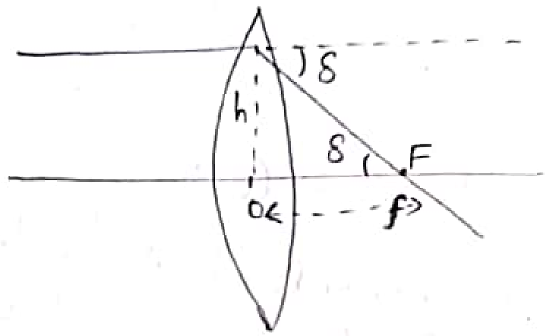
Power of a lens is a measure of convergence or divergence produced by a lens in the light falling on it. It is defined as the tangent of the angle by which it converges or diverges a beam of light falling at unit distance from optical centre.

$\tan \delta = \frac{h}{f}$

if $h = 1$; $\tan \delta = \frac{1}{f}$

or $\delta = \frac{1}{f}$ (for small values of δ).

$\therefore \; P = \frac{1}{f}$



SI unit of power of a lens is dioptre (D)

$1D = 1m^{-1}$.

Power of a lens is positive for a converging lens and negative for a diverging lens.

Combination of thin lenses in contact

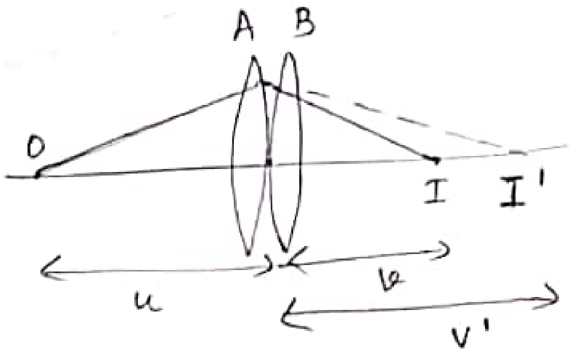
Consider two lenses A and B of focal length f_1 and f_2 placed in contact with each other. Let a point object 'O' be placed beyond the focus of lens A. 'A' produces an image at I'. Since image I' is real, it serves as a virtual object for the second lens B, producing the final image at I (Since the lenses are thin, optic centres are coincident).

For the image formed by first lens A,

$$\frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1} \quad \text{—(1)}$$

For the image formed by the second lens B,

$$\frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2} \quad \text{---(2)}$$



Add (1) and (2)

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$$

If the two lens system is considered equivalent to a single lens of focal length f, then

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\therefore \boxed{\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}}$$

* The above eqn is valid for any no. of lens. Hence the effective power of combination will be

$$\boxed{P = P_1 + P_2}$$

* The total magnification of the combination is

$$m = m_1 \times m_2 .$$

Dispersion by a prism

The phenomenon of splitting of light into its component colours is known as dispersion. The pattern of colour components of light is called the spectrum of light.

persion takes place because the refractive index of medium for different colours (wavelength) is different. For eg: when white light is incident on a prism, the bending of red component is least while it is most for violet. Equivalently, red light travels faster than violet light in a glass prism.

* A medium or material in which the refractive index (n) of the medium varies with the wavelength (λ) of the incident light, is called dispersive medium.
Eg: glass.
* while in non-dispersive medium like vacuum, different component colours (wavelength) travel with same speed.

[* The ref. index is related to the formula (Cauchy's formula)

$$n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \dots$$

where (A, B, C are Cauchy's constants)]

[* Rainbow is formed by refraction, internal reflection and dispersion of white light by the water droplets suspended in air].

Optical Instruments

(i) Simple microscope: A simple microscope consists of a converging lens of short focal length which is used for observing magnified image of tiny objects. Eg: magnifying lens used in palmistry, jewellers or watchmakers.

When the convex lens of focal length 'f' is held near the object AB, at a distance less than its focal length, such that $u \approx f$, an erect, virtual and magnified image $A'B'$ is formed on the same side of the object.

* When object is at f, image is formed at infinity
* When object is at a distance less than f, i.e. $u < f$, image formed is closer than infinity.
* The image formed is distinctly visible when it is formed at the near point of the eye (least distance of distinct vision $D \approx 25$ cm) as shown in fig(i)

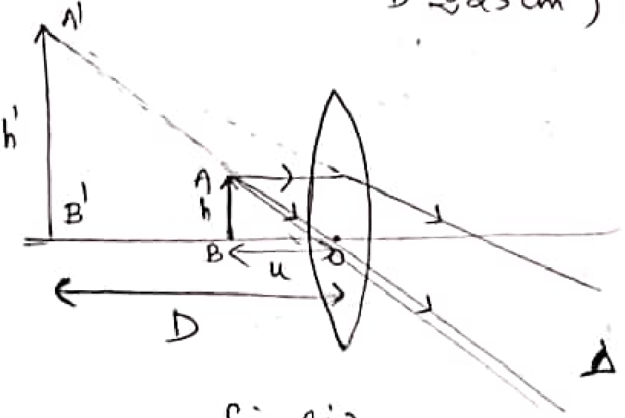


fig (i).

<u>Magnification</u> (image formed at D).

$$m = \frac{\text{Size of image}}{\text{Size of object}} = \frac{\text{Image distance}}{\text{Object distance}}$$

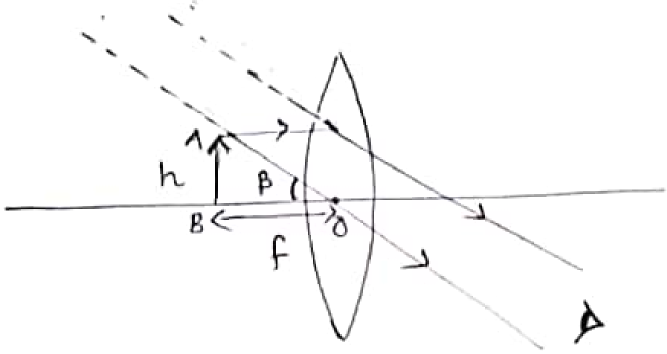
$$m = \frac{h'}{h} = \frac{v}{u} = v \times \frac{1}{u} = v \times \left[\frac{1}{v} - \frac{1}{f}\right]$$

$$= 1 - \frac{v}{f}$$

Applying sign convention, $v = -D$,

$$m = \frac{h'}{h} = \left[1 - \left(\frac{-D}{f}\right)\right] = 1 + \frac{D}{f}$$

Image formed at infinity



fig(ii)

fig (iii)

* Although the comfortable distance of viewing an image is at near point D, however it causes some strain on the eye. So the image A'B' formed at infinity is often considered more comfortable for viewing by the relaxed eye.

* when object is at f, image is formed at infinity.

* Angular magnification is defined as the ratio of the angle subtended by the image at the eye to the angle subtended by the object, if placed at D for comfortable viewing.

* If the size of the object is 'h', the maximum ∠le it can subtend at the eye when it is at near point D (without the lens) is α as shown in fig (iii).   ie $\tan\alpha = \frac{h}{D} \approx \alpha$

* Angle subtended by the image at eye when object is at $u = f$.

$$m = \frac{h'}{h} = \frac{v}{u} \quad \text{——(1)}$$

from (1) $h' = h \cdot \frac{v}{u}$.

$$\tan\beta = \frac{h'}{(-v)} = \frac{h \cdot v}{(-v)\,u} = \frac{h}{-u}$$

ie $\beta = \frac{h}{-u}$

$u = -f$

$$\therefore \quad \beta = \frac{h}{-(-f)} = \frac{h}{f}.$$

$$m = \beta/\alpha = \frac{K}{f} \times \frac{D}{K} = \frac{D}{f}$$

$$\boxed{m = \frac{D}{f}}$$

Com...
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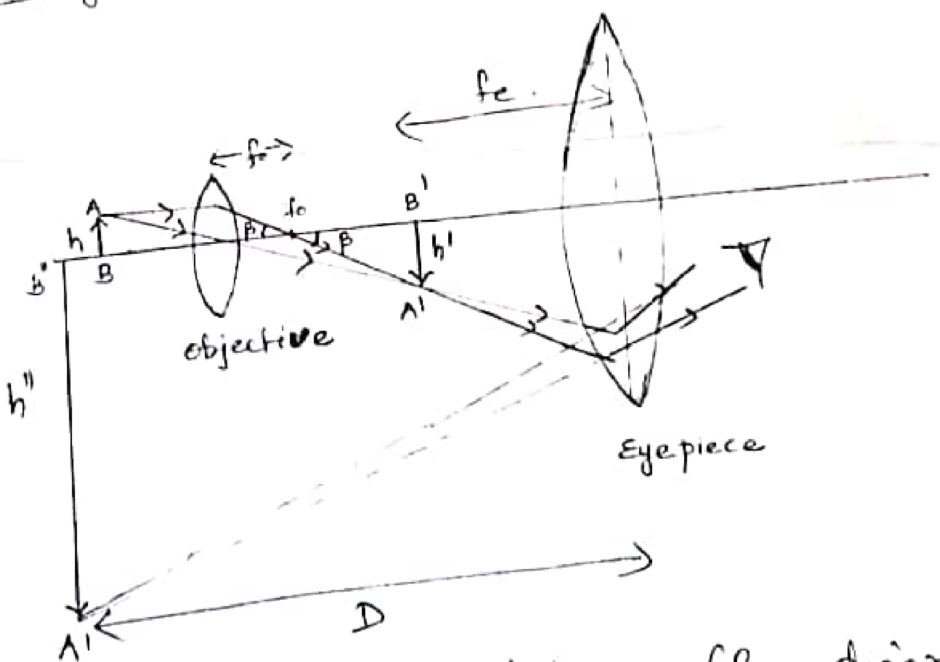
Scanned with CamScanner

Compound Microscope : It is an optical instrument used to see magnified image of small objects.

(Construction : It Consists of 2 convex lenses of short focal length arranged coaxially at the ends of two sliding metal tubes)

* objective is a convex lens of short focal length fo positioned near the object.
* Eyepiece (ocular) – is a convex lens of comparatively larger focal length fe and larger aperture such that (fe > fo) positioned near the eye.

when the final image is formed at the near point D.



Schematic diagram (Ray diagram) for the formation of image by a Compound microscope at D.

A compound microscope has 2 lenses one compounding the effect of other. The objective produces a real, inverted, magnified image which acts as a virtual object for the eyepiece and the final enlarged, virtual image.

telescope magnif... tan β is ... and ...

The linear magnification for objective, $m_o = \frac{h'}{h} = \frac{L}{f_o}$ $\left[\frac{h'}{L} = \frac{h}{f_o}\right.$ is ...

L is the distance b/w the second focal point of the objective and the first focal point of the eyepiece known as the tube length of the microscope.

As the final image is formed at the near point D, then magnification for eyepiece,

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

* when the final image is formed at infinity, use the result $m_e = \frac{D}{f_e}$.

∴ total magnification, $m = m_o \times m_e$

ie $\boxed{m = \frac{L}{f_o} \times \frac{D}{f_e}}$ (image formed at ∞)

or $\boxed{m = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)}$ (image formed at D)

* we can also use the formula, (for solving problems).

$$m = -\frac{v_o}{u_o}\left[1 + \frac{D}{f_e}\right]$$

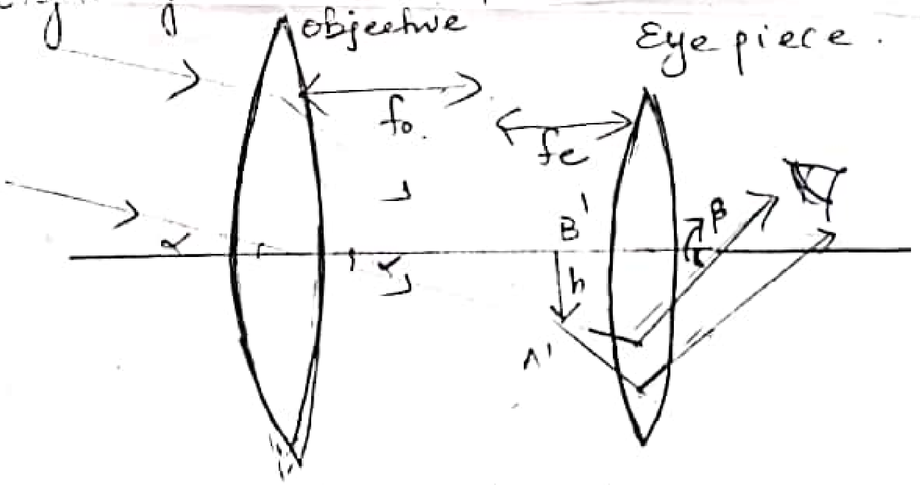
separation b/w lenses, $\boxed{d = v_o + f_e}$.

or $d = v_o + |u_e|$

Telescope : optical device used to provide angular magnification of distant objects. It has an objective and an eyepiece such that focal length of objective is greater than focal length of eyepiece ($f_o > f_e$) Light from a distant object enters the objective and a real image is formed at the second focal point inside the tube. The eye magnifies this image producing a final inverted image. The magnification is the ratio of angle subtended at the eye by the final image to the angle which the object subtends at the lens.

$$\text{ie} \quad m = \beta/\alpha \approx \frac{h}{f_e} \cdot \frac{f_o}{h} = \frac{f_o}{f_e}.$$

- tube length of the telescope is $L = f_o + f_e$.



Refracting telescope.

* Terrestrial telescopes have a pair of inverting lenses to make the final image erect.

* The resolving power of a telescope is the ability to observe two objects distinctly. It depends on its light gathering power which in turn depends on the area of the objective (large diameter objective)

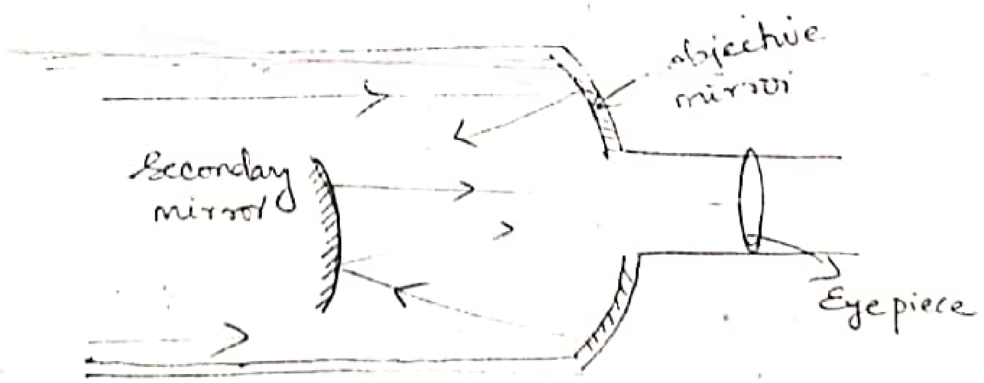
disadvantages of refracting type telescope.

* It thus puts a limitation that the lens becomes heavy and difficult to support at the edges.
* It is expensive to make such large sized lenses free from chromatic aberration and distortions.

The above limitations are overcome by reflecting telescopes which have concave mirror objective

Advantages.

* free from chromatic aberrations
* Using a parabolic mirror removes spherical aberration
* It is easier to support a mirror over its back surface than supporting a lens at the rim.



Schematic diagram of a reflecting telescope (Cassegrain)