Linear magnification

XII- SCIENCE

SUBJECT : PHYSICS
CHAPTER NUMBER: 9
CHAPTER NAME : RAY OPTICS

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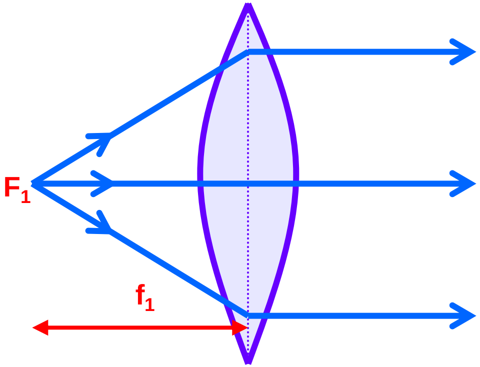
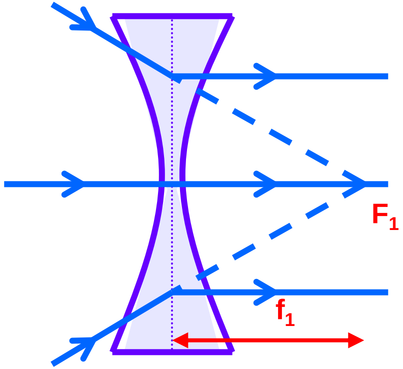
First Principal Focus:

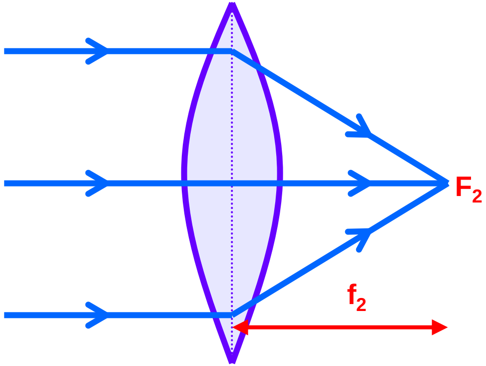
First Principal Focus is the point on the principal axis of the lens at which if an object is placed, the image would be formed at infinity.

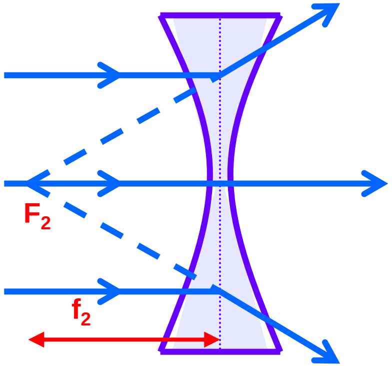




Second Principal Focus:

Second Principal Focus is the point on the principal axis of the lens at which the image is formed when the object is kept at infinity.





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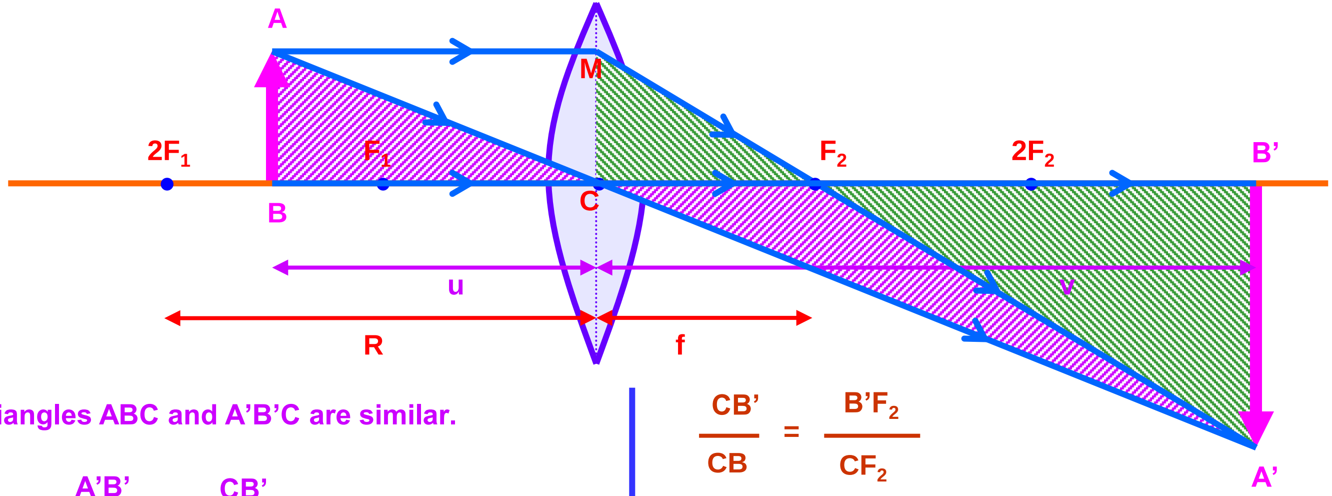
Thin Lens Formula (Gaussian Form of Lens Equation): For Convex Lens:



Triangles ABC and A'B'C are similar.

$$\frac{A'B'}{AB} = \frac{CB'}{CB}$$

Triangles MCF_2 and $A'B'F_2$ are similar.

$$\frac{A'B'}{MC} = \frac{B'F_2}{CF_2}$$

or

$$\frac{A'B'}{AB} = \frac{B'F_2}{CF_2}$$

$$\frac{CB'}{CB} = \frac{B'F_2}{CF_2}$$

$$\frac{CB'}{CB} = \frac{CB' - CF_2}{CF_2}$$

According to new Cartesian sign conventions,

$CB = -u$, $CB' = +v$ and $CF_2 = +f$.

$$\therefore \quad \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

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Linear Magnification:

Linear magnification produced by a lens is defined as the ratio of the size of the image to the size of the object.

$$m = \frac{I}{O}$$

$$\frac{A'B'}{AB} = \frac{CB'}{CB}$$

According to new Cartesian sign conventions,

A'B' = + I, AB = - O, CB' = + v and CB = - u.

$$\frac{+I}{-O} = \frac{+v}{-u}$$ or $$m = \frac{I}{O} = \frac{v}{u}$$

Magnification in terms of v and f:

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

Magnification in terms of u and f:

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

Power of a Lens:

Power of a lens is its ability to bend a ray of light falling on it and is reciprocal of its focal length.
When f is in metre, power is measured in Dioptre (D).

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

End of Ray Optics - I

Image formation by convex lens:

Position of object	Position of image	Nature of Image	Magnification
a. At ∞	At F	Real and inverted	Highly diminished
a. Beyond -2F	Between F and 2F	Real and inverted	diminished
a. On -2F	On 2F	Real and inverted	Same size
a. Between -2F and F	Beyond 2F	Real and inverted	magnified
a. On F	At ∞	Real and inverted	Highly magnified
a. Between F and lens	In the same side of object	Virtual and erect	magnified

Image formation by concave lens:

Position of object	Position of image	Nature of Image	Magnification
a. At ∞	At - F	Virtual and erect	Highly diminished
a. At any finite position	Between – F and lens	Virtual and erect	diminished

NUMERICAL

Numerical: A beam of light converges at a point P. Now a lens is kept in the path of the convergent beam 12 cm from P. At what point does the beam converge if the lens is (a) a convergent lens of focal length 20 cm ? (b)a concave lens of focal length 16 cm ? (NCERT)

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Solution: This is the case of virtual object.

(a) u = 12 cm , f = 20 cm

As; $\frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{12} + \frac{1}{20} = \frac{5+3}{60} = \frac{8}{60cm} \Rightarrow v = \frac{60}{8} cm = 7.5cm$

(b) u = 12 cm , f = - 16 cm

As; $\frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{12} - \frac{1}{16} = \frac{4-3}{48} = \frac{1}{48cm} \Rightarrow v = 48cm$

Numerical

Numerical: Show that minimum distance between object and its real image by a convex lens is 4F. OR Show that maximum focal length to keep the object and real image distance at L is L/4.

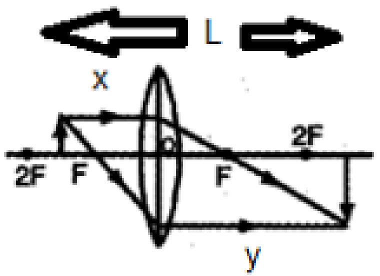
Numerical

Numerical: Show that minimum distance between object and its real image by a convex lens is 4F. OR Show that maximum focal length to keep the object and real image distance at L is L/4.

Solution: Let u = - x and v = y

So distance between object and its real image is L = x + y

Hence y = L –x



By lens formula ; $\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{L-x}+\frac{1}{x}=\frac{1}{f}$

$$\Rightarrow \frac{L}{Lx-x^2}=\frac{1}{f} \Rightarrow x^2-Lx+Lf=0$$

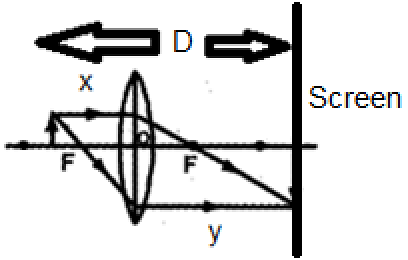
To have real solution of the equation condition to be satisfied is ;

$$(-L)^2 \geq 4Lf \Rightarrow L \geq 4f \Rightarrow f \leq \frac{L}{4}$$

So $L_{minimum}=4f$ OR $f_{maximum}=\frac{L}{4}$

NUMERICAL

Numerical: An object is placed at a distance D from a screen. A convex lens is placed in between the object and screen. It is observed that for two positions of lens separated by a distance d. Find expression for the focal length of the lens.



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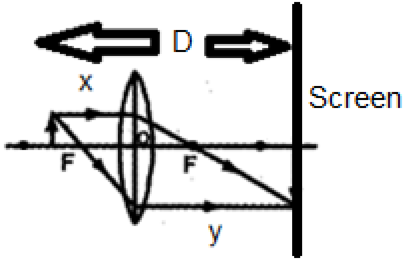

Solution: Let for a position of lens at distance x from object image be formed on the screen.

So by sign convention , u = -x and v = D - x

By lens formula ; $\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{D-x}+\frac{1}{x}=\frac{1}{f}$

$$\Rightarrow \frac{D}{Dx-x^2}=\frac{1}{f} \Rightarrow x^2-Dx+Df=0$$

Solutions of this quadratic equation represents two positions (x_1 and x_2) of lens for producing image on the screen. As given , $x_2 - x_1 = d$

$$\Rightarrow 2\frac{\sqrt{(-D)^2-4.Df.1}}{2\times1}=d \Rightarrow D^2-4Df=d^2 \Rightarrow f=\frac{D^2-d^2}{4D}$$

$$\therefore x=\frac{D\pm\sqrt{D^2-4D\left(D^2-d^2\right)/4D}}{2\times1}=\frac{D\pm d}{2}$$

NUMERICAL

So image distance ; $v = D - x = (D-d)/2$ if $x = (D+d)/2$ and $v = (D+d)/2$ if $x = (D-d)/2$.
So magnification ; $m = (D-d)/(D+d)$ or $m = (D+d)/(D-d)$

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