Optical Instruments

Microscope

It is an optical instrument used to see very small objects. It's magnifying power is givenby

$$m = \frac{\text{Visual angle with instrument } (\beta)}{\text{Visual angle when object is placed at least distance of distinct vision } (\alpha)}$$

(1) **Simple microscope**

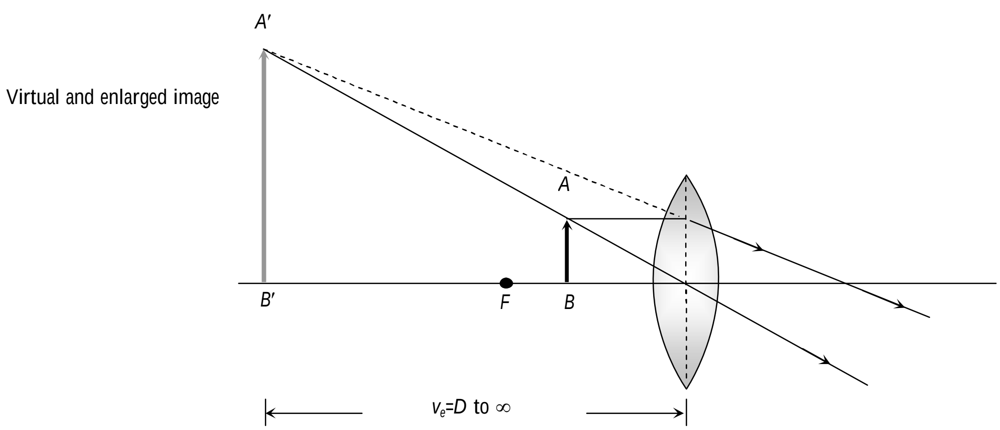
(i) It is a single convex lens of lesser focal length.

(ii) Also called magnifying glass or reading lens.

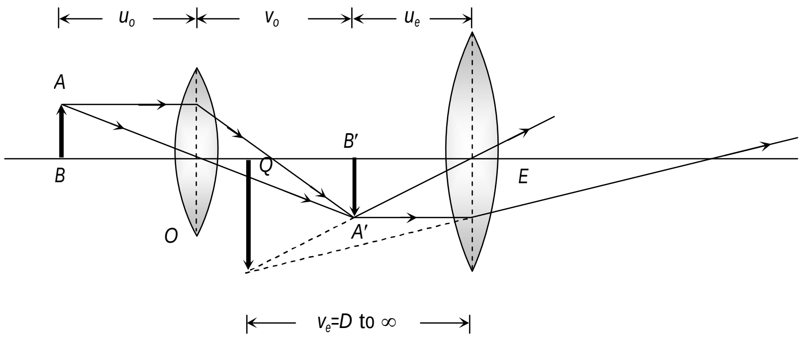
(iii) Magnification's, when final image is formed at D and ∞ (*i.e.* m_D and m_∞)

$m_D = \left(1 + \frac{D}{f}\right)_{\max}$ and $m_\infty = \left(\frac{D}{f}\right)_{\min}$

(iv) If lens is kept at a distance a from the eye then $m_D = 1 + \frac{D-a}{f}$ and $m_\infty = \frac{D-a}{f}$



(2) Compound microscope



(i) Consist of two converging lenses called objective and eye lens.

(ii) $f_{\text{eye lens}} > f_{\text{objective}}$ and $(\text{diameter})_{\text{eye lens}} > (\text{diameter})_{\text{objective}}$

(iii) Intermediate image is real and enlarged.

(iv) Final image is magnified, virtual and inverted.

(v) $u_o =$ Distance of object from objective (o), $v_o =$ Distance of image $(A'B')$ formed by objective from objective, $u_e =$ Distance of $A'B'$ from eye lens, v_e = Distance of final image from eye lens, f_o = Focal length of objective, f_e = Focal length of eye lens.

(vi) **Final image is formed at *D* :** Magnification $m_D = -\frac{v_o}{u_o}\left(1+\frac{D}{f_e}\right)$ and length of the microscope tube (distance between two lenses) is $L_D = v_o + u_e$.

Generally object is placed very near to the principal focus of the objective hence $u_o \cong f_o$. The eye piece is also of small focal length and the image formed by the objective is also very near to the eye piece.

So $v_o \cong L_D$, the length of the tube.

Hence, we can write $m_D = \frac{-L}{f_o}\left(1+\frac{D}{f_e}\right)$

(vii) **Final image is formed at ∞ :** Magnification

$m_\infty = -\frac{v_0}{u_0}.\frac{D}{f_e}$ and length of tube $L_\infty = v_0 + f_e$

In terms of length $m_\infty = \frac{(L_\infty - f_o - f_e)D}{f_o f_e}$

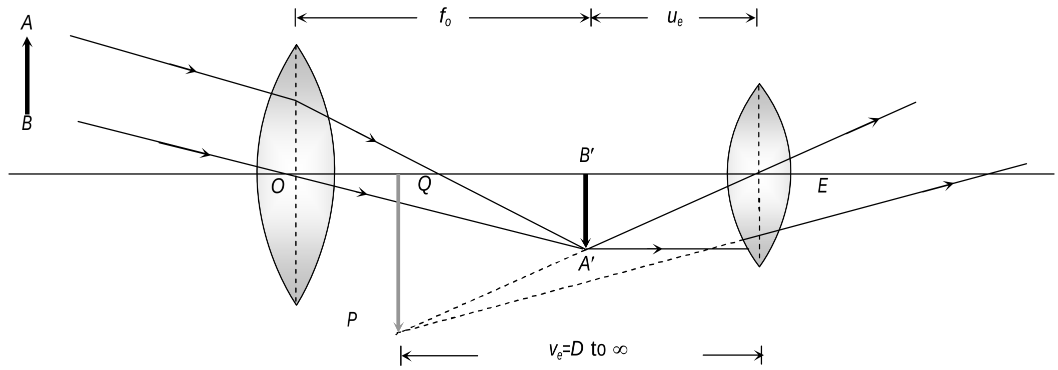
(viii) For large magnification of the compound microscope, both f_o and f_e should be small.

(ix) If the length of the tube of microscope increases, then its magnifying power increases.

(x) The magnifying power of the compound microscope may be expressed as $M = m_o \times m_e$; where m_o is the magnification of the objective and m_e is magnifying power of eye piece.

Astronomical Telescope (Refracting Type)

By astronomical telescope heavenly bodies are seen.



(1) $f_{\text{objective}} > f_{\text{eyelens}}$ and $d_{\text{objective}} > d_{\text{eye lens}}$.

(2) Intermediate image is real, inverted and small.

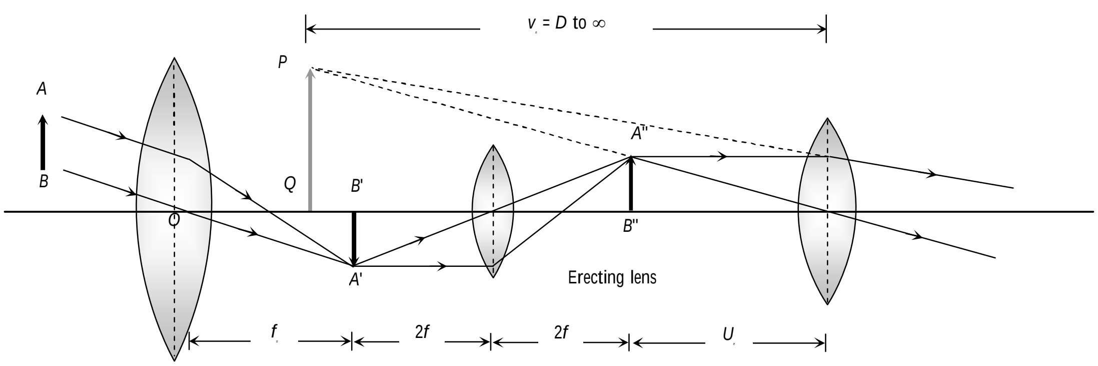
(3) Final image is virtual, inverted and small.

(4) Magnification : $m_D = -\frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$ and $m_\infty = -\frac{f_o}{f_e}$

(5) Length : $L_D = f_0 + u_e$ and $L_\infty = f_0 + f_e$

Terrestrial Telescope

It is used to see far off object on the earth.



(1) It consists of three converging lens : objective, eye lens and erecting lens.

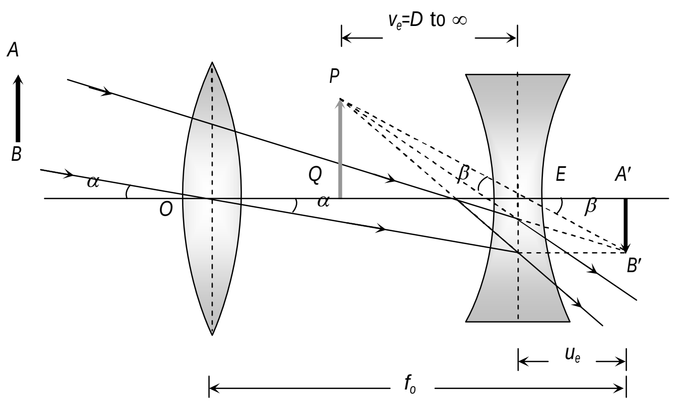
(2) It's final image is virtual, erect and smaller.

(3) Magnification : $m_D = \frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$ and $m_\infty = \frac{f_0}{f_e}$

(4) Length : $L_D = f_0 + 4f + u_e$ and $L_\infty = f_0 + 4f + f_e$

Galilean Telescope

It is also type of terrestrial telescope but of much smaller field of view.



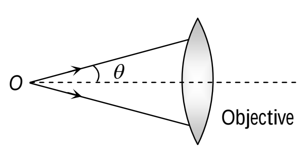
(1) Objective is a converging lens while eye lens is diverging lens.

(2) Magnification : $m_D = \frac{f_0}{f_e}\left(1-\frac{f_e}{D}\right)$ and $m_\infty = \frac{f_0}{f_e}$

(3) Length : $L_D = f_0 - u_e$ and $L_\infty = f_0 - f_e$

Resolving Limit and Resolving Power

(1) **Microscope :** In reference to a microscope, the minimum distance between two lines at which they are just distinct is called Resolving limit (*RL*) and it's reciprocal is called Resolving power (*RP*)



$R.L. = \frac{\lambda}{2\mu \sin\theta}$ and $R.P. = \frac{2\mu \sin\theta}{\lambda} \Rightarrow R.P. \propto \frac{1}{\lambda}$

λ = Wavelength of light used to illuminate the object,

μ = Refractive index of the medium between object and objective,

θ = Half angle of the cone of light from the point object, $\mu \sin\theta$ = Numerical aperture.

(2) **Telescope :** Smallest angular separations ($d\theta$) between two distant objects, whose images are separated in the telescope is called resolving limit. So resolving limit $d\theta = \frac{1.22\lambda}{a}$

and resolving power $(RP) = \frac{1}{d\theta} = \frac{a}{1.22\lambda} \Rightarrow R.P. \propto \frac{1}{\lambda}$ where a = aperture of objective.