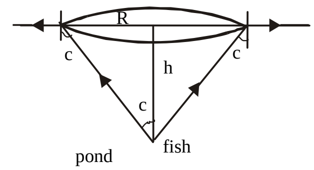
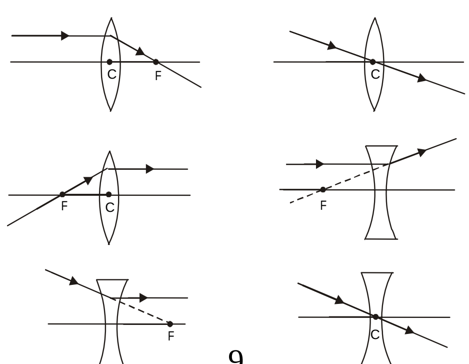
Lenses & Prism



1. A transparent substance bounded by two surfaces of definite geometrical shape is called **Lens**.
2. A lens may be considered to be made up of a number of small prisms put together.
3. **Principal axis**: The line joining the two centres of curvature of the spherical surfaces constituting a lens is called principal axis.
4. **Radius of curvature**: A double convex lens or a concave lens is bounded by two spherical surfaces which are parts of spheres. The centre of such a sphere is called the centre of curvature and the distance from this centre upto the spherical surface is called the radius of curvature.
5. **Optic centre**: When a ray of light incident on one surface of a lens meets the second surface of the lens after refraction and passes through a particular point on the principal axis inside the lens such that the emergent ray is parallel to the incident ray, then that point on the axis is called optic centre (C).
6. **Principal focus** : When a narrow beam of light parallel to the principal axis strikes a lens, the rays after refraction either focus at a point (in the case of convex lens) or appear to diverge from a fixed point on the principal axis (in the case of a concave lens) of the lens. This point is called principal focus (F).
7. **Focal length**: The distance between the optical centre and the principal focus is called focal length (f).



8. Types of images formed with a convex lens

Position of object	Position of image	Nature of image	Application
At infinity	At F	Point size; real; inverted	Astronomical telescope
Beyond 2F	Between F and 2F	Diminished; real; inverted	Camera
At 2F	At 2F	Same size; real; inverted	Erecting lens of terrestrial telescope
Between F and 2F	Beyond 2F	Magnified; real; inverted	Projector
At F	At infinity	Real	
Within the focal length	On the same side	Magnified; virtual; erect	Simple microscope

9. With a concave lens, irrespective of the position of the object, the image is formed on the same side as the object within the focal length. It is always diminished, erect and virtual.

10. The shape of u-v graph in the case of a convex lens or concave mirror is a rectangular hyperbola.

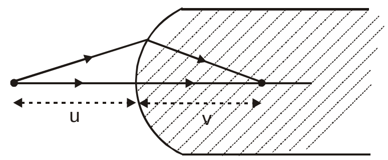
11. The shape of $\frac{1}{u} - \frac{1}{v}$ graph in the case of a convex lens or concave mirror is a straight line.

12. Lens formulae

$$\frac{1}{f}=\frac{1}{u}+\frac{1}{v};\quad f=\frac{uv}{u+v};\quad m=\frac{v}{u};$$

$$v=f(1+m);\quad u=f(1+\frac{1}{m})$$

13. Refraction at curved surfaces :



$$\frac{\mu_1}{u}+\frac{\mu_2}{v}=\frac{\mu_2-\mu_1}{R}$$

Where μ_1 = refractive index of the medium in which the object lies.

μ_2 = refractive index of the medium on the other side of curved surface

R = radius of curvature of curved surface

Sign convention

R is positive, if object faces convex surface

R is negative, if object faces concave surface

v is positive, if image is real (forms on the other side of the lens)

v is negative, if image is virtual (form on the same side of the lens)

First principal focus is the object point for which image point lies at infinity.

$$u=f_1;\ v=\infty \text{ and } \frac{\mu_1}{f_1}=\frac{\mu_2-\mu_1}{R}$$

Power of refracting surface is given by $\frac{1}{f_1}=\frac{\mu_2-\mu_1}{\mu_1 R}$

Second principal focus is the image point for which object point lies at infinity.

$$u=\infty;\ v=f_2 \text{ and } \frac{\mu_2}{f_2}=\frac{\mu_2-\mu_1}{R}$$

Power of refracting surface is given by $\frac{1}{f_2} = \frac{\mu_2 - \mu_1}{\mu_2 R}$

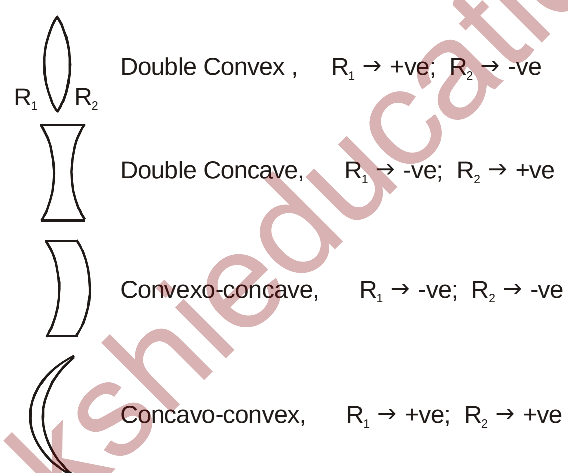
14. **Lens maker's formula** is

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = \left(\frac{\mu_l - \mu_m}{\mu_m}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Where μ_l = refractive index of the material of lens and μ_m = refractive index of the surrounding medium of the lens.

This formula is applicable for thin lens and for paraxial rays.



15. The focal length of a plane glass plate is infinity.

16. The reciprocal of focal length of a lens measured in metres is called its **focal power (P).**

$$P = \frac{1}{f \text{ in metres}} \text{ (or) } P = \frac{100}{f \text{ in cm}}$$

17. The unit of focal power is **dioptre**.

18. One dioptre is the focal power of a lens of focal length one metre.

19. When two thin lenses of focal lengths f_1 and f_2 are kept in contact and f is the focal length of the combination, then $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ or $P = P_1 + P_2$.

20. When two thin lenses are separated by a distance d then

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1f_2} \text{ or } f=\frac{f_1f_2}{f_1+f_2-d} \text{ Or}$$

$P = P_1+P_2-P_1P_2d$. It acts as a glass slab if $f_1+f_2=d$.

21. If a double convex lens is vertically cut into two pieces, each piece will have a focal length equal to twice the original.

22. If a convex lens of focal length f is broken into two semicircular pieces, each piece will have a focal length f.

23. An air bubble in water behaves like a divergent lens (i.e., concave lens)

24. If a convex lens of focal length f made of glass (μ=1.5) is immersed in water (μ=4/3), its focal length becomes 4f. The focal power decreases by a factor 4.

25. If a glass lens is immersed in a liquid of the same refractive index, it disappears and does not act like a lens. i.e., the lens will have infinite focal length or zero focal power.

26. A convex lens immersed in a liquid of refractive index greater than the refractive index of the lens behaves like a concave lens.

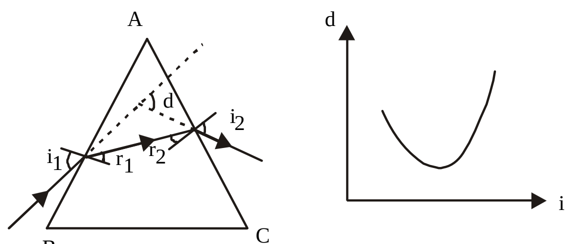
27. If a planoconvex lens of radius of curvature R and of focal length f is silvered on the plane surface, it acts like a concave mirror of focal length $\frac{f}{2}$ or $\frac{R}{2(\mu-1)}$.

28. If a planoconcave lens of radius of curvature R and of focal length f is silvered on the plane surface, it acts like a convex mirror of focal length $\frac{f}{2}$ or $\frac{R}{2(\mu-1)}$.

29. If a planoconvex lens of radius of curvature R and of focal length f is silvered on the curved surface, it acts like a concave mirror of focal length $R/2\mu$.

30. **PRISM**

a) A prism is a piece of gas or any other transparent material, bounded by two triangular and three rectangular surfaces.



b) When a light ray passes through a prism it bends towards the base of the prism.

c) The angle made by emergent ray with incident ray is called angle of deviation (d).

d) $d=i_1+i_2-A$, $A=r_1+r_2$ where i_1 – angle of incidence,

i_2 – angle of emergence, A – angle of prism,

r_1 – angle of refraction at first retracing face,

r_2 – angle of refraction at second refracting face.

e) As the angle of incidence increases, angle of deviation first decreases to a minimum value (D) and then increases.

f) If d=D, then $i_1=i_2=i$ and $r_1=r_2=r$

$\Rightarrow D = 2i - A, \;\; A = 2r$

g) $$\mu = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\frac{A}{2}}$$

h) The prism whose angle is very small is called thin prism.

i) For a thin prism $D= (\mu-1) A$.

31. Refraction through a prism

A → angle of the prism or refracting angle

D → angle of deviation

i_1, i_2 → are the angles of refraction

i. Angle of prism, $A=r_1+r_2$

ii. Angle of deviation $D=i_1+i_2-A$

iii. Refractive index of the prism, $\mu = \frac{\sin i_1}{\sin r_1} = \frac{\sin i_2}{\sin r_2}$

32. Limiting angle of the prism

a) It is the angle of the prism for which a ray grazing on one of the face of the prism after refraction grazes out from the second face.

b) In this case $i_1=i_2=90°$, $r_1=r_2=C$

As $A=r_1+r_2$

$\therefore$ A=2C

c) $\mu = \frac{1}{\sin C} = \frac{1}{\sin(A/2)}$

d) Angle of deviation, $D=i_1+i_2-A=90+90-2C$. $\therefore D=180-2C$

33. Deviation in a small angled prism :

a) From Snell's law

$\sin i_1=\mu \sin r_1$ and $\sin i_2=\mu \sin r_2$

For a small angled prism, i_1, i_2, r_1 and r_2 are small

$\therefore$ $i_1=\mu r_1$ and $i_2=\mu r_2$

$d=(i_1+i_2)-A=\mu(r_1+r_2)-A=\mu A-A$

$\therefore$ $d=(\mu-1)A$

b) As $\mu_V > \mu_R$. Therefore the deviation for violet colour is more than the deviation for red colour ($d_v>d_r$).

c) For a given colour of light the deviation increases as the angle of the prism increases.

d) For a given monochromatic light $\frac{d_1}{d_2} = \frac{A_1}{A_2}$.

e) In case of thin prism, the angle of minimum deviation, $d_m= (\mu-1)$ A.