05. REFRACTION OF LIGHT AT PLANE SURFACES

Questions and Answers

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

A. Due to refraction at water and air interface, the fish appears to be raised and seems to be close to the surface. The is called apparent depth. The shooter aims the gun to apparent position of fish instead of real position. Hence it is very difficult to shoot a fish swimming in water.

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 is 3,00,000 km/s.

A. Speed of light in air (v_1) =300000km/s

Speed of light in diamond (v_2) =124000km/s

Refractive index of diamond = $\frac{v_1}{v_2}$

$= \frac{300000}{124000} = 2.42$

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

A. Refractive index of glass relative to water is

$$n_{gw} = \frac{n_g}{n_w} = \frac{9}{8}$$

Refractive index of water relative to glass is

$$n_{wg} = \frac{n_w}{n_g} = \frac{8}{9}$$

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

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

Critical angle (c) = ?

$\text{Sin C} = \frac{1}{n}$

$\text{Sin C} = \frac{3}{4} = 0.75 = \text{Sin } 48^{o}36^{l}$

➔ $C = 48^{o}36^{l}$

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

A. Refractive index of Benzene (n) = ?

Critical angle (c) = 42^o

$\text{Sin C} = \frac{1}{n} \rightarrow n = \frac{1}{\text{Sin C}} = \frac{1}{\text{Sin } 42} = \frac{1}{0.6691} = 1.4945$

6. Explain the formation of mirage?

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.

The formation of a mirage is the best example where refractive index of a medium varies throughout the medium.

During a hot summer day, air just above the road surface is very hot, acts as rearer medium. And the air at higher altitudes is cool,acts as denser medium.

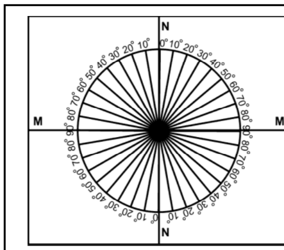
Thus the refractive index of the cooler air at the top is greater than the refractive index of hotter air just above the road.

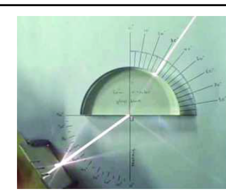
When the light from a tall object such as tree passes through a medium just above the road, whose refractive index decreases towards ground, it suffers, refraction and takes a curved path because of total internal reflection.

Hence we feel the illusion of water being present on road which is the virtual image (mirage) and an inverted image of tree on the road.

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

A.





Procedure: Take a wooden plank. Cover with white chart. Draw two perpendicular lines, passing through the middle of the paper. Mark one line as NN which is normal to the 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'.

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Take a protractor and place it along NN (its centre coincides with O). Then mark the angles from 0^o to 90^o on both sides of the line NN. Repeat the same on the other side of the line NN.

Now place a semi-circular glass disc so that its diameter coincides with the interface line (MM) and its center coincides with the point O. Point a laser light along NN in such a way that the light propagates from air to glass through the interface at point O and observe the path of laser light coming from other side of disc.. Send Laser light along a line which makes15^o (i) with NN and see that it passes through point O. Measure its corresponding angle of refraction (r). Note these values in table.

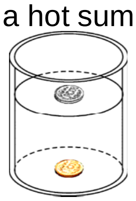
Find **sin i**, **sin r** and also the ratio $\frac{\sin i}{\sin r}$.

Do the same experiment for the angles of incidence such as 20^o,25^o, 30^o,and 35^o. In each and every case , we get the ratio $\frac{\sin i}{\sin r}$ as a constant.

Sl. No.	(i)	(r)	Sin i	Sin r	$\frac{\sin i}{\sin r}$
1	15^o				
2	20^o				
3	25^o				
4	30^o				
5	35^o				

8. Explain the phenomenon of total internal reflection with one or two activities.

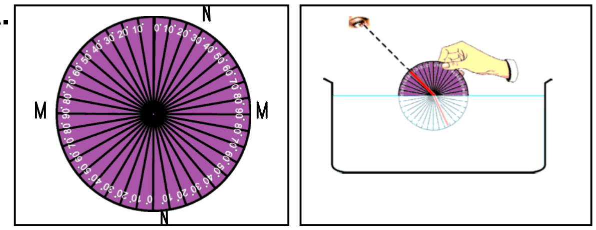
A. Take a cylindrical transparent vessel of 1 lit. Place a coin at the bottom of the vessel. Now pour water until you get the image of the coin on the water surface (look at the surface of water from a side). This is the phenomenon of total internal reflection. One of that is a mirage which we witness while driving or while walking on a road during a hot summer day.



If light ray passes from denser medium to rarer medium then the refractive angle is more than the incident angle. The incident angle for which the angle of refraction is 90^o, is called critical angle. If the angle of incidence is more than critical angle, then total internal reflection occurs.

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.

A.



Take a circular metal disc. Cover with white chart. Mark one line as NN which is normal to the 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 (its centre coincides with O). Then mark the angles from 0^o to 90^o on both sides of the line NN. Repeat the same on the other side of the line NN.

Arrange two straws at the centre of the disc in such a way that they can be rotated freely about the centre of the disc. Adjust one of the straws to make an angle 10^0 with the normal NN (angle of incidence). Immerse half of the disc vertically into the water, filled in a transparent vessel. (MM coincides the surface of the water)

From the top of the vessel try to view the straw which is inside the water. Then adjust the other straw which is outside the water until both straws appear to be in a single straight line. Then take the disc out of the water and observe the two straws on it. We find that they are not in a single straight line.

Measure the angle between the normal and second straw. (angle of refraction). Note down the angle of incidence and angle of refraction in the table. Do the same for various angles like 15^o, 20^o, 25^o, 30^o, 35^o and 40^o. Find the corresponding angles of refraction and note them.

Sl. No.	(i)	(r)
1	10^o	
2	15^o	
3	20^o	
4	25^o	
5	30^o	
6	35^o	
7	40^o	

We observed that the angle of refraction(r) is always greater than the angle of incidence (i).

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

A. Take a metal ball and make it black with soot in a candle flame. Immerse the ball in a water beaker. A thin air/empty layer is formed between water and soot. The light ray travels from denser medium (water) to rarer medium(air/empty layer). If the angle of incidence is greater than the critical angle, then total internal reflection takes place. Hence metal ball appears in shining.

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

(a) What changes do you notice?

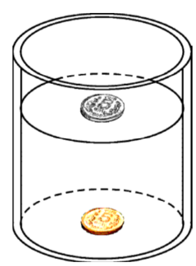
(b) What could be the reasons for these changes?

A. Take a glass vessel and pour some glycerine into it. Then pour water up to the brim. Let a quartz glass rod be Kept in the vessel. The part of glass rod in the glycerine disappears and invisible. As the refractive index of glass rod and glycerine are same, we can not identify the interface of these two mediums. Here no refraction takes place.

But the refractive indexes of water and glass rod are different. So the glass rod appears with big size due to refraction.

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

A. Take a cylindrical transparent vessel of 1 lit. Place a coin at the bottom of the vessel. Now pour water until we get the image of the coin on the water surface (look at the surface of water from a side). This is the phenomenon of total internal reflection.



When light ray passes from denser medium to rarer medium and If the angle of incidence is more than critical angle, then total internal reflection occurs.

Critical angle of water :

Applying Snell's law

$$n_1 . \text{Sin } i = n_2 . \text{Sin } r$$

$$n_{water} . \text{Sin } C = n_{air} . \text{Sin } 90^o$$

$$1.33 \times \text{Sin } C = 1.0003 \times 1$$

$$\text{Sin } C = \frac{1.0003}{1.33} = 0.7521$$

$$\text{Sin } C = \text{Sin } 48^o 46^I$$

$$C = 48^o 46^I = 48.75^o \text{ (approx)}$$

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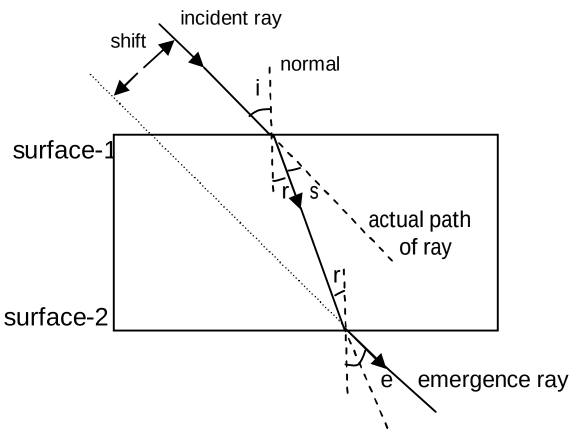
16. Explain the refraction of light through a glass slab with a neat ray diagram.

A. When light travels from one medium to another medium, its direction changes at the interface. This phenomenon is called refraction.

If light travels from rarer medium to denser medium, it bends towards the normal and if light travels from denser medium to rarer medium, it bends away to the normal.

The refracting surfaces of glass slab are parallel to each other. When light ray incident on one surface of the glass slab, it refracted twice and finally emerges from the second surface.

At first refraction it travels from rarer medium to denser medium. And at the second refraction it travels from denser medium to rarer medium.

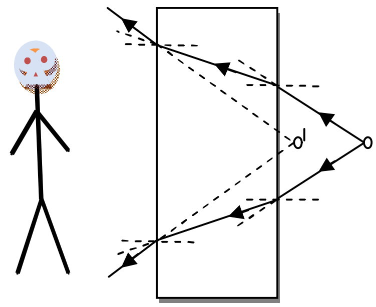


The perpendicular distance between the incident ray and emergence ray is called as lateral shift, if the slab is placed horizontally on the plane.

The perpendicular distance between the incident ray and emergence ray is called as vertical shift, if the slab is placed vertically on the plane. The angle between the actual path of ray and refracted ray is called angle of deviation(s).

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.

A.



Place of the Object is 'O'

Place of the Image is 'O'^{l}'

Arrow marks shows the path of the light ray.

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

A. Diamonds have high refractive index (2.42). The critical angle of diamond is very less (24.4^o). By cutting the faces of diamond in such a way that most of the incident rays at every face get total internal reflection. This is the reason for shining of diamonds.

19. How do you appreciate the role of Fermat principle in drawing ray diagrams.

A. Fermat principle: Light selects the path which takes the least time to travel.

When the light gets reflected from a surface, it selects the paths which takes the least time. This principle is very useful to prepare ray diagrams for the formation of images.

20. A light ray is incident on air-liquid interface at $45^0$and is refracted at 30^0. What is the refractive index of the liquid? For what angle of incidence will the angle between reflected ray and refracted ray be 90^0?

A. Case(i) : angle of incidence (i) = 45^o

angle of refraction (r) = 30^o

Refractive index (n) = $\frac{Sin\ i}{Sin\ r}$

$= \frac{Sin\ 45}{Sin\ 30} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}}$

$= \frac{2}{\sqrt{2}} = \sqrt{2}$

$= 1.414$

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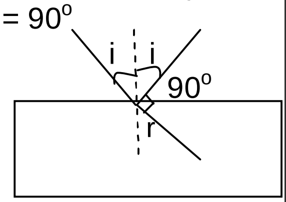
Case(ii) : Angle between reflected ray and refracted ray = 90^o



As per the figure : $i + 90^o + r = 180^o$

$$\Rightarrow r = 90^o - i$$

$$n = \frac{\sin i}{\sin r} = \frac{\sin i}{\sin(90-i)} = \frac{\sin i}{\cos i} = \tan i$$

$\tan i = n$

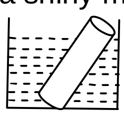
$\tan i = 1.414$

$\tan i = \tan 54.7^o$

$i = 54.7^o$

21. 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?

A. A test tube immersed at a certain angle in a tumbler of water. The surface of the test tube separates water and air. That means the light ray travels from denser medium (water) to rarer medium (air). This leads to total internal reflection at some particular angles of incidence. So the test tube appears as a shiny mirror surface.



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

A. In the following cases the light ray does not deviate at the interface.

Case(i): If the refractive indexes of two mediums are equal.

Case(ii): When the incident ray coincides with the normal drawn to the interface.

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

A. At camp fire, heat is transformed to the surroundings by convection. Due to this process, the density of surrounding air changes continuously. The refractive index continuously changes slightly. As a result the objects beyond the fire are seen swaying.

24. Why do stars appear twinkling?

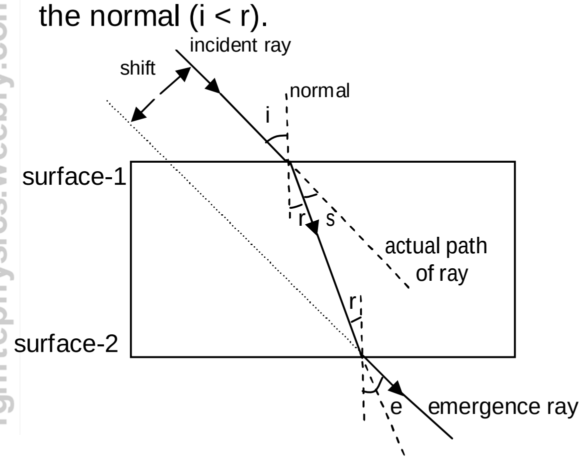
A. The light rays from the stars travel through many layers of earth's atmosphere which are having different refractive index values. The rays bent many times and in random directions. As a result, the stars appear twinkling.

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

A. Refractive index of diamond is very high (2.42). It is more than normal glass. Due to high refractive index, critical angle for diamond is very less. So most of the ray incident on the diamond surface, gets total internal reflection. So it shines more.

26. What is the angle of deviation produced by a glass slab? Explain with ray diagram.

A. If light travels from rarer medium to denser medium, it bends towards the normal (i > r)and if light travels from denser medium to rarer medium, it bends away to the normal (i < r).

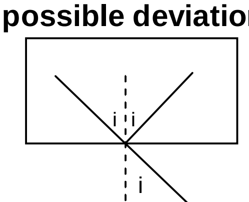


The angle between the actual path of ray and refracted ray is called angle of deviation (s).

$$s = i - r$$

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

A.



A ray of light travels from an optically denser to rarer medium.

The critical angle of the two media is 'c'.

The angle of deviation = $\pi - 2c$

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