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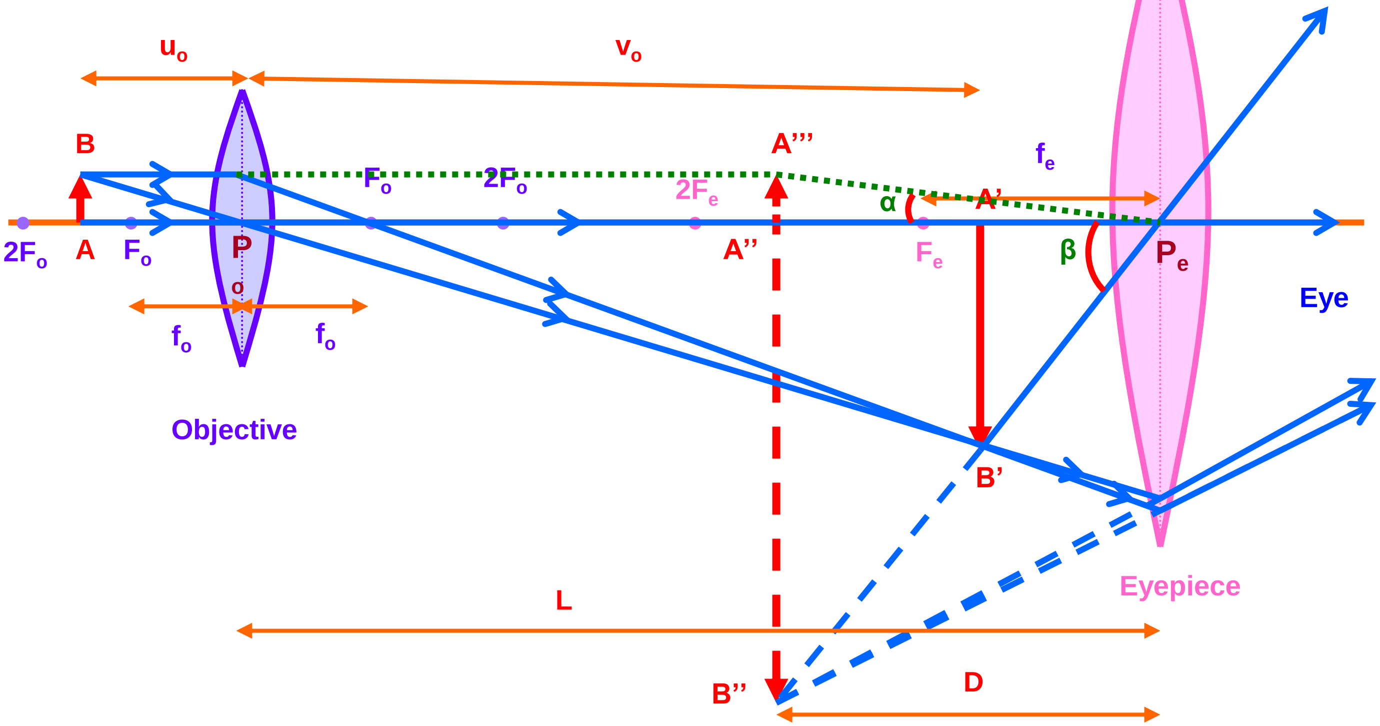
Microscope and astronomical telescope and their magnifying power

XII- SCIENCE

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

Compound Microscope:



Objective: The converging lens nearer to the object.

Eyepiece: The converging lens through which the final image is seen.

Both are of short focal length. Focal length of eyepiece is slightly greater than that of the objective.

Angular Magnification or Magnifying Power (M):

Angular magnification or magnifying power of a compound microscope is defined as the ratio of the angle β subtended by the final image at the eye to the angle α subtended by the object seen directly, when both are placed at the least distance of distinct vision.

$$M = \frac{\beta}{\alpha}$$

Since angles are small, $\alpha = \tan\alpha$ and $\beta = \tan\beta$

$$M = \frac{\tan\beta}{\tan\alpha}$$

$$M = \frac{A''B''}{D} \times \frac{D}{A''A'''}$$

$$M = \frac{A''B''}{D} \times \frac{D}{AB}$$

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

$$M = \frac{A''B''}{A'B'} \times \frac{A'B'}{AB}$$

$$M = M_e \times M_o$$

$$M_e = 1 - \frac{v_e}{f_e} \quad \text{or} \quad M_e = 1 + \frac{D}{f_e}$$

($v_e = - D = - 25$ cm)

and $M_o = \dfrac{v_o}{-u_o}$ $\therefore$

$$M = \frac{v_o}{-u_o}\left(1 + \frac{D}{f_e}\right)$$

Since the object is placed very close to the principal focus of the objective and the image is formed very close to the eyepiece,

$u_o \approx f_o$ and $v_o \approx L$

$$M = \frac{-L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

or

$$M \approx \frac{-L}{f_o} \times \frac{D}{f_e}$$

(Normal adjustment i.e. image at infinity)

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(vi) From equations (v) and (vii) it is evident that , for a compound microscope focal lengths of objective and eye piece should be very small to have greater magnification .

(vii) Difference between objective and eye piece of a microscope :

Objective lens	**Eye piece lens**
(i)Kept close to the object.	(i) Kept close to eye .
(ii)Small focal length and small aperature.	(ii) Comparatively large focal length and large aperature .
(iii)Always produce real and magnified image.	(iii) Produces virtual, erect and magnified image .

Numerical : A compound microscope consists of an objective lens of focal length 2.0 cm and an eye piece lens of focal length 6.25 cm separated by a distance of 15 cm . How far from the objective should an object be placed in order to obtain the final image at (a) the least distance of distinct vision(25 cm) and (b) at infinity ?

What are the magnifying power of the microscope in each case ? (NCERT)

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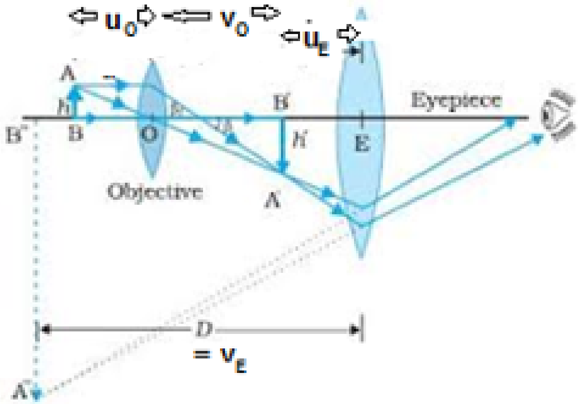
Solution : (a) Given that , $v_E = -D = -25$ cm , $f_E = 6.25$cm

By lens formula for eye piece ;

$$\Rightarrow \frac{1}{u_E} = \frac{1}{v_E} - \frac{1}{f_E} = \frac{1}{-25} - \frac{1}{6.25} = \frac{-1}{5}$$

$$\Rightarrow u_E = -5cm$$

$$\because u_E = v_O - d_{OE} \Rightarrow v_O = u_E + d_{OE} = (-5+15)cm = 10cm$$



By lens formula for objective lens ;

$$\Rightarrow \frac{1}{u_O} = \frac{1}{v_O} - \frac{1}{f_O} = \frac{1}{10} - \frac{1}{2} = \frac{-2}{5} \Rightarrow u_O = -2.5cm$$

Here ; $m = \frac{v_O}{u_O}\left[1 + \frac{D}{f_e}\right] = \frac{10}{-2.5}\left[1 + \frac{25}{6.25}\right] = -20$

OR (other method of calculation of m)

Here L = separation between 2nd focus of objective and 1st focus of eye piece

$= 15$ cm – ($f_O + f_E$) = 15 cm – 8.25 cm = 6.75 cm

So , $m = \frac{L}{f_O}\left[1 + \frac{D}{f_e}\right] = \frac{6.75}{2}\left[1 + \frac{25}{6.25}\right] = 16.875$

(b) Given that , $v_E = - D = - \infty$, $f_E = 6.25$cm

By lens formula for eye piece ;

$$\Rightarrow \frac{1}{u_E} = \frac{1}{v_E} - \frac{1}{f_E} = \frac{1}{-\infty} - \frac{1}{6.25} = \frac{-1}{6.25} \Rightarrow u_E = -6.25cm$$

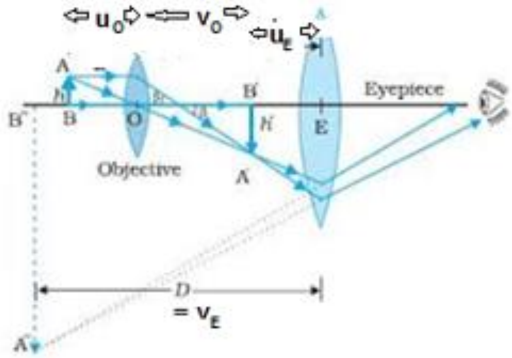
$$\because u_E = v_O - d_{OE} \Rightarrow v_O = u_E + d_{OE} = (-6.25 + 15)cm = 8.75cm$$

By lens formula for objective lens ;

$$\Rightarrow \frac{1}{u_O} = \frac{1}{v_O} - \frac{1}{f_O} = \frac{1}{8.75} - \frac{1}{2} = \frac{-27}{70} \Rightarrow u_O = -2.6cm$$

Here ; $m = \frac{v_O}{u_O}\left[\frac{D}{f_e}\right] = \frac{8.75}{-2.6}\left[1 + \frac{25}{6.25}\right] = -16.825cm$

Numerical : An angular magnification of 30X is required for a compound microscope using an objective lens of focal length 1.25 cm and an eye piece lens of focal length 5 cm . How will set up the microscope ? (NCERT)



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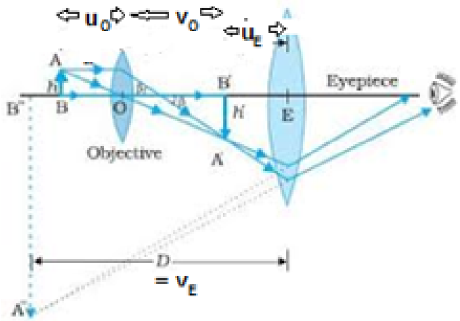

Solution : Now for microscope , m = 30X

As final image is inverted , m = -30 X

$$\Rightarrow \frac{v_O}{u_O}\left[1+\frac{D}{f_E}\right] = -30 \Rightarrow \frac{v_O}{u_O}\left[1+\frac{25}{5}\right] = -30$$

$$\Rightarrow \frac{v_O}{u_O} = -5 \Rightarrow v_O = -5u_O$$

By lens formula for objective lens ;

$$\frac{1}{v_O} - \frac{1}{u_O} = \frac{1}{f_O} \Rightarrow \frac{1}{-5u_O} - \frac{1}{u_O} = \frac{1}{f_O} \Rightarrow -\frac{6}{5u_O} = \frac{1}{f_O} \Rightarrow u_O = -\frac{6f_O}{5} = -\frac{6\times 1.25cm}{5} = -1.5cm$$

By lens formula for eye piece ;

$$\Rightarrow \frac{1}{u_E} = \frac{1}{v_E} - \frac{1}{f_E} = \frac{1}{-25} - \frac{1}{5} = \frac{-6}{25}$$

$$\Rightarrow u_E = -(25/6)cm = -4.2cm$$

$$\because u_E = v_O - d_{OE} \Rightarrow d_{OE} = v_O - u_E = -5u_O - u_E = -5(-1.5cm) - (-4.2cm) = 11.7cm$$

So lenses should be separated by 11.7 cm and object should be kept 1.5 cm from objective lens .

THANKING YOU

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