COMPOUND MICROSCOPE AND TELESCOPE

Compound Microscope

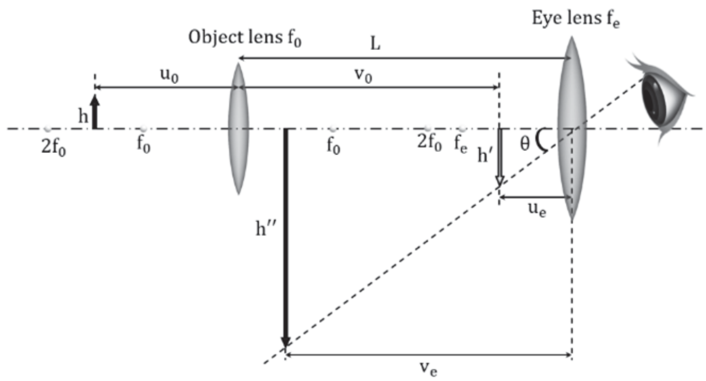
Objective lens: Near the object.

Eyepiece: Near the eye.

u_0: The distance of the object from the objective lens

v_0: The distance of the image formed by the objective lens in relation to itself

u_e: The distance of the image formed by the objective lens in relation to the eyepiece



The image produced by the objective lens serves as the object for the eyepiece, and it's crucial for magnification that this image falls between the focus and the optical center of the eyepiece.

Using the lens, the visual angle becomes,

$$\tan\theta = \theta \approx \frac{h'}{u_e}$$

Without using the lens, the visual angle becomes,

$$\theta = \frac{h'}{d}$$

Therefore, the angular magnification or the magnifying power becomes,

$$M\cdot P = \frac{-\theta}{\theta_0}$$

$$M\cdot P = \frac{-h'}{u_e\cdot h'}D$$

Given that h and h represent the height of the object and image with respect to the objective lens. $\frac{h'}{h}$ represents the lateral magnification for the objective lens, and $\frac{D}{u_e}$ denotes the magnifying power of the eyepiece.

Alternatively, the lateral magnification for the objective lens can be expressed as:

$$\frac{h'}{h} = \frac{-v_0}{-u_0} \Rightarrow \frac{h'}{h} = \frac{v_0}{u_0}$$

So, the angular magnification for the compound microscope is:

$$\text{M.P.} = -\frac{v_0}{u_0}\times\frac{D}{u_e}$$

Minimum Magnifying Power

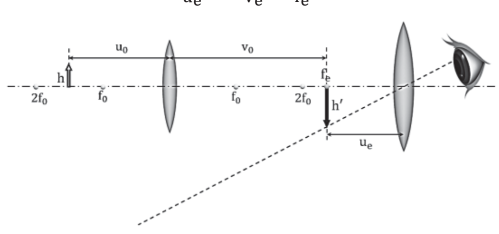
Normal State

Applying thin lens formula for eyepiece,

$$-\frac{1}{v_e}+\frac{1}{u_e}=\frac{1}{f_e}$$

$$[\because u = -u_e, v = -v_e \text{ and } f = f_e]$$

$$\frac{1}{u_e} = [\frac{1}{v_e}+\frac{1}{f_e}]$$



For normal state, $v_e = \infty \Rightarrow u_e = f_e$

Therefore, the magnifying power becomes,

$$M.P. = -\frac{v_0}{u_0} \times \frac{D}{u_e}$$

$$u_e = f_e$$

$$\text{Minimum M.P.} = -\frac{v_0}{u_0} \times \frac{D}{f_e}$$

Minimum Magnifying Power:

Normal State

$\triangle$ ABC and $\triangle$ ADE are similar triangle. Thus, we can write:

$$\frac{DE}{BC} = \frac{AE}{AC} \Rightarrow \frac{h'}{h} = \frac{L}{f_0}$$

L represents the distance between the second focus of the objective and the first focus of the eyepiece.

Hence, the magnification power is obtained as

$$M \cdot P = -\frac{v_0}{u_0} \times \frac{D}{fe}.$$

$$= -\left[\frac{h'}{h}\right]\frac{D}{fe}$$

$$= -\frac{L}{f_0} \cdot \frac{D}{f_e}$$

$$\text{Minimum M. P.} = -\frac{L}{f_0} \times \frac{D}{f_e}$$

To enhance the magnification power, both the focal lengths of the objective lens and the eyepiece should be minimized.

Maximum Magnifying Power

$$v_e = D$$

Applying thin lens formula for eyepiece:

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

$$[\because u = -u_e, v = -v_e = -D \text{and } f = f_e]$$

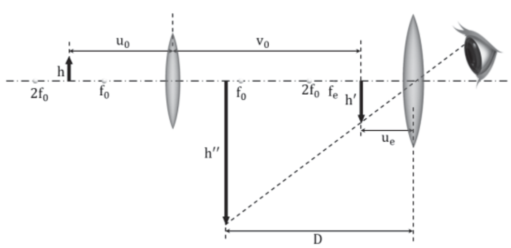
$$\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D}$$

Therefore, the magnifying power becomes,

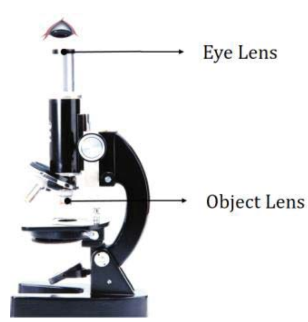
$$M.P. = -\frac{v_0}{u_0} \times \frac{D}{u_e} \Rightarrow M.P. = -\frac{v_0 D}{u_0} \times \left(\frac{1}{f_e} + \frac{1}{D}\right)$$

$$\text{Maximum M.P.} = -\frac{v_0}{u_0} \times \left(1 + \frac{D}{f_e}\right)$$

Compound Microscope



Real Set Up



Simple Microscope vs Compound Microscope

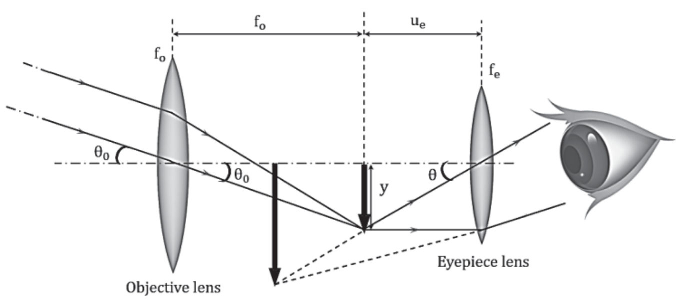
Simple Microscope	Compound Microscope
$(\text{M. P.})_{\text{min}} = \frac{D}{f}$	$(\text{M.P.})_{\text{min}} = -\frac{v_0}{u_0} \times \frac{D}{f_e} = -\frac{L}{f_0} \cdot \frac{D}{f_e}$
$(\text{M.P.})_{\text{min}} = -\frac{v_0}{u_0} \times \frac{D}{f_e} = -\frac{L}{f_0} \cdot \frac{D}{f_e}$	$(\text{M. P.})_{\text{max}} = -\frac{v_0}{u_0} \times (1 + \frac{D}{f_e})$

Telescope

Telescope
- Refracting Telescope — Lenses are used
  - Astronomical Telescope
  - Terrestrial Telescope
- Reflecting Telescope — Converging mirror Are used

Astronomical Telescope
Magnifying power

The telescope serves to enhance the angular size of remote objects, such as stars or planets.
Objective: In the direction of the object (with a longer focal length and larger aperture).
Eyepiece: Near the eye (with a shorter focal length and smaller aperture).
Due to the incident ray on the objective lens being a parallel beam of light but not parallel to the principal axis, the image produced by the objective lens will appear at the focal plane of the object.

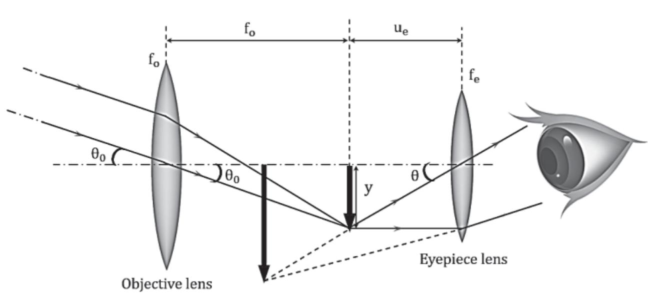


The angle subtended by the object (θ_0) at the optical center of the objective.$\frac{y}{f_0}$
The angle subtended by the final image (θ) at the optical center of the eyepiece.$\frac{y}{u_0}$
Therefore the magnifying power of telescope is given by

$$\text{M.P.} = \frac{\theta}{\theta_0} = \frac{l}{u_e} \times \frac{f_0}{l}$$

$$\text{M.P.} = -\frac{f_o}{u_e}$$

(The – ve sign signifies0 the final image is inverted w.r.t the object)



Magnifying Power : Minimum

Utilizing the lens formula for the eyepiece:

$$\frac{1}{-ve}+\frac{1}{u_e}=\frac{1}{f_e}$$

$$\left[\begin{matrix} u=-u_e \\ v=-v_e \end{matrix}\right]$$

$$\frac{1}{ue}=\frac{1}{fe}+\frac{1}{ve}$$

Hence the magnifying power become

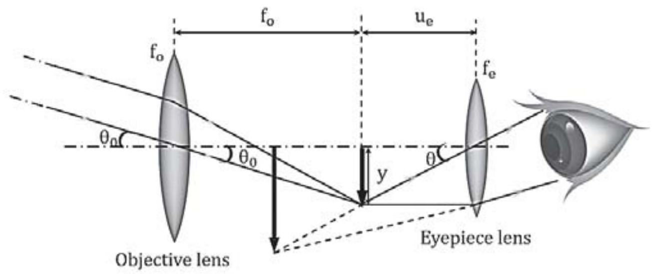
$$\text{M.P.} = -\frac{f_o}{u_e}=-f_0\left[\frac{1}{v_e}+\frac{1}{f_e}\right]$$

For minimum magnifying power final image is formed at infinity i.e. $v_e \to \infty$

Therefore minimum magnifying power is.

$$M \cdot P_{min} = -\frac{f_o}{f_e}$$

$$u_e = f_e$$



Magnifying Power: Maximum

We have:

$$\frac{1}{ue}=\frac{1}{f_e}+\frac{1}{ve}$$

In this case final image formed at the least distance of district vision, thus.

$$|v_e| = D$$

Therefore the magnifying power become.

$$M \cdot P = -\frac{f_o}{u_e}$$

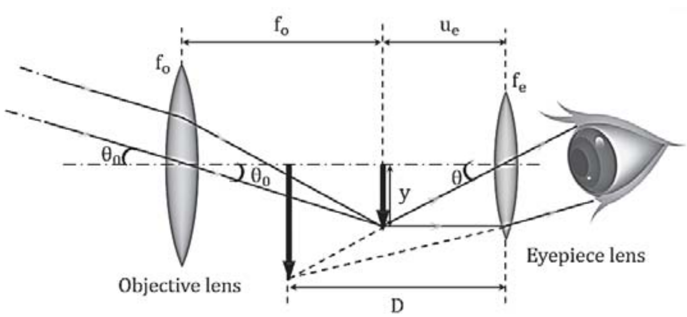
$$\Downarrow$$

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

$$\Downarrow$$

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

To increase the magnifying power, the focal length of objective lens should be large and that of the eyepiece should be small.



Tube length

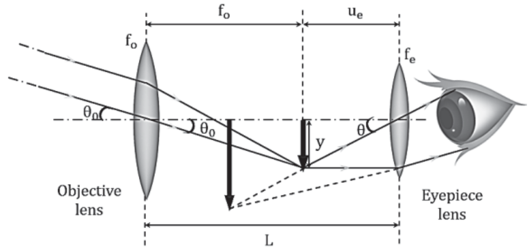
The length of the telescope tube is determined by

$$L = f_o + u_e$$

Maximum value of tube length

Maximum possible value of u_e is $U_{max} = f_e$

Maximum value of L is, $L_{max} = f_o + f_e$



Minimum value of tube length:

In this case the required condition is $v_e = D$

Therefore, $u = -u_e, v = -v_e = -D$ and $f = f_e$ applying then lens formula for eyepiece we get.

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

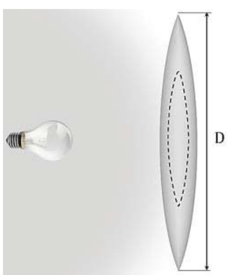
$$\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D}$$

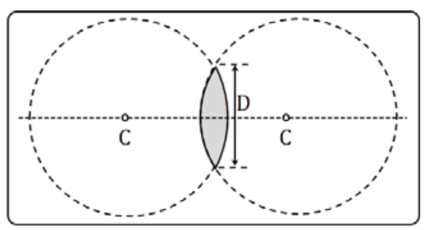
$$u_e = \frac{f_e D}{f_e + D}$$

Hence minimum value of L is, $L_{min} = f_o + \frac{f_e D}{f_e + D}$

In order to capture the maximum amount of light from distant objects, the aperture of the objective lens should be sizable.

Tube length (L)





For decent intensity of light, $D_o > D_e$

$R_0 \uparrow f \uparrow$

$f_o > f_e$

In general case, $f_o \ggg f_e$

For minimum magnifying power we have:

$$u_e = f_e$$

Thus, tube length becomes:

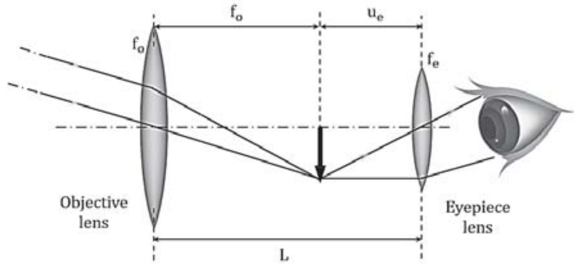
$$L = f_o + u_e \Rightarrow L = f_o + f_e$$

In general case, $f_o \ggg f_e$

Therefore, $L \cong f_o$

Formula of minimum magnifying power is approximately written as follows:

$$M \cdot P = -\frac{f_0}{f_e} \approx -\frac{h}{f_e}. \Rightarrow \text{Normal adjustment}$$

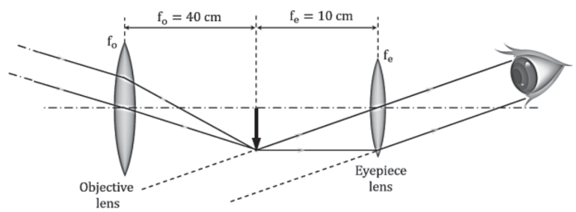


Ex. An astronomical telescope has an objective lens of focal length 40 cm and eyepiece lens of focal length 10 cm. Find the minimum magnifying power and tube length of telescope.

Sol. Given:

The focal length of the objective lens: $f_o = +40$ cm

The focal length of the eyepiece: $f_e = +10$ cm



Minimum magnifying power is given by,

$$M \cdot P_{min} = -\frac{f_o}{f_e} = \frac{-40}{+10} = -4$$

The tube length of the telescope is given by,

$$L = f_o + f_e = 40 + 10 = 50\text{cm}$$

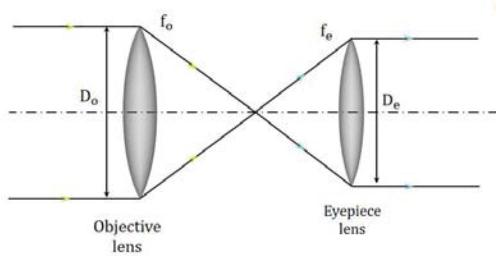
$$M.P_{min} = -4$$

$$L = 50 \text{ cm}$$

Ex. Aperture of an objective and eyepiece lens are D_o and D_e respectively of object I splaced at infinity and its final image is formed at infinity then find the minimum magnifying power of an astronomical telescope.

Sol. Since the and the final image both are formed at infinity the ray diagram for the problem will be as shown in the adjacent figure and from the figure we can write.

$$\frac{f_o}{D_o} = \frac{f_e}{D_e}$$



The minimum magnifying power of an astronomical telescope becomes.

$$M \cdot P_{min} = -\frac{f_o}{f_e} = \frac{-D_0}{D_e}$$

$$M \cdot P_{min} = -\frac{D_o}{D_e}$$

Terrestrial Telescope

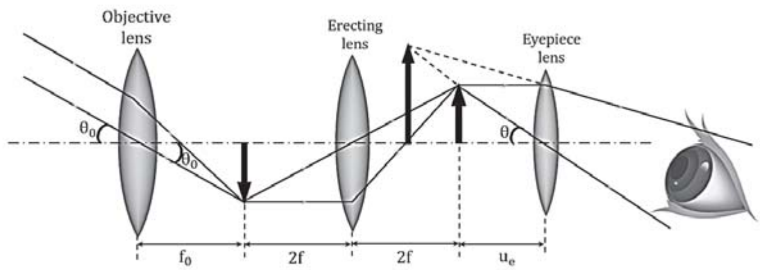
Employing an astronomical telescope for observation.

Outer – space object Terrestrial Object

The astronomical telescope produces an inverted image, thus making it unsuitable for viewing objects on Earth.

A convex lens exhibits a characteristic: When an object is positioned at twice the focal length (2f), an inverted image is created at twice the focal length on the opposite side of the object.

Therefore, in the configuration of an astronomical telescope, a convex lens is placed between the objective and the eyepiece, causing it to produce an erect image.



The magnification capability and the length of the telescope tube will be:

$$M.P = -\frac{f_0}{u_e}$$

$$L = f_o + 4f + u_e$$

[f is the focal length of the erecting lens]

Used to see erect images of distant earthly objects.

Astronomical telescope ⇒ Inverted image

Terrestrial telescope ⇒ Erect image

Length is much larger than the astronomical telescope.

Extra reflection at erecting lens result in decrease in intensity of final image.