1.3.Optical Devices

- There are 3 optical devices that extend human vision.
- It is **magnifier, compound microscope** and **telescope**.

2.3. Angular Magnification (magnifying power) M_a

- The angular magnification of an optical device is defined

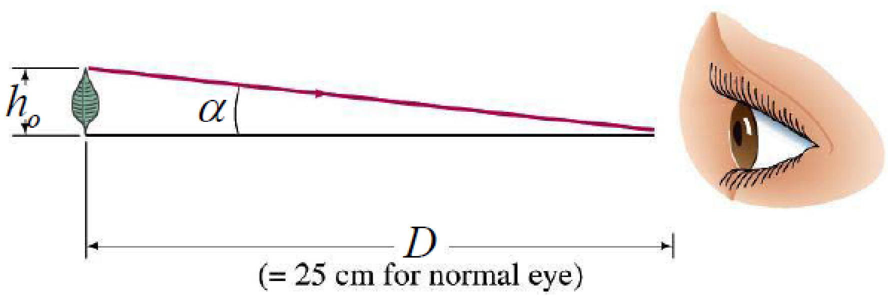
  as the ratio of the angle subtended at the eye by the image , β to the angle subtended at the unaided eye by the object (without lens), α.

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

- In order to determine the angle α it is necessary to specify the position of the object.
  - For **microscope**, the best object position is at the **near point**.
  - For telescope, the object position is not meaningful because the telescope is used for viewing distant object.
- Near point is defined as *the nearest point at which an object is seen most clearly by the human eye.*
  - The distance between the near point to the eye is **25 cm** and is known as distance of distinct vision (D).

3.3.Magnifier

- It also known as **magnifying glass** or **simple microscope**.
- It is an optical device used for viewing near object.
- It consists of single converging (biconvex) lens.
- Suppose a leaf is viewed at near point of the human eye as shown in figure below.



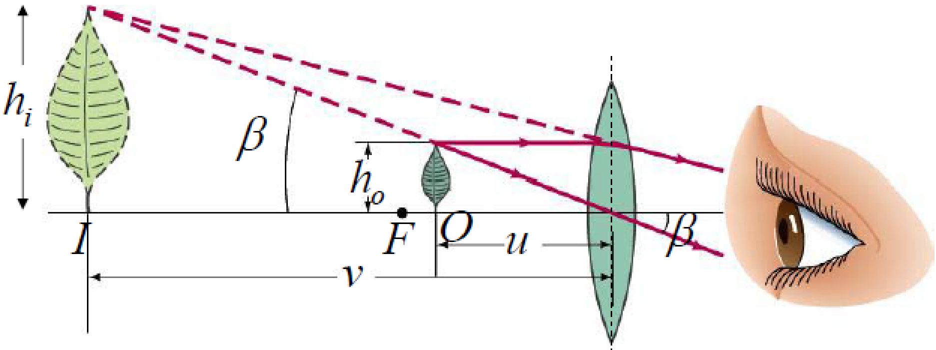
- From the figure,

$$\tan\alpha = \frac{h_o}{D}$$

By making small angle approximation, we get

$$\tan\alpha \approx \alpha = \frac{h_o}{D}$$

- To increase the apparent size of the leaf, a converging lens can be placed in front of the eye as shown in figure below.



- The apparent size of the leaf is **maximum** when the image is at the near point where

$$v = -D = -25\ cm$$

- From the figure above,

$$\tan\beta = \frac{h_i}{D} = \frac{h_o}{u}$$

By making small angle approximation, we get

$$\tan\beta \approx \beta = \frac{h_i}{D} = \frac{h_o}{u}$$

The properties of the image are
  - Virtual, upright and magnified ⟹ $u < f$

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- The angular magnification in terms of D and f can be evaluated by derivation below.
  - By applying the thin lens formula,

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \quad \text{where } v = -D$$

$$u = \frac{Df}{D+f} \quad \text{......(1)}$$

  - From the definition of angular magnification,

$$M_a = \frac{\beta}{\alpha} = \frac{\left(\frac{h_o}{u}\right)}{\left(\frac{h_o}{D}\right)}$$

$$M_a = \frac{D}{u} \quad \text{......(2)}$$

  - By substituting eq. (1) into eq. (2), thus

$$M_a = \frac{D}{f} + 1$$

where
f : focal length
D : distance of distinct vision = 25 cm

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- The relationship between linear magnification, M with angular magnification, M_a
  - From the definition of angular magnification,

$$M_a = \frac{\beta}{\alpha} = \frac{\left(\frac{h_i}{D}\right)}{\left(\frac{h_o}{D}\right)}$$

then

$$M_a = \frac{h_i}{h_o} = M$$

- Note:
  - If the object placed at the focal point of the converging lens, the **image formed at infinity**. Thus

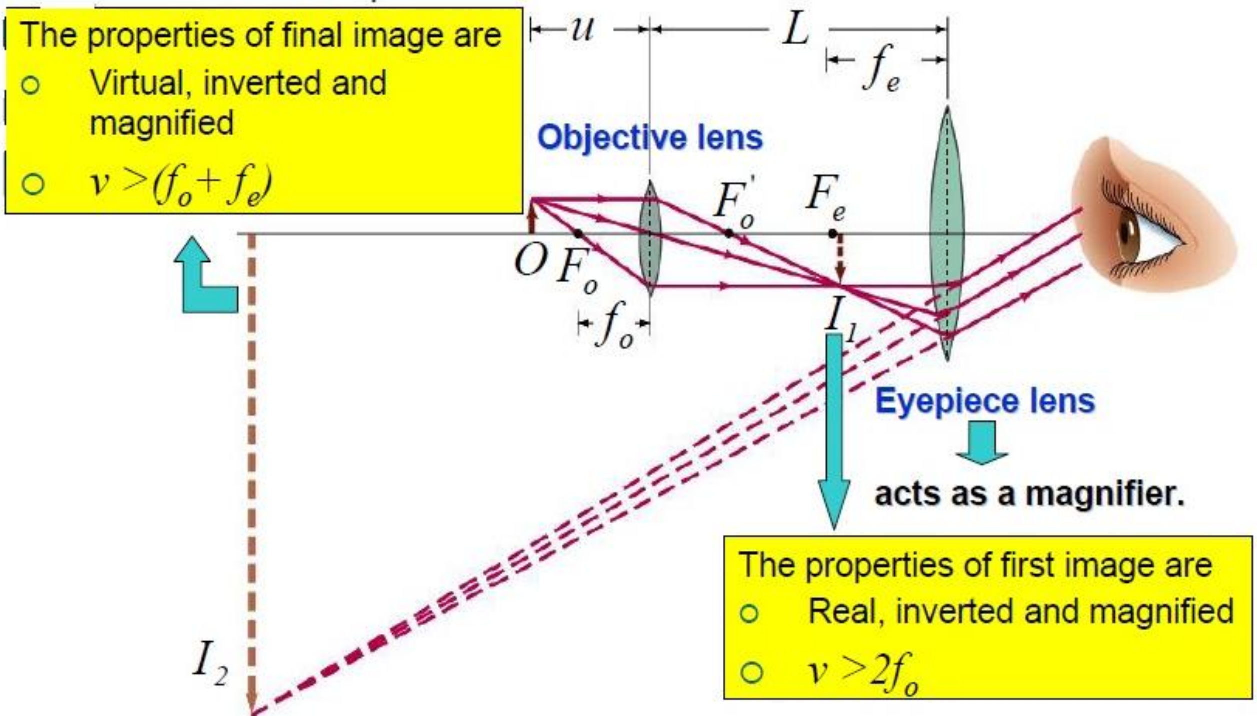
$$\beta = \frac{h_o}{f}$$

  - Therefore, since $M_a = \frac{\beta}{\alpha}$ then $M_a = \frac{\left(\frac{h_o}{f}\right)}{\left(\frac{h_o}{D}\right)}$ ⇒ $M_a = \frac{D}{f}$

The eye is relax.

3.3.Compound Microscope

- Because it makes use of two lenses, the magnifying power of the compound microscope is much greater than that of the magnifier.
- The two lenses are converging lens and is known as **objective lens** (close to the object) and **eyepiece lens** (close to the eye).
- The figure below shows the schematic diagram of the compound microscope.



- The properties of the compound microscope are
  - *The distance between two lenses,* $L > (f_o + f_e)$
  - $f_o < f_e$
  - *The final image is* I_2*.*
  - *The angular magnification formula is given by*

$$M_a = -\frac{L}{f_o}\left(\frac{D}{f_e}\right)$$

where

f_e : focal length of the eyepiece lens

f_o : focal length of the objective lens

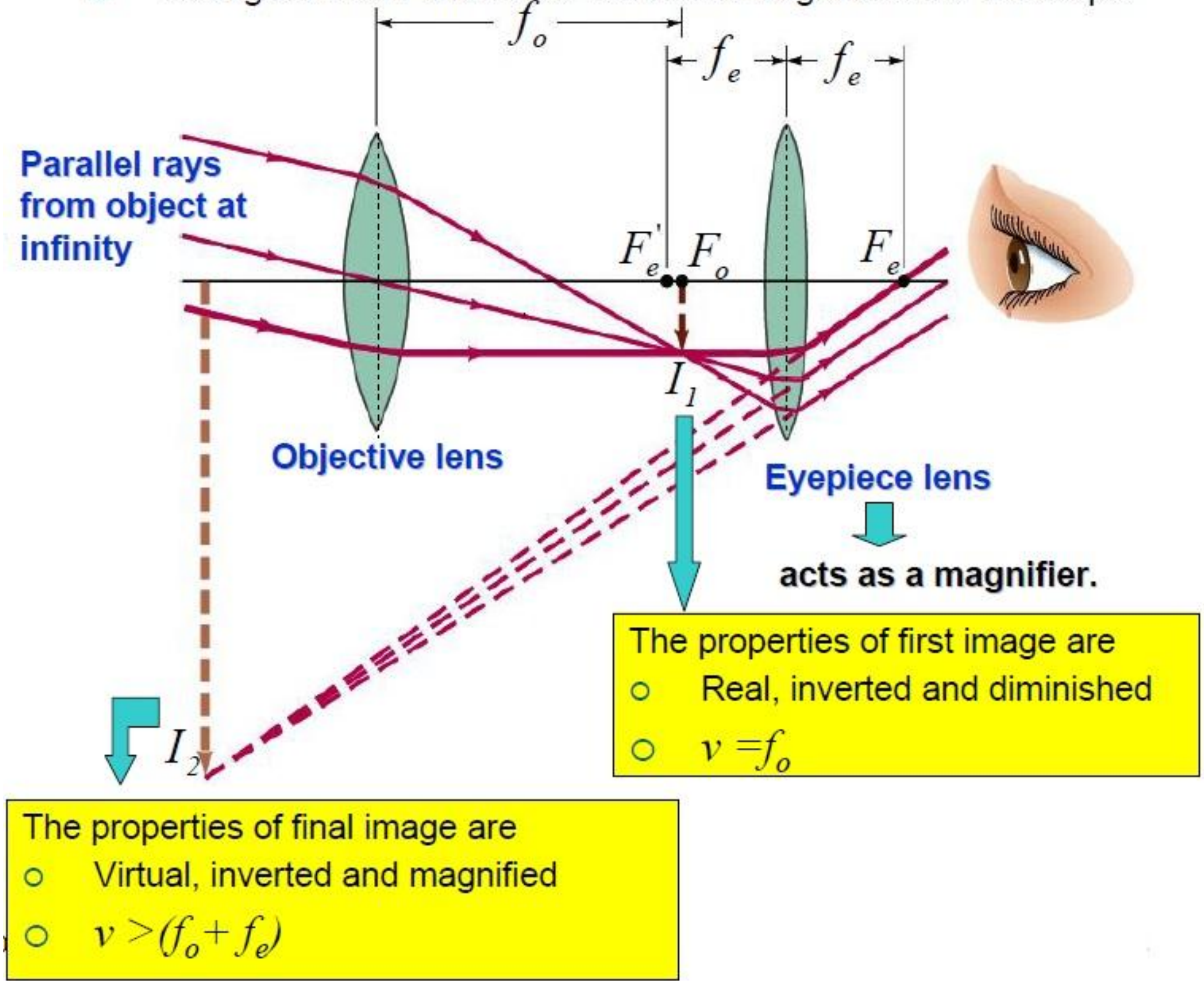
D : distance of distinct vision = 25 cm

The negative sign indicates that the image is inverted.

- It is used for viewing small objects that are very close to the objective lens.

4.3. Astronomical (refracting) Telescope

- This telescope consists of two converging lenses.
- Like compound microscope, the two lenses are **objective** and **eyepiece** lens.
- It is used to magnify objects that are very far away (considered to be at infinity).
- The figure below shows the schematic diagram of the telescope.



- The properties of the telescope are
  - *The distance between two lenses,* $L < (f_o + f_e)$
  - $f_o > f_e$
  - *The final image is* I_2.
  - *The angular magnification formula is given by*

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

The negative sign indicates that the image is inverted.