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Microscope and astronomical telescope and their magnifying power

XII- SCIENCE

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

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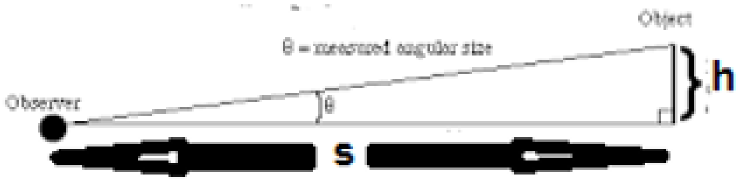
Optical instruments :

- Optical instruments are the devices used to view objects clearly with larger size.
- Generally size of an object that appears to us is its angular size i.e. the angle(θ) formed by it at our eye .

  From figure, $\tan\theta = \dfrac{h}{s}$

  Where s = distance between object and observer which is between D (i.e minimum distance of distinct vision = 25 cm) and infinity .

  If , $\theta \to 0 \Rightarrow \tan\theta \to \theta. \Rightarrow \theta = h/s$ =angular size of object that appears to naked eye

  .
- Optical instruments are used to enlrge this angular size . This can be made by ***(i) increasing the size of image and (ii) by reducing the apparent distance of image*** .
- The ratio between the angular sie of image and angular size of object is called as angular magnification or magnifying power . i.e. $m_\theta = \theta_I/\theta_O$.

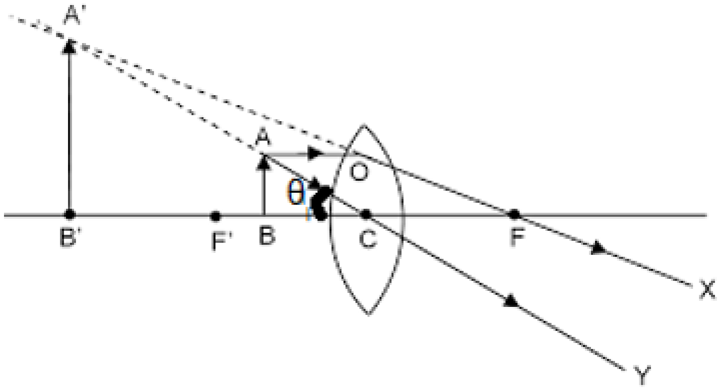
- **Difference between linear magnification and angular magnification :**

Linear magnification (m)	**Angular magnification (m_θ)**
(i)It is the ratio between image height and object height . i.e. $m = h_I / h_O$	(i) It is the ratio between angular size of imge and angular size of object . i.e. $m_\theta = \theta_I / \theta_O$
(ii) m >1 means image height is greater than object height .	(ii) m_θ>1 doesn't mean image height is greater than object height. In some cases image height is less than object height also .

- **Difference between Power of lens and magnifying power :**

Power of lens (P)	**Magnifying power (m_θ)**
(i)It is the reciprocal of focal length i.e. $P = 1/f$	(i) It is the ratio between angular size of imge and angular size of object . i.e. $m_\theta = \theta_I / \theta_O$
(ii) Its unit is dioptre (D)	(ii) It is unitless .
(iii)It depends only on focal length and independent of image and object disance .	(iii)It depends on image and object positions.

Simple microscope or magnifying glass or magnifier :



- It is used to view magnified and erect image of very small objects like very small letters
- **Magnifying power of simple microscope :**

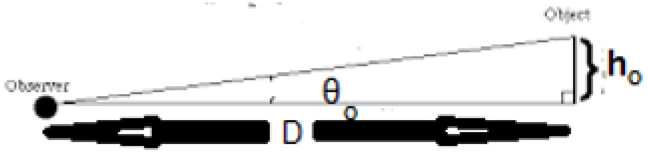
By defination ; $m_\theta = \frac{\theta_I}{\theta_O}$ ....(i)

As $\theta_I \to 0 \Rightarrow \tan\theta_I \to \theta_I$

From figure ,

$\tan\theta_I = \frac{AB}{BC} = \frac{h_O}{u} \Rightarrow \theta_I = \frac{h_O}{u}$ ....(ii)

Again ; when object is viewed through naked eye,



$\theta_O \to 0 \Rightarrow \tan\theta_O \to \theta_O$

And $\tan\theta_O = \frac{h_O}{D} \Rightarrow \theta_O = \frac{h_O}{D}$ ....(iii)

Using equations (ii) and (iii) in equation (i) we get ,

$$m_\theta = \frac{\theta_I}{\theta_O} = \frac{h_O/u}{h_O/D} = \frac{D}{u} \qquad \Rightarrow m_\theta = \frac{D}{u} \text{ ....(iv)}$$

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- **Linear magnification of simple microscope :**

  By defination ; $m = \frac{v}{u}$ ....(v)

- **When final image is formed at minimum distance of distinct vision :**

  i.e v = -D and u = -u by sign convention .

  Then , $m = \frac{D}{u} = m_\theta$

  By lens formula , $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

  Using v = - D and u = -u as per sign convention ;

  $$\frac{1}{-D} - \frac{1}{-u} = \frac{1}{f} \Rightarrow \frac{1}{u} = \frac{1}{D} + \frac{1}{f} = \frac{D+f}{Df}$$

  $$\Rightarrow m_\theta = m = D\left(\frac{D+f}{Df}\right) = \left(\frac{D+f}{f}\right) = 1 + \frac{D}{f} \text{ ....(vi)}$$

  This is the minimum angular magnification by mgnifying glass .

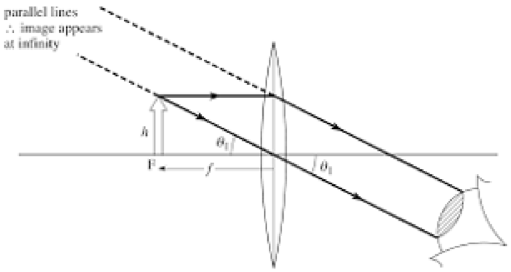
- **When final image is formed at infinity i.e. for normal adjustment :**

  i.e v = infinity and hence u= f

  Using the conditions in equation (iv) we get

  ; $m_\theta = \frac{D}{f}$ ......(vii)

  This is the minimum angular magnification by mgnifying glass .



(Ray diagram of simple microscope for normal setting)

- From expressions (iv) and (vii) it is clear that , to get more angular magnification , focal length of the lens should be smller .

Numerical : A magnifying glass of focal length 10 cm is kept in front of an object at a distance 8 cm

(a) Calculate the linear and angular magnification produced by the lens .

(b) When will be the linear and angular magnification be equal .

(c) Find the maximum and minimum angular magnification produced by the lens .

Solution : (a) $m = \frac{v}{u} = \frac{f}{f + (-u)} = \frac{10cm}{(10-8)cm} = 5$

$$m_\theta = \frac{D}{u} = \frac{25cm}{8cm} = 3.125 \ .$$

(b)When final image is produced at minimum distance of distinct vision then both linear and angular magnification be equal .

(c) Angular magnification will be maximum when final image is at D .

$$(m_\theta)_{max.} = 1 + \frac{D}{f} = 1 + \frac{25}{10} = 3.5$$

Angular magnification will be minimum when final image is at infinity .

$$(m_\theta)_{min.} = \frac{D}{f} = \frac{25}{10} = 3.5$$

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