REFRACTION OF LIGHT

Refraction of light:

1. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant whose value depends on the nature of the two mediums. This is called as **Snell's law**. According to this law, $\frac{\sin i}{\sin r} \quad \frac{v_1}{v_2} \quad \frac{\ _2}{\ _1} \quad {}^1\ _2$

   where ${}^1\ _2$ is called the refractive index of medium 2 with respect to medium 1.
2. If the medium 1 is vacuum, then $v_1 = c$ and the index of refraction of the medium w.r.t. the vacuum is: $\ = c/v$. It is also called absolute refractive index of medium.
3. Because the speed of light is different in different mediums and frequency remains unchanged on passing from one medium to other, hence wavelength of light gets changed with change in medium. The relation is: $\ _{medium} \quad \frac{\ _{air}}{\ }$. Thus, when a light ray from a rarer medium is refracted into a denser medium, its velocity decreases and wavelength decreases but the frequency does not change.
4. For air $\ = 1.0003$ which may be taken as 1. Therefore, when light passes from air into any transparent solid the refractive index is always > 1.
5. The value of refractive index depends on nature of medium and wavelength or colour of light.
6. Refractive index is independent of the angle of incidence.
7. Refractive index decreases with increase in temperature.
8. When the medium is same on both sides of a glass slab, then the deviation of the emergent ray is zero. That is the emergent ray goes parallel to the incident ray and lateral displacement of the emergent ray $y = \frac{t \sin(i \quad r)}{\cos\ r}$ (where t = thickness of slab).
9. **Cauchy's formula :** The refractive index of a material depends on the wavelength of light according to the relation: $\ \quad A \quad \frac{B}{\ ^2}$ (where A and B are constants)
10. If ${}^a n_g$ and ${}^a n_w$, are the refractive indices of glass and water w.r.t. air respectively, then refractive index of glass w.r.t. water is: ${}^w n_g \quad \frac{{}^a n_g}{{}^a n_w}$

Real and apparent depth:

1. If a beaker is filled with water and a person in air observes an object lying at its bottom, then the object appears raised. The apparent depth d_{ap} is less than the actual depth t_{ac} can be shown that apparent depth $(d_{ap}) \quad \frac{\text{actual depth } (d_{ac})}{\text{refractive index}(\ )}$
2. If there is an ink spot at the bottom of a glass slab, it appears to be raised by a distance $y \quad d_{ac} \quad d_{ap} \quad d \quad \frac{d}{\ } \quad d\ 1 \quad \frac{1}{\ }$

   where d is the thickness of the glass slab and $\ $ is its refractive index.
3. If a beaker is filled with immissible transparent liquids of refractive indices $\ _1, \ _2, \ _3$ and individual depth d_1, d_2, d_3 respectively, then the apparent depth of the beaker is found to be: $d_{ap} \quad \frac{d_1}{\ _1} \quad \frac{d_2}{\ _2} \quad \frac{d_3}{\ _3}$

Total internal reflection:

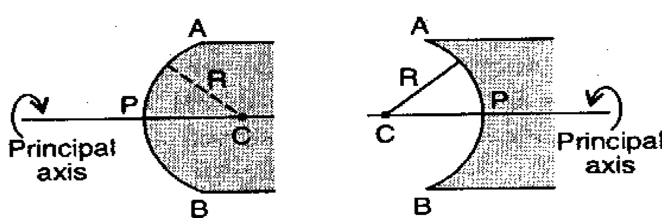
1. For the phenomenon of total internal reflection to take place, it is necessary that a light ray must travel from a denser medium to a rarer medium, and the angle of incidence in the denser medium must be greater the critical angle for the given two media.
2. The critical angle is that angle of incidence for which the angle of refraction becomes 90°. It is given by: $\sin i_c = \frac{1}{{}_1\mu_2} = \frac{1}{{}_R\mu_D}$ If the rarer medium is air or vacuum, then $\sin i_c = \frac{1}{\mu}$
3. Critical angle for red light is more than that for blue light.
4. Critical angle increases with the increase in temperature of the medium.
5. Critical angle depends on (i) nature of medium, (ii) temperature of medium and (iii) wavelength of light.
6. Air bubbles in glass appear silvery white due to total internal reflection.
7. A diver in water at a depth d sees the world outside through a horizontal circle of radius $r = d \tan i_c = d/\sqrt{\mu^2 - 1}$
8. The brilliance of diamond is due to the phenomenon of total internal reflection.
9. Mirages in deserts are also due to refraction and total internal reflection.
10. The working of optical fibre is based on the phenomenon of total internal reflection.

Optical fiber:

1. It is a glass fiber through which light is transmitted by total internal reflections from one end to other end
2. An optical fiber may be between 0.01 mm and 0.002 mm in diameter and may be used in bundles with the same relative positions at both the ends. It is also called as light pipe.
3. For working of the optical fiber, the angle of incidence should be according to relation $\sin i \le \sqrt{\mu_2^2 - \mu_1^2}$, where μ_1 is the refractive index of the material used for cladding of the pipe and μ_2 is the refractive index of the core of the pipe.
4. Optical fibers are used in the field of communications and computers for transmitting and receiving signals converted into light pulses. They also have medical uses such as in Endoscopy.

Spherical refracting surface:

1. A spherical refracting surface is a portion of a refracting medium whose curved surface is a part of a sphere. Convex and concave spherical refracting surfaces are shown in Fig.



2. The pole, centre of curvature, radius of curvature, aperture, the principal axis, etc., are defined in the same manner as for mirrors.
3. Suppose an object is placed in a medium of refractive index μ_1. The spherical curved surface (convex or concave) separates it from another medium of refractive index μ_2 Then, if u, v and R are respectively the object distance, the image distance and the radius of curvature of the refracting surface, then the formula for relating u, v and R is: $$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$
4. If the object is placed in the medium of refractive index μ_2 and the curved surface separates it from medium μ_1 then the formula is $$\frac{\mu_1}{v} - \frac{\mu_2}{u} = \frac{\mu_1 - \mu_2}{R}$$

Lenses:

1. A lens is a piece of transparent refractive medium (such as glass, plastic or liquid) bounded by two surfaces one of which at least must be spherical.
2. When a lens is thicker in the middle than at the edges, it is called a convex lens or converging lens. When the lens is thicker at the edges than in the middle, it is called as concave lens or diverging lens.
3. A thin lens is one in which the distance between the two surfaces along the principal axis is negligibly small. In case of a thin lens, distances measured from the poles of the refracting surfaces can be taken as the distances measured from the optical centre of the lens. Optical centre is a point through which a light ray passes undeviated if the lens is quite thin,

Lens Maker's formula and thin lens formula:

1. When medium is same on both sides of a lens, then $\frac{1}{f} \quad \frac{1}{v} \quad \frac{1}{u} \quad (\quad 1) \; \frac{1}{R_1} \quad \frac{1}{R_2}$ where *f* = focal length of the thin lens, = refractive index of the material of lens with respect to the medium surrounding it, R_1 = radius of curvature of the first surface and R_2 = radius of curvature of the second surface.
2. For a plano-convex lens or plano-concave lens, $\frac{1}{f} \quad \frac{(\quad 1)}{R}$ The focal length is positive for a plano-convex lens, while it is negative for a plano-concave lens.
3. If radii of curvatures of the two surfaces are the same, say R, then $f \quad \frac{R}{2(\quad 1)}$.

Power & magnification due to a lens:

1. Linear magnification is the ratio of the size of image (I) to the size of the object (O), i.e., m = I/O.
2. For a thin lens (convex or concave) $m \quad \frac{v}{u}$ or $m \quad \frac{f \quad v}{f}$ or $m \quad \frac{f}{f \quad u}$
3. For a real image m is negative and for a virtual image m is positive.
4. The power of a lens P = 1/f dioptre (D). where f is focal length in metre.

Combination of Lenses:

1. Whenever two lenses are in contact, the reciprocal of effective focal length is equal to the sum of the reciprocals of focal lengths of the lenses in contact. $\frac{1}{f} \quad \frac{1}{f_1} \quad \frac{1}{f_2}$
2. The power of the combination of two lenses in contact is equal to the sum of the powers of the individual lenses, i.e., $P = P_1 + P_2$.
3. If two thin lenses are separated by a small distance d, then the focal length of the combination is: $\frac{1}{f} \quad \frac{1}{f_1} \quad \frac{1}{f_2} \quad \frac{d}{f_1 f_2}$

Some more points about lenses:

1. When a lens is kept in a medium other than air, then $\frac{1}{f_m} \quad \frac{{}_g}{{}_m} \quad 1 \; \frac{1}{R_1} \quad \frac{1}{R_2}$ where $_m$ is the refractive index of the medium in which lens is placed.
2. When a lens is placed in a medium for which is less than that of the lens, its focal length increases and power decreases- The nature of the lens remains unchanged.
3. When the lens is placed in a medium for which is equal to that of the lens, the focal length of the lens becomes infinity and power becomes zero. The lens behaves like a plane glass plate.

4. When the lens is placed in a medium for which is greater than that of the lens, the nature of the lens changes. (Air bubble in water behaves as a divergent lens.)
5. When a lens of focal length *f* is cut into two equal halves perpendicular to principal axis, then each part of the lens has a focal length 2*f*.
6. When a lens of focal length *f* is cut into two equal halves parallel to principal axis, then each part has a focal length *f*. The intensity of image is decreased.
7. For a real image the distance (d) between convex lens and screen must be greater or equal to 4f.

   When d < 4f then there is no real image on screen.

   When d = 4f then there is only one positions of the lens for which image of the object on the screen is distinct and clear

   When d > 4f then there are two positions of the lens for which the image of the object on the screen is distinct and clear. In these two positions of lens, the distances of object and image from the lens are interchanged. In this case if size of image in one position is I_1 and in other I_2 then size of object (O) is given by O $\sqrt{I_1 I_2}$

REFRACTION OF LIGHT Assignment

1. The refractive index of water with respect to air is 4/3 and the refractive index of glass with respect to air is 3/2. Then the refractive index of water with respect to glass is;
   (a) 9/8 (b) 8/9 (c) 1/2 (d) 2
2. If μ_{ij} represents the refractive index when a light ray goes from medium i to medium j then the product μ_{21} x μ_{32} x μ_{43} is equal to:
   (a) μ_{32} (b) μ_{42} (c) μ_{31} (d) $1/\mu_{14}$
3. The refractive index of a given piece of transparent quartz is greatest for:
   (a) red light (b) violet light
   (c) green light (d) yellow light
4. A plane glass slab is kept over various coloured letters; the letter which appears least raised is:
   (a) blue (b) violet (c) green (d) red
5. A glass slab (= 1.5) of thickness 3.0 cm is placed on an ink spot. A person looks at it from a distance of 5.0 cm above the ink spot. The distance of the spot will appear to be:
   (a) 2.0 cm (b) 3.5 cm (c) 4.0 cm (d) 5.0 cm
6. The length of a vertical pole at the surface of a lake of water (= 4/3) is 24 cm. Then to an under-water fish just below the water surface the tip of the pole appears to be:
   (a) 18 cm above the surface
   (b) 24 cm above the surface
   (c) 32 cm above the surface
   (d) 36 cm above the surface
7. An air bubble in a glass slab (μ = 1.5) is 5 cm deep when viewed from, one face and 2 cm deep, when viewed from the opposite face. The thickness of the slab is;
   (a) 7.5 cm (b) 10.5 cm (c) 7 cm (d) 10 cm
8. A bird in air looks at a fish vertically below it and inside water; h_1 is the height of the bird above the surface of water and h_2 the depth of the fish below the surface of water. If refractive index of water with respect to air be μ then the distance of the fish as observed by the bird is:
   (a) $h_1 + h_2$ (b) $h_1 + h_2/\mu$
   (c) $\mu h_1 + h_2$ (d) $\mu (h_1 + h_2)$
9. Critical angle of light passing from glass to air is minimum for:
   (a) red (b) green (c) yellow (d) violet
10. The refractive index of water is 4/3 and that of glass is 5/3. Then the critical angle for a ray of light entering water from glass will be:
    (a) $\sin^{-1}$ (4/5) (b) $\sin^{-1}$ (5/4)
    (c) $\sin^{-1}$ (20/9) (d) $\sin^{-1}$ (9/20)
11. A diver in a swimming pool wants to signal his distress to a person lying on the edge of the pool by flashing his waterproof flash light:
    (a) he must direct the beam vertically upwards
    (b) he has to direct the beam horizontally
    (c) he has to direct the beam at an angle to the vertical which is slightly less than the critical angle of incidence for total internal reflection
    (d) he has to direct the beam at an angle to the vertical which is slightly more than the critical angle of incidence for total internal reflection
12. The critical angle for light going from medium x into medium y is θ. The speed of light in medium x is v. The speed of light in medium y is:
    (a) v(l - cos θ) (b) v/sin θ
    (c) v/cos θ (d) v cos θ
13. A point source of light is placed 4 m below the surface of water of refractive index 5/3. The

minimum diameter of a disc, which should be placed over the source, on the surface of water to cut off all light coming out of water is:

(a) 1 m (b) 4 m (c) 3 m (d) 6 m

14. A thin convergent glass lens ($_g$ = 1.5) has a power of +5.0. When this lens is immersed in a liquid of refractive index $_1$ it acts as a divergent lens of focal length 100 cm. The value of $_1$ is

(a) 4/3 (b) 5/3 (c) 5/4 (d) 6/5

15. A double convex lens of focal length 6 cm is made of glass of refractive index 1.5. The radius of curvature of one surface is double that of the other surface. The value of smaller radius of curvature is:

(a) 6 cm (b) 4.5 cm (c) 9 cm (d) 4 cm

16. To obtain magnified virtual image of an object by a convex lens of focal length f, the distance between the object and the lens should be:

(a) > 4f (b) between 2f and 4f (c) < f (d) >6f

17. A thin lens has focal length f and its aperture has diameter d. It forms an image of intensity I, Now, the central part of the aperture up to diameter (d/2) is blocked by an opaque paper. The focal length and image intensity will change to:

(b) (f/2) and (I/2) (b) f and (I/4)
(c) (3f/4) and (I/2) (d) f and (3I/4)

18. Diameter of a plano-convex lens is 6 cm and thickness at the centre is 3 mm. If the speed of light in the material of the lens is 2 x 10^8 m/s, the focal length of the lens is:

(a) 15 cm (b) 20 cm (c) 30cm (d) 10cm

19. A magnifying glass is to be used at the fixed object distance of 2 cm. If it is to produce an erect image magnified 5 times its focal length is

(a) 2.5 cm (b) -2.5 cm
(c) 5.0cm (d) none of these

20. Two thin lenses are in contact and the focal length of the combination is 80 cm. If the focal length of one of the lenses is 20 cm, the power of the other lens is:

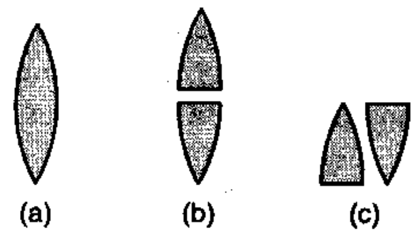
(a) 1.66 (b) 4.00 (c) -1.00 (d) -3.75

21. A convex lens of power + 6 is placed in contact with a concave tens of power – 4. What is the nature and focal length of the combination?

(a) Concave, 25 cm (b) Convex, 50 cm
(c) Concave, 20 cm (d) Convex, 100 cm

22. An equiconvex glass lens (a) has a focal length f and power P. It is cut into two symmetrical halves (b) by a plane containing the principal axis. The two pieces are recombined as shown in Fig (c). The power of new combination is:

(a) P
(b) P/2
(c) 2P
(d) zero



23. Two thin convex lenses of focal lengths 20 cm and 5 cm, respectively, are placed at a distance d. If a parallel beam incident on the first lens emerges as a parallel beam from the second lens, then the value of d is:

(a) 5 cm (b) 15 cm (c) 20cm (d) 25cm

24. Focal length of a lens for red colour is:

(a) same as that for violet
(b) greater than that for violet
(c) lesser than that of violet
(d) none of the above

25. A thin convex lens of crown glass (= 1.5) has a power of 1. Another convex lens with the same radii of curvature and made up of a glass material with refractive index 1.6 will have a power of:

(a) 1.2 (b) -0.9 (c) -0.8 (d) -1.06

26. A lamp is placed 6.0 m from a wall. On putting a lens between the lamp and the wall at a distance of 1.2 m from the lamp, a real image of the lamp is formed on the wall. The magnification of the image is:

(a) 3 (b) 4 (c) 5 (d) 6

27. A plano-convex lens of focal length 20 cm silvered at the plane surface will behave as convergent mirror of focal length:

(a) 20 cm (b) 30 cm (c) 40cm (d) 10cm

28. A real image is formed by a convex lens. If we put it in contact with a concave lens and the combination again forms a real image, which of the following is true for the new image from the combination?

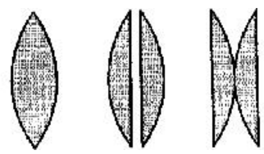
(a) Shifts towards the lens system
(b) Shifts away from the lens system
(c) Remains at the original position
(d) No image is formed

29. A concave lens of focal length 20 cm placed in contact with a plane mirror acts as a:

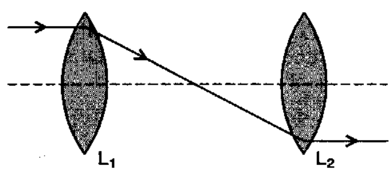
(a) convex mirror of focal length 10 cm
(b) concave mirror of focal length 40 cm
(c) concave mirror of focal length 60 cm
(d) concave mirror of focal length 10 cm

30. A symmetrical double convex lens is cut in two equal parts by a plane containing the principal axis. If the power of the original lens was 4 , the power of a divided lens will be:
(a) 2 (b) 3 (c) 4 (d) 5

31. A convex lens of focal length 20 cm is cut into two equal parts so as to obtain two plano-convex lenses as shown in figure, The two parts are then put in contact as shown in figure. What is the focal length of the combination?
(a) Zero
(b) 5 cm
(c) 10 cm
(d) 20 cm



32. In the figure given below there are two convex lenses L_1 and L_2 having focal lengths F_1 and F_2 respectively. The distance between L_1 and L_2 will be:
(a) F_1
(b) F_2
(c) $F_1 + F_2$
(d) $F_1 - F_2$



33. f_B and f_R are the focal lengths of a convex lens for blue and red light respectively and F_B and F_R are the focal lengths of a concave lens for blue and red light respectively. We must then have:
(a) $f_B < f_R$ and $F_B < F_R$ (b) $f_B < f_R$ and $F_B > F_R$
(b) $f_B > f_R$ and $F_B > F_R$ (d) $f_B > f_R$ and $F_B < F_R$

ANSWERS

1b ,2d ,3b ,4d ,5c ,6c ,7b ,8b ,9d ,10a ,11c ,12b ,13d ,14b ,15b ,16c ,17d ,18c ,19a ,20d ,21b ,22d ,23d ,24b ,25a ,26b ,27d ,28b ,29a ,30c ,31d ,32c ,33a