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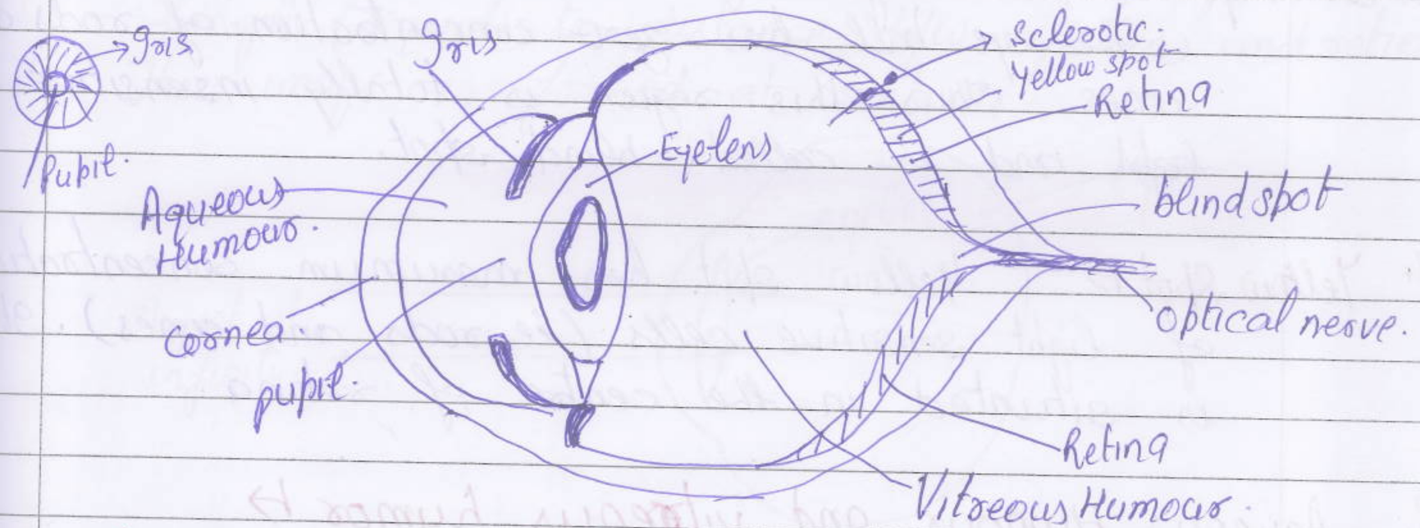
Optical Instruments ↦ are the instruments which make use of mirrors, lenses or prisms to extend the range of vision of human eye.
eg. telescope, microscope, spectrometer etc

Human Eye ↦ Human eye is a remarkable optical instrument. The main parts of human eye are as follows:



Sclerotic ↦ It is a tough and opaque white covering which ~~pro~~ holds and protect the eye ball.

Cornea ↦ It is the transparent membrane in front of eye ball.

~~Choroid ↦~~

Iris or Pupil ↦ Iris is an opaque circular diaphragm having a small central hole called pupil. Under the muscular action of iris size of pupil becomes smaller in bright light and larger in dim light

Eyelens ↦ It is a double convex lens made up of a jelly like material. Eye lens is connected to sclerotic with the help of ciliary muscles. By contracting or relaxing the ciliary muscles, the shape and curvature of the lens changes and hence its focal length changes. This ability of the eye lens

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to change its focal length is called accommoda

5. Retina ↦ It is a light sensitive membrane behind eye lens. It contains light sensitive cells ca rods and cones. These cells change light energy into electrical signals and transfers messa to the brain via optical nerve.

6. Blind Spot ↦ The region from which optical nerve ente the eye ball has zero concentration of rods a cones. Thus this region is totally insensitive light and is called blind spot.

7. Yellow Spot ↦ Yellow spot has maximum concentratio of light sensitive cells (ie rods and cones). It is situated in the centre of retina.

8. Aqueous Humour and vitreous humor ↦

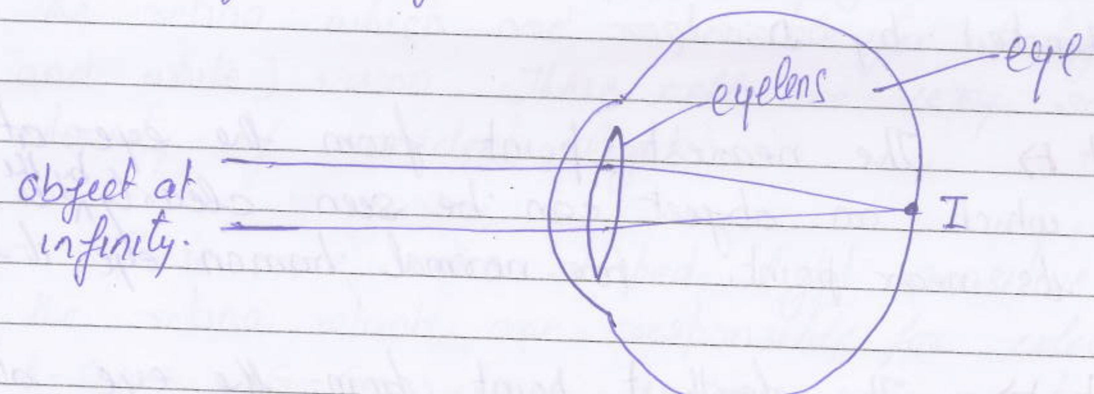
Aqueous humour is salty fluid of ref. index 1.337 filled b/w cornea and eyelens.

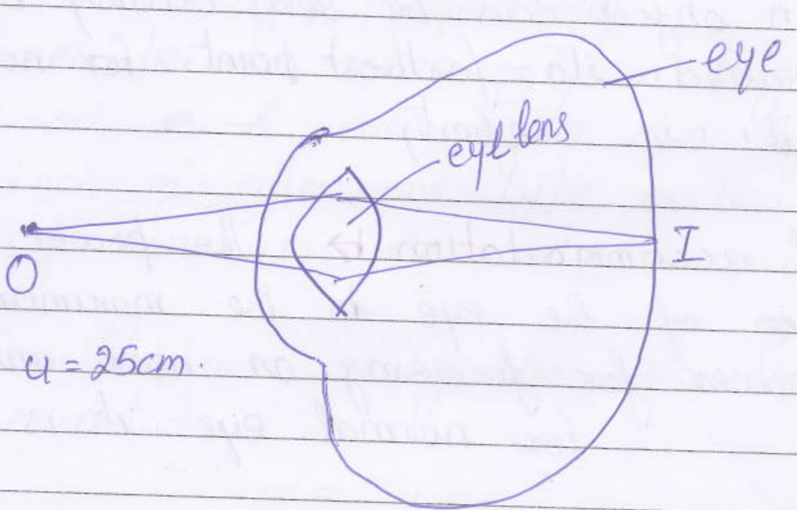
Vitreous humour is a jelly like fluid of ref. index 1.437 filled b/w eyelens an retina.

Action of eye ↦ Human eye behaves as a convergi lens. Rays from the object enter the eye and suffer refraction and real and inverted image is formed on the retina Thus light sensitive cells of retina generate the electrical signal which is send to the brain through optical nerves. Our brain translates the inverted image

Accommodation ⇒. The ability of the eye lens due to which it can change its curvature and hence its focal length so that image of the objects at ~~the~~ various distances can be formed on the same retina is called accommodation.

(a) when we look at ~~view~~ the far off object, the ciliary muscles are relaxed. Thus the eye lens becomes thin and has large focal length (equals to distance b/w eye lens and retina). Thus image is formed at retina.





(b) when we look at the nearby object ciliary muscles get contracted and hence eye lens become thick and hence of small focal length. Thus the image of the ~~nearby near~~ nearby object is again formed at the retina.

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Range of normal vision ⟼ Due to accommodation propert of eye lens, a normal eye can ~~see~~ clearly see an object b/w 25 cm and infinity.
This distance b/w 25 cm and ∞ is called range of normal vision.

Least Distance of distinct vision ⟼ The least distance upto which the eye can see the object clearly and distinctly is called least distance of distinct visio
for normal eye its value is 25 cm. It is denoted by D.

Near point ⟼ The nearest point from the eye at which an object can be seen clearly by the eye is called its near point. for normal human eye it is 25

Far Point ⟼ The farthest point from the eye at which an object can be seen clearly by the eye is called its farthest point. for normal human eye it is infinity.

Power of accommodation ⟼ The power of accommodation of the eye is the maximum variation of power for focusing on near and far objects.
for normal eye it is 4 D. (4 diopt

Persistance of vision ⟼ The impression of an image re on the ~~retina~~ retina for about 1/16 th of sec even after the removal of object.
This phenomenon of continuation of impression of an image on retina even after the removal of object is called persistance of vision.

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Cinematography works on the principle of persistance of vision. Video camera takes the picture of moving objects at the interval of $1/24^{th}$ seconds when we see these pictures at the same rate, then due to persistance of vision of previous picture, ~~we get the impression of moving object~~ before we see the next picture, we get the impression of moving object.

Rodes ↦ These are rod shaped light sensitive cells of the retina which are responsible for twilight (black and white) vision. These cells are very sensitive to intensity of incident light.

Cones ↦ These are cone shaped light sensitive cells of the retina which are responsible for colour vision. R-Cones, G-Cones and B-Cones are sensitive to red, green and blue light respectively.

Cones become active only in bright light, hence we cannot see ~~a~~ colours in dim light.

Lack of either one type or two type or all three types of cones in the retina causes colour blindness.

Colour blindness is genetic disorder and cannot be cured even today.

Cataract ↦ In old age, the crystalline lens of some people become hazy or opaque, due to development of membrane over it. This causes loss of vision. The vision can be restored after getting the cataract removed.

Defects of vision and their correction ↦
Due to loss of power of accommodation, human eye cannot see the objects clearly b/w 25 cm and ∞. ie our vision becomes defective.
The most common eye defects which can be corrected with the help of suitable eye glass are.
(1) Myopia or (Near sightedness)
2. Hypermetropia (far sightedness)
3. Presbyopia
4. Astigmatism.

Myopia or Near sightedness ↦ In this vision defect a person cannot see the distant objects clearly beyond certain point.
This defect is common among children. for myopic eyes far point is less than (a few meters from eye)
~~Myp~~ Myopia or near sightedness is ~~due~~ either due to the reason that distance b/w eye lens and retina becomes larger or the focal length of eye lens becomes too short.
As a result of these reasons image of the distant object get formed in front of retina ~~for~~ as shown in fig 1,
Thus ~~object has~~ the distant object has to be moved to the far point of the eye so that it's image is formed at retina

Correction of myopia ↦ A myopic eye can be corrected by using concave lens of focal

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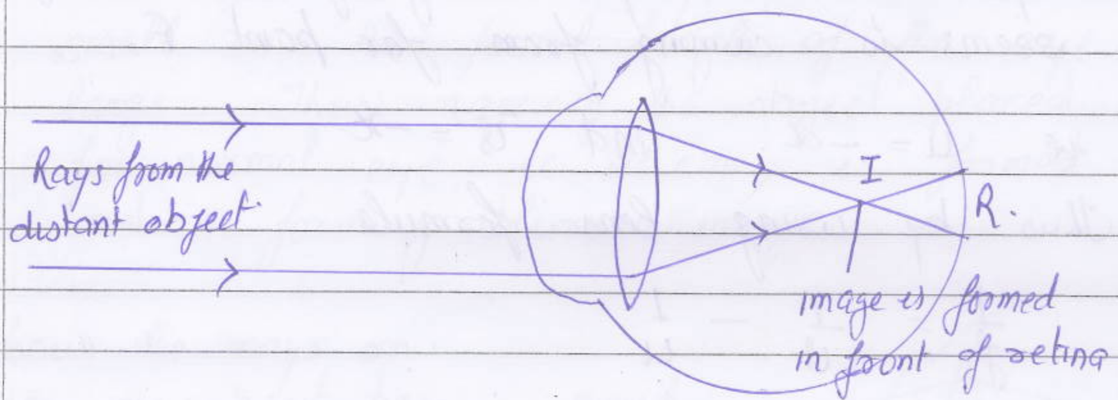
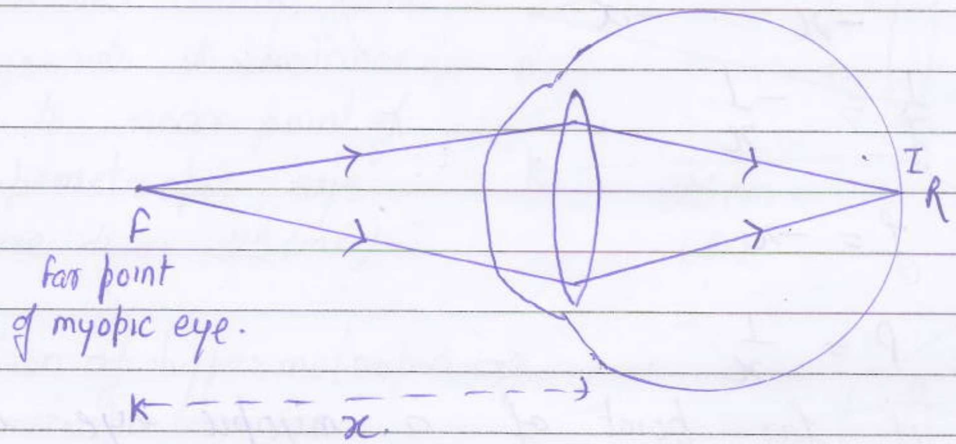
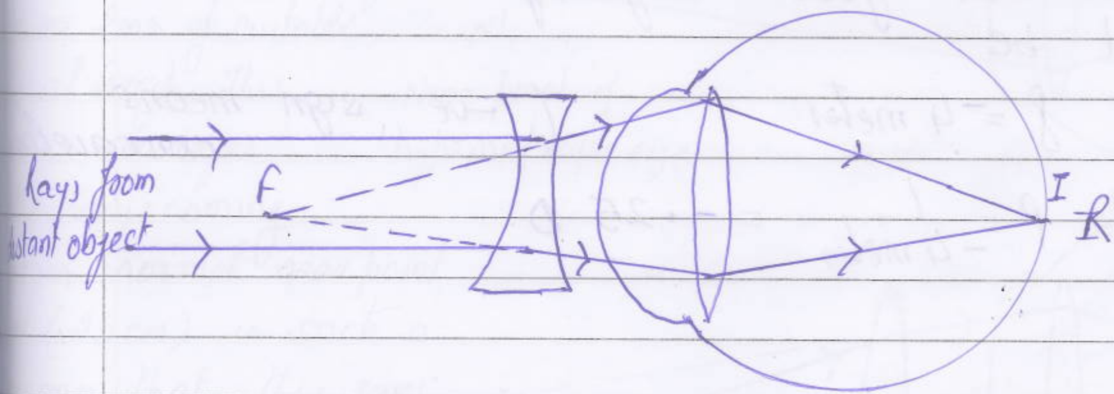
length equals to the distance of the far point f from the eye. This lens diverges the parallel rays coming from the distant objects in such a manner that they appears to come from far point.
Thus eye lens forms a clear image at retina







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Calculation of focal length and power of correcting lens in myopia ↦

Let a myopic eye can see the distant objects placed at x meters clearly. ie far point of the myopic eye is x meter.

Thus a concave lens is placed close to the eye so that rays coming from the object at ∞ seems to coming from far point F.

ie $u = -\infty$ and $v = -x$.

Thus by using lens formula

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

$$= \frac{1}{-x} - \frac{1}{-\infty}$$

$$\Rightarrow \frac{1}{f} = \frac{-1}{x}$$

$$\Rightarrow f = -x$$

$$\therefore P = \frac{1}{-x}$$

ie if far point of a myopic eye is 4 meter then focal length of the concave lens should be

$f = -4$ meter (-ve sign means concave)

and $P = \frac{1}{-4 \text{ meter}} = -.25$ D.

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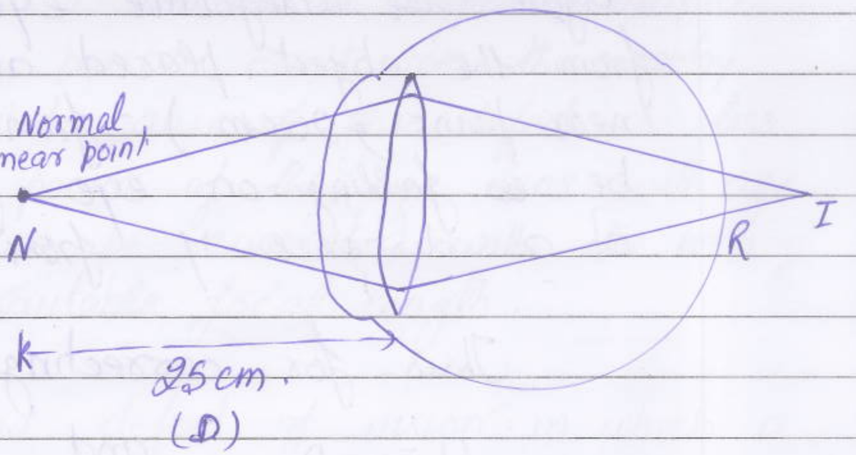
Hypermetropia ↦ or long sightedness ↦ In this vision defect, a person cannot see the nearby objects clearly.

For hypermetropic eye near point is more than 25 cm.

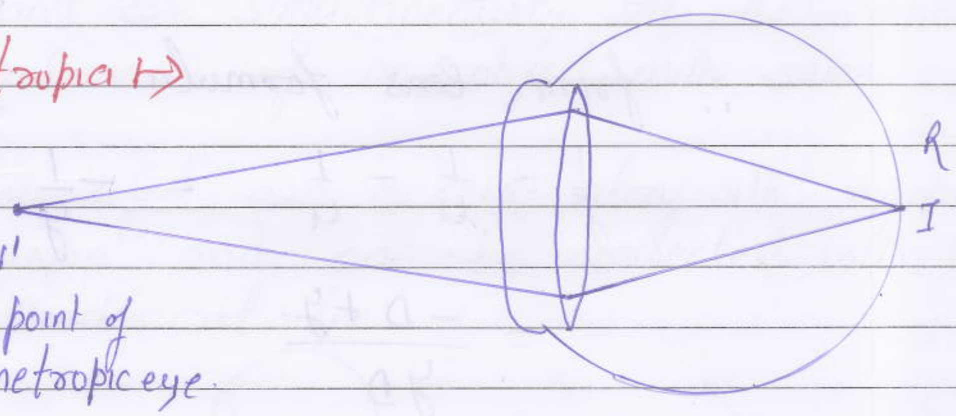
Hypermetropia is either due to the reason that distance between eye lens and retina becomes small or the focal length of the eye lens becomes large. Thus image of the object placed at near point for normal eye ie 25 cm, is formed beyond retina forming blurred image.

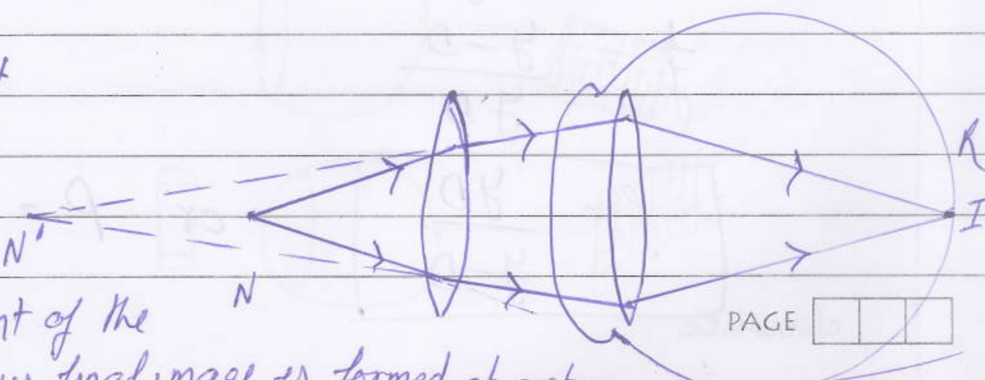
To focus the rays on retina, the object has to be moved away from the eye to a distance equal to near point of the hypemetropic eye. (ie more than 25 cms)



Correction of hypermetropia ↦

A hypermetropic eye can be corrected by using convex lens of suitable focal length. This lens converges the rays coming from normal near point N (25 cm) in such a manner that they seems to come from point N' ie near point of the defective eye. Thus final image is formed at retina





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Calculation of focal length and power of correcting lens in hypermetropia ↦

Let hypermetropic eye can see the object placed beyond ~~y meters~~ distance y, i.e. near point of hypermetropic eye is y.

~~Thus a convex lens has to placed before defective eye so that rays from the object placed at a distance D (near point for normal eyes) appears to be coming from ~~at~~ the distance~~

Thus a convex lens has to placed before the defective eye so that ray coming from the object placed at a distance D (normal near point = 25 cm) from the eye seem to be ~~co~~ falling on eye from the object placed at a distance y from eye (defective near point)

Thus for correcting convex lens.

$u = -D$ and $v = -y$

∴ from lens formula

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = -\frac{1}{y} + \frac{1}{D}$$

$$= \frac{-D + y}{yD}$$

$$\frac{1}{f} = \frac{y - D}{yD}$$

$$\therefore \boxed{f = \frac{yD}{y - D}} \quad \text{or} \quad P = \frac{y - D}{yD}.$$

Thus if for a defective eye near point is 40 ~~30~~ cm ie defective eye can see the objects clearly place beyond 40 ~~30~~ cm then

$$f = \frac{40 \times 25}{40 - 25} = \frac{1000}{15}\ cm = \frac{10}{15}\ m$$

~~ie $f = 1.5\ m$~~ $\therefore f = \frac{2}{3}\ m = 66\ cm$.

~~or $P = \frac{1}{1.5\ m} = .66\ D$.~~

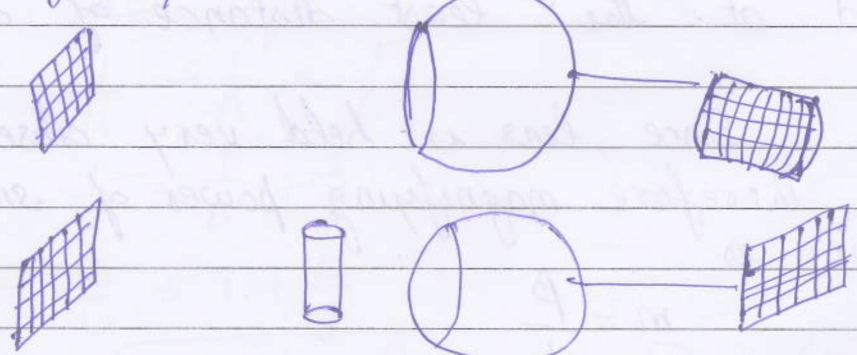
or $P = \frac{15}{10}\ D = 1.5\ D$.

Presbyopia ↦ This defect is similar to hypermeteropia. In this defect a person can't see the nearby objects clearly. But cause of this defect is loss of accommodating power of the eye lens with age.

This defect can be corrected with the help of convex lens of suitable focal length.

Astigmatism ↦ It is the defect of vision in which a person can't ~~see~~ simultaneously see the vertical and horizontal view of an object with same clarity.

This defect can occur alongwith myopia or ~~and~~ hypermyopia and can be corrected with the help of cyllinderical lens.



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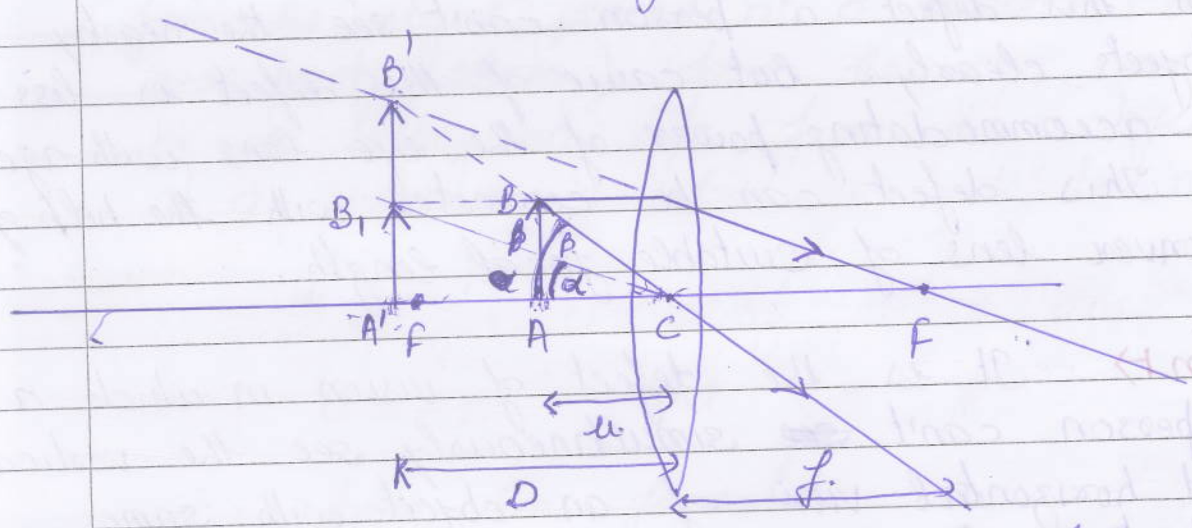
Simple Microscope ↦ A simple microscope or a magnifying glass is just a convex lens of small focal length.

A simple microscope can be used in two ways.

① **when final image is formed at the least distance of distinct vision ↦**

when object is placed between optical centre and focal length of the convex lens, a virtual erect and highly magnified image is formed at the least distance of distinct vision.



Magnifying power ↦ Magnifying power of the simple microscope in this adjustment is d/a the ratio of angle subtented by image to the angle subtended by object on eye when both are placed at the least distance of distinct vis

Since lens is held very close to the eye therefore magnifying power of simple microscope is

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

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$\Rightarrow m = \frac{\tan\beta}{\tan\alpha}$ —— ① ($\because \alpha, \beta$ are small an

In Δ ABC

$\tan\beta = \frac{AB}{AC}$ —— ②

In Δ $A'B_1C$

$\tan\alpha = \frac{A'B_1}{A'C}$ —— ③

Put ② and ③ in eqn. no 1 we get

$m = \frac{AB}{AC} \times \frac{A'C}{A'B_1}$

$= \frac{AB}{AC} \times \frac{A'C}{AB}$ ($\because A'B_1 = AB$)

$\Rightarrow m = \frac{A'C}{AC}$

here $A'C = -D$ and $AC = -u$

$\therefore m = \frac{-D}{-u}$

$\Rightarrow \boxed{m = \frac{D}{u}}$ —— ④

Also from lens formula

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

here $u = -u$, $v = -D$ and $f = f$.

Thus we get

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

$\Rightarrow \frac{1}{u} = \frac{1}{D} + \frac{1}{f}$

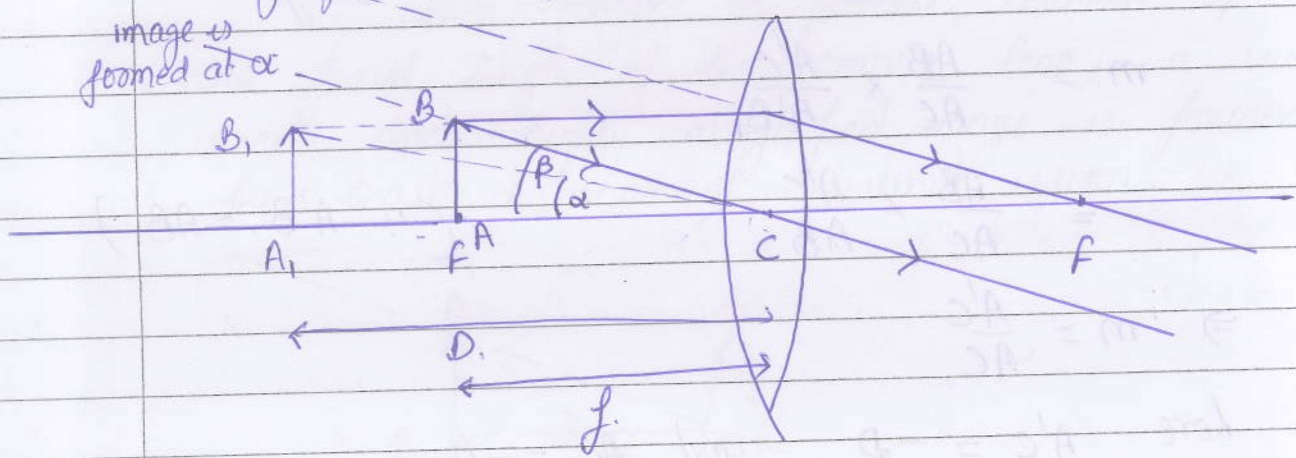
$\Rightarrow \frac{D}{u} = 1 + \frac{D}{f}$

$\Rightarrow \boxed{m = 1 + \frac{D}{f}}$ —— (A) (using ④)

(2.) When final image is formed at ∞ ↦

when ~~the~~ we see the image at the least distance of distinct vision (Near point), it causes strain in the eye.

Thus we adjust the position of convex lens, so that object lies at its focus point and thus final virtual erect and highly magnified image is formed at ∞.



Magnifying power ↦ Magnifying power of simple microscope this adjustment is d/a the ratio of angle subtended by the image on eye when situated at ∞, to the angle subtend by the object on eye when situated at the least distance of distinct vision.

Since lens is held very close to eye therefore angle subtended on optical centre of lens are almost equal to the angle subtended on eye.

$$\therefore \quad m = \frac{\beta}{\alpha}$$

$$\Rightarrow \quad m = \frac{\tan\beta}{\tan\alpha} \quad \text{——} ① \qquad (\because \alpha \text{ and } \beta \text{ are small angles.})$$

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In Δ ABC

$$\tan\beta = \frac{AB}{AC} = \frac{AB}{FC} \quad \text{--- (2)}$$

If the object is situated at the least distance of distinct vision then from ΔA_1B_1C

$$\tan\alpha = \frac{A_1B_1}{A_1C} = \frac{AB}{A_1C} \quad \text{--- (3)}$$

Put (2) and (3) in (1) we get

$$m = \frac{AB}{FC} \times \frac{A_1C}{AB}.$$

$$\Rightarrow m = \frac{A_1C}{FC}$$

here $A_1C = -D$ and $FC = -f$.

$$\therefore m = \frac{-D}{-f}$$

$$\Rightarrow \boxed{m = \frac{D}{f}} \quad \text{--- (B)}$$

However magnifying power in this adjustment is one less than the magnifying power when image is formed at least distance of distinct vision. But viewing is much more comfortable to eye as the image is formed at ∞

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Compound microscope ↦ It cosist of two convex lenses named as object lens and eye lens fitted at the two ends of a co-axial tube provided with rack and pinion arrangement. Object lens is of small aperture and small focal length where as ~~eye~~ focal length of eye lens is moderate.

A micro object AB is placed ~~very clos~~ just beyond the focus point of the object lens Thus its real and inverted image A'B' is for on the other side of the object lens. Now the position of eye lens is adjusted in such a manner that A'B' lies in b/w the focus F_e and optical centre C_e of the eye lens. Thus final virtual, erect and highly magni image is formed at the least distance of distin vision as shown.

Magnifying power ↦ Magnifying power of the compound microscope is d/d the ratio of angle subtended by the image to the angle subt by the object on eye when both are pla at the least distance of distinct vision.

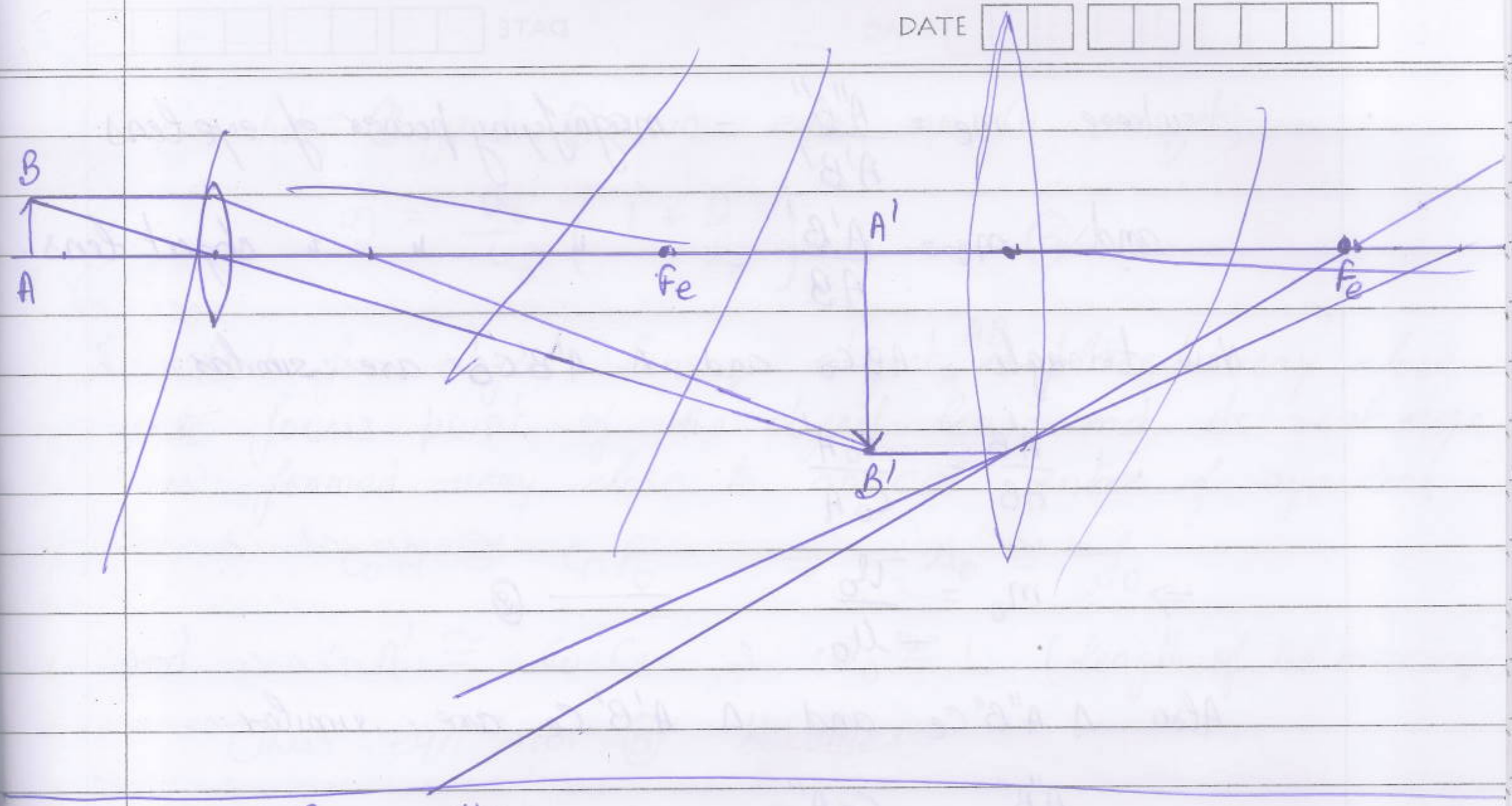
Since eye lens is very close to eye, angles subtended on the optical centre of eye ar equal to angles subtended on eye.

$$\therefore \quad m = \frac{\beta}{\alpha}$$

$$\Rightarrow \quad m = \frac{\tan\beta}{\tan\alpha}$$

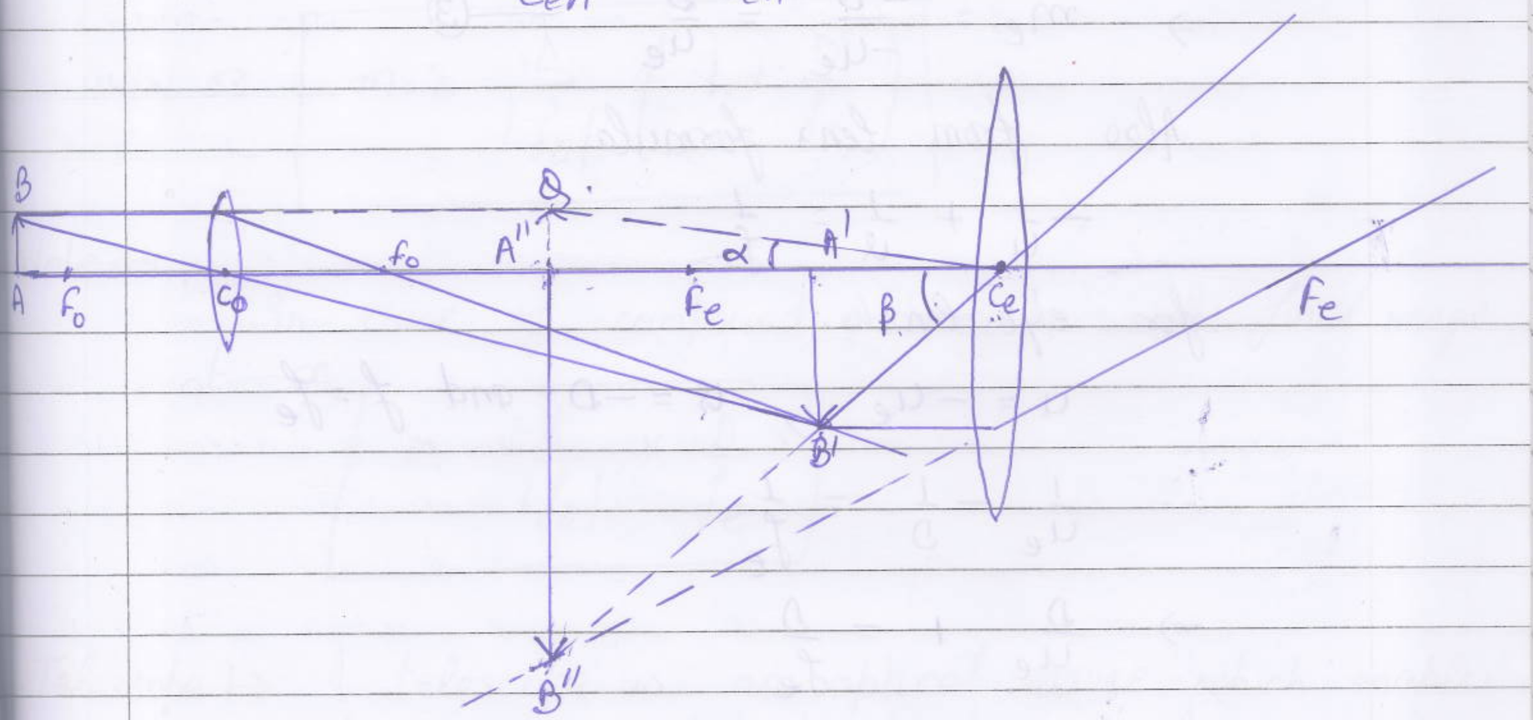
In $\Delta\ A''B''C_e$

$$\tan\beta = \frac{A''B''}{\ldots}$$



In $\Delta\ A''QC_e$

$$\tan\alpha = \frac{A''Q}{C_eA''} = \frac{AB}{C_eA''} \qquad (\because A''Q = AB)$$



$$\therefore\ m = \frac{A''B''}{C_eA''} \times \frac{C_eA'}{AB}$$

$$\Rightarrow\ m = \frac{A''B''}{AB}$$

 or $m = \dfrac{A''B''}{A'B'} \times \dfrac{A'B'}{AB} \Rightarrow m = m_e \times m_o$ —(1)

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where $m_e = \frac{A''B''}{A'B'}$ = magnifying power of eyelens

and $m_0 = \frac{A'B'}{AB}$ = " " " object lens

Now triangle ABC_0 and $\Delta A'B'C_0$ are similar.

$$\therefore \frac{A'B'}{AB} = \frac{C_0A'}{C_0A}$$

$$\Rightarrow m_0 = \frac{v_0}{-u_0} \quad \text{———} \quad (2)$$

Also $\Delta A''B''C_e$ and $\Delta A'B'C_e$ are similar.

$$\therefore \frac{A''B''}{A'B'} = \frac{C_eA''}{C_eA'}$$

$$\Rightarrow m_e = \frac{-D}{-u_e} = \frac{D}{u_e} \quad \text{———} \quad (3)$$

Also from lens formula

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

for eye lens.

$u = -u_e$, $v = -D$ and $f = f_e$

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

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

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

$$\Rightarrow m_e = \left(1 + \frac{D}{f_e}\right) \quad \text{———} \quad (4)$$

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Put ④ and ③ in eqn. no. ① we get,

$$m = \frac{v_0}{-u_0}\left(1 + \frac{D}{f_e}\right) \quad \text{--- ⑤}$$

But for object lens, object AB is placed very close to focus point of the object lens and its real image is formed very close to optical centre of eye lens

$\therefore \quad C_oA \cong C_of_o \Rightarrow -u_0 \cong -f_0$

and $C_oA' \cong C_oC_e \Rightarrow v_0 \cong L$ (length of the microscope)

Thus eqn no. ⑤ becomes

$$m = \frac{L}{-f_0}\left(1 + \frac{D}{f_e}\right)$$

or

$$\boxed{m = \frac{L}{|f_0|}\left(1 + \frac{D}{f_e}\right)}$$

Note ↦

In case of compound microscope with final image at ∞

$$\boxed{m = \frac{L}{|f_0|} \times \frac{D}{f_e}}$$

Telescope ↦ A telescope is an optical device which enables us to see the distant objects clearly.

I Refracting telescopes ↦
(a) Astronomical Telescope.
(b) Terrestrial Telescope.

II Reflecting Telescope
(a) Newtonian Telescope (b) Cassegrain Telescope

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Astronomical Telescope ↦ It is a refracting type telescope used to see heavenly bodies. In this telescope final image formed is inverted and highly magnified. Since heavenly objects are spherical in shape, therefore inverted image does not make any difference.

Astronomical Telescope in normal adjustment ↦

In astronomical telescope an object lens or objective is of large focal length and large aperture. The rays from the object at ∞ falls on the objective and inverted image $A'B'$ is formed at the focus point f_0 of the objective. In normal adjustment eyelens or eyepiece is placed in such a way that the image $A'B'$ (which acts as object for eyelens) lies at the focus point f_e of the ~~e~~ eyelens. Thus final inverted and highly magnified image is formed at ∞ as shown.

Magnifying power ↦ of the astronomical telescope in normal adjustment is defined as the ratio of angle subtended by image to the angle subtended by object on eye, when both are at ∞.

Since the object is at ∞, therefore angle subtended by object on C_0 is approximately equal to angle subtended by object on C_e ie on eye.

$$\therefore \; m = \frac{\beta}{\alpha}$$

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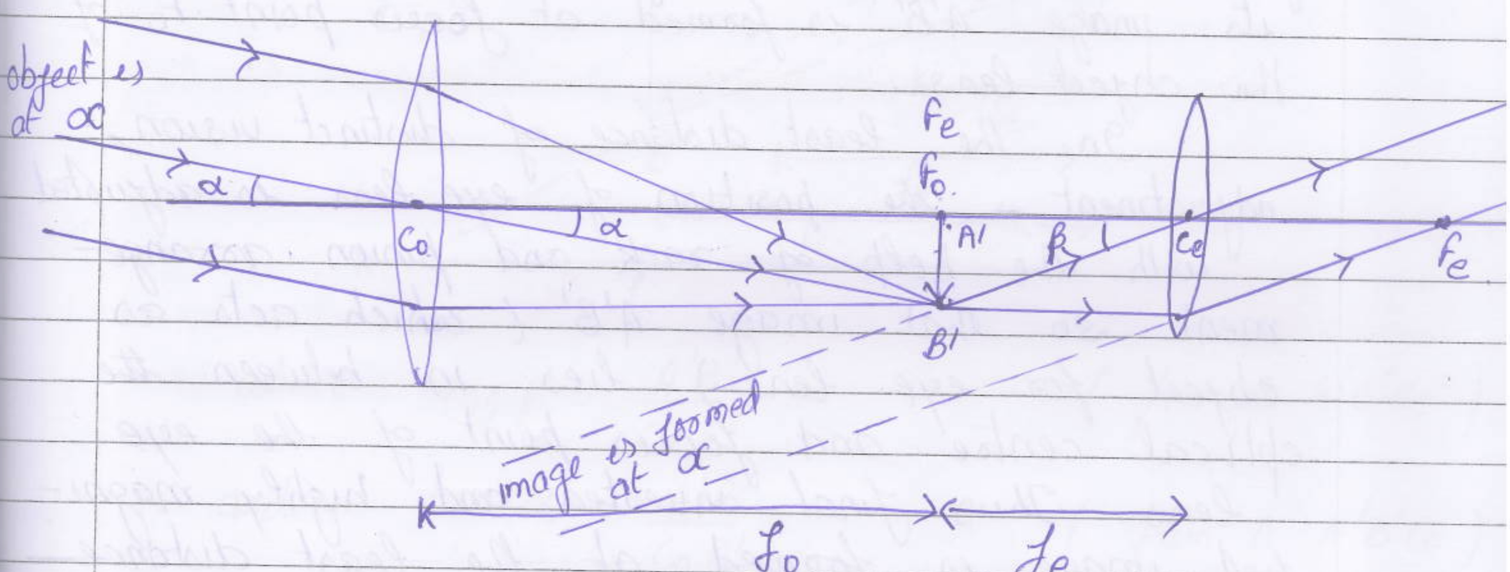
$$\Rightarrow m = \frac{\tan \beta}{\tan \alpha}.$$

$$\Rightarrow m = \frac{A'B'}{C_eA'} \times \frac{C_oA'}{A'B'} = \frac{C_oA'}{C_eA'}$$



$$\Rightarrow m = \frac{C_oF_o}{C_eF_e}$$

using sign conventions

$$C_oF_o = f_o \quad \text{and} \quad C_eF_e = -f_e.$$

$$\therefore m = \frac{f_o}{-f_e}$$

$$\text{or} \quad \boxed{m = \frac{f_o}{|f_e|}}$$

Also length of astronomical telescope in ~~max~~ normal adjustment is $(f_o + f_e)$

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Astronomical telescope in the adjustment when final image is formed at the least distance of distinct vision ↦

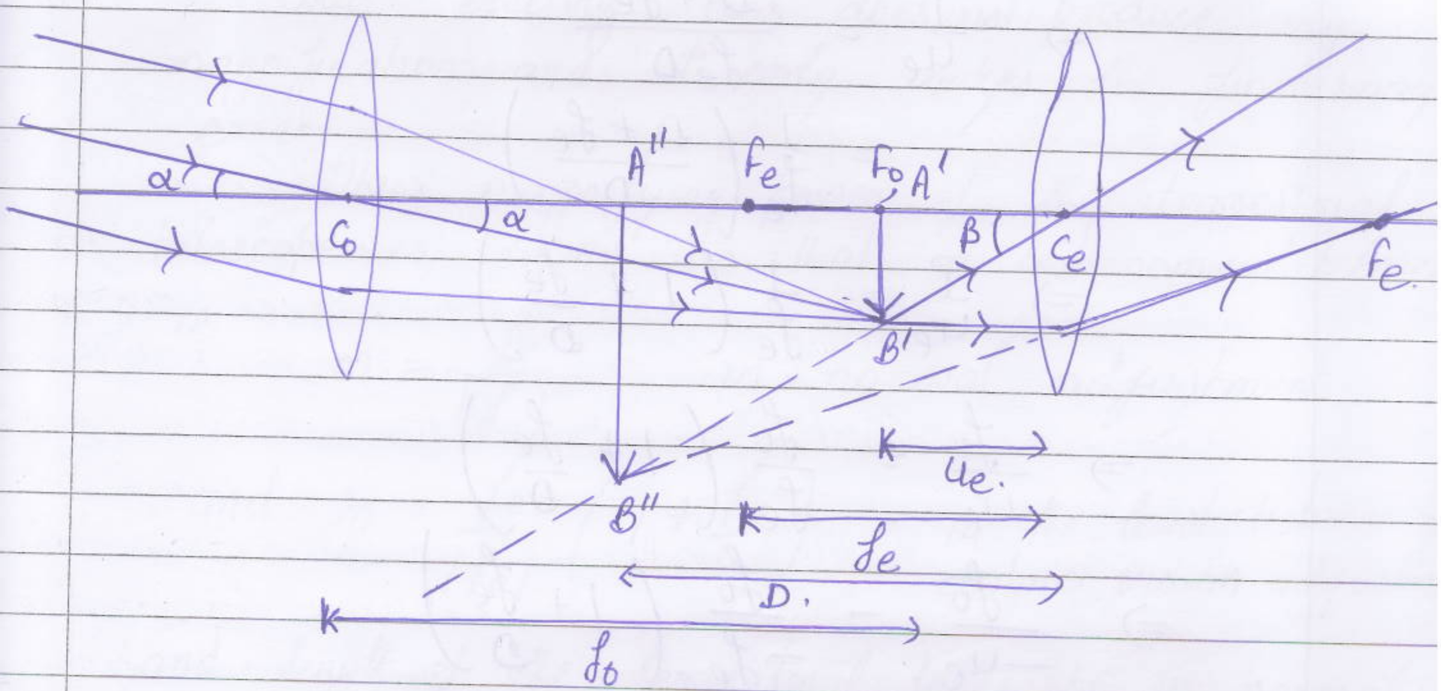
In astronomical telescope, object lens is large aperture and large focal length. The ra[y] from the object at ∞ falls on object lens its image A'B' is formed at focus point F_o [of] the object lens.

In the least distance of distinct vision adjustment, the position of eye lens is adju[sted] with the help of rack and pinion arrangement so that image A'B' (which acts as object for eye lens) lies in between th[e] optical centre and focus point of the eye lens. Thus final inverted and highly magnified image is formed at the least distanc[e] of distinct vision as shown.

Magnifying power ↦ Magnifying power of the astronomical telescope in this adjustment d/a the ratio of angle subtended by the image on eye to the angle subtended b[y] object on eye when object is at ∞ and image is at the least distance of distinct vision.

Since object is at ∞, therefore angle subtended by object on C_o is approximatel[y] equal to angle subtended by object on ie on eye.

$$\therefore \quad m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha}.$$



where $\tan\beta = \frac{A'B'}{C_eA'}$ (from $\Delta A'B'C_e$)

and $\tan\alpha = \frac{A'B'}{C_oA'}$ (from $\Delta A'B'C_o$)

$$\therefore \quad m = \frac{A'B'}{C_eA'} \times \frac{C_oA'}{A'B'} = \frac{C_oA'}{C_eA'}$$

$$\Rightarrow \quad m = \frac{C_oA'}{C_oF_o} \quad \therefore \quad m = \frac{C_oF_o}{C_eA'}$$

here $C_oA' = -u_e$ and $C_oF_o = f_o$

$$\therefore \quad \sout{m = \frac{-u_e}{f_o}} \quad \therefore \quad m = \frac{f_o}{-u_e} \quad \text{——} (1)$$

from lens formula

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

for eye lens $u = -u_e$, $v = -D$ and $f = f_e$

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

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

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

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

$$\Rightarrow \frac{1}{u_e} = \frac{1}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$\Rightarrow \frac{f_0}{u_e} = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$\Rightarrow \frac{f_0}{-u_e} = \frac{f_0}{-f_e}\left(1 + \frac{f_e}{D}\right)$$

$$\Rightarrow m = \frac{f_0}{-f_e}\left(1 + \frac{f_e}{D}\right) \quad \{\text{using } (1)\}$$

$$\Rightarrow m = \frac{f_0}{|f_e|}\left(1 + \frac{f_e}{D}\right)$$

Terrestrial telescope ↦ It is a reflecting type telescope used to see the distant objects placed on earth. In terrestrial telescope an erecting lens is placed between object lens and eye lens, which makes the final image erect.

In terestorial telescope ~~obj~~ image A'B' (which acts as object for ~~terrestrial~~ erecting lens) is formed at 2F of the erecting lens. Thus image A''B'' ~~is form~~ of same size is formed at 2F of the erecting lens on the other side of the erecting lens.

Thus erecting lens does not produce any magnification and it only makes the final image erect.

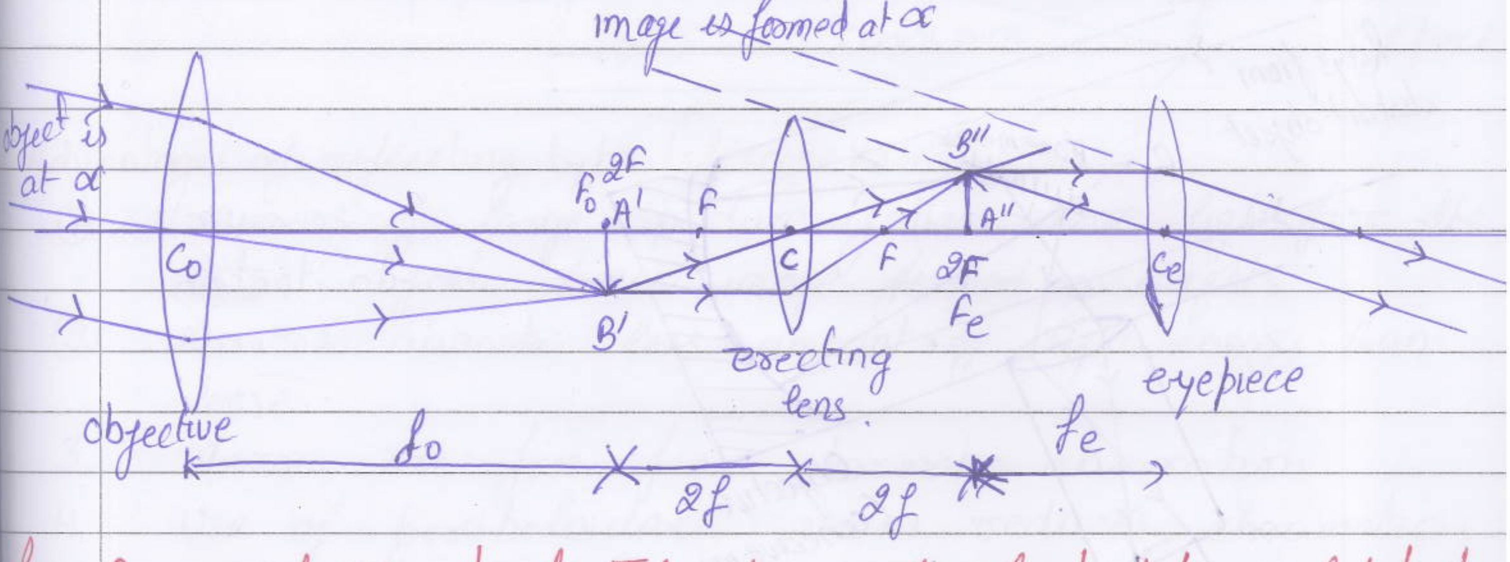
Thus magnifying power of the terrestrial telescope is same as that of astronomical telescope

ie $m = \frac{f_o}{|f_e|}$ in normal adjustment

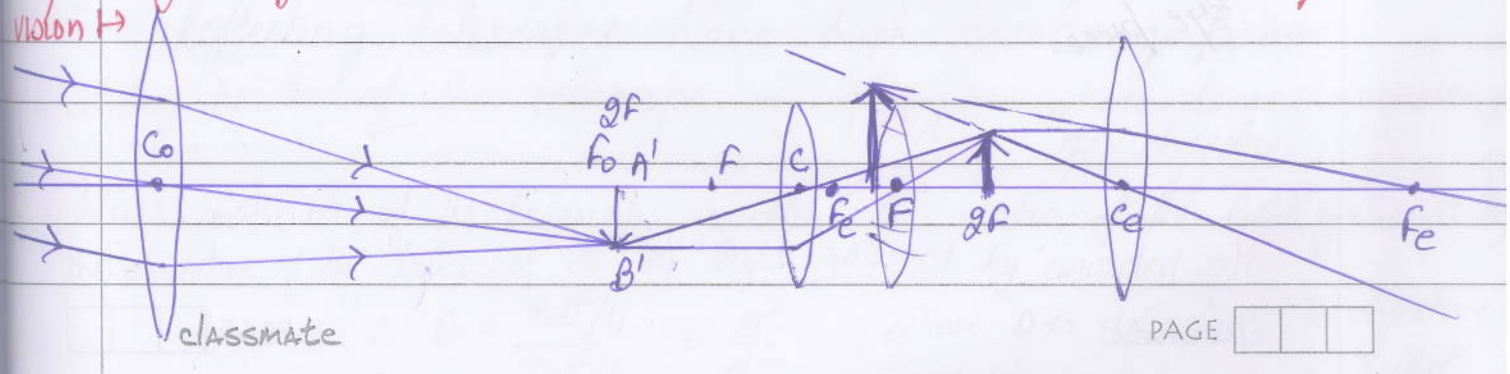
and $m = \frac{f_o}{|f_e|}\left(1 + \frac{f_e}{D}\right)$ in the least distance of distinct vision adjustment

and length of the terrestrial telescope in normal adjustment is $f_o + 4f + f_e$.

Ray diagram of Terrestrial telescope in normal adjustment ↦

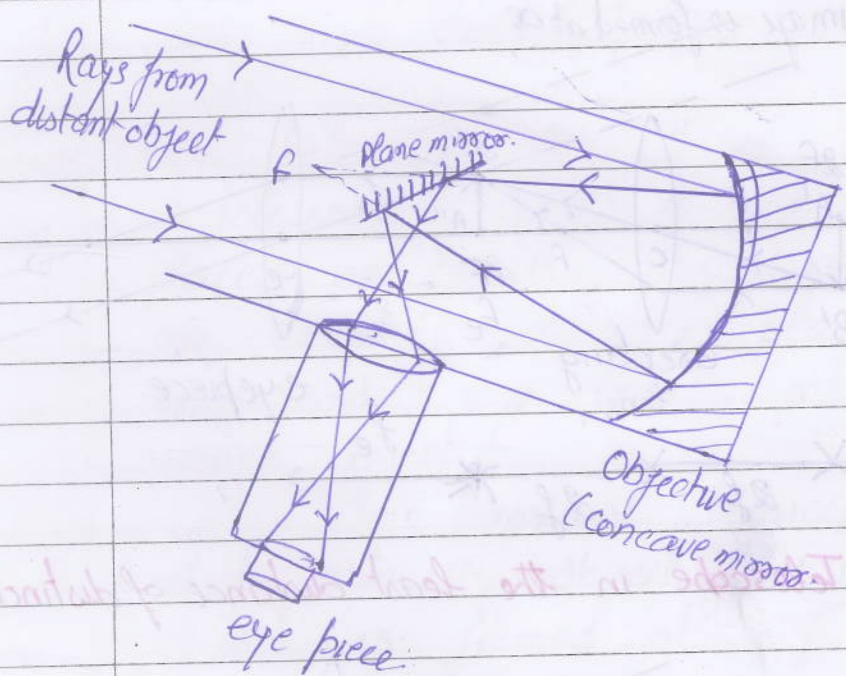


Ray Diagram of Terrestrial Telescope in the least distance of distinct vision ↦



Reflecting Telescopes ↦

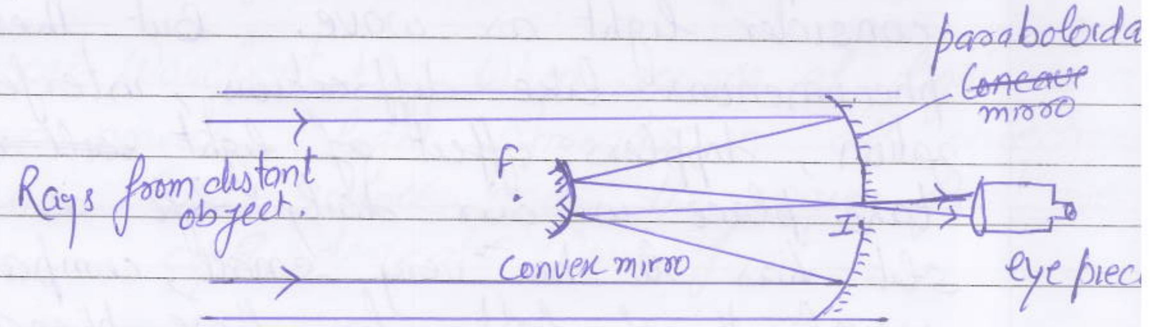
Newtonian Reflecting Telescope ↦ It consist of a large concave mirror of large focal length as the objective. Rays of light from a distant star are allowed to fall on the objective. A plane mirror inclined at an angle of 45° is placed just bef the focus point of objective. This mirror interc the rays coming from objective and turn them towards the eye piece as shown in ray dia The eye-piece forms a highly magnified, virt erect and bright image of the distant objec The objective is of large aperture and ga a sufficient amount of light from the distant object thus image formed is quite bright.



DATE

Cassegrain Reflecting Telescope ↦ It consist of a large paraboloidal ~~concave~~ primary mirror of large aperture and large focal length, with a small hole at its centre. There a small convex secondary mirror placed just before the focus point of primary mirror. An eyepiece is placed near the hole of primary mirror.

The rays from the distant object are reflected by the large concave primary mirror. Before the ray meet at F, they are reflected by secondary convex mirror and get converged at point I just outside the hole, where eye piece forms a magnified inverted image.



Advantages of reflecting type telescope ↦

(1) Mirrors of large aperture gathers more light from the distant objects hence image formed is bright.

(2) Mirrors absorbs less amount of light energy than lenses.

3. Mirrors are free from chromatic aberration.

4. Use of paraboloidal mirrors reduces chromatic aberration.

5. Reflecting telescopes have high resolving power.

Resolving power of the telescope $= \frac{D}{1.22\lambda}$ where D is diameter of the objective.

Brightness ratio ↦ of the telescope is d/a the ratio of the light gathered by the objective of the telescope to the light gathered by unaided eye.

$\therefore B = \frac{\pi D^2/4}{\pi d^2/4} = \frac{D^2}{d^2}$ where D is diameter of the objective and d " " " " pupil.