EXERCISE - 4 (A)

Question 1:
What do you understand by refraction of light?
Solution 1:
The change in the direction of the path of light, when it passes from one transparent medium to another transparent medium, is called refraction of light.

Question 2:
Draw diagrams to show the refraction of light from (i) air to glass, (ii) glass to air. In each diagram, label the incident ray, refracted ray, the angle of incidence (*i*) and the angle of refraction (r).
Solution 2:
Diagram showing the refraction of light from Air to glass

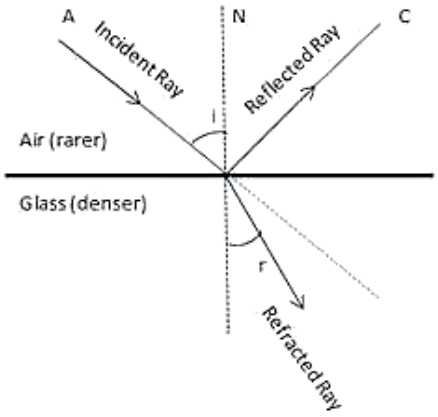
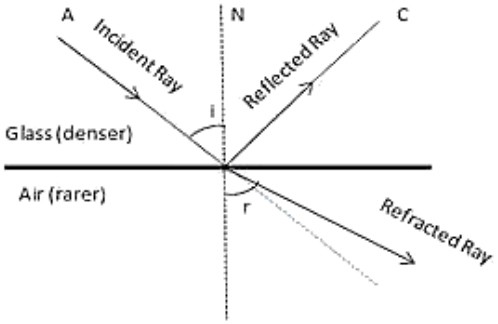


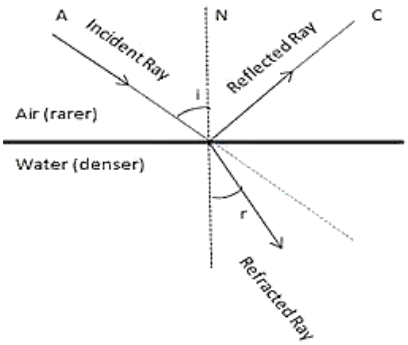
Diagram showing the refraction of light from Glass to Air



Question 3:
A ray of light is incident normally on a plane glass slab. What will be (i) the angle of refraction and (ii) the angle of deviation for the ray?
Solution 3:
The ray of light which is incident normally on a plane glass slab passes undeviated. That is such a ray suffers no bending at the surface because here the angle of incidence is 0°. Thus if angle of incidence ∠i= 0°, then the angle of refraction ∠r = 0°. And the angle of deviation of the ray will also be 0°.

Question 4:
What is the cause of refraction of light when it passes from one medium to another?
Solution 4:
The refraction of light (or change in the direction of path of light in other medium) occurs because light travels with different speeds in different media. When a ray of light passes from one medium to another, its direction (except for ∠i = 0°) changes because of change in its speed.

Question 5:
A light ray suffers reflection and refraction at the boundary in passing from air to water. Draw a neat labelled ray diagram to show it.
Solution 5:
Air is a rarer medium while water is denser than air with refractive index of 1.33. Therefore when light ray will travel from air to water it will bend towards the normal.



Question 6:
A ray of light passes from medium 1 to medium 2. Which of the following quantities of the refracted ray will differ from that of the incident ray: Speed, intensity, frequency, wavelength?
Solution 6:
Speed, intensity and wavelength

Question 7:
State the snell's laws of refraction of light.
Solution 7:
The Snell's laws of refraction are:

1. The incident ray, the refracted ray and the normal at the point of incidence, all lie in the same plane.
2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for the pair of the given media.
   $\frac{sini}{sinr} = {}_1\mu_2$

where ${}_1\mu_2$ is known as the refractive index of the second medium with respect to the first medium.

Question 8:
Define the term refraction index of a medium. Can it be less than 1?
Solution 8:
The refractive index of second medium with respect to first medium is defined as the ratio of the sine of angle of incidence in the first medium to the sine of the angle of refraction in the second medium.

Refractive index of a medium is always greater than 1 (it cannot be less than 1) because the speed of light in any medium is always less than that in vacuum.

Question 9:
How is the refractive index of a medium related to the speed of light in it?
Solution 9:
Denser medium has a higher refractive index and therefore the speed of light in such medium is lower in comparison to the speed of light in a medium which has a lower refractive index.

Question 10:
A light ray passes from to (a) air, (b) glass. In each case state, how does the speed of light change.
Solution 10:
(a) **Air** (its refractive index is less than that of water)
(b) **Glass** (its refractive index is more than that of water)

Question 11:
A light ray in passing from water to a medium (a) speeds up (b) slows down. In each case, give one example of the medium.

Solution 11:
In case (i) the refractive index of the medium 2 is less than the refractive index of medium 1 because the ray of light speeds up.
While in case (ii) the refractive index of the medium 2 is greater than the refractive index of medium 1 due to because here the ray of light slows down.

Question 12:
How does the speed of light change when it passes from glass to water?
Solution 12:
Refractive index of water, $\mu w = 1.33$
Refractive index of air, $\mu a = 1.0003$
Refractive index of glass, $\mu g = 1.5$
This implies that $\mu a < \mu w < \mu g$
The speed of light decreases when it enters from a rarer medium to denser medium and increases when it enters from a denser medium to rarer medium.
Therefore, the speed of light increases when light ray passes from water to air and the speed of light decreases when light ray passes from water to glass.

Question 13:
A ray of light is passing from a transparent medium 1 to another transparent medium 2 (i) Speed up (ii) slows down. In each case, state whether the refractive index of medium 2 is equal to, less than or greater than the refractive index of medium 1.
Solution 13:
In case (i) the refractive index of the medium 2 is less than the refractive index of medium 1 because the ray of light speeds up.
While in case (ii) the refractive index of the medium 2 is greater than the refractive index of medium 1 due to because here the ray of light slows down.

Question 14:
What do you understand by the statement the refractive index of glass is 1.5 for white light?
Solution 14:
The refractive index of glass is 1.5 for white light means white light travels in air 1.5 times faster than in glass.

Question 15:
A monochromatic ray of light passes from air to glass. The wavelength of light in air is λ, the speed of light in air is c and in glass is ν. If the absolute refractive index of glass is 1.5, write down (a) the relationship between *c* and ν, (b) the wavelength of light in glass.

Solution 15:
(a) The relation between speed of light in air c and in glass v is given by

$$\frac{c}{v} = \mu \; Or \; c = 1.5\, v$$

(b) The wavelength of light in glass (λ^1)

$$\mu = \frac{\lambda}{\lambda^1} = \frac{\lambda}{1.5}$$

Question 16:
For which colour of white light, is the refractive index of a transparent medium (a) the least (b) the most?
Solution 16:
(a) The least for red colour and (b) the most for violet colour.

Question 17:
Name two factors on which the refractive index of a medium depends? State how does it depend on the factors stated by you.
Solution 17:
The two factors on which the refractive index of a medium depends are:

1) Nature of a medium i.e. its optical density (e.g. $\mu_g = 1.5$, $\mu_w = 1.33$) - Smaller the speed of light in a medium relative to air, higher is the refractive index of that medium.
2) Physical condition such as temperature - with increase in temperature, the speed of light in medium increases, so the refractive index of medium decreases.

Question 18:
How does the refractive index of a medium depend on the wavelength of light used?
Solution 18:
Refractive index of a medium decreases with increase in wavelength of light.
Refractive index of a medium for violet light (least wavelength) is greater than that for red light (greatest wavelength).

Question 19:
How does the refractive index of a medium depend on its temperature?
Solution 19:
Refractive index of a medium decreases with the increase in temperature.

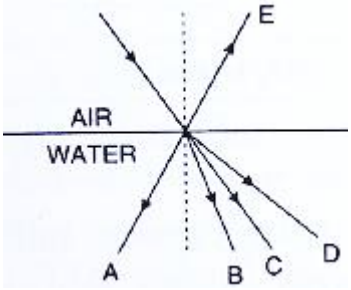
With increase in temperature, the speed of light in that medium increases; thus, the refractive index (= velocity of light in vacuum/velocity of light in medium) decreases.

Question 20:

A ray of light from air suffers partial reflection and refraction at the boundary of water. In Fig. 4.16, which of the ray A, B, C, D and E is the correct

(i) refracted ray

(ii) partially reflected ray?



Solution 20:

(i) Ray 'B' is the correct refracted ray as a ray of light bends towards the normal while going from rarer to denser medium.

(ii) Ray 'E' is the partially reflected ray, as reflection of light takes place in the same medium.

Question 21:

The diagram alongside shows the refraction of a ray of light from sir to a liquid.

(a) write the values of (i) angle of incidence, (ii) angle of refraction.

(b) use snell's law to find the refractive index of liquid with respect to air.

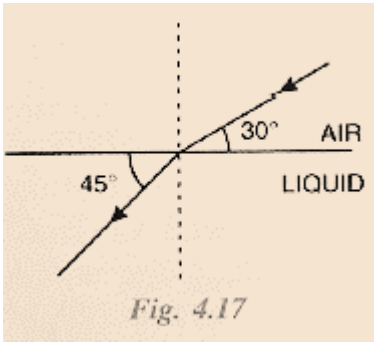


Fig. 4.17

Solution 21:

(a)

(a) Angle of incidence is the angle which the incident ray makes with the normal.

$\therefore \angle i = 90° - 30° = 60°$

(b) Angle of refraction is the angle which the refracted ray makes with the normal.

$\therefore \angle i = 90° - 45° = 45°$

(b) According to snell's law.

$$_{air}\mu_{liquid} = \frac{\sin i}{\sin r} = \frac{\sin 60°}{\sin 45°}$$

Or $$_{air}\mu_{liquid} = \frac{\frac{\sqrt{3}}{2}}{\frac{1}{\sqrt{2}}}$$

$$= \sqrt{\frac{3}{2}} = 1.22$$

Question 22:

The refractive index of water with respect to air is a $^{\mu}$w and of glass with respect to air is a $^{\mu}$g. express the refractive index of glass with respect to water.

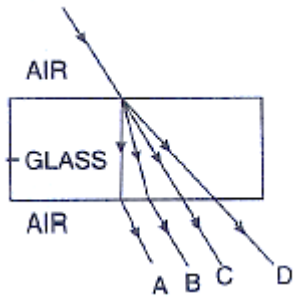
Solution 22:

Refractive index of glass with respect to water $_{w}{}^{\mu}{}_{g}$ is given by

$$_{w}{}^{\mu}{}_{g} = \frac{a\,\mu\,g}{a\,\mu\,w}$$

Question 23:

In fig 4.18, name the ray which represents the correct path of light while emerging out through a glass block.



Solution 23:

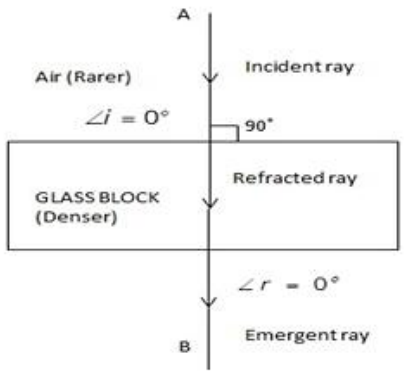
The correct ray is B

Question 24:

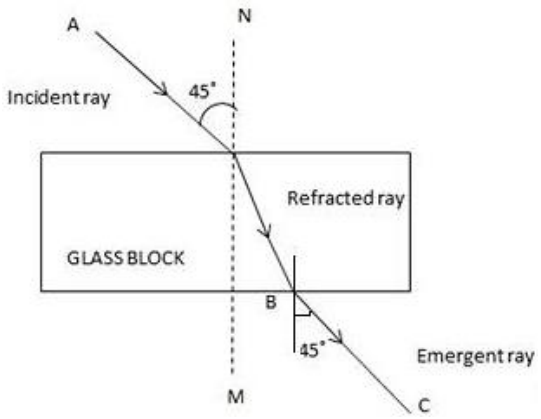
A ray of light strikes the surface of a rectangular glass block such that the angle of incidence in air is (i) 0°, (ii) 45°. In each case, draw diagram to show the path taken by the ray as it passes through the glass block and emerges from it.

Solution 24:

Case (i) when angle of incidence is 0^o.



Case (ii) When angle of incidence is 45^o.



Question 25:

In the adjacent diagram, AO is a ray of light incident on a rectangular glass block.

(a) complete the path of the ray till it emerges out of the block.

(b) In the diagram, mark the angles of incidence (i) and the angle of refractive index of glass related to the angles i and r ?

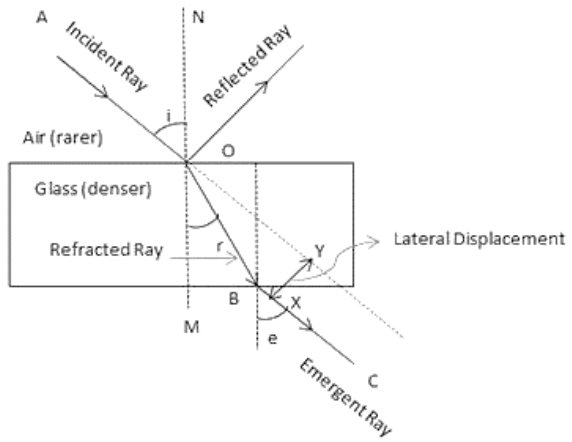
(c) mark angles of emergence by the letter *e*. How are the angles I and e related?

(d) which two rays are parallel to each other? Name them.

(e) Indicate in the diagram the lateral displacement between the emergent ray and the incident ray.

Solution 25:

(a) The complete path of incident ray in glass block is drawn in figure below.



(b) Angle of incidence (i) and angle of refraction (r) are marked in part (a).
Refractive index (μ) of glass is related to the angles as

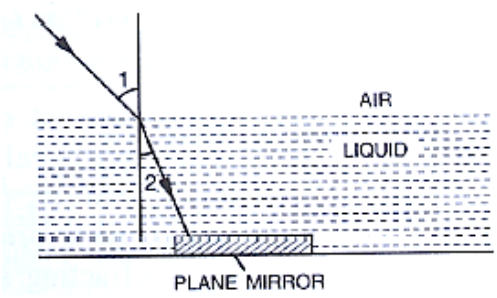
$$\frac{\sin i}{\sin r} = \mu$$

(c) Angle of emergence (e) is marked in part (a)
The two angles are related to each other by the relation

$$\angle i = \angle e$$

(d) Incident ray and emergent ray are parallel to each other.
(e) Lateral displacement is indicated in the figure by XY.

Question 26:
A ray of monochromatic green light enters a liquid from air, as shown in Fig 4.20. The angle 1 is 45° and angle 2 is 30°.



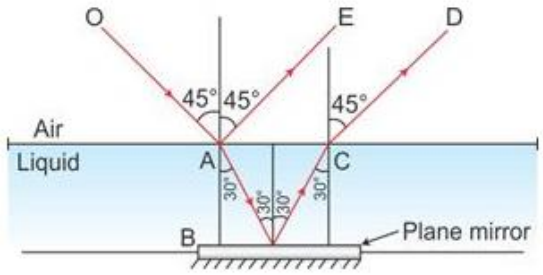
(a) Find the refractive index of liquid.
(b) Show in the diagram the path of the ray after it strikes the mirror and re-enters in air. Mark in the diagram the angles where ever necessary.
(c) Redraw the diagram if plane mirror becomes normal to the refracted ray inside the liquid. State the principal used.

Solution 26:
(a) Refractive index of the liquid =

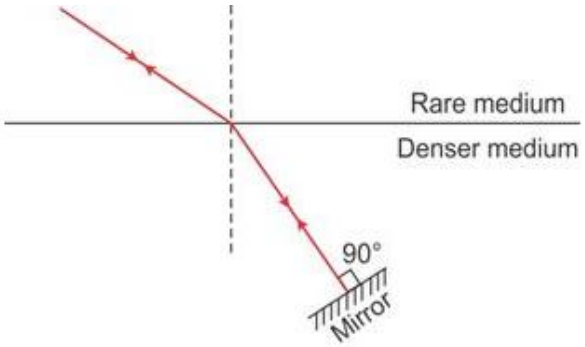
$$a^{\mu} i = \frac{\sin i}{\sin r}$$

$$a^{\mu} i = \frac{\sin 45°}{\sin 30°} = \frac{1/\sqrt{2}}{1/2} = \sqrt{2} = 1.414$$

(b)



(c)



Here the 'Principle of Reversibility' is used.

Question 27:

Light of a single colour is passed through a liquid having a piece of glass suspended in it. On changing the temperature of liquid, at a particular temperature the glass piece is not seen.

(i) When is the glass piece not seen?

(ii) Why is the light of a single colour used?

Solution 27:

(i) The glass piece is not seen when the refractive index of liquid becomes equal to the refractive index of glass.

(ii) Light of a single colour is used because the refractive index of a medium (glass or liquid) is different for the light of different colours.

Question 28:
When a lighted candle is held in front of a thick plane glass mirror, several images can be seen, but the second image is the brightest, give reason.
Solution 28:
When a ray of light from lighted candle fall on the surface of a thick plane glass mirror, a small part of light (nearly 4%) is reflected forming first image which is faint virtual image, while a large part of light (nearly 96%) is refracted inside the glass. This ray is now strongly reflected back by the silvered surface inside the glass. This ray is then partially refracted in air and this refracted ray forms another virtual image. This image is the brightest image because it is due to the light suffering a strong reflection at the silver surface.

Question 29:
Fill in the blanks to complete the following sentences:
(a) When light travels from a rarer to a denser medium, its speed. ……..
(b) When light travels from a denser to a rarer medium, its speed …….
(c) The refractive index of glass with respect to air is 3/2. The refractive index of air with respect to glass will be …….
Solution 29:
(a) When light travels from a rarer to a denser medium, its speed decreases
(b) When light travels from a denser to a rarer medium, its speed increases
(c) The refractive index of glass with respect to air is 3/2. The refractive index of air with respect to glass will be 2/3

MULTIPLE CHOICE TYPE:

Question 1:
When a ray of light from air enters a denser medium, it:
(a) bends away from the normal
(b) bends towards the normal
(c) goes undeviated
(d) is reflected back
Solution 1:
The ray of light bends towards the normal.
Reason: As the speed of light decreases in the denser medium, it bends towards the normal.

Question 2:
A light ray does not bend at the boundary in passing from one medium to the other medium if the angle of incident is:
(a) 0° (b) 45° (c) 60° (d) 90°

Solution 2:
(a) 0°
Reason: A ray of light which is incident normally (i.e. at angle of incidence = 0°) on the surface separating the two media, passes undeviated.

Question 3:
The highest refractive index is of:
(a) Glass (b) Water (c) Diamond (d) Ruby
Solution :
Diamond
Reason: As the speed of light in diamond is the least, diamond has the highest refractive index.

NUMERICALS:

Question 1:
The speed of light in air is 3×10^8 m s^{-1}. Calculate the speed of light in glass. The refractive index of glass is 1.5
Solution 1:
Given,
Speed of light in air, $c = 3 \times 10^8$ m/s
Refractive index of glass, $\boldsymbol{\mu} = 1.5$
Speed of light in glass, v = ?
We know that,

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

$$\therefore v = \frac{3 \times 10^8\ m/s}{1.5}$$

$V = 2 \times 10^8$ m/s

Question 2:
The speed of lllight in diamond is 125,000 km s^{-1}. What is its refractive index? (speed of light in air = 3×10^8 m s^{-1}).
Solution 2:
Given,
Speed of light in diamond, $v = 125 \times 10^6$ m/s
Speed of light in air, $c = 3 \times 10^8$ m/s
Refractive index of diamond, μ_D = ?
We know that,

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

$\therefore \mu = \frac{3 \times 10^8\ m/s}{125 \times 10^6\ m/s} = 2.4$

Question 3:
The refractive index of water with respect to air is 4/3. What is the refractive index of air with respect to water?
Solution 3:
Given =, refractive index of water w.r.t. air
${}_{air}\mu_{water} = \frac{4}{3}$
∴ refractive index of air w.r.t. water is:
${}_{water}\mu_{air} = \frac{1}{{}_{air}\mu_{water}} = \frac{3}{4} = 0.75$

Question 4:
A ray of light of wavelength 5400 Å suffer refraction from air to glass. Taking $\alpha\mu_g$ = 3/2, find the wavelength of light in glass.
Solution 4:
Given, refractive index of glass w.r.t. air.
${}_a\mu_g = \frac{3}{2}$
Also, ${}_a\mu_g = \frac{wavelength\ of\ light\ in\ air}{wavelength\ of\ light\ in\ glass}$

$\therefore \frac{3}{2} = \frac{wavelength\ of\ light\ in\ air}{wavelength\ of\ light\ in\ glass}$

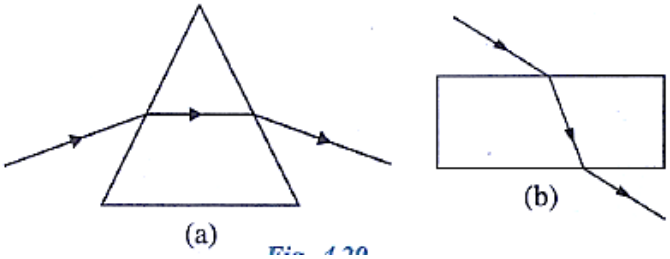
$\Longrightarrow \frac{3}{2} = \frac{5400\ Å}{wavelength\ of\ light\ in\ glass}$
$\Longrightarrow$ Wavelength of light in glass = $\frac{2}{3} \times 5400\ Å = 3600\ Å$

EXERCISE – 4(B)

Question 1:
What is a prism?
With the help of diagram of a prism, indicate its refracting surfaces, refracting edge and base.
Solution 1:
A prism is a transparent refracting medium bounded by five plane surfaces inclined at some angle.

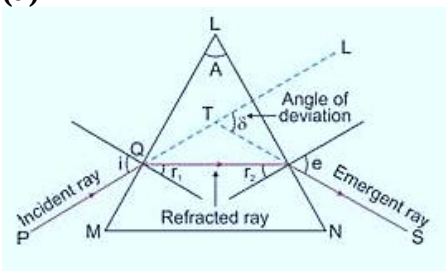
Question 2:

The diagrams (a) and (b) in Fig. 4.29 below show the refraction of a monochromatic ray of light through a parallel sided glass block and a prism respectively. In each diagram, label the incident, refracted emergent rays and the angle of deviation.

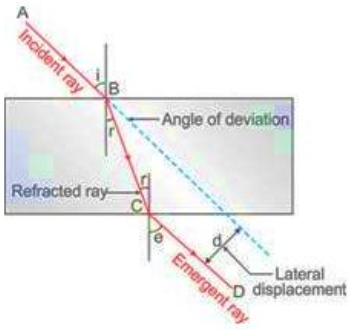


Solution 2:

(a)



(b)



Question 3:

Define the term angle of deviation

Solution 3:

The angle between the direction of incident ray and the emergent ray, is called the angle of deviation.

Question 4:

Complete the following sentence:

Angle of deviation is the angle which the ……. Ray makes with the direction of …….. ray.

Solution 4:

Angle of deviation is the angle which the emergent ray makes with the direction of incident ray.

Question 5:

What do you understand by the deviation produced by a prism? Why is it caused? State three factors on which the angle of deviation depends.

Solution 5:

In a prism the ray of light suffers refraction at two faces. The prism produces a deviation at the first surface and another deviation at the second surface. Thus a prism produces a deviation in the path of light.

The value of the angle of deviation (or the deviation produced by a prism) depends on the following four factors:

(a) the angle of incidence (i),
(b) the material of prism(i.e., on refractive index μ),
(c) the angle of prism (A),
(d) The colour or wavelength (λ) of light used.

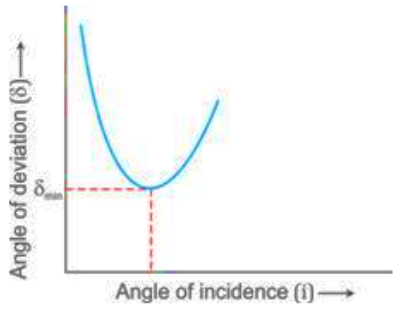
Question 6:

How does the angle of deviation produced by a prism change with increase in the angle of incidence. Draw a curve showing the variation in the angle of deviation with the angle of incidence at a prism surface.

Solution 6:

As the angle of incidence increases, the angle of deviation decreases first and reaches to a minimum value (δ_m) for a certain angle of incidence. By further increasing the angle of incidence, the angle of deviation is found to increase.

Variation of angle of deviation (δ) with angle of incidence(i):



Question 7:
State whether the following statement is 'true' or 'false'
The deviation produced by a prism is independent of the angle of incidence and is same for all the colours of light.
Solution 7:
False.

With the increase in the angle of incidence, the deviation produced by a prism first decreases and then increases.
A given prism deviates the violet light most and the red light least.

Question 8:
How does the angle of minimum deviation produces by a prism change with increase in (i) the wavelength of incident light and (ii) the refracting angle of prism?
Solution 8:
Changes in the angle of deviation as we increase
(i) The wavelength of incident light
As we increase the wavelength, angle of deviation decreases.
(ii) The refracting angle of the prism
The angle of deviation increases with the increase in the angle of prism.

Question 9
Write a relation for the angle of deviation (δ) for a ray of light passing through an equilateral prism in terms of the angle of incidence (i) angle of emergence (e) and angle of prism(A).
Solution 9:
The relation between the angle of incident (i), angle of emergence (e), angle of prism (A) and angle of deviation (δ) for a ray of light passing through an equilateral prism is

$\delta = (i+e) - A$

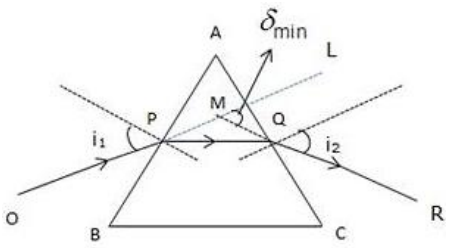
Question 10:
A ray of light incident at an angle of incidence i_1 passes through an equilateral glass prism such that the refracted ray inside the prism is parallel to its base and emerges at an angle of emergence i_2. (i) How is the angle of emergence 'i_2' related to the angle of incidence 'i_2'. (ii) what can you say about the angle of deviation in such a situation?
Solution 10:
(i) $i_2 = i_1$
(ii) Angle of deviation is minimum

Explanation: In minimum deviation position, the refracted ray inside the prism travels parallel to it if the prism is equilateral and the angle of incidence is equal to the angle of emergence.

Question 11:
How is the angle of emergence related to the angle of incidence when prism is in the position of minimum deviation? Illustrate your answer with help of a labelled diagram using an equilateral prism?

Solution 11:
In case of an equilateral prism, when the prism is in the position of minimum deviation $\delta = \delta_{min}$, the angle of incidence i_1 is equal to the angle of emergence i_2.

$i_1 = i_2 = i$



Question 12:
A light ray of yellow colour is incident on an equilateral glass prism at an angel of incidence equal to 48° and suffers minimum deviation by an angle of 36°. (i) What will be the angle of emergence? (ii) If the angle of incidence is changes to (a) 30°, (b) 60°, state whether the angle of deviation will be equal to, less than or more than 36° ?

Solution 12:
(i) As the ray is suffering minimum deviation in an equilateral glass prism so

$i_1 = i_2$

$\therefore i_2 = 48°$

(ii) If the angle of incidence is changed to

(a) 30^o, the angle of deviation will be more than 36^o.

(b) 60^o, the angle of deviation will be more than 36^o.

Question 13:
Name the colour of white light which is deviated (i) the most, (ii) the least, on passing through a prism.

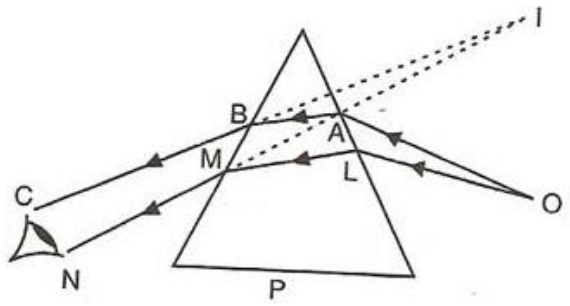
Solution 13:
(i) Violet colour will deviate the most and (ii) Red colour will deviate the least.

Question 14:
Which of the two prism, A made of crown glass and B made of flint glass, deviates a ray of light more?

Solution 14:
B made of flint glass. Because it has higher refractive index.

Question 15:
How does the angle of deviation depend on the refracting angle of the prism?
Solution 15:
The angle of deviation (δ) increases with the increase in the angle of prism (A).

Question 16:
An object is viewed through a glass prism with its vertex pointing upwards. It appears to be displaced upward. Explain the reason.
[Hint: see solved example 1]
Solution 16:
Let two rays OA and OL from a source O are incident on the prism. They are refracted along AB and LM from first face of the prism. These two rays again refract from the second face of the prism emerge out along BC and MN respectively such that they appear to come from I.



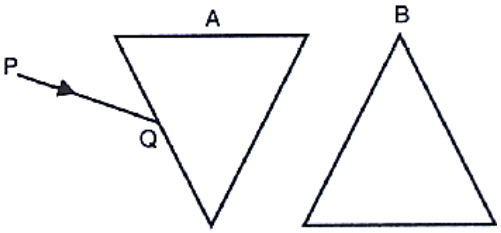
Thus, observer sees the object O raised to the position I.

Question 17:
A ray of light is normally incident on one face of an equilateral glass prism. Answer the following:
(a) What is the angle of incidence on the first face of the prism?
(b) What is the angle of refraction from the first face of the prism?
(c) what will be the angle of incidence at the second face of the prism?
(d) will the light ray suffer minimum deviation by the prism?
Solution 17:
(a) If the incident ray normal to prism then angle of incidence is 0^o.
(b) In this case the angle of refraction from the first face $r_1 = 0^o$.
(c) As the prism is equilateral so $A = 60^o$ and $r_1 = 0^o$. So at the second face of the prism, the angle of incidence will be 60^o.

(d) No the light will not suffer minimum deviation.

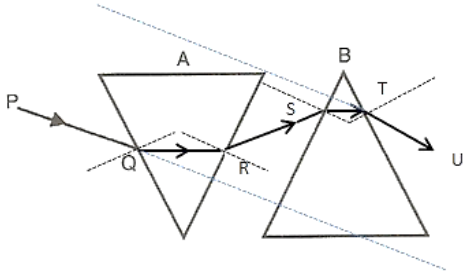
Question 18:

Fig. 4.30 below shows two identical prisms A and B placed with their faces parallel to each other A ray of light of single colour PQ is incident at the face of the prism A. complete the diagram to show the path of the ray till it emerges out of the prism B.



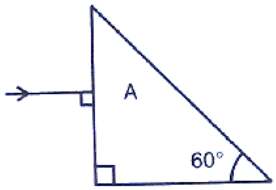
[Hint: The e mergent ray out of the prism B will be parallel to the incident ray PQ]

Solution 18:

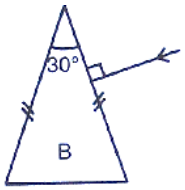


Question 19:

Fig 4.31 below shows a light ray of single colour incident normally on two prisms A and B. In each case draw the path of the ray of light as it enters and emerges out of the prism. Mark the angle wherever necessary.



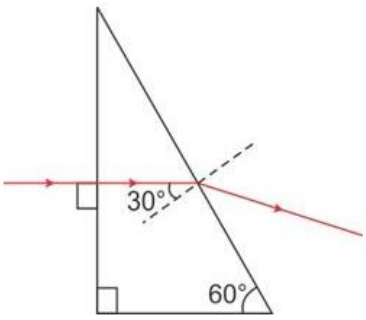
(i)



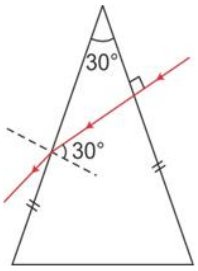
(ii)

Solution 19:

(i)

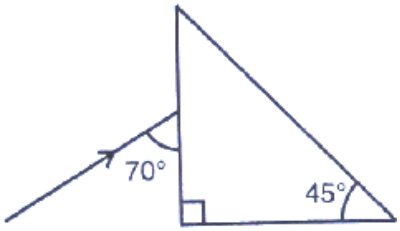


(ii)

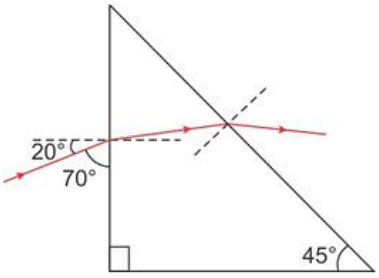


Question 20:

Complete Fig. 4.32 to show the path of the ray of single colour as it enters the prism and emerges out of it. Mark the angles wherever necessary.



Solution 20:



MULTIPLE CHOICE TYPE:

Question 1:
In refraction of light through a prism, the light ray:
(a) Suffers refraction only at one face of the prism.
(b) emerges out from the prism in a direction parallel to the incident ray.
(c) bends at both the surfaces of prism towards its base.
(d) bends at both the surfaces of prism opposite to its base.
Solution 1:
The light ray bends at both the surfaces of prism towards its base.

Question 2:
A ray of light suffers refraction through an equilateral prism. The deviation produced by the prism does not depend on the:
(a) angle of incidence
(b) colour of light
(c) material of prism
(d) size of prism
Solution 2:
The deviation produced by the prism does not depend on the size of prism.

NUMERICALS:

Question 1:
A ray of light incident at an angle 48° on a prism of refracting angle 60° suffers minimum deviation. Calculate the angle of minimum deviation.
[Hint: $\delta_{min} = 2i - A$]
Solution 1:
Given,
Angle of incidence, i = 48°
Refracting angle, A = 60°
Angle of minimum deviation, δ_{min} =?
As $\delta_{min} = 2i - A$
$\delta_{min} = 2(48) - 60$
$\delta_{min} = 36°$

Question 2:
What should be the angle of incidence for a ray of light which suffers a minimum deviation of 36° through an equilateral prism?
[Hint: A = 60°, $i = (A + \delta_{min})/2$]

Solution 2:
Given,
Angle of prism, A = 60°
Angle of minimum deviation, = 36°
Angle of incidence, i =?
As $\delta_{min} = 2i - A$
$36° = 2i - 60$
$i = 48°$

EXERCISE – 4 (C)

Question 1:
How is the refractive index of a medium related to the real and apparent depths of an object in that medium?

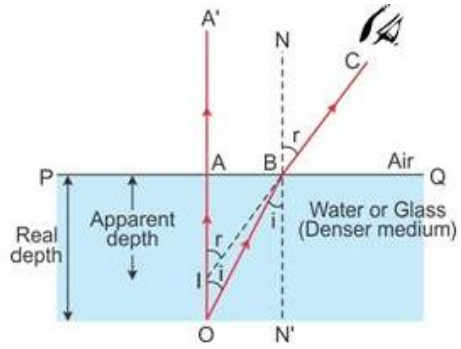
Solution 1:
Relation of refractive index μ wih real and apparent depths

$$\mu = \frac{\text{Real depth}}{\text{Apparent Depth}}$$

Question 2:
Prove that

Refractive index = $\frac{Real\ depth}{Apparent\ depth}$

Solution 2:



Consider a ray of light incident normally along OA. It passes straight along OAA'. Consider another ray from O (the object) incident at an angle i along OB. This ray gets refracted and passes along BC. On producing this ray BC backwards, it appears to come from the point I, and hence, AI represents the apparent depth, which is less than the real depth AO.

Since AO and BN^I are parallel and OB is the transversal,
$\angle AOB = \angle OBN^I$ (Alternate angles)
$\angle BIA^I = \angle CBN$ (Corresponding angles)

In ΔBAO, Sin i = $\frac{BA}{OB}$

In ΔIAB, Sin r = $\frac{BA}{IB}$

We know that refractive index of air w.r.t the medium

$$_a\mu_m = \frac{\sin i}{\sin r} = \frac{BA/OB}{BA/IB} = \frac{IB}{OB}$$

∴ Refractive index of medium w.r.t. air is,

$$_a\mu_m = \frac{1}{_m\mu_a} = \frac{OB}{IB}$$

Since the point B is very close to point A, i.e the object is viewed from a point vertically above the object.

∴ IB = IA and OB = OA.

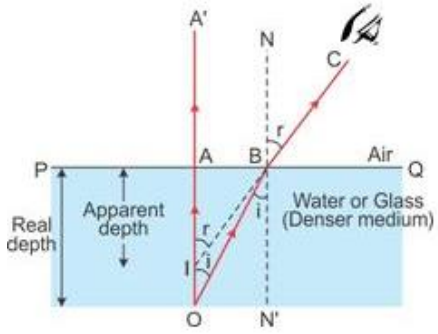
Hence, $_a\mu_m = \frac{OA}{IA} = \frac{Real\ depth}{Apparent\ depth}$

Question 3:

A tank of water is viewed normally from above. State how does the depth of tank appear to change. Draw a labelled ray diagram to explain your answer.

Solution 3:

The depth of the tank appears to be lesser than its real depth. This happens due to the refraction of light from a denser medium (water) to a rarer medium.



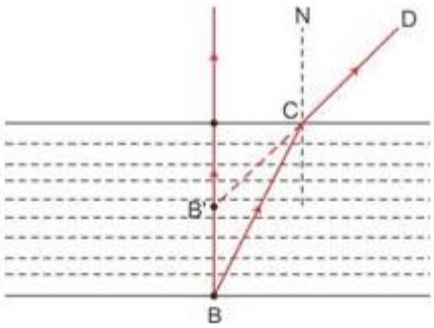
Question 4:

Water in a pond appears to be only three – quarters of its actual depth. What property of light is responsible for this observation? Illustrate your answer with the help of a ray diagram. How is the refractive index of water calculated from its real and apparent depth?

Solution 4:

'Refraction of light' is responsible for this property.

When light coming from denser medium enters rarer medium, it is bent away from the normal.



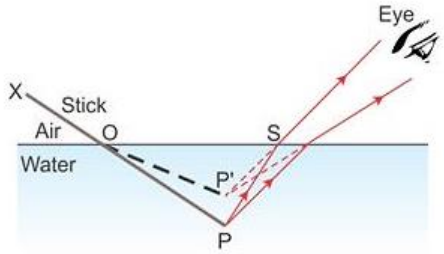
Let any object B is at the bottom of a pond. Consider a light ray BC from the object that moves from water to air. After refraction from the water surface, the ray moves away from the normal N along the path CD. The produce of CD appears from the point B' and a virtual image of the object at B appears at B'.

Refractive index of water = $\frac{Real\ depth}{Apparent\ depth}$

Question 5:

Draw a ray diagram to show the appearance of a stick partially immersed in water explain your answer.

Solution 5:



A stick partially immersed in water in a glass container appears bent or raised as shown in figure above. This happens because the rays appear to come from P' (which is the virtual image of the tip P of the stick) due to refraction from denser medium (water) to rarer medium (air) at the surface separating two media.

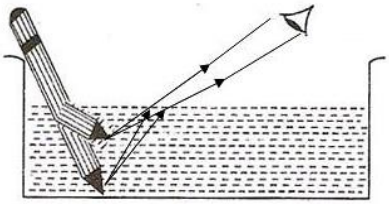
Question 6:

A student puts his pencil into an empty trough and observes the pencil from the position as indicated in Fig. 4.37

(i) What change will be observed in the appearance of the pencil when water is poured into the trough?
(ii) Name the phenomenon which accounts for the above stated observation.
(iii) complete the diagram showing how the student's eye sees the pencil through water.

Solution 6:

(i) Part of the pencil which is immersed in water will look short and raised up.
(ii) The phenomena which is responsible for the above observation is refraction of light.
(iii) The required figure is

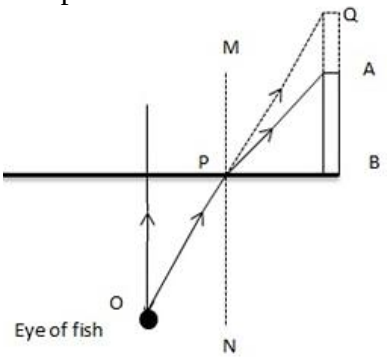


Question 7:

A fish is looking at a 1.0m high plant at the edge of the pond. Will the plant appear shorter or taller than its actual height, to the fish. Draw a ray diagram to support your answer.

Solution 7:

The plant will look taller than its actual height.



Let the fish is looking from the point O. As the ray OP emerges out from water to air, it will bend away from the normal MN because air is a rarer medium in comparison of water. But if we extend ray OP then it will meet at Q due to which the plant AB will look taller than its actual height.

Question 8:

An object placed in one medium when seen from the other medium, appears to be vertically shifted. Name two factors on which the magnitude of shift depends and state how does it depend on them.

Solution 8:
The factors on which the magnitude of shift depends are:
(a) The refractive index of the medium,
(b) The thickness of the denser medium and
(c) The colour (or wavelength) of incident light.

The shift increase with the increase in the refractive index of medium. It also increases with the increase in thickness of denser medium but the shift decreases with the increases in the wavelength of light used.

MULTIPLE CHOICE TYPE:

Question 1:
A small air bubble in a glass block when seen from above appears to be raised because of:
(a) refraction of light
(b) reflection of light
(c) reflection and refraction of light
(d) none of the above
Solution 1:
Refraction of light
Hint: When a ray of light travels from denser to rarer medium, it moves away from the normal.

Question 2:
An object in a denser medium when viewed from a rarer medium appears to be raised. The shift is maximum for:
(a) red light
(b) violet light
(c) yellow lighten
(d) green light
Solution 2:
The shift is maximum for violet light.

Hint: The shift is maximum for violet light because the refractive index of glass is the most for the violet light and apparent = (real depth)/(refractive index)

NUMERICALS:

Question 1:
A Water pond appears to be 2.7 m deep. If the refractive index of water is 4/3, find the actual depth of the pond.

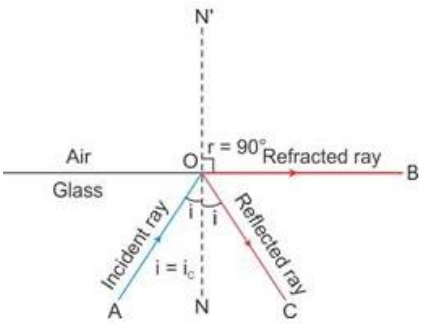
Solution 1:
Apparent depth = 2.7 m
$\boldsymbol{\mu}_w = \frac{4}{3}$
Real depth = apparent depth × $\boldsymbol{\mu}_w$
$= 2.7 \times \frac{4}{3} = 3.6\ m$

Question 2:
A coin is places at the bottom of a beaker containing water (refractive index = 4/3) to a depth of 12 cm. By what height the coin appears to be raised when seen from vertically above?
Solution 2:
Refractive index of the water, $\boldsymbol{\mu}_w$ = 4/3
Real depth at which the coin is places = 12 cm
Shift in the image = ?
Shift = real depth × $\left(1 - \frac{1}{\mu}\right)$
Shift = $12 \times \left(1 - \frac{3}{4}\right)$
R = $\frac{12}{4} = 3cm$

Question 3:
A postage stamp kept below a rectangular glass block of refractive index 1.5 when viewed from vertically above it, appears to be raised by 7.0 mm. calculate the thickness of the glass block.
Solution 3:
Refractive index of the glass block, $\boldsymbol{\mu}_g$ = 1.5
Shift in the image = 7mm or 0.7 cm
Thickness of glass block or real depth =?
Shift = Real depth × $\left(1 - \frac{1}{\mu}\right)$
$0.7 = R \times \left(1 - \frac{1}{1.5}\right)$
R = $\frac{0.7 \times 1.5}{0.5} = 2.1\ cm$

EXERCISE – 4 (D)

Question 1:
Explain the term critical angle with the aid of a labelled diagram.
Solution 1:
Critical angle: The angle of incidence in the denser medium corresponding to which the angle of refraction in the rarer medium is 90^o is called the critical angle.



Question 2:
How is the critical angle related to the refractive index of a medium?
Solution 2:
The critical angle is related to the refractive index of a medium by the relation
$\mu = \frac{1}{\sin i_c} = \text{coseci}_c$

Question 3:
State the approximate value of the critical angle for
(a) glass-air surface
(b) water-air surface.
Solution 3:
(a) The critical angle for glass-air surface is
For glass, refractive index ${}_a\mu_g = \frac{3}{2}$
$\sin i_c = \frac{1}{a\mu g} = \frac{2}{3}$ *or* $i_c = 42°$
(b) The critical angle for water-air surface is
For water, refractive index ${}_a\mu_w = \frac{4}{3}$
$\therefore \sin i_c = \frac{1}{a\mu w} = \frac{3}{4}$ *or* $i_c = 49°$

Question 4:
What is meant by the statement the critical angle for diamond is 24°?
Solution 4:
The critical angle for diamond is 24°. This implies that at an incident angle of 24° within the diamond the angle of refraction in the air will be 90°. And if incident angle will be more than this angle then the ray will suffer total internal reflection without any refraction.

Question 5:
A light ray is incident from a denser medium on the boundary separating it from a rarer medium at an angle of incident equal to the critical angle, what is the angle of refraction for the ray?
Solution 5:
When a ray is incident from a denser medium to a rarer medium at angle equal to critical angle ($i=i_c$), the angle of refraction becomes 90°

Question 6:
Name two factors which affect the critical angle for a given pair of media. State how do the factors affect it.
Solution 6:
The factors which affect the critical angle are:
(i) The colour (or wavelength) of light, and
(ii) The temperature

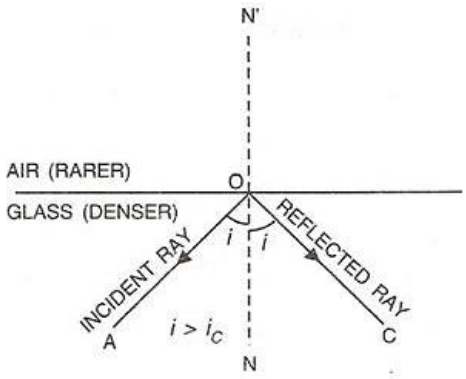
(i) Effect of colour of light: The critical angle for a pair of media is less for the violet light and more for the red light. Thus critical angle increases with increase in wavelength of light.
(ii) Effect of temperature: The critical angle increases with increase in temperature because on increasing the temperature of medium, its refractive index decreases.

Question 7:
The critical angle for glass-air is 45° for the light of yellow colour. State whether it will be less than, equal to, or more than 45° for (i) ref light, (ii) blue light?
Solution 7:
As the wavelength decreases (or increases) refractive index becomes more (or less) and critical angle becomes less (or more).
(i) For red light the critical angle will be more than 45° and
(ii) For blue light the critical angle will be less than 45°.

Question 8:
(a) What is total internal reflection?
(b) State two conditions necessary for total internal reflection to occur.
(c) Draw diagram to illustrate the total internal reflection
Solution 8:
(a) Total internal reflection: It is the phenomenon when a ray of light travelling in a denser medium, is incident at the surface of a rarer medium such that the angle of incidence is greater than the critical angle for the pair of media, the ray is totally reflected back into the denser medium.
(b) The two necessary conditions for total internal reflection are:
i.The light must travel from a denser medium to a rarer medium.

ii. The angle of incidence must be greater than the critical angle for the pair of media.

(c) When incidence angle is more than critical angle i.e., in case of total internal reflection.



Question 9:

Fill in the blanks to complete the following sentence:

(a) Total internal reflection occurs only when a ray of light passes from a …….. medium to a ……. Medium.

(b) critical angle is the angle of ……. In denser medium for which the angle of …….. in rarer medium is…….

Solution 9:

(a) Total internal reflection occurs when a ray of light passes from a denser medium to a rarer medium.

(b) Critical angle is the angle of incidence in denser medium for which the angle of refraction in rarer medium is 90°.

Question 10:

State whether the following statement is true or false: If the angle of incidence is greater than the critical angle, light is not refracted at all, when it falls on the surface from a denser medium to a rarer medium.

Solution 10:

True.

Question 11:

The refractive index of air with respect to glass is expressed as ${}_g\mu_a = \frac{Sin\ i}{\sin r}$.

(a) Write down a similar expression for ${}_a\mu_g$ in terms of the angles *i* and *r*.

(b) if angle r = 90°, what is the corresponding angle *i* called?

(c) what is the physical significance of the angle *i* in part (b)?

Solution 11:

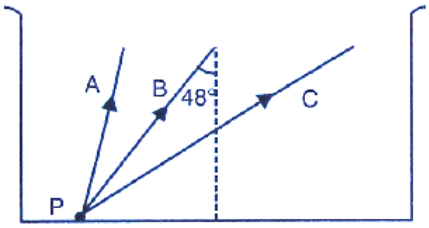
(a) $_a\mu_g = \frac{\sin r}{\sin i}$

(b) If refractive angle, r = 90°, the corresponding angle of incidence, i will be equal to critical angle.

(c) If the angle of incidence exceeds the value of I obtained in part (b) (i.e., critical angle), total internal reflection will occur.

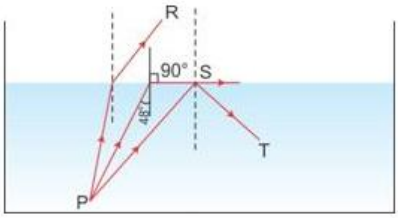
Question 12:

The given figure shows a point source P inside a water container three rays A,B and C starting from the source P are shown up to the water surface. (a) show in the diagram the path of these rays after striking the water. The critical angle for water-air surface is 48°. (b) Name the phenomenon which the rays A, B and C exhibit.



Solution 12:

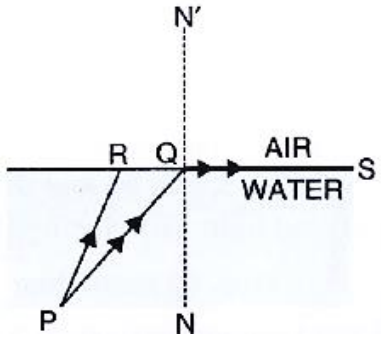
(a)



(b) Rays A and B exhibit the phenomenon of 'refraction of light'.
Rays C exhibits the phenomenon of 'total internal reflection'.

Question 13:

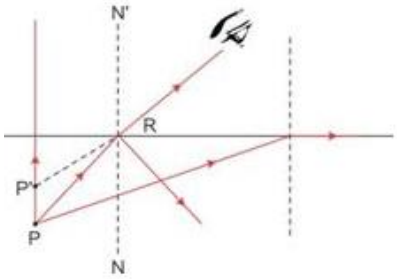
In the given figure PQ and PR are the two light rays emerging from an object P. The ray PQ is refracted as QS.



(a) state the special name given to the angle of incidence ∠PQN of the ray PQ.
(b) what is the angle of refraction for the refracted ray QS?
(c) name the phenomenon that occurs if the angle of incidence ∠ PQN is increased.
(d) The ray PR suffers partial reflection and refraction on the water-air surface. Give reason. Draw in the diagram the refracted ray for the incident ray PR and hence show the position of image of the object P by the letter P' when seen vertically from above.

Solution 13:

(a) Critical angle
Hint: The angle of incidence in the denser medium for which the angle of refraction in rarer medium is 90^o is called the critical angle.
(b) 90^o
(c) Total internal reflection.
Hint: When the angle of incidence is greater than the critical angle, the phenomenon of total internal reflection occurs due to which the ray of light is not refracted but is reflected back in the same medium.
(d) For the ray PR, the angle of incidence is less than the critical angle (i.e. ∠PQS); hence, at the interface of two media as per the laws of reflection, ray PR suffers partial reflection and refraction.

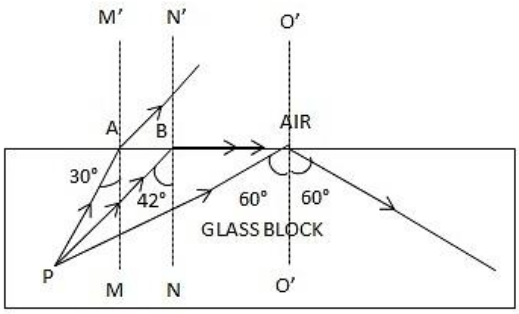


Question 14:

The refractive index of glass os 1.5. From a point P inside a glass block, draw rays PA, PB and PC incident on the glass air surface at an angle of incidence 30°, 42° and 60° respectively.
(a) In the diagram show the approximate direction of these rays as they emerge out of the block.
(b) What is the angle of refraction for the ray PB?
(Take sin 42° = $\frac{2}{3}$)

Solution 14:

(a)
$\boldsymbol{\mu} = 1.5$
$\text{Sin}i_c = \frac{1}{\mu} = \frac{1}{1.5} = 0.667$
$i_c = 41.8 \approx 42°$



(b)
As angle of incidence inside glass block is 42°

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

$\sin r = {}_a\boldsymbol{\mu}_g \times \sin 42°$

Take $\sin 42° = \frac{2}{3}$ and ${}_a\boldsymbol{\mu}_g = \frac{3}{2}$

$\text{Sin}r = \frac{3}{2} \times \frac{2}{3} = 1$

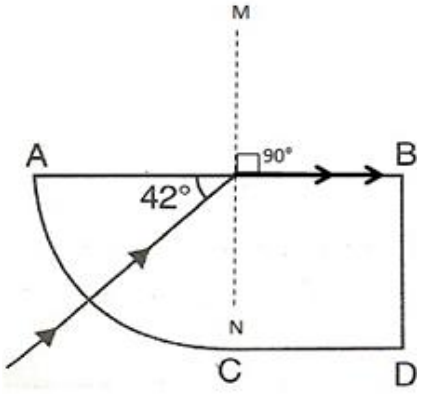
$\Longrightarrow r = 90°$

This also follows from the fact that the ray PB is incident at the critical angle.

Question 15:

A ray of light enters a glass slab ABDC as shown in fig. 4.59 and strikes at the centre O of the circular part AC of the slab. The critical angle of glass is 42°. Complete the path of the ray till it emerges out from the slab. Mark the angles in the diagram wherever necessary.

Solution 15:

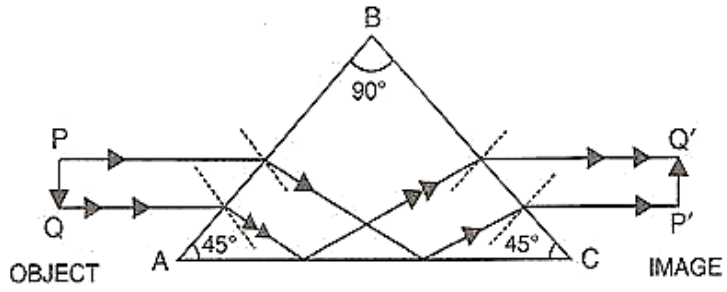


The angle of refraction will be 90° because the ray is incident on the glass at its critical angle.

Question 16:
What is a total reflecting prism? State three actions that it can produce. Draw a diagram to show one action of the total reflecting prism.

Solution 16:
A prism having an angle of 90° between its two refracting surfaces and the other two angles each equal to 45°, is called a total reflecting prism. The light incident normally on any of its faces, suffers total internal reflection inside the prism.
Due to this behavior, a total reflecting prism is used to produce following three actions:

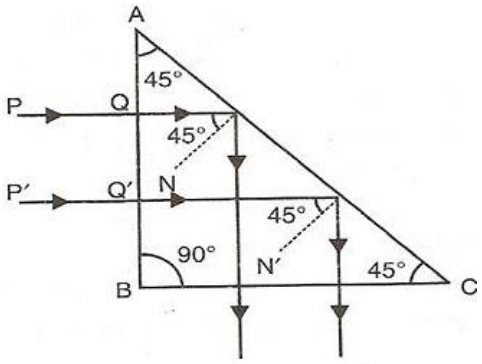
(a) To deviate a ray of light through 90°,
(b) To deviate a ray of light through 180°, and
(c) To erect the inverted image without producing deviation in its path.



It is an erecting prism which is used to erect the inverted image without producing deviation in its path.

Question 17:
Show with the help of a diagram how a total reflecting prism can be used to turn a ray of light through 90°. Name one instrument in which such a prism is used.

Solution 17:

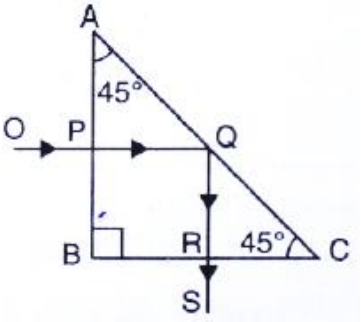


As shown in diagram, a beam of light is incident on face AB of the prism normally so it passes undeviated and strikes the face AC where it makes an angle of 45° with the normal to AC. Because here the incident angle is more than critical angle so rays suffer total internal reflection and reflect at angle of 45°. The beam then strikes face BC, where it is incident normally and so passes undeviated. As a result the incident beam gets deviated through 90°.

Such a prism is used in periscope.

Question 18:

A ray of light OP passes through a right angles prism as shown in the adjacent diagram.
(a) State the angles of incidence at the faces AC and BC.
(b) Name the phenomenon which the ray suffers at the face AC.

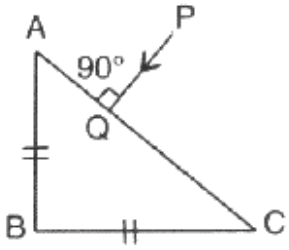


Solution 18:

(a) The angle of incidence at the face AC is 45° and angle of incidence at the face BC is 0°.
(b) The ray suffers total internal reflection at the face AC.

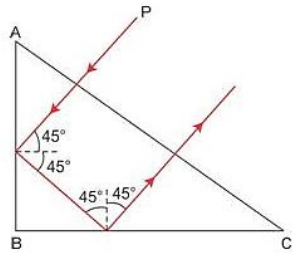
Question 19:

In fig. 4.61, a ray of light PA is incident normally on the hypotenuse of an isoceles right angle prism ABC. (a) Complete the path of the ray PQ till it emerges from the prism. Mark in the diagram the angle wherever necessary. (b) what is the angle of deviation of the ray PQ? (c) Name a device in which this action is used.



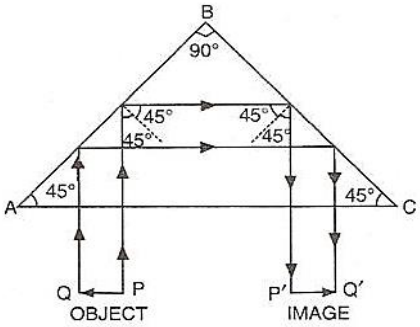
Solution 19:

(a)



(b) Angle of deviation = 180^{o}
(c) Prism binocular

Question 20:
What device other than a plane mirror can be used to turn a ray of light through 180°? Draw a diagram in support of your answer. Name an instrument in which this device is used.
Solution 20:
A total reflecting prism can be used to turn a ray of light by 180°. The following diagram can make it further clear.

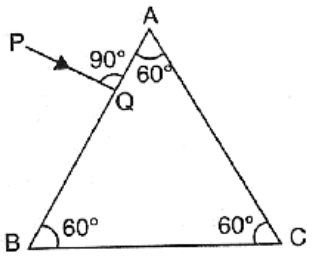


This action of prism is used in binocular.

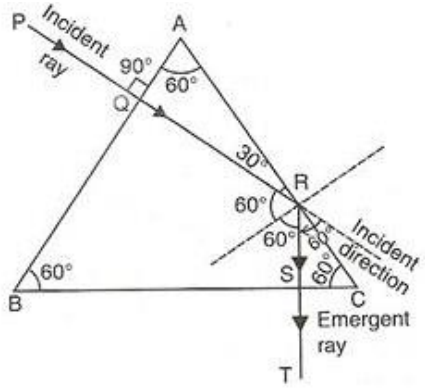
Question 21:
Mention one difference between reflection of light from a plane mirror and total internal reflection of light from a prism.
Solution 21:
When total internal reflection occurs from a prism, the entire incident light (100%) is reflected back into the denser medium. Whereas in ordinary reflection from a plane mirror, some light is refracted and absorbed so the reflection is partial.

Question 22:
State one advantage of using a total reflecting prism as a reflector in place of plane mirror.
Solution 22:
A total reflecting prism gives us an image much brighter than that obtained by using a plane mirror.

Question 23:
In given figure a ray of light PQ is incident normally on the face AB of an equilateral glass prism. Complete the ray diagram showing its emergence into air after passing through the prism.
(a) Write the angles of incidence at the faces AB and AC of the prism.
(b) name the phenomenon which the ray of light suffers at the face AB, AC and BC of the prism.



Solution 23:



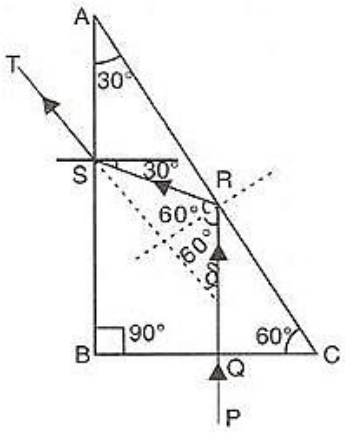
(a) At the face AB, i=0° and at the face AC, i= 60°
(b) At the face AB – refraction,
At the face AB – total internal reflection,

At the face BC – refraction.

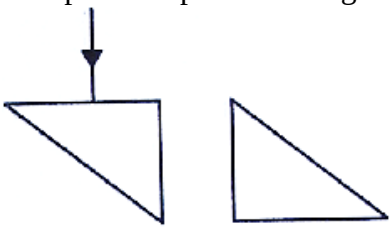
Question 24:

Draw a neat labelled ray diagram to show the total internal reflection of a ray of light normally incident on one face of a 30°, 90°, 60° prism.

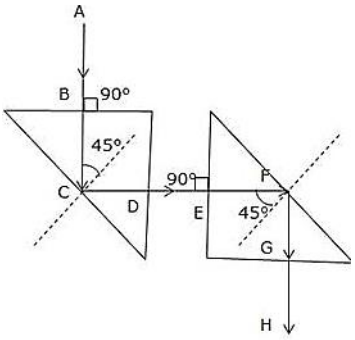
Solution 24:



Question 25:
Two isosceles right –angles glass prisms are placed near each other as shown in Fig. 4.63. Complete the path of the light ray entering the first prism till it emerges out of the second prism.



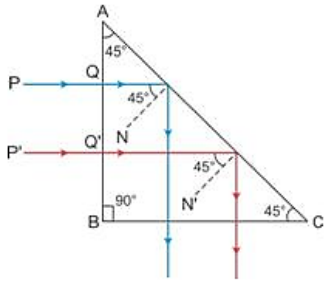
Solution 25:



MULTIPLE CHOICE TYPE:

Question 1:
The critical angle for glass-air interface is:
(a) 24° (b) 48° (c) 42° (d) 45°
Solution 1:
42°

Question 2:
A total reflecting right angled isosceles prism can be used to deviate a ray of light through:
(a) 30° (b) 60° (c) 75° (d) 90°.
Solution 2:
90°
Hint:

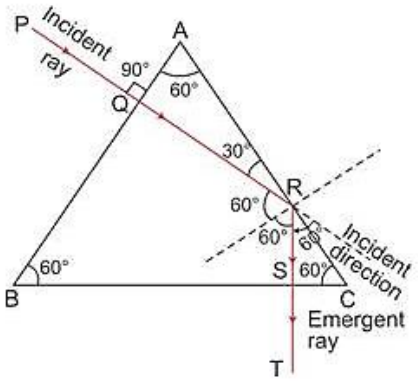


Question 3:

A total reflecting equilateral prism can be used to deviate a ray of light through:

(a) 30° (b) 60° (c) 75° (d) 90°

Solution 3:

60°

Hint: