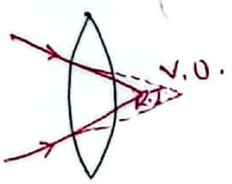
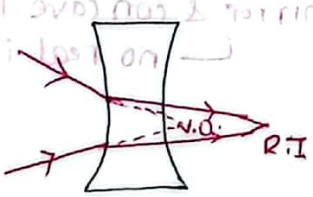
LENS

• convex lens → concave mirror

• concave lens → convex mirror.
convex lens → concave mirror

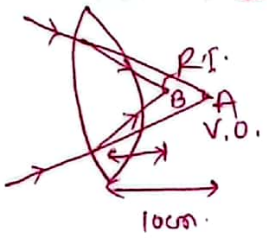
$$\Rightarrow \frac{1}{F} = \frac{1}{u} + \frac{1}{V}$$





Q. The converging beam of light are focused at any point A. A convex lens of focal length 20cm is placed on the path of these light at a distance. 10cm from point A. now these lights are converged at other point B. What is the distance btw A & B?

(a) 6.7cm (b) 16.7cm (c) 3.3cm (d) 10cm.



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

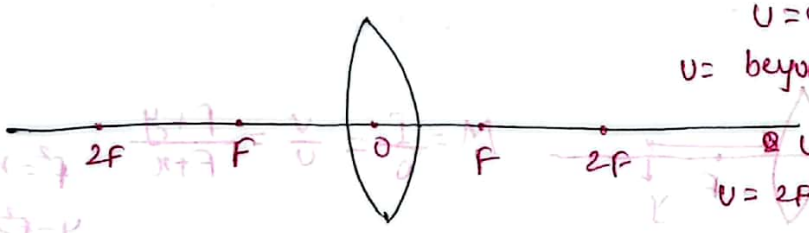
$$\frac{1}{20} = \frac{1}{-10} + \frac{1}{v}$$

$$\therefore v = 6.7\text{cm}.$$

distance btw A & B = 10 - 6.7 = 3.3cm.

Note: convex lens always form real image of virtual object.

For real object,



$u = \infty$, $v = f$

u = beyond 2f, v = F & 2F (real, inverted diminished)

u = 2f, v = 2f (same size.

u = 2f & f, v = beyond 2f. (real, inverted magnified)

u = f, $v = \infty$.

u = f & 0, v = virtual erect, magnified at the same side of object.

Note: For real object → convex lens forms both real & virtual image depending on the position of real obj.

Q. A convex lens:—

(a) always forms real image. (b) always form virtual image.

(c) always forms real image of virtual obj (d) None.

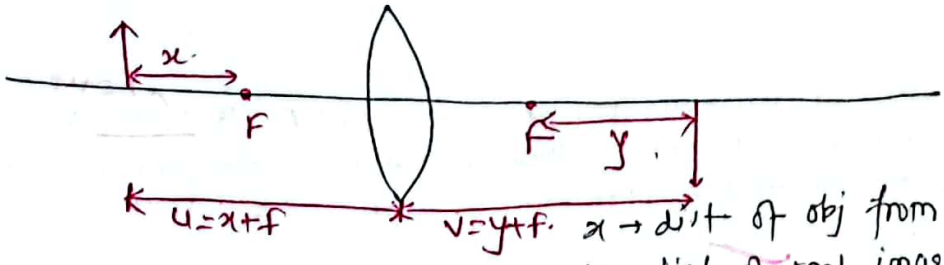
Q. What is the minimum distance between object & its real image in case of convex lens of focal length(f) ?

(a) F (b) 2F (c) 4F (d) 0

but in case of concave mirror → zero.

(convex mirror & concave lens → quest. wrong
└ no real image.

Newton's formula



x → dist of obj from focus.
y → dist. of real image from focus.

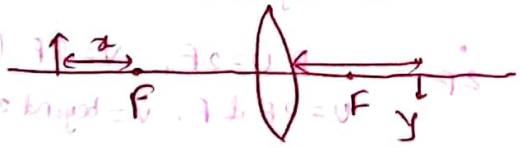
$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{1}{F} = \frac{1}{x+F} + \frac{1}{y+f}$$

$$F^2 = xy \quad \therefore \boxed{F = \sqrt{xy}}$$

Q. Object is at distance x from focus of a convex lens of focal length(f) what is the ratio of size of real image to that of an object?

(a) x/F (b) F/x (c) F^2x (d) F.x.



$$M = \frac{I}{O} = \frac{V}{U} = \frac{f+y}{F+x}$$

$f^2 = xy$

$y = f^2/x$.

$$= \frac{F + F^2/x}{F+x}$$

$$= \frac{F(x+F)}{x(F+x)} = F/x.$$

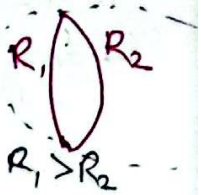
or,

$$\frac{V}{U} = \frac{F}{U-F} = \frac{F}{x+F-f} = \frac{F}{x}$$ or.

$$\boxed{M = \frac{f}{x} = \frac{\sqrt{xy}}{x} = \sqrt{\frac{y}{x}}}$$

Len's maker's formula

$$\frac{1}{F} = \left(\frac{\mu_{lens}}{\mu_{surrounding}} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$ → Biconvex lens ($R_1 \neq R_2$)



$$\frac{1}{F} = \left(\frac{\mu_{lens}}{\mu_{surrounding}} - 1\right)\frac{2}{R}$$ ⇒ equiconvex lens ($R_1 = R_2 = R$)

$$\frac{1}{F} = \left(\frac{\mu_{lens}}{\mu_{surrounding}} - 1\right)\frac{1}{R}$$ ⇒ plano convex lens ∞ | R

Q. The focal length of a convex lens ($\mu_g = 3/2$) is 10cm in air. What is its new focal length when immersed inside water of ($\mu_w = 4/3$)?

→ if lens is in air

$$\frac{1}{f_a} = \left(\frac{3}{2} - 1\right)K \quad - (i)$$

if lens is in water

$$\frac{1}{f_w} = \left(\frac{3/2}{4/3} - 1\right)K \quad - (ii) \qquad \left(K = \frac{1}{R_1} + \frac{1}{R_2}\right)$$

(i) ÷ (ii)

$$\frac{f_w}{f_a} = \frac{\left(\frac{3}{2} - 1\right)}{\left(\frac{9}{8} - 1\right)} = 4$$

$$f_w = 4 f_a$$

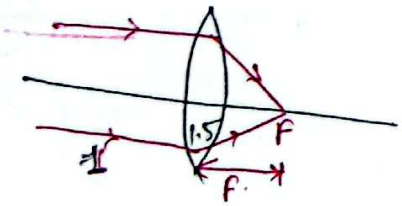
$$= 4 \times 10$$

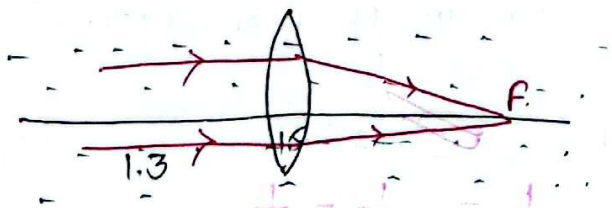
$$= 40cm$$

but in case of mirror
↓
focal length remains same.

Case(i):- If $\mu_{lens} > \mu_{liq.}$

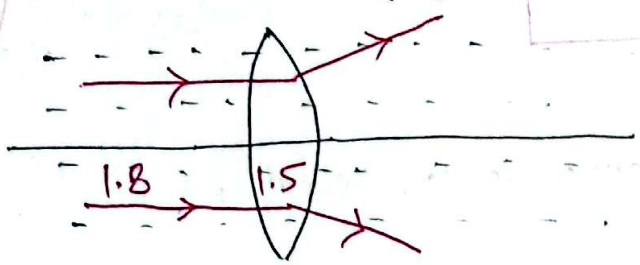
In this case, nature of lens remains same i.e. converging lens becomes less converging or diverging lens becomes less diverging.





Case(ii): If $\mu_{lens} < \mu_{liquid}$.

In this case, nature of lens changes i.e. converging lens becomes diverging & diverging become converging.

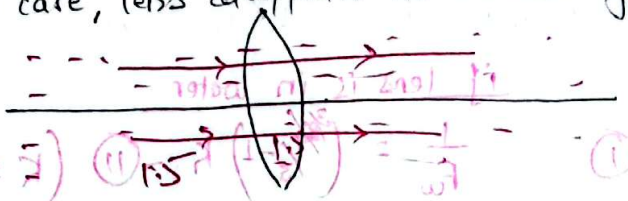


Case(iii): If $\mu_{lens} = \mu_{liquid}$

Focal length of lens becomes infinity & power zero.

- lens act as plane glass slab or plane mirror.

→ In this case, lens disappears in surrounding medium.



Q. A lens is converging in air and diverging in water. The R.I. of that lens is :-

(a) < 1.33 (b) > 1.33 (c) in betw 1.33 & 1 (d) 1.

water air

Two thin lenses in contact

$$\rightarrow \frac{1}{F_{eq}} = \frac{1}{F_1} + \frac{1}{F_2}$$



$$\rightarrow P_{eq} = P_1 + P_2.$$

Q. ~~Two thin~~ A convex lens of focal length (F_1) is placed in contact with concave lens of focal length (F_2). The combined lens is converging then:-

(a) $F_1 > F_2$ (b) $F_2 > F_1$ (c) $F_1 = F_2$ (d) F_1/F_2

$$\frac{1}{F_{eq}} = \frac{1}{F_1} - \frac{1}{F_2}$$

$$F_{eq} = \frac{F_1 F_2}{F_2 - F_1}$$

for $F_{eq} = +ve$

$F_2 > F_1$

Q. A convex lens of power 12D & concave lens of power 2D are in contact. Then F_{eq} = ?

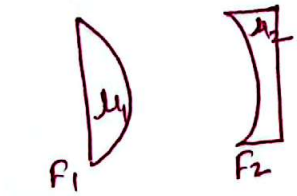
(a) 0.1cm · (b) 1cm (c) 10cm (d) 100cm

$P_{eq} = 12 - 2 = 10D$

$F_{eq} = \frac{1}{P_{eq}} = 0.1m = 10cm.$

Q. A plano convex lens of refractive index μ_1, fits exactly into a plano-concave lens of R.I μ_2. If their plane faces are parallel and curve face has radius (R). Find equivalent focal length?

(a) $\frac{\mu_1 - \mu_2}{R}$ (b) $\frac{R}{\mu_1 - \mu_2}$ (c) $\frac{\mu_1 - \mu_2}{2R}$ (d) ∞



$\frac{1}{F_1} = (\mu_1 - 1)\frac{1}{R}$ → in contact →

$\frac{1}{F_2} = -(\mu_2 - 1)\frac{1}{R}$



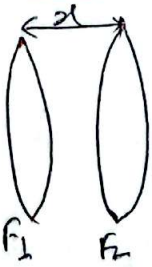
$\frac{1}{F_{eq}} = \frac{1}{F_1} + \frac{1}{F_2}$

$= \frac{\mu_1 - 1}{R} - \frac{(\mu_2 - 1)}{R}$

$= \frac{\mu_1 + \mu_2}{R}$.

$\therefore \boxed{F_{eq} = \frac{R}{\mu_1 - \mu_2}}$

If two thin lenses at separation 'x'



$$\boxed{\frac{1}{F_{eq}} = \frac{1}{F_1} + \frac{1}{F_2} - \frac{x}{F_1 F_2}}$$

$$\boxed{P_{eq} = P_1 + P_2 - x P_1 P_2}$$

Q. Two thin convex lenses of focal length F_1 and F_2 are at separation 'x' so their equivalent power is zero. Find x :-

(a) $F_1 - F_2$ (b) $F_1 + F_2$ (c) $F_1 F_2$ (d) F_1/F_2.

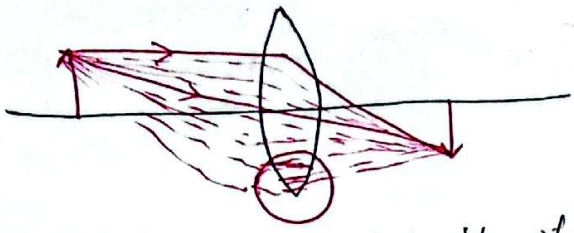
$P_{eq} = \frac{1}{F_{eq}} = \frac{1}{F_1} + \frac{1}{F_2} - \frac{x}{F_1 F_2}$

$0 = \frac{1}{F_1} + \frac{1}{F_2} - \frac{x}{F_1 F_2}$

$\Rightarrow \frac{x}{F_1 F_2} = \frac{F_1 + F_2}{F_1 + F_2}$

$\therefore \boxed{x = F_1 + F_2}$.

Cutting of lens



→ when lens is cut only intensity of image formed by it will reduce.

$$I \propto A \quad \left(\text{Area of aperture} = \frac{\pi d^2}{4}\right)$$

→ If $d/4$ part of the original diameter is cut or blocked or painted, then

remaining area $(A') = \frac{\pi d^2}{4} - \frac{\pi (d/4)^2}{4}$

$$= \frac{\pi d^2}{4}\left(1 - \frac{1}{16}\right) = \frac{15}{16}\cdot\frac{\pi d^2}{4}$$

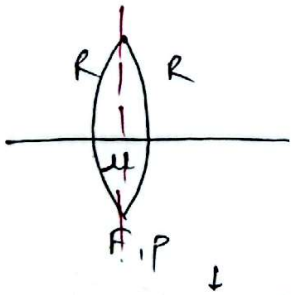
$$= \frac{15}{16} \cdot A'$$

$$\therefore \boxed{I' = \frac{15}{16} A'}$$

• perp. to the axis

Q. An equiconvex lens of focal length 20cm is cut into two equal part perp. to the axis, then focal length of each part will be - -.

(a) 20cm (b) 40cm (c) 10 cm (d) 5 cm.



$$\frac{1}{F} = (\mu - 1)\frac{2}{R}$$

$$\frac{1'}{F} = \frac{2}{f} \quad \therefore \boxed{f = 2F}$$

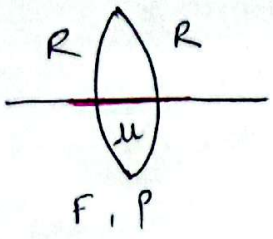


$$\frac{1}{f} = (\mu - 1)\frac{1}{R}$$

then, $\boxed{P' = \frac{P}{2}}$

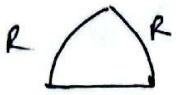
→ intensity of image remains same.

• Along the axis



F, P

$$\frac{1}{F} = (\mu - 1)\frac{2}{R}$$



f, P

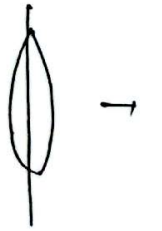
$$\frac{1}{F} = (\mu - 1)\frac{2}{R}$$

→ Focal length & power remain same.
→ Intensity reduced.

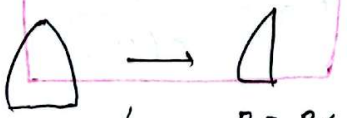
Note:

→ If thickness half – power half
→ " " double → " double.
→ " " same → " same.

eg.

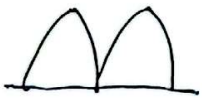


$P = P/2$
$F = 2f$



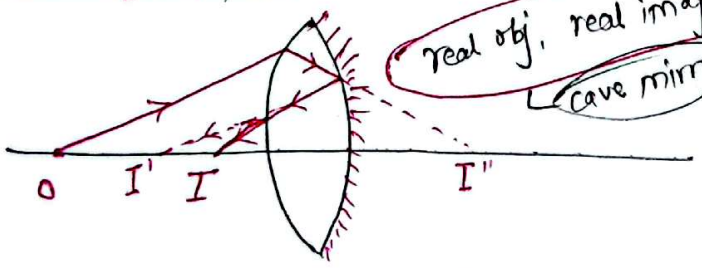
$P = P$
$F = F$

$P = P/2$
$F = 2f$



$P_{eq} = 2P$
$F_{eq} = F/2$

Silvering of lens



$$\frac{1}{F_L} = (\mu - 1)\,2/R.$$

$$f_m = R/2.$$

$$\frac{1}{F_{eq}} = \frac{1}{F_L} + \frac{1}{f_m} + \frac{1}{F_L}$$

$$\frac{1}{F_{eq}} = \frac{2}{F_L} + \frac{1}{f_m}$$

$$= \frac{4(\mu - 1)}{R} + \frac{2}{R} = \frac{2(2\mu - 1)}{R}.$$

$$\therefore \boxed{F_{eq} = \frac{R}{2(2\mu - 1)}}$$

→ It act as concave mirror.

For equiconcave lens

$$F_{eq} = \frac{-R}{2(2\mu-1)}$$

For planoconvex lens

① If plane face is silvered

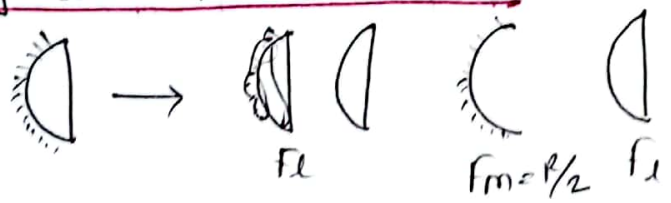


$$\frac{1}{F_{eq}} = \frac{2}{F_1} + \frac{1}{F_m}$$

$$= \frac{2(\mu-1)}{R} + \frac{1}{\infty} \to 0$$

$$\therefore \boxed{F_{eq} = \frac{R}{2(\mu-1)}}$$ act as concave mirror.

② If curve face is silvered



$$\frac{1}{F_1} = (\mu-1)\frac{1}{R}$$

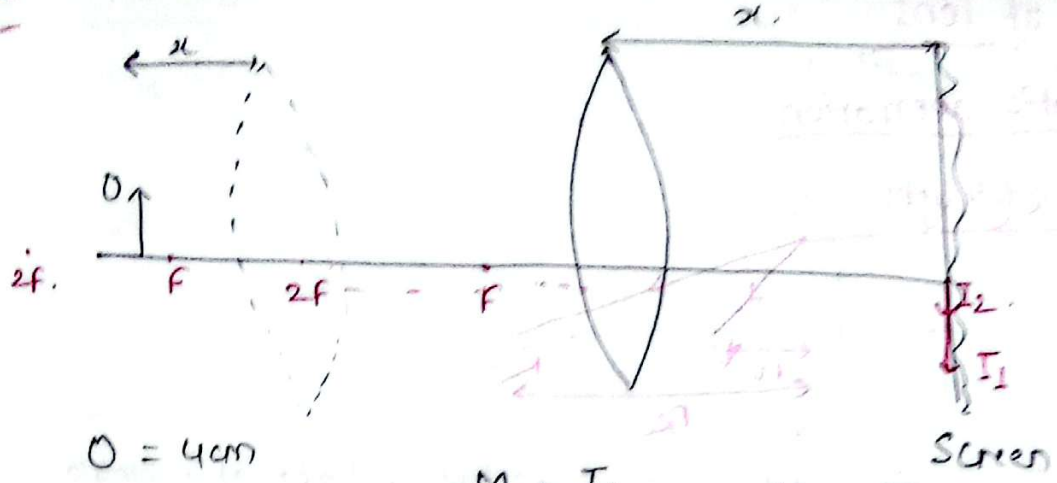
$$\frac{1}{F_{eq}} = \frac{2}{F_1} + \frac{1}{F_m}$$

$$= \frac{2(\mu-1)}{R} + \frac{2}{R}$$

$$\frac{1}{F_{eq}} = \frac{2\mu}{R}$$

$$\therefore \boxed{F_{eq} = \frac{R}{2\mu}}$$ → act as concave mirror.

#



$O = 4cm$

$I_1 = 8cm$

$I_2 = 2cm$

$M_1 = \frac{I_1}{O}$ (2) , $M_2 = \frac{I_2}{O}$ (1/2)

$\boxed{M_2 = \frac{1}{M_1}}$

$M_1 = 3$. then $M_2 = \frac{1}{3}$

$$M_1 \times M_2 = \frac{I_1}{O} \times \frac{I_2}{O}$$

$$1 = \frac{I_1 \times I_2}{O^2}$$

$$\boxed{O = \sqrt{I_1 I_2}}$$

O → size of obj

I_1 & I_2 → size of images.

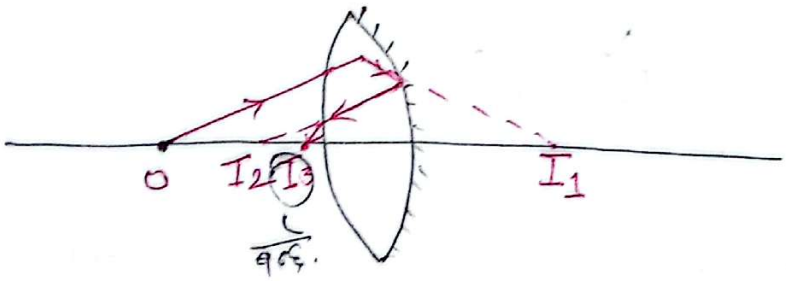
Q. Image of size 16cm and 4cm are obtained on the screen when lens is shifted without disturbing object & screen. What is the size of object?

(a) 4cm (b) 8cm (c) 12cm (d) 6cm

$$O = \sqrt{16 \times 4} = \sqrt{64} = 8cm$$

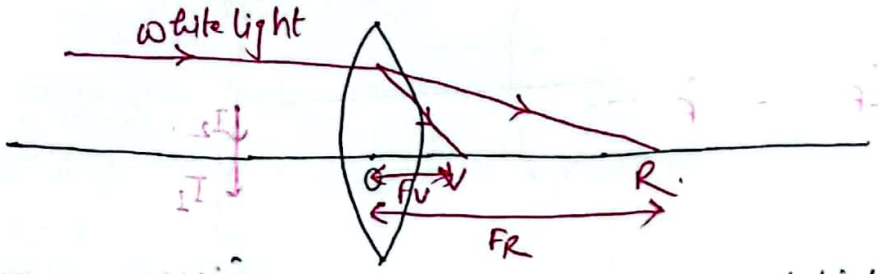
Silvering of lens

① If anyone face of an equiconvex lens is silvered:-



Defect of lens

① Chromatic (color) aberration (defect).



→ Inability of lens to focus all the colors of light at a single p... of principal axis.

→ Focal length of Red is maximum and violet is minimum.

$f_R > f_V$

* Longitudinal chromatic aberration ⇒ $f_R - f_V$

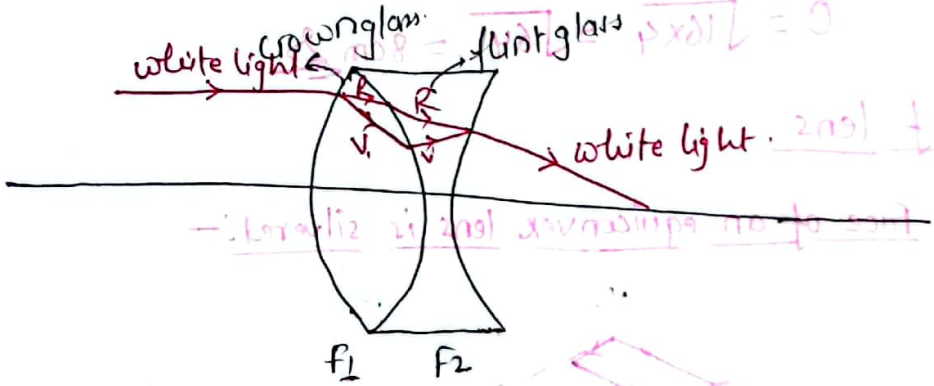
$f_R - f_V = \omega F$

ω → dispersive power of lens.

$\omega = \frac{\mu_V - \mu_R}{\mu - 1}$ $\quad \mu = \frac{\mu_V + \mu_R}{2}$

Note:- No chromatic aberration in curve mirror.

Achromatic combination



* For achromatism

① One convex lens & another concave lens in contact.
② Focal length is same for all colors.
③ Color of image is white.
④ also known as deviation without dispersion. (scattering)

For achromatism

$$\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$$

$$\boxed{\frac{\omega_1}{\omega_2} = -\frac{f_1}{f_2}}$$

Q. Focal length of achromatic converging lens is 20cm. The ratio of dispersive power of lens used for that combination is 1:2. Find the focal length of component lenses?

→ $F = 20cm.$ $\quad \frac{\omega_1}{\omega_2} = \frac{1}{2} = -\frac{f_1}{f_2}$

$\therefore f_2 = -2f_1$

$\because \frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

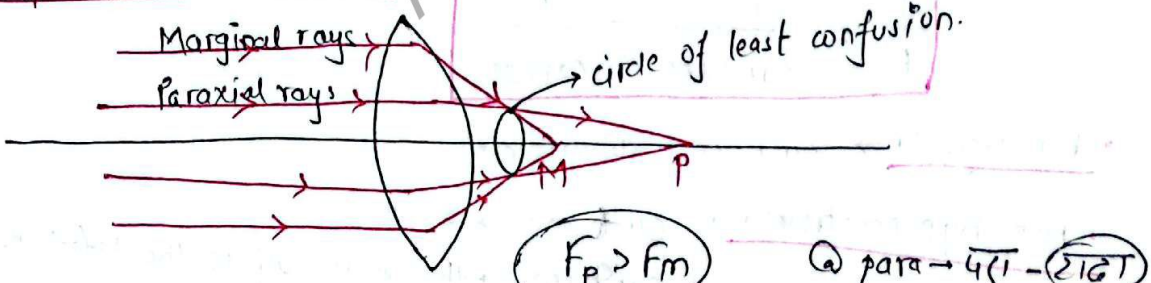
$\frac{1}{20} = \frac{1}{f_1} - \frac{1}{2f_1}$

$\Rightarrow \frac{1}{20} = \frac{2}{2f_1}$

$\therefore f_1 = 10cm.$

$f_2 = -2 \times 20 = -20cm.$

② Spherical aberration



$F_p > F_m$ ② para → बड़ा - छोटा

Note:- spherical aberration also takes place in curve mirror.

* To minimize it

→ Either marginal rays are cutoff or paroxial rays are cutoff.
→ Using thin lens or lens having larger focal length or larger radius of curvature.
→ Using plano convex or plano-concave lens.
→ Using parabolic mirrors in automobile headlights.

Abishek singh