Chapter -5

Refraction of Light at Plane Surfaces

SYNOPSIS

Light travels different speeds in different media depend upon the densities of the substances.

When light rays travel from rare medium to denser medium it bends towards the normal. If the light rays travels from denser to rarer medium it bends away from the normal.

Speed of light is maximum in vacuum. It travels with a speed of 3×10^8 m/s. When it propagates in any medium its velocity is less than 3×10^8 m/s. The ratio of these two velocities is constant. The constant is called “refraction index” (n).

Snell’s law is relation between incident angle (i) to the refracted angle (r)

i.e. $n_1 \sin i = n_2 \sin r$.

When light travels from denser medium to rare medium, at a particular incident angle i.e. angle more than the critical angle the total interval reflection takes places. To internal reflection is a phenomenon behind mirage and shining of diamond.

2 Mark Questions

1. Write the laws of refraction?

A. There are two laws of refraction.

1) The incident ray, the refracted ray and the normal to interface of two transparent media at the point of incidence all lie in the same place.

2) During the refraction light follows Snell's law constant.

$$n_1 \sin i = n_2 \sin r$$

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

2. Define Total internal reflection? Given two examples?

A. **Total internal Reflection:** When the angle of incidence is greater than critical angle, the light ray gets reflected into the denser medium at the interface i.e. light never enter the rarer medium. This phenomenon is called internal reflection.

Ex: 1) Formation of mirages.

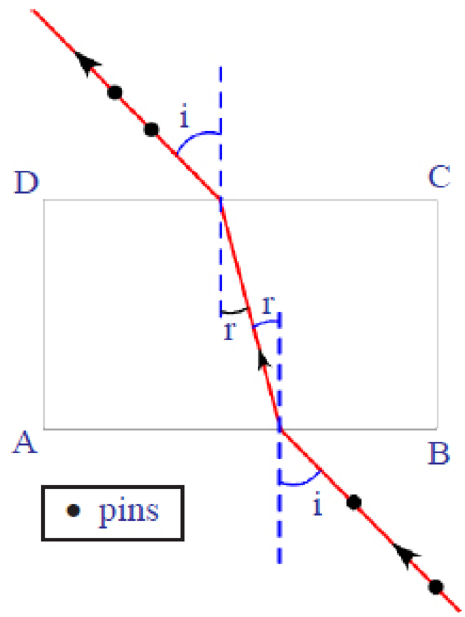
2) Brilliance of diamonds.

3. What is the reason behind the shimming of diamond and how do you appreciate it?

A. Total internal reflection is the main cause for brilliance of diamonds. The critical angle of diamonds is very low (24.4^0). Diamond sparkles due to repeated internal reflections. But cutting diamond in such a way that incident angle greater than critical angle (c) so that total internal reflection takes place again and again.

4. What is the angle of deviation produced by a glass slab? Explain with ray diagram (AS_7)?

A. **Angle of Deviation:** The angle between incident ray and emergent ray is known as angle of deviation (δ).



A glass slab is having two parallel sides. At first surface DC the light ray is travelling from rarer to denser. Hence the light ray bends towards normal i.e., i > r

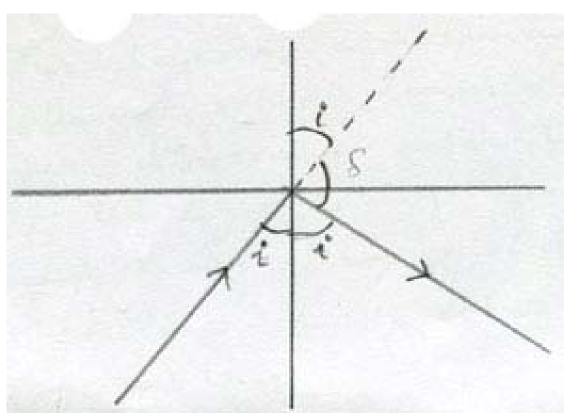
∴ Deviation angle $(\delta_1) = (i_1 - r_1)$

When light ray travels from denser to rarer it moves away from the normal i.e. r > i

∴ Deviation angle $(\delta_2) = (r_2 - i_2)$

5. A ray of light travels from an optically denser to rarer medium. The critical angle of two media is 'c'. What is the maximum possible deviation of the ray? (AS_7)

A.



If the light incident at an angle $i > c$ as shown in the figure the angle of deviation is given by $\delta = \pi - 2i$

The maximum value of δ occurs when $i = c$ and is equal to $\delta_{max} = \pi - 2c$.

6. When we sit at a camp fire, objects beyond the five is seen swaying. Give the reason for it (AS7).

A. From the campfire, heat is carried into surrounding air by the process of convection. During this process the density of surrounding air changes continuously, thus changes its refraction index slightly.

This continuous change in refraction index gives rise to continuous change in angle of refraction which results in the objects seeming to be swaying.

7. Why do stars appear twinkling?

A. Stars appear twinkling due to atmospheric refraction. The layers of atmosphere on the earth have different optical densities due to which they offer different refractive index values to the light coming from stars. So, the light bends many times giving different apparent positions of the star which we see as twinkling.

1 Mark Questions

1. What is refraction of light?

A. **Refraction of light:** The process of changing speed at an interface when light travels from medium to another resulting in a changes in direction is called refraction of light.

2. How light ray moves when it enters from rarer medium to denser medium?

A. If light ray enters from rarer medium to denser medium then refracted ray moves towards the normal.

3. What is the speed of light in vacuum?

A. Speed of light in vacuum $c = 3 \times 10^8$ m/s.

4. Define refractive index (n)?

A. Refractive index (n): The ratio of the speed of light in vacuum to the speed of light in that medium is defined as refraction index (n). It is also called absolute refractive index

$$\text{Absolute refractive index} = \frac{Speed\ of\ light\ in\ vaccum}{Speed\ of\ light\ in\ medium}$$

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

5. Which factor decides the speed of light in the medium?

A. Refraction index (n)

6. On what factors does the refractive index of a medium depend?

A. Refractive index of the material depends on the following factors.

1) Nature of the material.

2) Wavelength of light used.

7. What is mirage?

A. **Mirage:** mirage is an optical illusion where it appears that water has collected on the road at a distant place but when we get there we don't find any water.

8. What is the critical angle of a diamond?

A. Critical angle of a diamond is 24.4^0.

9. How do you appreciate the sole of Fermat principle in drawing ray diagrams?

A. Fermat's principle says that light selects a shortest path to travel. This is the basic reason for the straight line propagation of light using this principle, we can draw ray diagram to trace the image formed by mirrors to understand reflection and refraction.

10. Define rarer medium?

A. A medium in which the speed of light is more is known as optically rarer medium.

11. Define denser medium?

A. A medium in which the speed of light is less is known as optically denser medium.

12. What is the use of refractive index of a light?

A. Refractive index gives the idea of how fast the light travels in a medium.

13. For which medium refractive index is minimum and maximum?

A. Refractive index is minimum for vacuum (n = 1). Refractive index is maximum for diamond (n = 2.42).

4 Mark Questions

1. Why is it difficult to shoot fish swimming in water?

A. When light ray enters from one medium to another it deviates from its actual path. This phenomenon is called as refraction.

Due to refraction the depth of pond, well appears to rise upwards. Hence we cannot estimate the actual depth of the object in the water.

When we shoot the fish in water, we cannot judge the actual position of fish, because it appears to be raised due to refraction.

2. Explain the formation of mirage? (AS1)

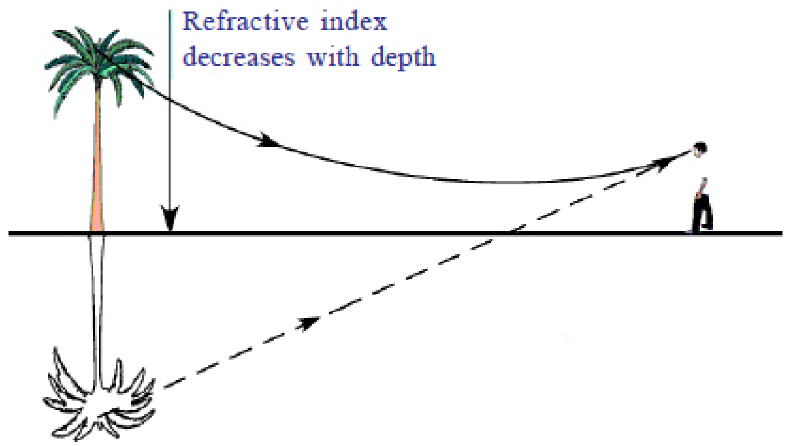
A. Mirage is an optical illusion where it appears that water has collected on the road at a distant place but when we get there, we don't find any water.

Explanation: During the hot summer day, due to temperature differences at different altitudes the refractive indices of air are different.

The cooler air at the top has greater refraction index than hotter air just above the road.

When the light from a tall object such as tree or from the sky passes through a medium just above the road, whose refractive index decreases towards ground, it suffers refraction and takes a curved path because of total internal reflection as shown in the figure.

This refraction light reaches the observer in a direction shown in figure this appears to the observer as if the ray is reflected from the ground. Hence we feel the illusion of water being present on road. This is the virtual image of the sky and inverted image of tree on the road.



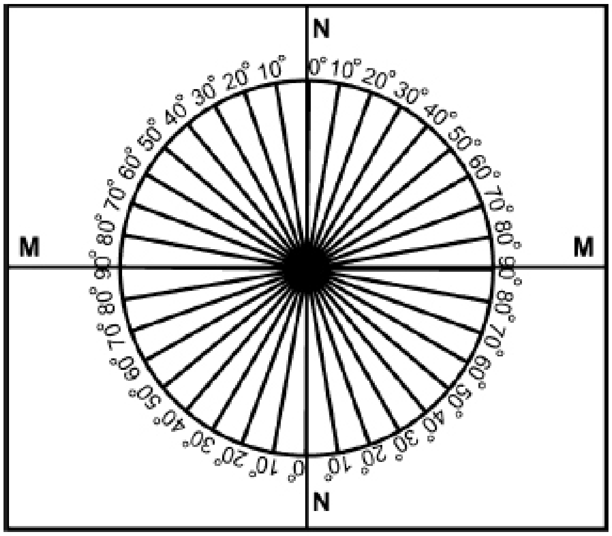
3. How do you verify experimentally that $\frac{\sin i}{\sin r}$ is a constant?

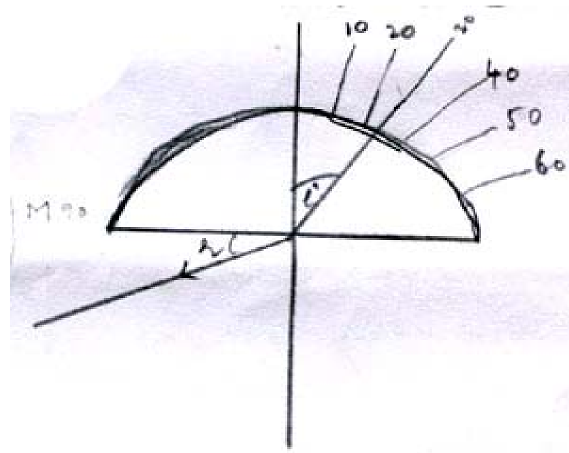
A. Aim: Obtaining a relation between angle of incidence and angle of refraction.

Materials required: A plank, white chart, protractor, scale, small black painted plank, a semi circular glass disc of thickness nearly 2cm, pencil and laser light.

Procedure: Take a wooden plank which is covered with white chart. Draw two perpendicular lines, passing through the middle of the paper as shown in the figure. Let the point of intersection be o. Mark one line as NN which is normal to another line marked as MM. Here MM represents the line drawn along the interface of two media and NN represents the normal drawn to this line at 'o'.

Take a protractor and place it along NN in such way that it centre coincides with 'o' as shown in figure. Then mark the angles from 0^0 to 90^0 on both sides of the line NN as shown in the figure. Repeat the same on the other side of line NN. The angles should be indicated on the curved line.





Now place a semi-circular glass disc so that its diameter coincides with the inter face line (MM) and its centre coincides with the point ‘o’.

Send laser light along a line which makes 15^0 with NN. Measure its corresponding angle of refraction. Repeat the experiment for 20^0, 30^0, 40^0, 50^0 and 60^0 and noted the corresponding angles of refraction.

S.No	i	r	Sin*i*	Sin*r*	$\frac{\sin i}{\sin r} =$

If we calculate sin*i*, sin*r* ratio we will get the ratio as a constant.

4. Explain the phenomenon of total internal reflection with one or two activities? (AS1)

Activity1: Place the semi circle glass disc in such a way that its diameter coincides with interface and its centre coincides with centre point of the interface.

Now send light from the curved side of the semicircular glass disc. Start with angle of incidence (i) equal to 0^0, i.e. along the normal.

Send laser light along angles of incidence 5^0, 10^0, 15^0 etc., and measure the angle of refraction we will observe that at a certain incident angle of incidence the refracted ray does not come out but grazes the interface of incidence separating air and glen is known as critical angle.

When the angle of the incidence is greater than critical angle, the light ray of get reflected into denser medium at the interface. This phenomenon is called internal reflection.

5. How do you verify experimentally that the angle of refraction is more than angle of incidence when light ray travel from the denser to rarer medium?

A. When light ray travel from the denser to rarer the angle of refraction is more than the angle of incidence. This can be verified by the below experiment.

Procedure: Take a metal disc and mark angles using protractor. Arrange two straws at the centre of disk. Adjust one of the straws to make an angle 10^0. Immerse the half of disc in transparent vessel containing water vertically. The straw should be at an angle 10^0 inside the water. Adjust the other straw which is outside the water until both the straws appears to be in straight line. Take the disc out of the water, we will find that the straws are not in straight line. Measure the angle between the normal and second straw. Do the same for various angles of incidence (i) and note down corresponding angles of refraction (r) in the given table.

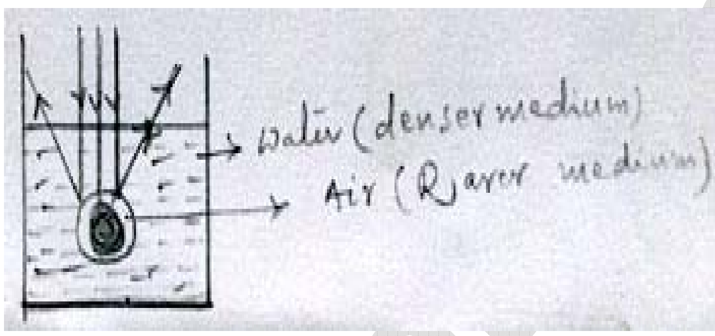
S.No	Angle of incidence (i)	Angle of refraction (r)

Observation: We will find the angle of refraction is more than angle of incidence.

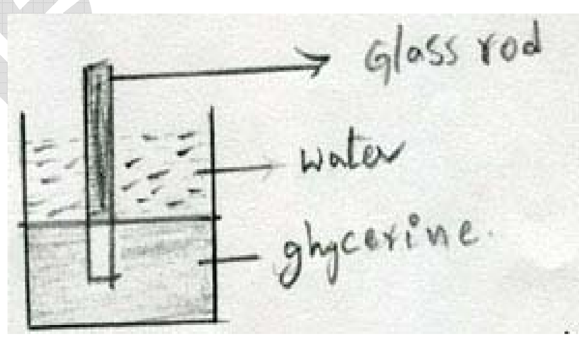
Conclusion: When light travels from douser (water) to rarer (air) it bends away from the normal.

6. **Take a bright metal ball and make it black with soot in a candle flame immerses it in water. How does it appear and why? (Make hypothesis and do the above experiment) As2**

Sol: Take a metal ball coated with soot of candle flame. Now in water beaker it appears shining. When immersed in water a thin air film is formed in between water and shoot. Light passes from denser medium (water) to rarer medium (air) total internal reflection takes place. This is cause for shining.



7. **Take a bright glass vessel and pour some glycerin into it and then pour water up to the brim. Take a Quartz glass rod. Keep it in the vessel. Observe glass rod from the sides of the glass vessel. What change of you notice? What could be the reasons for these changes? (AS2)**



A.

As shown in the figure, the vessel contains glycerin (n = 1.47) and water (n = 1.33) when glass rod immersed into the liquid the part in the glycerin disappear. This is due to the fact that both glass rod (n = 1.5) and glycerin (1.47) have same refractive index. When refractive Indies are same the light speed is same in both media. So no bending is takes place and hence no refraction takes place.

The part of the glass rod in water appears as larger than the original size of the rod. This is due to refraction.

8. Collect the values of refractive index of following media?

1) Water, 2) Coconut oil, 3) Flint glass, 4) Crown glass,

5) Diamond, 6) Benzene, 7) Hydrogen gas.

Sol: water = 1.33 Diamond: 2.42

Coconut oil = 1.445 Benzene: 1.50

Flint glass: 1.62 Hydrogen gas: 1.000132

Crown glass: 1.52

9. Collect information on working of optical fibres. Prepare a report about various uses of optical fibres in our daily life?

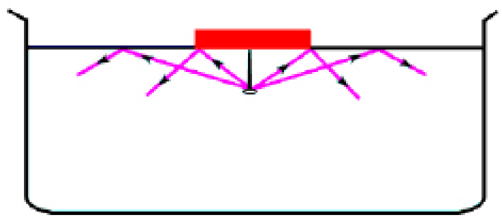
A. Optical fibres are working on the principle of Total Internal Reflection. It is very thin fibre made of glass or plastic having radius about a micro meter (10^{-6}m). Each fibre consists of a core (n_1) and cladding (n_2). Here $n_1 > n_2$. A bunch of thin fibres forms a light pipe.

Working: The light going into pipe make a nearly glancing incidence on the wall. The angle of incidence is greater than the critical angle and hence total internal reflection takes place. In this way Light is transmitted.

Uses: 1.Optical fibres are used in medical equipments such as laparoscope and endoscope to observe unreachable parts in human body.

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

10. **Take thin thermocol sheet. Cut it in circular discs of different radii like 2cm, 3cm, 4cm, 4.5cm, 5cm etc and mark centers with nearly 6 cm. pin a needle to each disc at its centre vertically. Take water in a large opaque tray and place the disc with 2 cm radius in such a way that the needle is inside the water as shown in fig-**



Now try to view the tree end (head) of the needle from surface of water.

a) **Are you able to see the head of the needle?**

Now do the same with other discs of different radii. Try to see the head of the needle, each time.

Note: The position of your eye and the position of the disc on water surface should not be changed while repeating the activity with other discs.

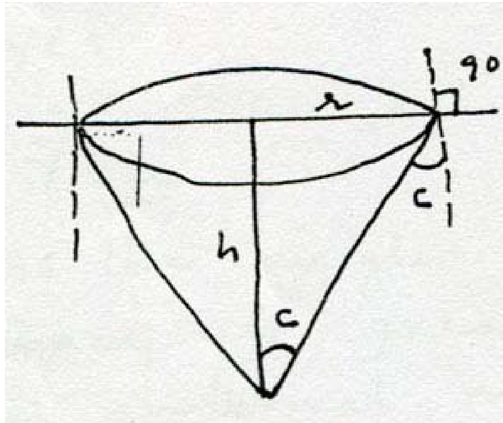
b) At what maximum radius of disc, were you not able to see the free end of the needle?

c) Why were you not able to view the head of the hail for certain radii of the discs?

d) Does this activity help you to find the critical angle of the medium (water)?

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

A) First we have to calculate the maximum radius of disc for which we can able to see the free end of the needle.



Here c: critical angle of water – air interface

r = radius of circular disc

h = height of the needle

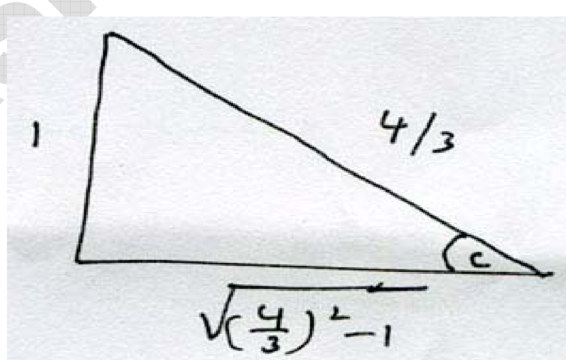
Apply Snell's law to water – air interface

$h_{water} \times \sin c = h_{air} \times \sin r$

$h_{water} \times \sin c = h_{air} \times \sin 90^0$

$h_{water} \times \sin c = 1 \times 1$

$$\sin c = \frac{1}{h_{water}} = \frac{1}{4/3} \quad (\because h_w = \frac{4}{3})$$



From right angle triangle-

$$\tan c = \frac{r}{h} = \frac{1}{\sqrt{\left(\frac{4}{3}\right)^2 - 1}}$$

$$r = \frac{h}{\sqrt{\left(\frac{4}{3}\right)^2 - 1}}$$

$$r = \frac{6}{\sqrt{\frac{16-9}{9}}} = \frac{6 \times 3}{\sqrt{16-9}} = \frac{18}{\sqrt{7}}$$

$$r = \frac{18}{2.645} = 6.8 \approx 7$$

a) Yes

b) 7cm

c) As the angle of incidence on water surface is greater than critical angle total internal reflection takes place no light ray incident on eye. Hence needle head cannot be seen.

d)Yes, applying Snell's law to water – air interface.

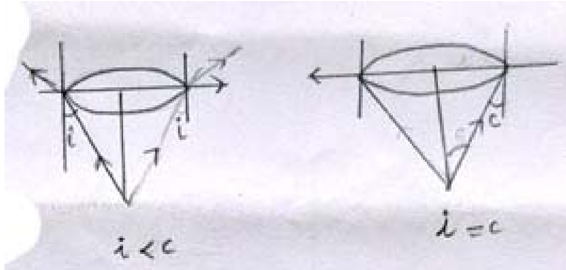
$$\sin c = \frac{1}{h_{water}}$$

$$\sin c = \frac{1}{\frac{4}{3}} = \frac{3}{4}$$

$$c = \sin^{-1}\left(\frac{3}{4}\right)$$

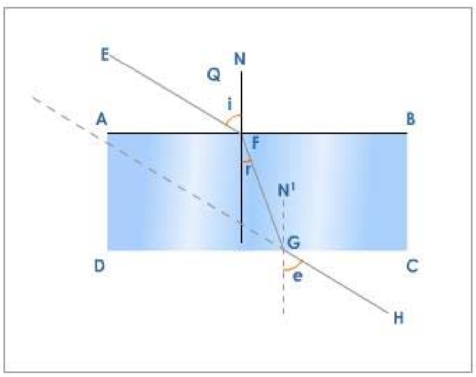
$$c = 49°$$

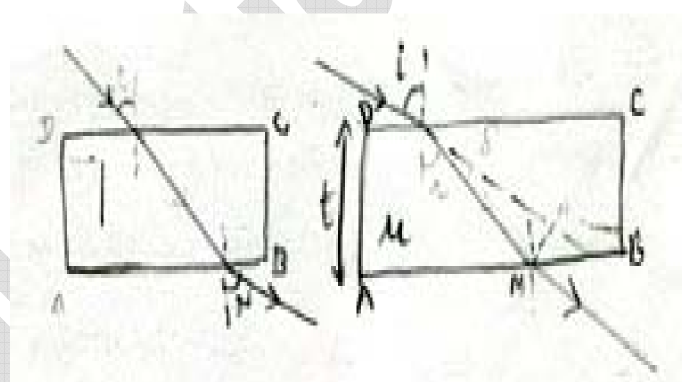
e) In all the cases.



11. Explain the refraction of light through a glass slab with a neat ray diagram.

A. The refracting surfaces of glass slab are parallel to each other. When light ray passes through a glass slab, it is refracted twice at the two parallel faces and finally emerges out parallel to its incident direction.





Here

i = Angle of incidence

r = angle of refraction

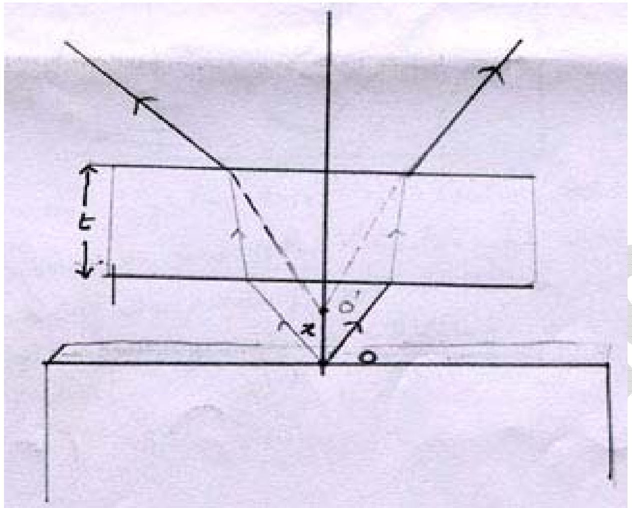
δ = angle of deviation

ABCD: Rectangular glass slab

MN: Lateral shift perpendicular distance between incident and the emergent ray.

12. 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 in this situation.

A.

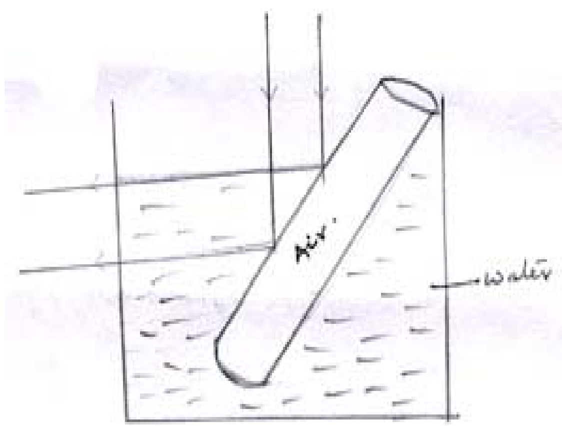


If a glass slab is placed in the path of a converging or diverging beam of light them point of convergence or point of divergence appears to be shifted as shown in the figure.

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

A. When a test tube is immersed at a certain angle in a tumbler of water appears to have a mirror surface for a certain viewing position.

Explanation:



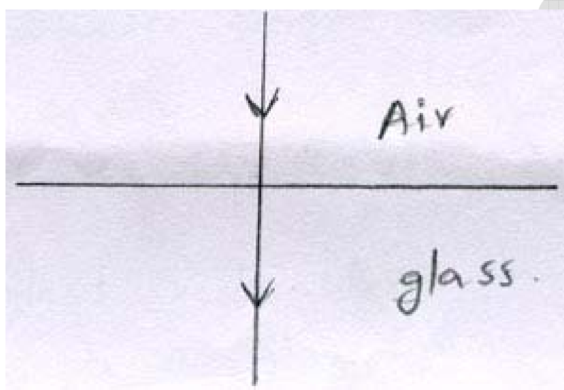
As light tries to enter air in the test tube it under goes total internal reflection bouncing back into water from the surface of the test tube giving it a shiny mirror like surface.

14. In what cases do a light ray does not deviate at the interface of two media?

A. A light ray does not deviate at the interface of two media in two cases-

Case (i):

When the incident ray strikes normally at the point of incidence it does not deviates from its path.



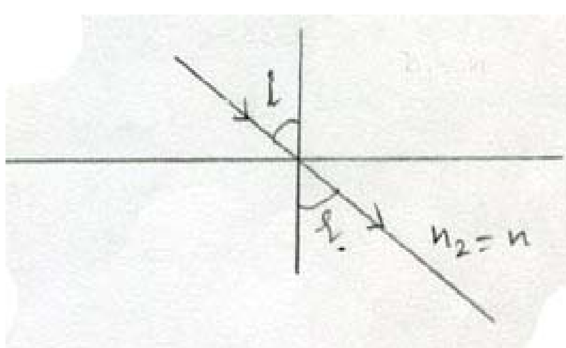
Li = 0

$\angle r = 0$

$\delta = 0$

Case (2): If the refractive indices of two media are equal

$n_1 = n_2 = n$



From Snell's law

$$n \sin i = n \sin r$$

$$\sin i = \sin r$$

$$\angle i = \angle r$$

Hence the ray passes without any deviation at the boundary.

15. Why does a diamond shine more than glass piece cut to the same shape?

A. Refractive index of diamond is 2.42. The critical angle of diamond – air interface is

$$\sin c = \frac{1}{n_d} = \frac{1}{2.42}$$

$$c = \sin^{-1}\left(\frac{1}{2.42}\right) = 24^\circ$$

So critical angle of diamond is very less. Hence the rays whose angle of incidence greater than 24°enter into the diamond and due to total internal reflection it shines more.

For glass refractive index is $\frac{4}{3} = 1.33$ critical angle of glass – air interface is-

$$\sin c = \frac{1}{n_g} = \frac{1}{1.33}$$

$$c = \sin^{-1}\left(\frac{100}{133}\right) = 42^\circ$$

For the glass critical angle value is more than diamond. Hence most of the incident ray refracts and less number of rays gets total internal reflection due to which less shines than diamond.

Problems

1. Find the speed of light in glass whose refractive index is $\frac{3}{2}$.

A. Given n = $\frac{3}{2}$, speed of light (v) = x

Refractive index (n) = $\frac{\textit{speed of light in vaccum}}{\textit{speed of light in glass}}$

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

$$\frac{3}{2} = \frac{3\times10^8}{x}$$

$$x = \cancel{3}\times10^8\times\frac{2}{\cancel{3}}$$

$$x = 2\times10^8 \text{ ms}^{-1}$$

Speed of light in glass = 2×10^8 ms^{-1}

2. The speed of light in a diamond is 1, 24,000 km/s. Find the refractive index of diamond if the speed of light in air is 3,00,000km/s. (AS1)

A. Give

Speed of light in air (c) = 3,00,000km/s

Speed of light in diamond (v) = 1,24,000 km/s

Refractive index of the diamond $n = \frac{c}{v}$

$$n = \frac{3,00,000}{1,24,000}$$

$$n = \frac{300}{124} = 2.419$$

Refraction index of diamond (n) = 2.419.

3. Refractive index of glass relative to water is 9/8. Then what is the refraction index of water relative to glass? (AS1)

Sol: Relative refractive index (n_{21}) = $\frac{R.I. of\ second\ medium\ (2)}{R.I. of\ first\ medium\ (1)}$

$$n_{21} = \frac{n_2}{n_1}$$

Refractive index of glass relative to water

$$n_{gw} = \frac{R.I. of\ glass}{R.I. of\ water} = \frac{9}{8}$$

Refractive index of water relative to glass

$$n_{wg} = \frac{R.I. of\ water}{R.I. of\ glass} = \frac{8}{9}$$

4. The absolute refraction index of water is $\frac{4}{3}$ what is the critical angle? (AS1)

Sol: Given-

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

Critical angle (c) =?

We know that

$$n = \frac{1}{sinc}$$

$$sinc = \frac{1}{n}$$

$$\sin c = \frac{1}{\frac{4}{3}} = \frac{3}{4} = 0.75$$

$C = \sin^{-1} (0.75)$

$\therefore$ Critical angle (c) = 48.59^0

5. Determine the refractive index of benzene if the critical angle is 42^0. (AS1)

Sol: Critical angle of the Benzene (c) =

$$\text{Sin } c = \sin 42 = 0.6691$$

Refractive index (n) = ?

We know that

Refractive index $n = \frac{1}{sinc}$

$$n = \frac{1}{sin42}$$

$$n = \frac{1}{0.6691} = 1.5$$

Refractive index n = 1.5

Important Table

Table:1 Refractive indices of some material media.

Material medium	Refractive index	Material medium	Refractive index
Air	1.0003	Canada balsam	1.53
Ice	1.31	Rock salt	1.54
Water	1.33	Carbon Diasulphide	1.63
Kerosene	1.44	Dense flint glass	1.65
Fused quartz	1.46	Ruby	1.71
Turpentine oil	1.47	Sapphire	1.77
Crown glass	1.52	Diamond	2.42
Benzene	1.50		

Matching

1. Group-A | **Group-B**

	Group-A		Group-B
1.	Snell's law	**[e]**	a) Used in communication
2.	Mirage	**[d]**	b) $\frac{c}{v}$
3.	Refractive index	**[b]**	c) $\sin c = \frac{1}{n}$
4.	Critical angle	**[c]**	d) Total internal reflection
5.	Optical fibres	**[a]**	e) $n_1 \sin i = n_2 \sin r$

Fill in the Blanks

1. At critical angle of incidence, the angle of refraction is ___________. **(90˚)**

2. $n_1 \sin i = n_2 \sin r$, is called ______. **(Snell's law)**

3. Speed of light in vacuum is ________. (**3×10^8 ms^{-1} constant**)

4. Total internal reflection takes place when a light ray propagates from ______ to _______ medium. (Denser, rarer)

5. The refractive index of a transparent material is 3/2. The speed of the light in that medium is __________. (2×10^8 ms^{-1})

6. Mirage is an example of ________. (Total internal reflection)

7. The process of changing speed when light travels from one medium to another is called __________ of light. (Refraction)

8. ________ is the basic principle for of optical fibre. (Total internal reflection)

9. Absolute refractive index = $\frac{?}{Speed\ of\ light\ in\ midium}$. (**Speed of light in vacuum**)

10. Refractive index value of ruby is _______. (**1.71**)

11. Refraction depends upon the ________ of the light in the medium. (speed)

12. Mirages form because of the _______. (**Total internal reflection**)

13. ______ is the main cause for brilliance of diamonds. (Total internal reflection)

14. The critical angle of diamond is _______. (**24.4°**)

15. An angel of incidence for which the angle of refraction is 90^0 for a given pair of media is called _________. (**Critical angle**)

16. Light travels in vacuum with a speed to _______ m/s. (**3×10^8**)

17. A light ray travelling obliquely from a denser medium to a rarer medium bends_______ the normal. (**Away from**)

18. The speed of light in a medium depends upon ______ of the medium. (optical density)

19. A light ray bends __________ the normal when it travels obliquely from rarer to a denser medium. (**Towards**)

20. The ratio of speed of light in vacuum to the speed of light in that medium is defined as __________. (**Refractive index**)

Multiple Choice Questions

1. **In medium water to air, rays of light-** [A]

A) Bend away from the normal

B) Travels in a straight line in the same direction

C) Travels in a straight line in the opposite direction

D) None of the above

2. **The basic cause of refraction is?** **[C]**

A) When light is incident on a boundary

B) When the refractive indices of two media are equal

C) The change in the speed of light in going from one medium to another

D) None

3. **A ray of light travels from a medium of refractive index 'n_1', to medium of refractive index n_2. If angle of incidence is 'i' and the angle of refraction is 'r'? Then $\frac{\sin i}{\sin r}$ is equal to?** **[D]**

A) n_1 B) n_2 c) n_{12} D) n_{21}

4. **Which of the following is Snell's law?** **[B]**

A) $n_1 \sin i = \sin r / n_2$ B) $n_1/n_2 = \sin r / \sin i$

C) $n_2/n_1 = \sin r / \sin I$ D) $n_2 \sin i = \text{constant}$

5. **A plane glass slab is placed over different colored letters. The color that appears to be raised by least amount is?** **[C]**

A) Violet B) Yellow C) red D) Green

6. **A ray of light passes from vacuum into a medium of refraction index if the angle of incidence is twice the angle of refraction, then angle of incidence is?**

[C]

A) $\cos^{-1}\left[\frac{n}{2}\right]$ B) $\sin^{-1}\left[\frac{n}{2}\right]$ C) $2\cos^{-1}\left[\frac{n}{2}\right]$ D) $2\sin^{-1}\left[\frac{n}{2}\right]$

7. **Light of wavelength 6000 A^0 enters glass from air. Its wave length in glass will be $\left[ng = \frac{3}{2}\right]$. Find the answer?** **[C]**

A) 6000 A^0 B) 9000 A^0 C) 2000 A^0 D) 4000 A^0

8. **The refractive index of glass with respect to air is 2. Then the critical angle of glass- air interface is ______.** **[C]**

A) 0^0 B) 45^0 C) 30^0 D) 60^0

9. **Which one of the following is not an application of total internal reflection?**

[A]

A) Sparkling diamond B) Optical fibre

C) Blue color of sky D) Mirage

10. **The angle of deviation produced by the glass slab is ______.** **[A]**

A) 0^0 B) 20^0 C) 90^0 D) 40^0

11. **Total internal reflection takes place when the light ray travels from _____.**

[D]

A) Rarer to denser medium B) Rarer to rarer medium

C) Denser to denser medium D) Denser to rarer medium

12. **When a pencil kept in a glass tumbler filled with water seen from the side of the glass it seems to bend. Due to** **[C]**

A) Reflection B) Dispersion C) Refraction D) Slattering

13. **The net deviation produced by a rectangular glass slab is?** **[C]**

A) Equal to angle of incidence B) Greater than angle of incidence

C) Less than angle of incidence D) Zero, always

14. **Which of the following absolute refractive index values is not possible?** **[D]**

A) $\sqrt{2}$ B) $\sqrt{3}$ C) $\sqrt{2}+1$ D) $\sqrt{2}-2$

15. **Twinkling of stars is due to?** **[D]**

A) Total internal reflection B) scattering

C) Dispersion D) atmosphere refraction

16. **The refractive index of medium 1 relative to medium 2 is $\frac{4}{3}$. Then the refractive index of medium 2 relative to medium 1 is?** **[A]**

A) $\frac{0.8}{9}$ B) $\frac{4}{3}$ C) $\frac{3}{4}$ D) $\frac{9}{16}$

17. **Which one of the following characteristics of light is not altered by refraction?** **[B]**

A) Speed B) frequency C) wave length D) intensity

18. **A coin is placed at a depth of 4cm in water. When seen from air it appears to be at a depth of** $\left[n_w = \frac{4}{3}\right]$**. Find the answer.** **[D]**

A) 4cm B) 3cm C) $\frac{9}{16}cm$ D) $\frac{16}{9}cm$

19. **If speed of light were same in all the media, which of these processes are (is) not possible?** **[B & C]**

A) Reflection B) refraction

C) Dispersion D) all the above

20. **The absolute refractive index of water and glass respectively are** $\frac{4}{3}$ **and** $\frac{3}{2}$**. Then the relative refractive index of glass with respect of water is?**

[A]

A) $\frac{8}{9}$ B) $\frac{17}{6}$ C) 2 D) $\frac{9}{8}$

21. **A ray of light is incident on a plane surface of refractive index** $\sqrt{3}$ **at certain angle. It is found that the reflected and refracted rays are perpendicular to each other. Then the angle of incidence is?** **[C]**

A) 30^0 B) 45^0 C) 60^0 D) 15^0