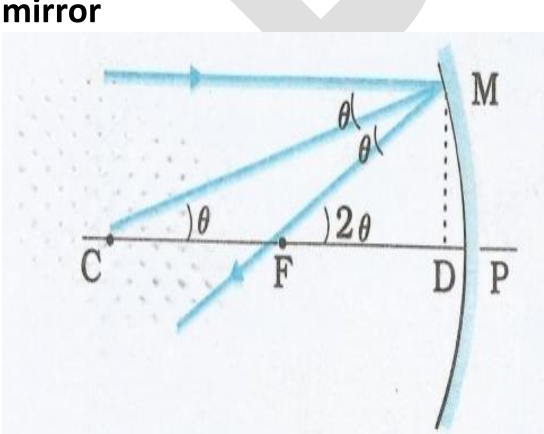
9. RAY OPTICS AND OPTICAL INSTRUMENTS

1. **Define the terms (a) ray of light & (b) beam of light**
   A ray is defined as the straight line path joining the two points by which light is travelling.
   A beam is defined as the bundle of number of rays
2. **State laws of reflection**
   I law:- the incident ray the reflected ray and the normal drawn at the point of incidence all lie in the same plane
   II law:- angle of incidence is equal to angle of reflection
3. **Write the sign conventions used for measuring distances in case of spherical surfaces**
   a) All the distances are measured from the pole or optical center of the lens
   b) The distances measured along the direction of incident light are taken as positive and negative in a direction opposite to it.
   c) The heights measured upwards with respect to X-axis are positive and negative downwards
4. **Define principal focus of a mirror.**
   It is a point on the principal axis where the parallel beams of light converge or appear to diverge after reflection
5. **Define focal length of a mirror.**
   It is the distance between the principal focus and the pole of the mirror.
6. **Derive the relation between focal length and radius of curvature of a spherical mirror**



C= center of curvature, F= focal point or principal focus

θ=angle of incidence = angle of reflection

PF = f= focal length PC= R = radius of curvature

MD = perpendicular to PC $M\hat{F}P = 2\theta$

Consider the ΔMCD $tan\theta = \frac{MD}{CD}$ & in ΔMFD $tan2\theta = \frac{MD}{FD}$

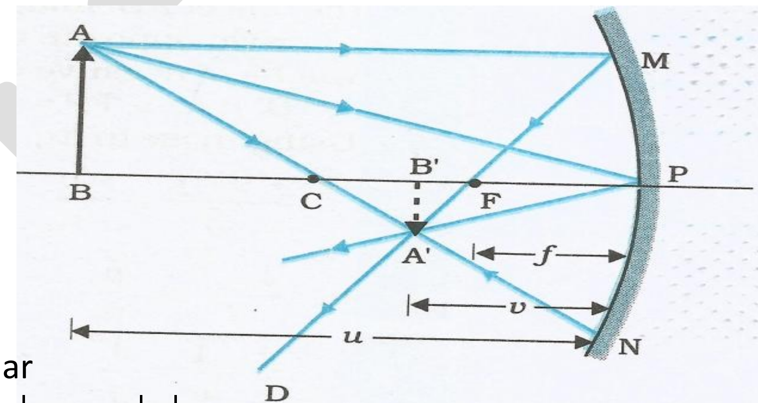
Since θ is very small tan θ ≈ θ and tan 2θ = 2θ

$\theta = \frac{MD}{CD}$ & $2\theta = \frac{MD}{FD}$ dividing, we get CD = 2 FD

D is a point very close to P. Therefore FD = FP = f CD =CP = R

$\therefore \mathrm{R} = 2\mathrm{f} \quad \mathrm{f} = \frac{\mathrm{R}}{2}$

7. **Derive mirror equation.**



MPN = spherical mirror,

AB = linear size of the object,

$A^{|}B^{|}$ = linear size of the image,

BP = u = object distance

$B^{|}P$ = v = image distance

FP = f =focal length

CP= R = radius of curvature

Triangles $A^{|}B^{|}F$ & MPF are similar

Therefore $$\frac{B^{|}A^{|}}{PM} = \frac{B^{|}F}{FP} = \frac{B^{|}A^{|}}{BA} ---------(1)$$

Triangles $A^{|}B^{|}P$ & ABP are similar

Therefore $$\frac{B^{|}P}{BP} = \frac{B^{|}A^{|}}{BA} ---------(2)$$

From (1) & (2) $$\frac{B^{|}P}{BP} = \frac{B^{|}F}{FP} = \frac{B^{|}P - FP}{FP}$$

Applying sign convention $B^{|}P$ = -v, FP = -f, BP = -u

$$\frac{-v+f}{-f} = \frac{-v}{-u} \Rightarrow \frac{v-f}{f} = \frac{v}{u} \qquad fv = u(v-f) = uv - uf$$

Divide throughout by uvf

$$\frac{1}{u} = \frac{1}{f} - \frac{1}{v} \qquad \frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

8. **Define linear magnification.**

It is the ratio of the height of the image to the height of the object

9. Write the expression for the magnification in terms of object and image distance.

$$m = -\frac{v}{u}$$

10. What is refraction of light?

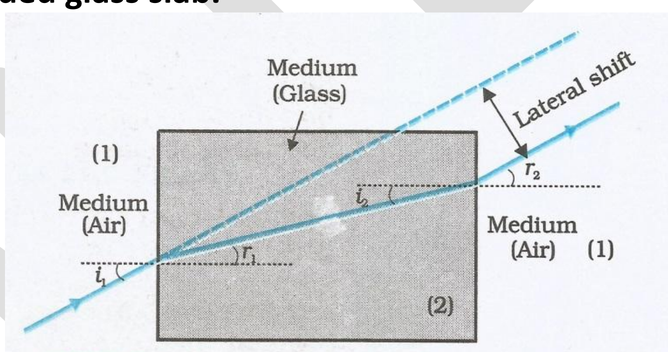
The phenomenon of bending of light when it travels from one optical medium to the other is called refraction

11. State laws of refraction.

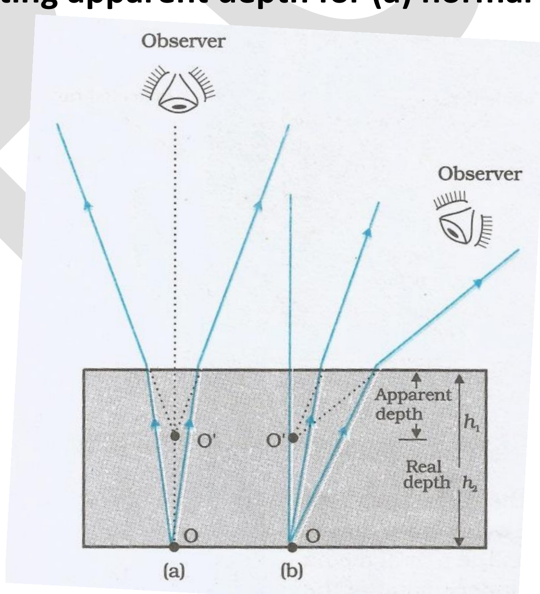
I law: the incident ray, the refracted ray and the normal drawn at the point of incidence all lie in the same plane

II law: the ratio of the sine of the angle of the incidence to the sine of the angle of refraction is constant for a given pair of media and given wavelength (color) of light

12. Draw diagram representing lateral shift (lateral displacement) of a ray passing through a parallel sided glass slab.



13. Draw diagram representing apparent depth for (a) normal and (b) oblique viewing



14. Mention a few illustrations that occur in nature due to refraction of light.

A) The apparent shift in the direction of the sun and hence 2 minute apparent delays between actual sun set and apparent sun set

B) The apparent flattening of the sun at sunrise and sunset

15. Write the formula for refractive index for normal refraction.

$$n = \frac{\text{Real depth}}{\text{Apparent depth}}$$

16.What happens to the direction of the incident ray when it travels from (a) optically denser medium to rarer medium & (b) optically rarer medium to denser medium?

(a) It bends away from the normal

(b) It bends towards the normal

17. Define critical angle.

It is a particular angle of incidence in denser medium for which the refracted ray grazes the surface of separation OR the angle of refraction is 90^0

18. Write the relation between refractive index and critical angle of a material

$n_{12} = \frac{1}{\sin i_c}$ Where n_{12} = refractive index of denser medium with respect to rarer medium and i_c =critical angle

19. What is total internal reflection?

When a ray of light travels from denser to rarer medium and if the angle of incidence is greater than the critical angle then the light gets totally internally reflected to the same medium. This phenomena is called total internal reflection

20.Write the conditions to have total internal reflection

(a) A ray of light should travel from denser to rarer medium

(b) Angle of incidence must be greater than the critical angle

21.Mention a few illustrations of total internal reflection

Mirage, sparkling of diamond, total internal reflecting prisms, optical fibers

22. **On what principle optical fiber does works?**

It works on the principle of total internal reflection.

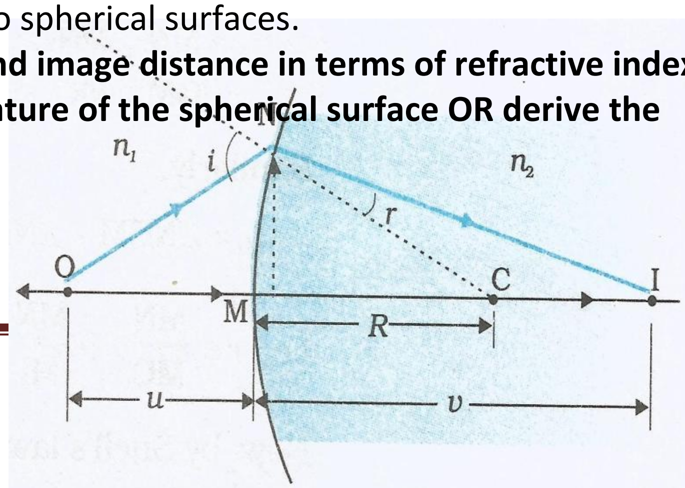
23.What is a lens?

It is an optical medium bounded by two spherical surfaces.

24. Derive the relation between object and image distance in terms of refractive index of the medium and the radius of curvature of the spherical surface OR derive the relation between n, u, v, & R

OM = u = object distance

MI = v = image distance



MC = R = radius of curvature
Angle i = angle of incidence
Angle r = angle of refraction
ON = incident ray
NI = refracted ray
NC = normal & n_1, n_2 are the refractive indices
From the figure for small angles

$$\tan\ N\hat{O}M = \frac{MN}{OM} \quad \tan\ N\hat{C}M = \frac{MN}{MC} \quad \tan\ N\hat{I}M = \frac{MN}{MI}$$

in the triangle NOC, $\hat{\imath}$ = exterior angle = sum of the interior opposite angle

$$\hat{\imath} = N\hat{O}C + N\hat{C}O = N\hat{O}M + N\hat{C}M = \frac{MN}{OM} + \frac{MN}{MC}$$

Similarly $N\hat{C}M = C\hat{N}I + N\hat{I}C = C\hat{N}I + N\hat{I}M$

$$\hat{r} = C\hat{N}I = M\hat{C}N - N\hat{I}M = \frac{MN}{MC} - \frac{MN}{MI}$$

From Snell's law $n_1 \sin i = n_2 \sin r$
For small angles $n_1 i = n_2 r$
Substituting the values of i & r we get

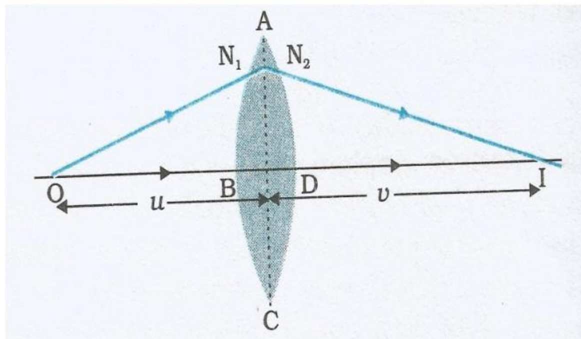
$$n_1\left(\frac{MN}{OM} + \frac{MN}{MC}\right) = n_2\left(\frac{MN}{MC} - \frac{MN}{MI}\right)$$

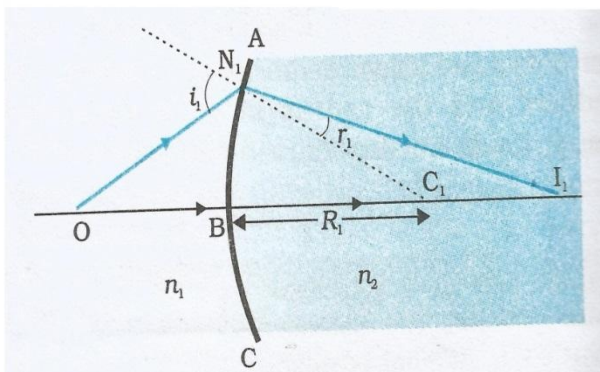
$$\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$$

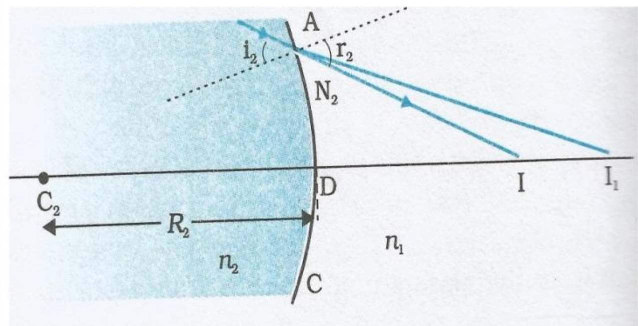
Applying sign convention, OM = -u , MI = v MC = R

$$\frac{n_1}{v} - \frac{n_2}{u} = \frac{n_2 - n_1}{R}$$

25. Derive lens maker's formula







Let u = object distance, v = image distance, R_1 & R_2 are the radii of curvatures of surface I and surface II.

Consider the I spherical surface ABC,

applying the formula $\frac{n_1}{\mathrm{v}} - \frac{n_2}{\mathrm{u}} = \frac{n_2 - n_1}{\mathrm{R}}$

$$\frac{n_1}{\mathrm{OB}} - \frac{n_2}{\mathrm{BI}_1} = \frac{n_2 - n_1}{\mathrm{B}C_1} - - - - - - - (1)$$

For the second surface ADC

$$\frac{n_1}{\mathrm{DI}} - \frac{n_2}{\mathrm{DI}_1} = \frac{n_2 - n_1}{\mathrm{D}C_2} - - - - - - - (2)$$

For a thin lens $BI_1 = DI_1$

Adding equations (1) & (2) $\frac{n_1}{\mathrm{OB}} + \frac{n_1}{\mathrm{DI}} = (n_2 - n_1)\left(\frac{1}{BC_1} - \frac{1}{DC_2}\right)$

But OB = u, DI = v, $BC_1 = R_1$, $BC_2 = R_2$ and $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

$$\frac{n_1}{\mathrm{u}} + \frac{n_1}{\mathrm{v}} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{n_1}{f} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

26. **Define power of a lens. Write its S.I unit.**

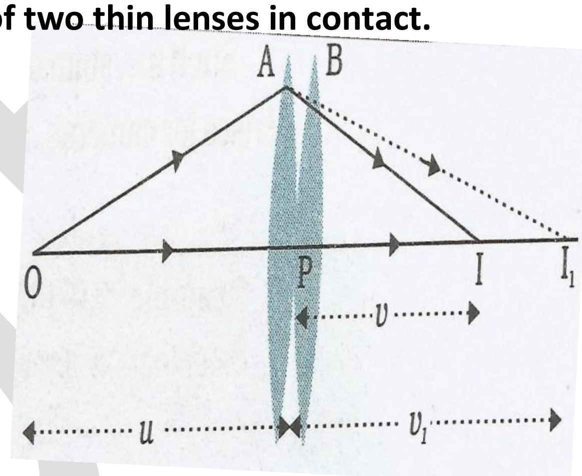
It is the ability of a lens to converge or diverge a beam of light falling on it.

S.I unit of power is diopter (D)

27.Write the expression for power of a lens

$P = \frac{1}{f}$

28. Derive the expression for effective focal length of two thin lenses in contact.



OP = u = object distance

PI = v= image distance due to the combination

$PI_1 = V_1$ = image distance due to first lens

For the lens A, $-\frac{1}{u} + \frac{1}{v_1} = \frac{1}{f_1} - - - - -(1)$

For the lens B, , $\frac{1}{v} + \frac{1}{v_1} = \frac{1}{f_2} - - - - -(2)$

Adding equations (1) & (2)

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f}$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

29. Write the expression for the power of a combination of number of thin lenses

$P = P_1 + P_2 + P_3 + \ldots\ldots\ldots\ldots\ldots$

30. Arrive at the expression for refractive index of material of prism in terms of angle of the prism and angle of minimum deviation.

ABC = principal section of the prism

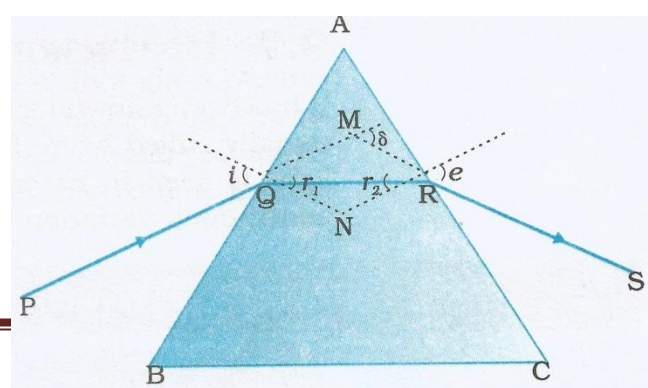
A = angle of the prism

PQ = incident ray

QR = refracted ray

RS = emergent ray

I=angle of incidence



e=angle of emergence

r_1 & r_2 angles of refraction

δ = angle of deviation

In the quadrilateral AQNR, $\hat{A} + Q\hat{N}R = 180^0$

In the triangle QNR $r_1 + r_2 + Q\hat{N}R = 180^0$

$$\therefore \hat{A} = r_1 + r_2$$

Exterior angle δ= sum of interior opposite angles

$$\delta = (i - r_1) + (e - r_2)$$

$$\delta = (i + e) - (r_1 + r_2) = (i + e) - A$$

A graph of angle of incidence with angle of deviation is as shown in the figure

At minimum deviation $\delta = D_m, \quad i = e, \quad r_1 = r_2 = r$

$$\therefore \mathrm{A} = 2\mathrm{r} \qquad \mathrm{r} = {}^{\mathrm{A}}/_{2} \qquad \mathrm{D_m} = 2\mathrm{i} - \mathrm{A} \qquad \mathrm{i} = \frac{\mathrm{A}+\mathrm{D_m}}{2}$$

$$\boldsymbol{n_{21} = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\left({}^{A}/_{2}\right)}}$$

31.What is dispersion of light?

The phenomenon of splitting of white light into its component colors is known as dispersion

32. State Rayleigh's law of scattering.

The intensity of the scattered light (the amount of scattering) is inversely proportional to the fourth power of the wavelength.

33. Why sky is blue in color?

Blue has a shorter wavelength than red and is scattered much more strongly than any other color. Violet scatters more than that of blue, but our eyes are more sensitive to blue than violet. Therefore sky appears blue.

34. Why sun is red at rise and set?

At sunset and sun rise, sun is at horizon. Sun rays have to pass through larger distance in the atmosphere. Most of the blue and other shorter wavelengths are removed by scattering. The least scattered red light reaches our eyes. Hence sun is red at rise and set.

35. What is accommodation of eye?

The modification of the focal length of the eye lens by the ciliary muscles to see the objects at all possible distances is called accommodation.

36. **What is least distance of distinct vision? Write its value.**

The closest distance for which the eye lens can focus light on the retina is called least distance of distinct vision

For normal vision it is 25 cm

37. Which are the common defects of human eye?

a) Myopia or near sightedness
b) Hypermetropia or far sightedness
c) Astigmatism

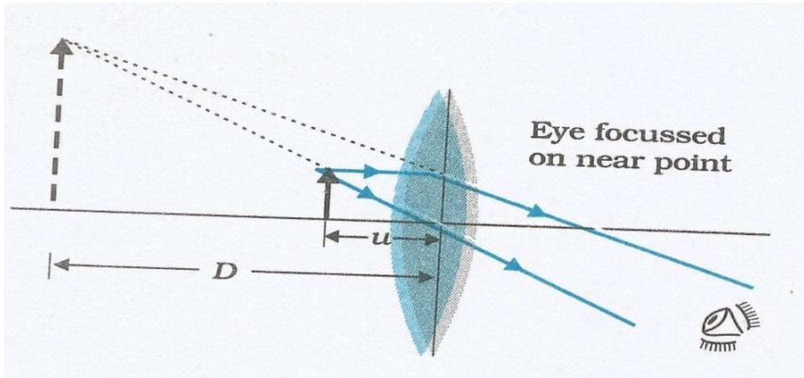
38. **What is myopia? Why it occurs? How to correct it?**

It is a defect in human eye where the image of the object is formed in front of the retina. This is due to too much of convergence produced by the eye lens. It can be corrected using a concave lens.

39. **What is hypermetropia? Why it occurs? How to correct it?**

It is a defect in human eye where the image of the object is formed behind the retina. This is due to too much of divergence produced by the eye lens. It can be corrected using a convex lens.

40. Draw ray diagram of a simple microscope.



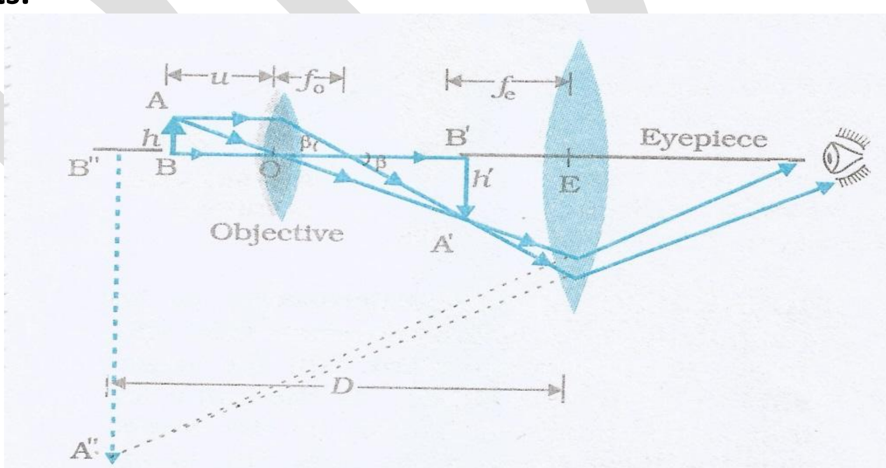
41. Mention the expression for linear magnification of a simple microscope.

$$m = 1 + \frac{D}{f}$$

42. Mention the expression for angular magnification of a simple microscope.

The angular magnification $m = \frac{\theta_i}{\theta_0} = \frac{h}{f}\frac{D}{h} = \frac{D}{f}$

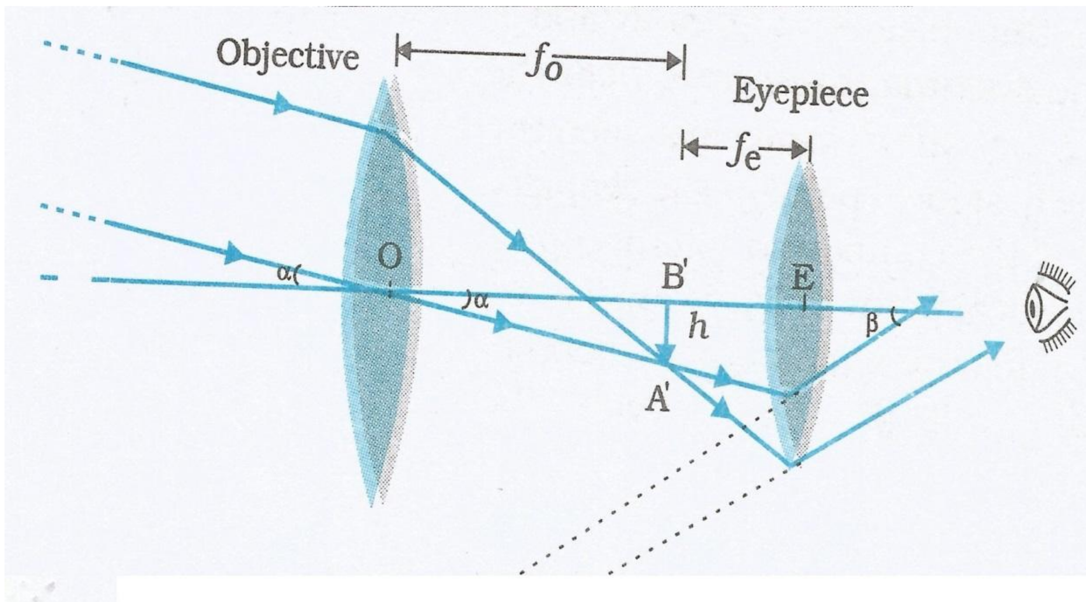
43. Draw ray diagram showing the image formation in a compound microscope and label the parts.



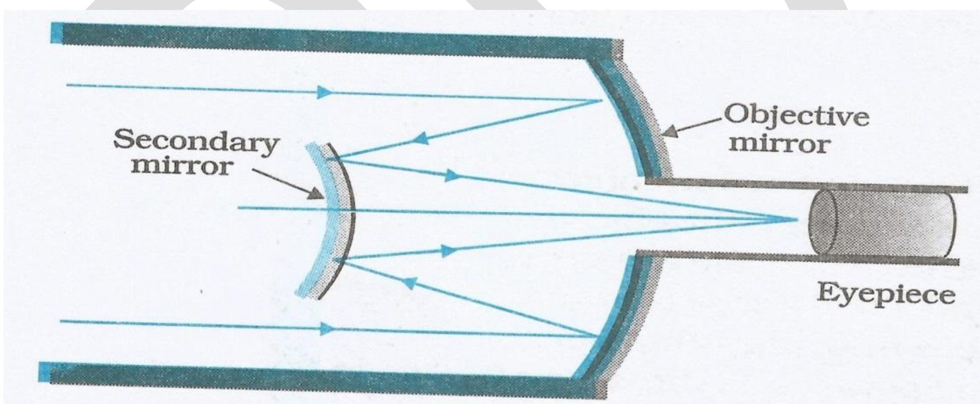
44. Mention the expression for magnification of a compound microscope.

Magnification $= m_o m_e = \frac{L}{f_o}\frac{D}{f_e}$.

45. Draw the ray diagram of a refracting telescope and label the parts.



46. Draw schematic diagram of a reflecting telescope



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