HUMAN EYE AND COLORFUL WORLD

TYPES OF EYE DEFECTS

DEFECTS OF VISION AND THEIR CORRECTION

The common defects of vision are as follows:

1. Myopia or short – sightedness
2. Hypermetropia or long – sightedness
3. Astigmatism
4. Presbyopia

1 Myopia or short – sightedness

A person suffering from myopia or short – sightedness can see nearby objects clearly but cannot see the far away objects clearly. In this case the image is formed in front of the retina.

The defect is due to the following reasons:

Eye ball is larger than the normal. The maximum focal length of the(due to excessive curvature of the cornea) of the lens is insufficient to produce clearly formed image on the retina.

Correction:

This defect can be corrected by using a **concave (diverging)** lens. So a man suffering from this defect wears spectacles of concave lens with sufficient focal length. Due to this lens, rays coming from infinite, diverge and seem to come from the far point of the defective eye. So the final image is formed at retina.

Focal length and power of concave lens used to correct short – sightedness:

If the focal length of the lens be f and d be the far point of defective eye. Then from the expression,

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

Here u = ∞ and v = – d

$$-\frac{1}{d}-\frac{1}{\infty}=\frac{1}{f}$$

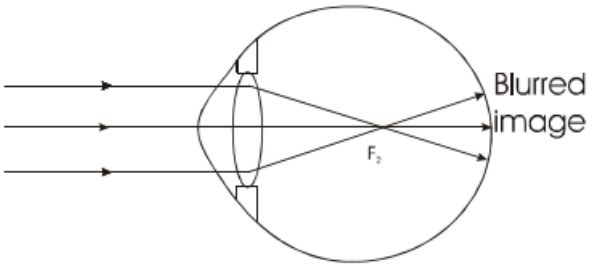
$$\frac{1}{-d}=\frac{1}{f}$$

f =-d

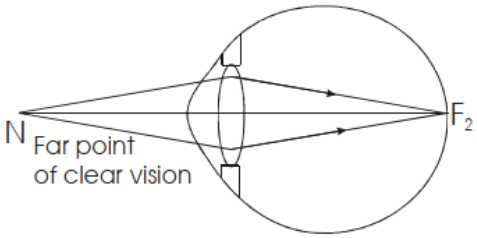
A shortsighted person therefore should use a divergent lens offocal length equal to hisfar point. If 'd'is measured in meter, then the power of lens is

p $=\frac{1}{f}$ dioptre With the use of extra lens, the near point of the defective eye also increases.

Figure shows a defective short sighted eye when the image of a far off object is formed infront of the retina.



(ii) Figure Shows a defective short sighted eye when the object is situated at thefar point of clear vision.



(iii) Figure shows a corrected short, sighted eye when image of a distant object is formed at the far point of clear vision.

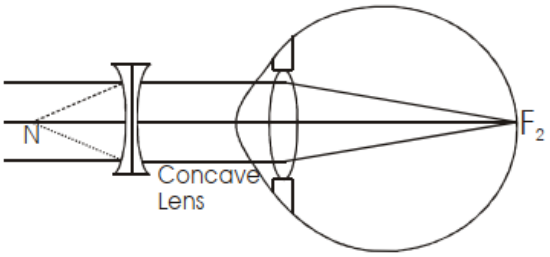


Image of far off object is formed at point N where the eye can see clearly.

Short-Sightedness or Myopia

Aperson sufferingfrom this defect can see the nearer objects clearly, but cannot see the far-off objects clearly.

Causes:

The focal length of eye lens becomes too small.

Sometimesthe eye ball gets elongated and thereforetheimageoffar-off objects areformed in front of theretina.

Correction :

AShort sightedperson can see clearlyto some distance.Beyondthisdistancetheimages get blurred.Thefarthest pointfromwhich a short sighted person can see clearlyis called far off point of clear vision.To enable such a person see the objects situated at infinity, we must use some lens, so that the image of the object is formed, at the far off point. Generally, the lens used is a concave lens and its focal length depends upon the degree of abnormalityin the eye.

Hypermetropia or long – sightedness

A person suffering from hypermetropia or long – sightedness can see distant object clearly but cannot see nearby objects clearly. In this case the image is formed behind the retina. The defect is due to the following reasons:

Either the eye ball is too small.

The minimum focal length of the eyelens is more.

Correction:

This defect can be corrected by using a convex lens of suitable focal length. So a man suffering from this defect wear spectacles of convex lens with sufficient focal length. The convex lens of

spectacles reduces the divergence of rays of light entering the eye, and final image is formed at retina.

Focal length and power of a convex lens used to correct long – sightedness : If the object is placed at O' (Near point of a normal eye) then the lens forms its image at O the near point of the

defective eye. Let 'D' be the least distance of distinct vision for the normal eye and 'd' the least distance

of distinct vision for the defective eye.

Then for extra lens u = – D and v = –d

Therefore from the lens equation

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

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

$$-\frac{1}{d}+\frac{1}{D}=\frac{1}{f}$$

$$\frac{1}{f}=\frac{d-D}{dD}$$

$$f=\frac{dD}{d-D}$$

If D is 25 cm then $f=\frac{25d}{d-25}cm$

d > 25 cm therefore f is positive and the lens is convex

$$in\ meter\ \ f=\frac{d}{4(d-25)}$$

$$power=\frac{4(d-25)}{d}dipoter$$

(I) Figure 1 shows a defective long sighted eye when the object is situated at the least distance of distinct vision. In this case, the image is formed behind the retina.

(ii) Figure 2 shows a defective long sighted eye when the object is situated at the near point of clear vision and its image is clearly formed on the retina.

(iii) Figure 3 Shows a corrected long sighted eye when the convex lens forms the image at the near point of the defective eye.

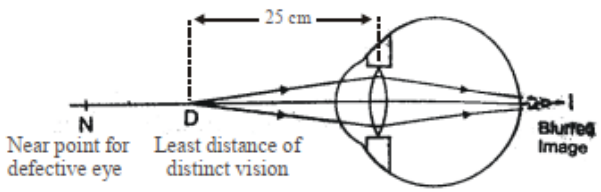


Figure 1

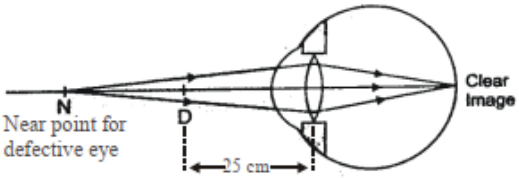


Figure 2

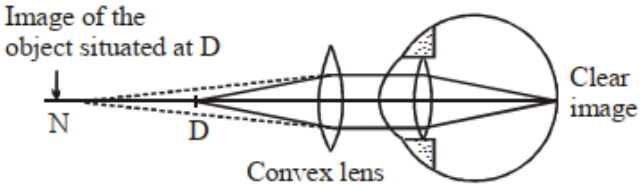


Figure 3

LONG SIGHTEDNESS OR HYPERMETROPIA

A person suffering from this defect can see far off objects clearly, but cannot see clearly the objects situated at a distance of 25 cm or at the least distance of distinct vision.

Causes:

(i) The minimum focal length of eye lens is too large.

(ii) Due to some reason, the eye ball becomes smaller in size and hence, the image of the object, situated at 25 cm or at the least distance of distinct vision, is formed behind the retina.

Correction:

A long sighted person can see a near object clearly only if it is held at some distance away from the least distance of distinct vision. This minimum distance from which a person can see clearly is called the near distance of clear vision. To enable such a person to see from a distance of 25 cm, a lens must be used, such that it forms the image of the object at the near point of defective eye distance of clear vision. Generally, the lens used is convex lens of suitable focal length.

Ex. Let the farsighted eye can see a minimum distance y(i.e. near point of the eye). If the eye is to see clearly
an object at the distance of distinct vision (i.e. at 25 cm), then the image of the object should form at a
distance of y.

$\therefore$ u = – 25 cm; v = – y; f = ?

Bylensformula,

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

$$=\frac{1}{-y}-\left[-\frac{1}{25}\right]$$

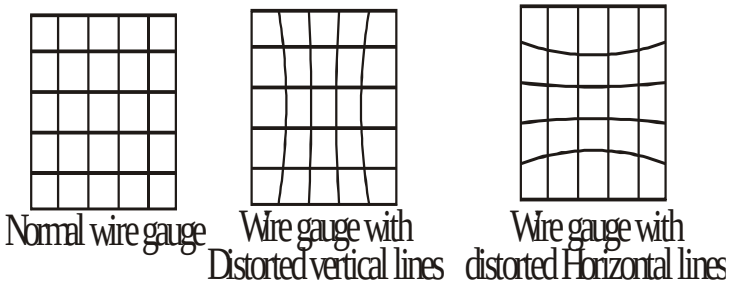
$$\frac{1}{f}=\frac{1}{25}-\frac{1}{y}$$

$$=\frac{y-25}{25y}$$

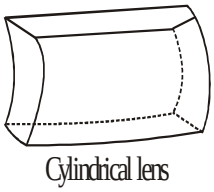
$$\text{Power of lens}=\frac{100(y-25)}{25y}=\frac{4(y-25)}{y}$$

Astigmatism

This defect arises due to different sections of cornea having different radii of curvature. One section of cornea may be more sharply curved than the other. The man cannot focus on both horizontal and vertical line simultaneously.



For remedy a cylindrical lens with the axis of the cylindrical lens parallel to the correct axis of the cornea, is used.



If along with astigmatism, myopia or hypermetropia is also associated, which is generallyvery common, then for the complete remedy of the defect, sphero–cylindrical (or compound) lensare used.Eye with this defect is unable to see the lines in different axes but at the same distance with sameclarity. It occurs due to irregular curvature of cornea / by birth or arises due to some injury.Horizontal and vertical lines can't be seen simultaneouslywith this defective eye. Objects in one direction get well focussed and in perpendicular direction remain blurred.

Correction: In this case, the spectacles are cylindrical lenses of suitable focal length.

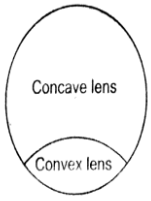
Presbyopia

It is purelyan old age problem due to which the person cannot see near byan object clearly. In other words, Presbyopia is old age hypermetropia.

Cause

In old age, the ciliarymuscles become stiff, and hence, theydo not contract. This theyare unable to make thecrystalline lens thicker, withthe result that the focal length of thecrystalline lens does not decrease as desired. Thus, the image of the object situated at the least distance of distinct vision is formed behind the retina.

Correction : Same as in the case of hypermetropia



Bifocal Lens

Note : Some times a person who already had myopia at younger age, may suffer from presbyopia at old age. Such persons overcome this by using bifocal lens as shown :

To rectify long sightedness, glasses fitted with convex lenses are used and for short sightedness, glasses fitted with concave lenses are used.

Defect	Description	Cause	Remedy
Myopia or short sightedness	Eye can see distinctly only to the near object. Far - point of eye comes closer than infinity.	Focal length of eye lens decreases. Rays from ∞ focus at a point in front of the retina.	Using a concave lens of focal length = distance of far point from defective eye.
Hypermetropia or far sightedness	Eye can see distinctly the far off objects. Near point of eye shifts away from the eye.	Focal length of eye lens increases. Rays from near point focus at a point at the back of retina.	Using a convex lens of focal length (f) where $\boxed{\frac{1}{f}=\frac{1}{v}-\frac{1}{u}}$ f, v ,u having usual meaning.
Astigmatism	Object gets focused in one direction but out of focus in perpendicular.	Cornea is not spherical but has a higher curvature at one plane.	By prescribing cylindrical lens in place of spherical
Presbyopia	Image of nearby objects appears blurred. Power of accommodation of the eye decreases.	Decreasing effectiveness of the ciliary muscles and loss of flexiblity of the lens with age.	By using a converging lens for reading and other intericate work.

Do you know that our eyes can live even after our death?

By donating our eyes, after we die, we can light the life of two blind persons.About 5 million people in developing countries are blind and most of them can be cured. Their blindness is due to cornea turning opaque, due to some disease or bad hygiene.

The opaque cornea can be removed and in its place healthy cornea from the donated eye can be transplanted. This allows the light to enter in the eye ball, and hence, the person can see. An eye bank collects, evaluates and distributes the donated eyes.All donated eyes are checked using strict medical standards. Those donated eyes found unsuitable for transplantation are used for valuable medical research.

What should be kept in mind while donating eyes?

- Eyes must be removed within 4-6 hours after death. Nearest eye bank should beinformedimmediately.
- Eye bank team removes eyes at the home of deceased or the hospital in which death occurs.
- Removalofeyestakes10-15minutes.Itdoesnotleadtodisfigurementofthedeceased.

- Eye donors can belong to any age group or sex. Even the people who wear spectacles or are operated for cataract can donate eyes. People suffering from diabetes, hypertension, asthma can also donate their eyes.
- PeoplewhowereinfectedwithAIDS,HepatitisB andC,rabies,tetanus, cholera, acuteleukaemia,meningitis, encephalitis, cannot donate eyes.

Other Problems of the Eye

Colour - Blindness :

The retina of our eye has large number of light sensitive cells having shapes of rods and cones. The rodshaped cells respond to the intensityof light with different degrees of brightness and darkness whereas the cone shaped cells respond to colours. In dim light rods are sensitive, but cones are sensitive only in bright light. The cones are sensitive to red, green and blue colours of light to different extents. Due to genetic disorder, some persons do not possess some cone-shaped cells that respond to certain specific coloursonly.Suchpersons cannot distinguishbetween certain coloursbut canseewell otherwise. Such person are said to have colour-blindness. Driving licenses are generally not issued to persons havingcolour-blindness.

Phorias :

Phorias is the defect and it can be corrected using spectacles with prismatic lenses. Phorias is a condition when a viewer sees two individual images using both eyes, instead of one image that a normal person sees i.e. merged by our brain. If both eyes are affected, a misconvergence occurs, meaning the images by both eyes need to be repositioned individuallyin order to get a single image. This is done with the help of prismatic eye glasses.

Cataract :

A common problem in old age is cataract, which gradually reduces the amount of light reaching the retina. The crystallinelens of the eye is made of proteins that are arranged in a regular pattern, which makes the lens transparent. When a group of these protein

molecules get lumped in a region, it becomes opaque, and we saythat a cataract has developed in the region. Graduallythe cataract grows, and finally, the whole lens becomes opaque.And as the cataract grows, the abilityof the person to see diminishes.

Correction for cataract :

To restore vision,the affected lens issurgicallyremoved, and an artificiallens is placed inits place. There are two methods to remove the cataract. In the first method cataract is removed by surgery and the patient has to use thick glasses. Due to it the objects appear larger and field of view is decreased. The second method is modern one in which an artificial lens is implanted in the patient's eye, which is called intraocular lens.After the removal of cataract the artificial lens is implanted in front of thin membrane. Surgical cut is minimum in this method, thick glasses are not required and field of view is increased. Apart from the common defects described above, a person may develop other problems that hinder clear vision. For example, looking at the sun with naked eyes during a solar eclipse can damage the retina.

Contact lens

A contact lens is a small lens which is worn directly on the cornea. It has one clear advantage over spectacles. When a person wearing spectacles looks through the corner of the eye, the cornea and the centre of the lens are not in line. As a result, the peripheral view gets distorted. Since a contact lens moves with the cornea, this problem does not arise.Apart from this, some people may prefer contact lenses for cosmetic reasons.

Illustration

The distance between the eye lens and retina is fixed. Then, how is the eye lens said to have adjustable focal length.

Solution

As per the lens formula, we have

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

In the eye, the distance between the eye lens of retina, called image. Distance 'v' is fixed. Therefore, eye lens adjusts its focal length 'f' for different object distances 'u'. Eyelens adjusts its focal length by changing its thickness.To see different distant objects, the eye lens changesits shape.This iswhyit is saidthat the eyelens has adjustablefocal length.

ANGULAR MAGNIFICATION

Angular magnification is defined as the ratio of the angle subtended by the image at the eye to

the angle subtended by the object at the eye of the observer. Thus,

$$M_0 = \frac{\text{angle subtended by the image at the eye.}}{\text{angle subtended by the object at the eye.}}$$

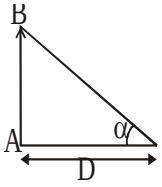
$$M_0 = \frac{\beta}{\alpha}$$

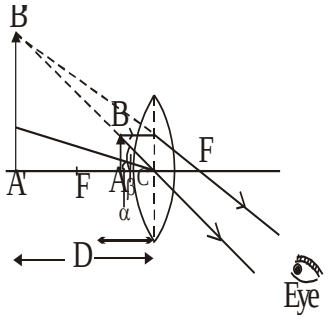
This is also known as the **magnifying power**.

Thus, the magnifying power is the factor by which the image on the retina can be enlarged by using the microscope.

Simple Microscope

It is a convex lens of small focal length, with a handle to hold. To see a small object by this instrument, the lens is moved towards the object till the object comes in between the focus and optical centre of the lens. So a virtual, erect and magnified image is formed. This is the principle of simple microscope. It is used in spectacles and by watch repairers.





Magnifying Power :

The ratio of the size of image and object is called the magnifying power.

Magnifying power of a simple microscope is given by following formula –

(i) When final image is formed at near point distance D :

$M = l + D/f$

D is the least distance of distinct vision which is 25 cm and f is the focal length of the convex lens.

(ii) When final image is formed at infinity

$M = D/f$

(iii) Magnifying power is inversely proportional to the focal length of lens.

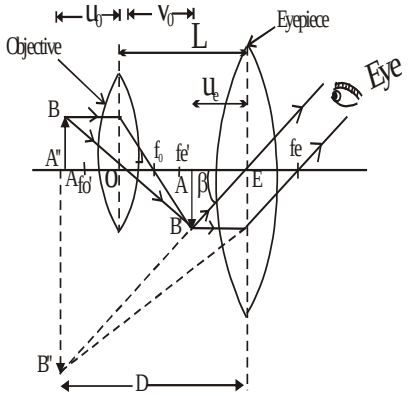
(iv) The magnifying power of a simple microscope is maximum when the image is formed at the least distance of distinct vision (D).

Compound Microscope

This instrument is used to view very small objects like structure of bacteria after .considerable magnification.

Construction:

It consists of a cylindrical metal tube with a convex lens of small aperture and short focal length fixed at one end of it. This lens is always towards the object and is called the objective. At the other end of the tube another smaller tube is fitted. At the outer end of this tube a convex lens E is fixed which has aperture and focal length greater than that of objective. This lens is directed towards the eye and is called eye piece. The tube as a whole can be moved in or out with the help of rack and pinion arrangement.



Working:

AB is an object which is placed in front of the objective at a distance slightly greater than the focal length of the objective lens. A real, inverted and magnified image A'B' of the object AB is formed on the other side of the lens. It acts as the object for the eye piece. The position of eye piece is so adjusted that A'B' lies between its focus (F_e) and optical centre (E). A virtual, erect and magnified image A"B" of the object A'B' is formed. It is clear that magnification of the object is achieved by both the lenses- objective and eye piece. Hence the final image will be highly magnified.

Magnifying power of a compound microscope

The magnifying power of a compound microscope is the ratio between the final size of the virtual image to the actual size of the object.

$$Magnifying\ \ power\ m = \frac{Final\ \ size\ of\ \ the\ image\ seen\ through\ the\ microscope}{Actual\ \ size\ of\ \ the\ object}$$

Mathematically, magnifying power of a microscope is given by the expression below, whose derivation is beyond the scope of this book.

$$\text{Magnifying power } m = \frac{D \times L}{f_0 \times f_e}$$

where D = Least distance of distinct vision (25 cm for a normal eye)

L = Distance between the objective lens and the eye piece or total length of the microscope tubes (in cm)

f_0 = focal length of the objective lens (in cm)

f_e = focal length of the eye piece (in cm)

Astronomical Telescope

Far off objects like planets, stars, aeroplanes etc. appears small and blurred, although being very large in size, due to their large distance from the eye. The instrument which is used to view these objects clearly and enlarged, is called telescope.Telescopes are of two types-

(A) Astronomical Refracting Telescope (B) Newton's Reflecting Telescope

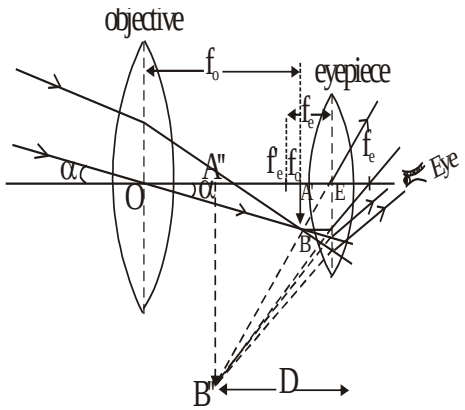
Astronomical Refracting Telescope:

It is used to view astronomical bodies. An inverted, virtual and enlarged image is formed by it.

Construction :

It consists of a long cylindrical metal tube with a convex lens of large focal length and large aperture fixed at one end of it. This lens is called objective (O). At the other end of the tube a smaller tube is fitted which can be moved in or out with the help of rack and pinion arrangement.

Magnification : $m = \frac{f_0}{f_e}$ **Lenght of telescope** $= f_0 + f_e$



A convex lens of small aperture and short focal length is fixed at the outer end of the smaller tube, which is called eye piece (E).

Working:

Image formation of a distant object AB by telescope is shown in Figure. A real, inverted and diminished image A'B' of the object AB is formed by the lens O on the other side of the lens at the principal focus F_o. This image acts as the object for the eye piece. The eye piece is so adjusted that the image A'B' lies between the principal focus (F_e) and optical centre (E) of the eye piece. An erect image of A'B' but virtual, inverted and magnified image of the distant object AB is obtained by the eye piece.

llustration

A telescope has an objective of focal length 140 cm and an eye piece of focal length 5 cm.

Find

(i) The magnification of the telescope for viewing distant objects for normal adjustment.

(ii) Sepration between the objective lens and the eye piece.

Solution

Objective of focal length, $f_0 = 140$ cm

Eyepiece of focal length, $f_e = 5$ cm

(i) The magnification of the telescope

$$m = \frac{f_0}{f_e} = \frac{140}{5} = 28$$

(ii) Separation between the object lens and the eye piece,

$L = f_0 + f_e = 140 + 5$

$= 145$ cm $= 1.45$ m