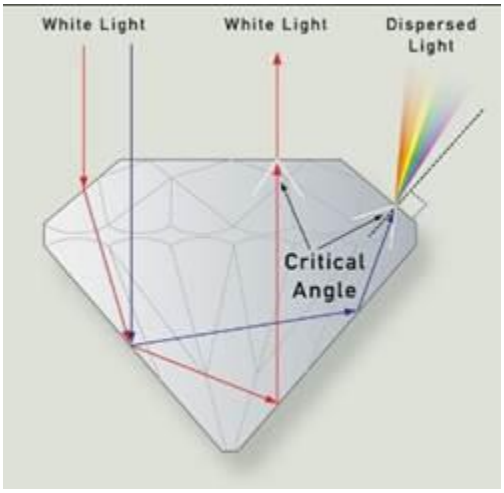
When the Ray of light goes from the denser medium (glass) to rare medium (air) it bends away from the normal and the object (O) appears close to us.

Q. 18. What is the reason behind the shining of diamonds and how do you appreciate it? (AS6)

Answer : Total internal reflection is the main reason

For brilliance of diamonds. The critical angle of a diamond is very low (24.4º). So if a light ray enters a diamond it is very likely to undergo total internal reflection which makes the diamond shine.

The figure below illustrates the total internal reflection in diamond.



Q. 19. How do you appreciate the role of Fermat principle in drawing ray diagrams. (AS6)

Answer : According to Fermat's principle that light selects the shortest path to travel.

1. This is the reason for the propagation of light in straight lines.

2. We use this principle, when we draw ray diagrams to find the image of an object formed by mirrors to illustrate the laws of reflection, refraction etc.

Q. 20. A light ray is incident on air-liquid interface at 45º and is refracted at 30°. What is the refractive index of the liquid? For what at angle of incidence will the angle between reflected ray and reflected ray be 90º? (AS7)

Answer : Given;

Angle of incidence i = 45°
Angle of refraction r = 30°

$$\text{Refractive index} = n = \frac{\sin I}{\sin r}$$

$$\Rightarrow n = \frac{\sin 45}{\sin 30}$$

$$\Rightarrow n = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}} = \frac{1}{\sqrt{2}} \times 2 = \sqrt{2} = 1.141.$$

Refractive index of liquid = 1.414

Given;

The angle between the reflected and refracted ray = 90°

⇒ angle of reflection (r) + angle of incidence (i) = 90°

⇒ Angle of refraction (r) = (90° - i)

$$\text{But refractive index } n = \frac{\sin i}{\sin r} = \frac{\sin i}{\sin(90-i)}$$

$$\Rightarrow n = \frac{\sin i}{\cos i}$$

Q. 21. Explain why a tube immersed at a certain angle in a tumbler of water appears to have a mirror surface for a certain viewing position? (AS7)

Answer : 1.) When rays of light travel through water strikes the water glass interface of test tube at an angle which is more than critical angle for water. Then the light ray suffers total internal reflection.

2.) When these totally reflected rays reach the eye, then they appear to come from surface of test tube.

3.) So, the test tube appears as it has mirror surface.

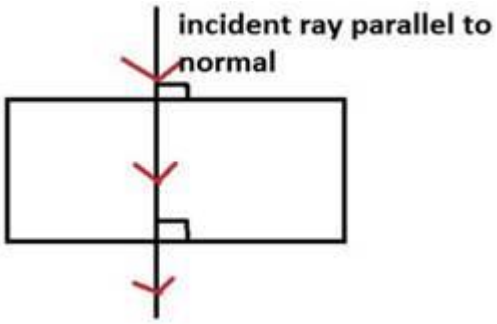
The figure below describes the same.

Q. 22. In what cases does a light ray not deviate at the interface of two media? (AS7)

Answer : A ray of Light does not deviate at interface of two media in two cases.

Case 1

When incidence ray strikes normally at the point of incidence. The figure below shows this.



Case 2

If the refractive indices of two media are equal.

That is n1 = n2 = n.

Q. 23. When we sit at a camp fire, objects beyond the fire are seen swaying. Give the reason for it. (AS7)

Answer :

• Above the fire, the temperature of the atmosphere is higher.

• And as we know that at constant pressure, the density and temperature is inversely related

• So the density above the fire is decreased.

• Due to this change in density the refractive index of the surrounding air, the angle of reflection and angle of deviation changes.

Thus the object beyond the fire is seen swaying.

Q. 24. Why do stars appear twinkling? (AS7)

Answer : The light from the stars reach us after passing through the many layers of the atmosphere. As the light passes through these layers it is refracted many times by the particles present in the atmosphere. This random refraction makes the stars to twinkle.

The figure below depicts the stars twinkling.

Q. 25. Why does a diamond shine more than a glass piece cut to the same shape? (AS7)

Answer : 1. The refractive index of diamond is higher than the refractive index of the glass.

2. Due to more refractive index diamond disperse more light and shines more than piece of glass.

3. The faces of diamond are cut in such a way that light undergoes total internal reflection.