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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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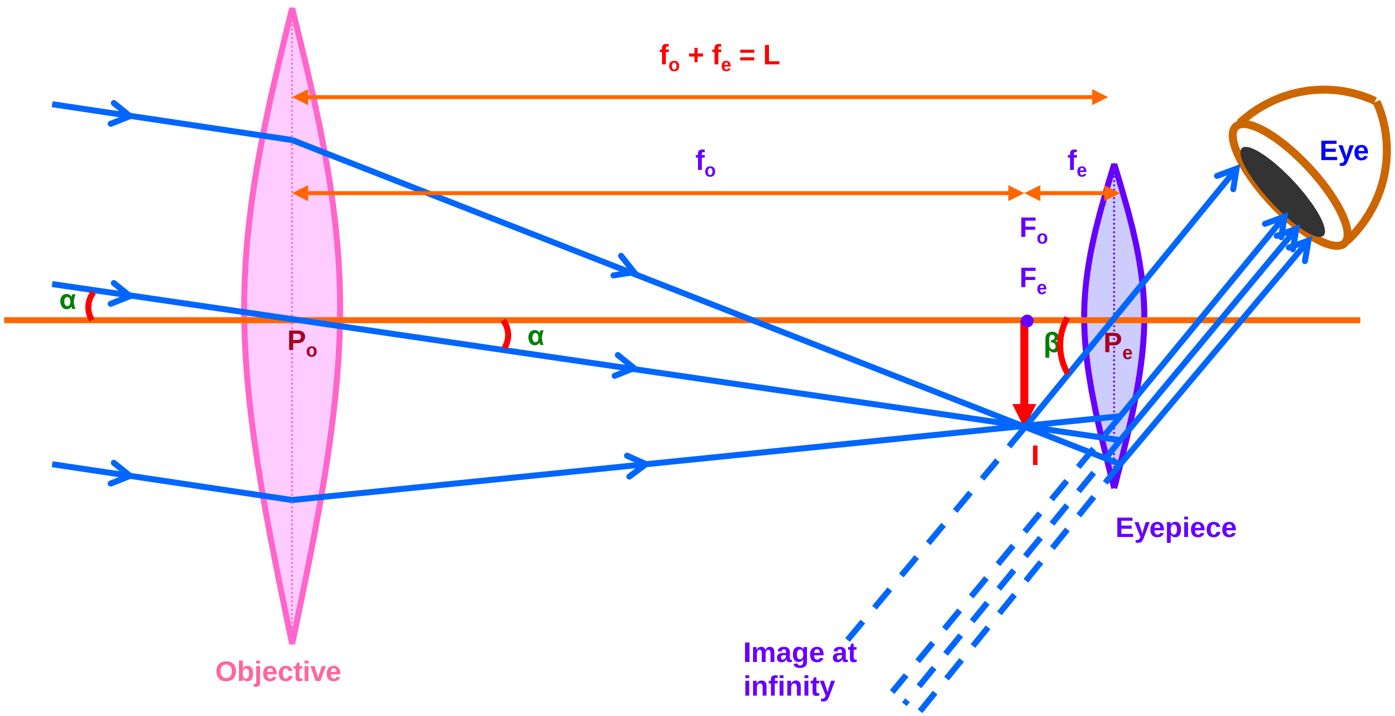
Astronomical Telescope: (Image formed at infinity – Normal Adjustment)



Focal length of the objective is much greater than that of the eyepiece.

Aperture of the objective is also large to allow more light to pass through it.

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Astronomical Telescope: (Image formed at infinity – Normal Adjustment)

Angular magnification or Magnifying power of a telescope in normal adjustment is the ratio of the angle subtended by the image at the eye as seen through the telescope to the angle subtended by the object as seen directly, when both the object and the image are at infinity.

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

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

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

$$M = \frac{F_e I}{P_e F_e} \Big/ \frac{F_e I}{P_o F_e}$$

$$M = \frac{-I}{-f_e} \Big/ \frac{-I}{f_o}$$

$$M = \frac{-f_o}{f_e}$$

($f_o + f_e = L$ is called the length of the telescope in normal adjustment).

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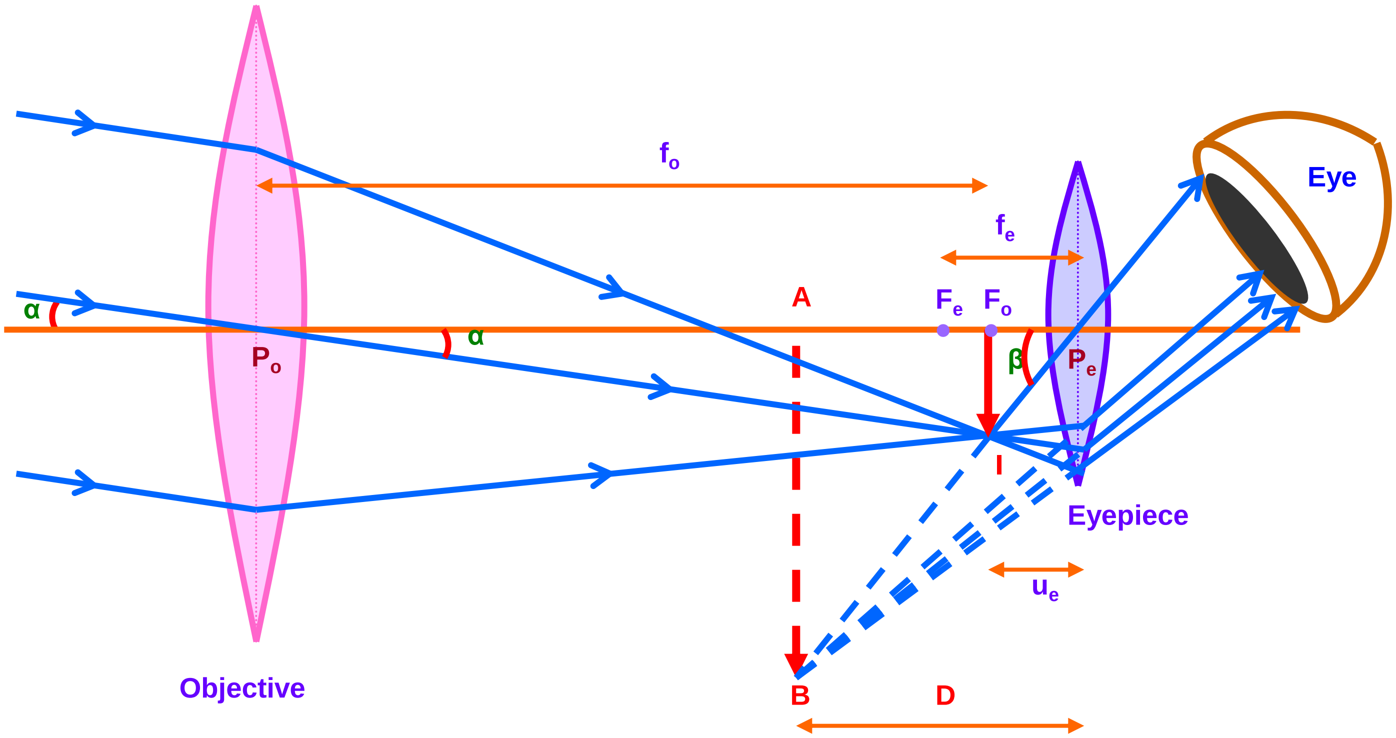
Astronomical Telescope: (Image formed at LDDV)



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Astronomical Telescope: (Image formed at LDDV)

Angular magnification or magnifying power of a telescope in this case is defined as the ratio of the angle β subtended at the eye by the final image formed at the least distance of distinct vision to the angle α subtended at the eye by the object lying at infinity when seen directly.

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

Since angles are small, α = tan α and β = tan β

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

$$M = \frac{F_o I}{P_e F_o} / \frac{F_o I}{P_o F_o}$$

$$M = \frac{P_o F_o}{P_e F_o} \quad \text{or} \quad M = \frac{+ f_o}{- u_e}$$

Lens Equation

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

$$\frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f_e}$$

$$\text{or} \quad \frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D}$$

Multiplying by f_o on both sides and rearranging, we get

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

Clearly focal length of objective must be greater than that of the eyepiece for larger magnifying power.

Also, it is to be noted that in this case M is larger than that in normal adjustment position.

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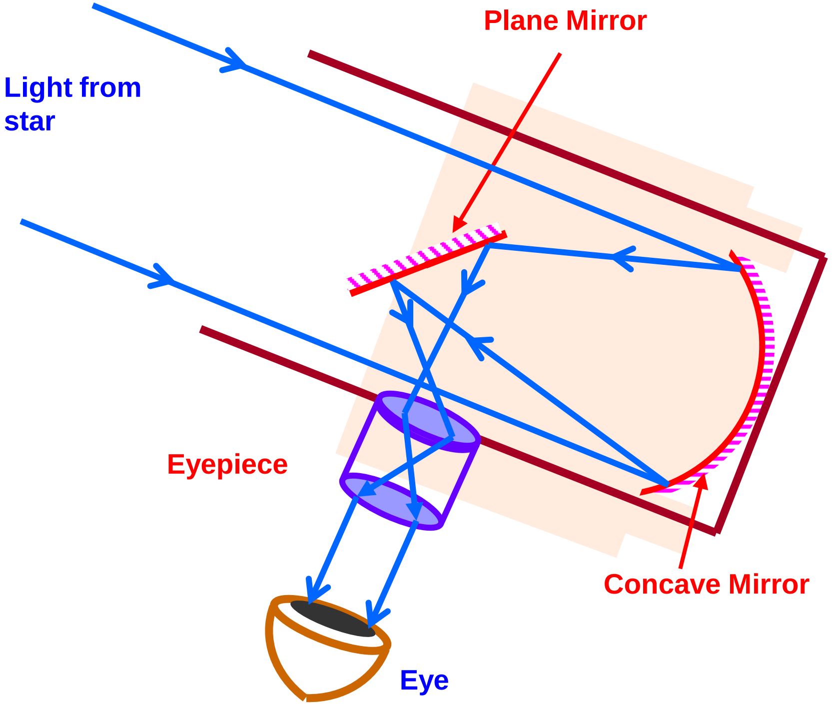
Newtonian Telescope: (Reflecting Type)



Magnifying Power:

$$M = \frac{f_o}{f_e}$$

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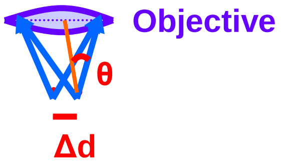
Resolving Power of a Microscope:

The resolving power of a microscope is defined as the reciprocal of the distance between two objects which can be just resolved when seen through the microscope.

$$\text{Resolving Power} = \frac{1}{\Delta d} = \boxed{\frac{2\,\mu \sin\theta}{\lambda}}$$



Resolving power depends on

i) wavelength λ,

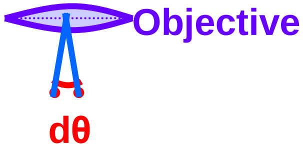
ii) refractive index of the medium between the object and the objective and

iii) half angle of the cone of light from one of the objects θ.

Resolving Power of a Microscope:

The resolving power of a telescope is defined as the reciprocal of the smallest angular separation between two distant objects whose images are seen separately.

$$\text{Resolving Power} = \frac{1}{d\theta} = \boxed{\frac{a}{1.22\,\lambda}}$$



Resolving power depends on i) wavelength λ, ii) diameter of the objective a.

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Resolving Power of a Microscope:

- **Difference between objective and eye piece of a microscope :**

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

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Numericals : (a) A giant refracting telescope at an observatory has an objective lens of focal length 15m . If eye piece lens has focal length 1.0 cm , then what is the angular magnification ?

(b)If this telescope is used to view moon with diameter 3.48 x 10^6 m orbiting earth in circular orbit of radius 3.8 x 10^8 m, then find the diametre of the image of moon through the objective lens .

(NCERT)

Solution : (a) $m_\theta = \frac{f_O}{f_E} = \frac{15m}{1.0cm} = 1500$

(b)As angular size of moon at objective = agular size of image of moon through objective

$$\Rightarrow \frac{\text{diametre of moon}}{\text{distance of moon}} = \frac{\text{diametre of image of moon}}{\text{image distance i.e. focal length of objective}}$$

$$\Rightarrow \text{diametre of image of moon} = \frac{\text{diametre of moon}}{\text{distance of moon}} \times f_O$$

$$= \frac{3.48 \times 10^6 m}{3.8 \times 10^8 m} \times 15m = 13.74 \times 10^{-2} m = 13.74 cm$$

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Numericals : A telescope has objective lens of focal length 140cm and eye piece lens of focal length 5.0 cm . Calculate its magnifying power and tube length if (a) final image at minimum distance of distinct vision and (b) final image at infinity .
(NCERT)

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Numericals : A telescope has objective lens of focal length 140cm and eye piece lens of focal length 5.0 cm . Calculate its magnifying power and tube length if (a) final image at minimum distance of distinct vision and (b) final image at infinity .
(NCERT)

Solution : (a) $m_\theta = \frac{f_O}{f_E} = \frac{140\,cm}{5.0cm} = 28$

And $L = f_O + f_E = 140\,cm + 5.0cm = 145cm$

(b) $m_\theta = \frac{f_O}{f_E}\left(1+\frac{f_E}{D}\right) = \frac{140cm}{5.0cm}\left(1+\frac{5.0cm}{25cm}\right) = 28\times 1.2 = 33.6$

And $L = f_O + \frac{f_E D}{f_E + D} = 140cm + \frac{5.0cm\times 25cm}{5.0cm + 25cm} = 144.17cm$

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Question: Some lenses are given with their specifications as shown in the table. Which lens will you prefer as objective and eye piece of (a) a telescope (b) compound microscope .

Explin the cause .

Lenses	**Focal length (in cm)**	**Aperature (in cm)**
L_1	1.0	5.0
L_2	2.0	8.0
L_3	10.0	20.0
L_4	100	80

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Question: Some lenses are given with their specifications as shown in the table. Which lens will you prefer as objective and eye piece of (a) a telescope (b) compound microscope .

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L_3	10.0	20.0
L_4	100	80

Answer : (a) For telescope , focal length and aperature of objective lens are very large and of eye piece are very small . So L_4 is preferred as objective lens and L_1 is preferred as eye piece lens .

(b) For compound microscope , focal length and aperature of objective lens are very small and of eye piece are comparatively larger but not very large . Because to have more magnification focal lengths of both objective and eyepiece of compound microscope are reuired to be small (As magnification is ; $m_\theta = \dfrac{L}{f_O}\left(1+\dfrac{D}{f_E}\right)$. So L_1 is preferred as objective lens and L_2 is preferred as eye piece lens .

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