Fsc Part 1 Chapter 10

Least Distance of Distinct Vision or Near Point

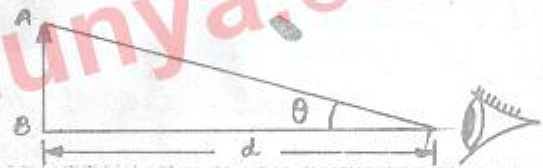
Definition: The minimum distance from the eye at which an object appears to be distinct is called the least distance of distinct vision or near point.

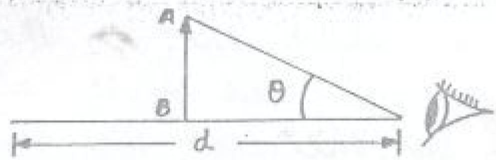
It is denoted by 'd'.

Explanation

The normal human eye can focus a sharp image of an object on the eye if object is located any where from infinity to a certain point called the near point.

Consider an object AB is placed at least distance of distinct vision 'd' as shown in figure. In this case, we can see a sharp and distinct image on the eye. But when the object AB is held closer to the eye than distance 'd', the image formed will be blurred and fuzzy. In this case, the image on the eye is much larger and we will be able to see the fine details of the object. For that purpose, we use a convex or converging lens.





The least distance of distinct vision is about 25cm from the normal eye. The position of the near point changes with age.

Magnification

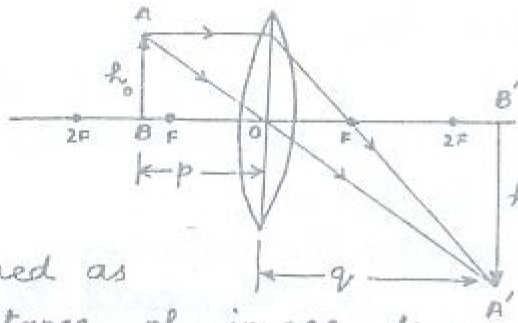
Definition: The ratio of the size of the image to the size of the object is called magnification.

It is also known as linear or transverse magnification and denoted by 'M'.

So

$$\text{MAGNIFICATION} = \frac{\text{Size of Image}}{\text{Size of Object}}$$

or $$\boxed{M = \frac{h_i}{h_o}} \longrightarrow (1)$$



Magnification is also defined as "The ratio between the distance of image from the lens (q) to the distance of object from the lens (p)". So

$$\text{MAGNIFICATION} = \frac{\text{Distance of image from the lens}}{\text{Distance of object from the lens}}$$

or $$\boxed{M = \frac{q}{p}} \longrightarrow (2)$$

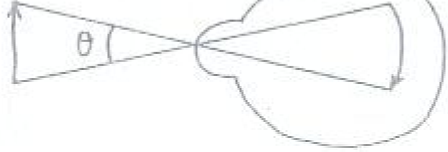
Comparing equation (1) and (2)

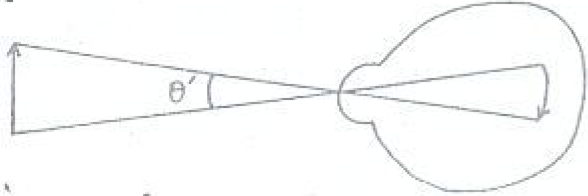
$$\therefore \quad \boxed{M = \frac{h_i}{h_o} = \frac{q}{p}}$$

ANGLE OF VISION

DEFINITION: The angle subtended by the object at the eye is called angle of vision.

The apparent size of the object depends upon the actual size of the object and on the angle subtended by it at the eye. The closer the object to the eye, the greater is the angle of vision subtended and the size of the object appears to be large. From figure, the angle θ subtends by the object is greater than θ'.





MAGNIFYING POWER OR ANGULAR MAGNIFICATION

DEFINITION: It is defined as the ratio of the angles subtended by the image as seen through the optical device to that subtended by the object at the unaided eye. Mathematically, magnifying power is

$$\boxed{\text{MAGNIFYING POWER} = M = \frac{\beta}{\alpha}}$$

Where

α = Angle subtended by the object at unaided eye.

β = Angle subtended at the eye by the image.

RESOLVING POWER

DEFINITION: The ability of an optical instrument to reveal the minor details of the object under examination is called its resolving power.

EXPLANATION

Resolving power is the ability of optical instruments to separate two close objects. It is denoted by "α_{min}" which is the minimum angle between two point sources that allow the two close images as two distinct spots of light rather than one. α_{min} is given as

$$\boxed{\alpha_{min} = 1.22\frac{\lambda}{D}}$$

This formula is derived by Rayleigh, called "Rayleigh Criterion". Where

λ = Wavelength of light

D = Diameter or Aperture of lens.

In case of Grating Spectrometer, the resolving power 'R' is defined as

$$\boxed{R = \frac{\lambda}{\lambda_2 - \lambda_1} = \frac{\lambda}{\Delta\lambda}}$$

Where $\lambda \approx \lambda_1 \approx \lambda_2$ and $\Delta\lambda = \lambda_2 - \lambda_1$

Hence a grating with high resolving power has a small difference in wavelength.

The resolving power R of grating if light is diffracted from the grating is

$$\boxed{R = N \times m}$$

Where

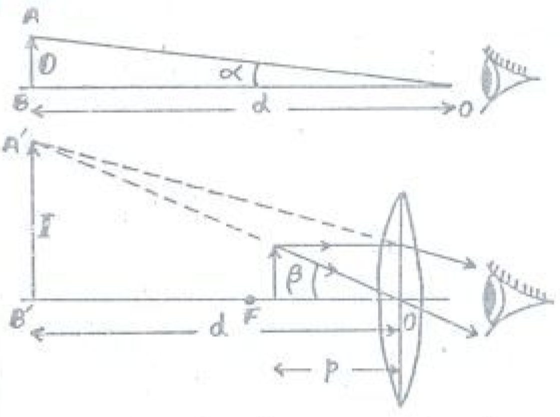
N = Number of rulings or slits on the grating.
m = mth order diffraction.

Simple Microscope or Simple Magnifier or Magnifying Glass

An optical instrument used to see small objects magnified which make small angle of vision with eye, called simple microscope.

Construction and Working

A simple microscope consists on a convex or converging lens used to help the eye to see small objects clearly.



Consider a small object AB is placed at near point 'd' from the eye, then its apparent size O appears to be small due to small angle of vision 'α' subtends at the eye as shown. Now place a convex lens in between eye and object so that object is found in between the focal plane of the lens. Hence, a virtual, erect and enlarged image A'B' is formed at near point 'd' from the eye as shown in figure.

Magnifying Power of Simple Microscope

It is defined as "The ratio between the angles β and α subtended by the image at the lens to the angle subtended by the object at the eye. So

$$M = \frac{\beta}{\alpha} \longrightarrow (1)$$

The angles are so small that they are nearly equal to their tangents. Hence

$$\alpha = \tan\alpha = \frac{AB}{OB} = \frac{\text{Size of Object}}{\text{Distance of object}} = \frac{O}{d}$$

and $$\beta = \tan\beta = \frac{A'B'}{OB'} = \frac{\text{Size of image}}{\text{Distance of image}} = \frac{I}{q}$$

Since the image is at near point 'd', so

Distance of Image $= q = d$

$$\therefore \beta = \frac{I}{q} = \frac{I}{d}$$

Put values in equation (1)

$$M = \frac{\beta}{\alpha} = \frac{I/d}{O/d} = \frac{I}{O}$$

As we know that

$$\frac{I}{O} = \frac{\text{Size of Image}}{\text{Size of Object}} = \frac{\text{Distance of the image}}{\text{Distance of the object}} = \frac{q}{p}$$

$$\therefore M = \frac{I}{O} = \frac{q}{p} \qquad (\because q = d)$$

$$M = \frac{d}{p} \longrightarrow (2)$$

Using lens formula, we have

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

As image formed is virtual, so q is negative

$$\therefore q = -d$$

So

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{(-d)}$$

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

Multiplying both sides by d, we get

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

$$\Rightarrow \frac{d}{p} = 1 + \frac{d}{f}$$

Put this value in equation ②, the magnifying power of simple microscope is given as

$$\boxed{M = 1 + \frac{d}{f}}$$

Hence, magnifying power of simple microscope depends upon the focal length of the lens. Smaller the focal length of the lens, greater will be the magnifying power of simple microscope.

For example, if $f = 5cm$ and $d = 25cm$, then

$$M = 1 + \frac{25}{5} = 1 + 5 = 6$$

So, object should be six times larger when viewed through such a lens.

COMPOUND MICROSCOPE

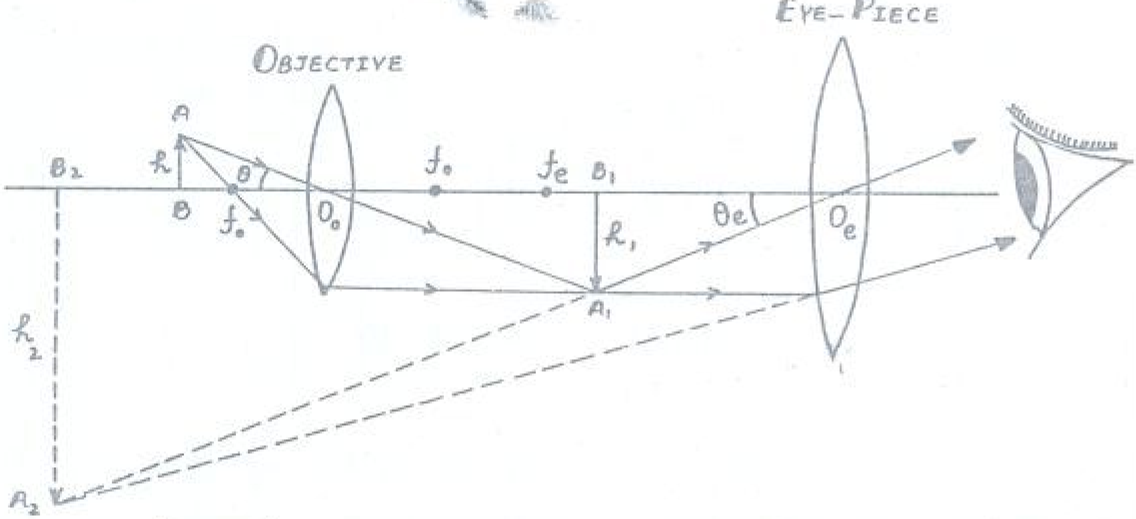
An optical instrument used to see very small objects magnified which can not be seen with unaided eye is called compound microscope.

CONSTRUCTION

It consists of two convex lenses. The lens close to object, called OBJECT LENS of very short focal length 'f_o' and short aperture while the other lens which is close to eye, called EYE-PIECE of comparatively large focal length 'f_e' and large aperture.

Object lens is mounted in a bigger tube and eye-piece lens is mounted in a smaller tube which can be slided in or out of the bigger tube so that distance between both lenses can be changed.

WORKING



Consider an object AB of height h is placed just beyond the principal focus of the objective, so it produces a real, inverted and magnified image A_1B_1 of height h_1 of the object AB at a place within the focal point of the eye-piece. This image A_1B_1 act as an object for eye-piece. Eye-piece act as a magnifying glass and formed a virtual, inverted and magnified image A_2B_2 of height h_2 as shown by ray diagram. In normal adjustment, the eye-piece is so adjusted that the final image A_2B_2 is formed at the near point of the eye at a distance 'd'.

MAGNIFYING POWER

The angular magnification or magnifying power M of compound microscope is defined as the ratio of angle θ_e subtended by the final image at the eye to the angle θ subtended by the object at the eye when both are at near point. So

$$M = \frac{\theta_e}{\theta}$$

These angles are so small that they are nearly equal to their tangents. Hence

$$\theta = \tan\theta = \frac{AB}{O_oB} = \frac{h}{d} \qquad (\because AB = h,\ O_oB = d)$$

$$\theta_e = \tan\theta_e = \frac{A_2B_2}{O_eB_2} = \frac{h_2}{d} \qquad (\because A_2B_2 = h_2,\ O_eB_2 = d)$$

So, magnification is given as

$$M = \frac{h_2/d}{h/d} = \frac{h_2}{h}$$

or $$M = \frac{h_1}{h} \times \frac{h_2}{h_1}$$

or $$M = M_1 M_2 \longrightarrow ①$$

Where

$M_1 = h_1/h$ = Linear magnification of the objective.

$M_2 = h_2/h_1$ = Linear magnification of the eye-piece.

These magnifications are given as

$$M_1 = \frac{h_1}{h} = \frac{q}{p} \quad \text{and} \quad M_2 = \frac{h_2}{h_1} = \left(1 + \frac{d}{f_e}\right)$$

Put these values in equation ①

$$\therefore \quad \boxed{M = \frac{q}{p}\left(1 + \frac{d}{f_e}\right)}$$

This is the angular magnification of microscope.

The resolving power of compound microscope depends on the width of the objective. A wider objective and use of blue light of short wavelength produces less diffraction and allows more details to be seen.

TELESCOPE

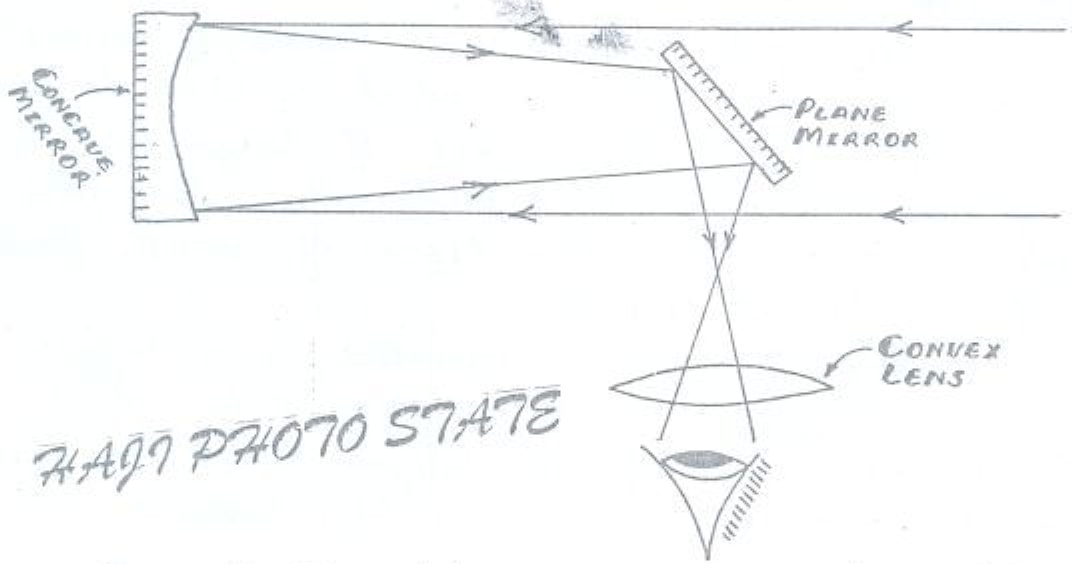
An optical instrument used to see distant objects, called telescope.

Their are two types of telescopes

(i) REFLECTING TELESCOPE

(ii) REFRACTING TELESCOPE

REFLECTING TELESCOPE



In reflecting telescope, concave mirror is used as an objective. Parallel rays from a distant object are incident on concave mirror and after reflection, these rays are converged at the focus of the mirror. Before these rays are actually focussed, reflected by a plane mirror and form a real image of the distant object in front of eye-piece lens as shown in figure. Eye-piece lens act as a magnifying glass and formed a virtual, enlarged image at a least distance of distinct vision.

Large astronomical telescopes are reflecting type made from specially shaped very large mirrors used as objectives. Astronomers used such telescopes to study stars which are millions light year away.

ASTRONOMICAL TELESCOPE

An optical instrument used to see heavenly objects like stars, moon etc is called astronomical telescope.

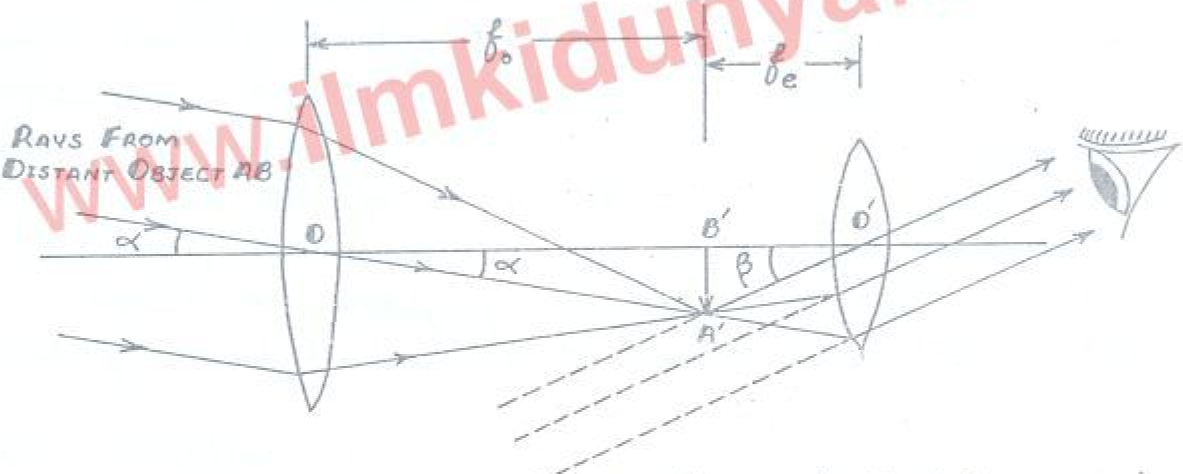
Initially, telescopes are used for astronomical observations, so these telescopes are called astronomical telescopes.

CONSTRUCTION

A simple astronomical telescope consists of two convex lenses. The lens which is close to object called **OBJECT LENS** or **OBJECTIVE** of large focal length 'f_o' and large aperture. While other lens which is close to eye, called **EYE-PIECE** of small focal length 'f_e' and small aperture.

Objective lens is mounted in a bigger tube and eye-piece in a smaller tube which can be slided in or out of the bigger tube, so that distance between both lenses can be changed.

WORKING



The ray diagram of astronomical telescope is shown in figure. The rays coming from a distant object AB are assumed to be parallel. When this parallel beam of rays coming from a distant object AB incident on the objective lens, it form a real, inverted and diminshed image A'B' at its focus. This real image A'B' act as object for the eye-piece which is used as a magnifying glass. The final image seen through the eye-piece is virtual, inverted and enlarged.

In order to see the final image through the eye-piece without any strain on the eye, the eye-piece must be placed so that the image A'B' lies at its focus. Now the rays after refraction from the eye-piece will become parallel and the final image appears to be formed at infinity. In this condition, the image A'B' formed by the objective lies at the focus of the both the objective and the eye-piece and the telescope is said to be in normal adjustment.

Magnifying Power

The ratio between angle β subtended by the final image at the eye to the angle α subtended by the object at the eye is called magnifying power of astronomical telescope.

So, magnifying power is given as

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

These angles are so small that they are nearly equal to their tangents. Hence

α = Angle subtended by the object at the eye and it is equal to $\angle A'OB'$

and β = Angle subtended by the final image at the eye and it is equal to $\angle A'O'B'$

Where

$$\alpha = \tan\alpha = \frac{A'B'}{OB'} = \frac{A'B'}{f_o} \qquad (\because OB' = f_o)$$

$$\beta = \tan\beta = \frac{A'B'}{O'B'} = \frac{A'B'}{f_e} \qquad (\because O'B' = f_e)$$

So

$$M = \frac{\beta}{\alpha} = \frac{A'B'/f_e}{A'B'/f_o}$$

or $$\boxed{M = \frac{f_o}{f_e}}$$

or $$\boxed{M = \frac{\text{Focal Length of the Objective}}{\text{Focal Length of the Eye-piece}}}$$

Hence magnifying power of astronomical telescope is equal to the ratio of objective focal length to the eye-piece focal length. Its magnifying power can be increased by using objective of larger focal length and eye-piece of smaller focal length. A good telescope has an objective of long focal length and large aperture so that it may collect more light from the object to form a bright image.

Length Of Telescope

The distance between objective and eye-piece lenses is called length of telescope.

From ray diagram, the length of telescope is

$$L = OO' = OB' + O'B'$$

$$\boxed{L = f_o + f_e}$$

Hence, length of astronomical telescope is equal to the sum of objective and eye-piece focal lengths.

Spectrometer

An optical instrument used to study the from different sources of light is called spectrometer.

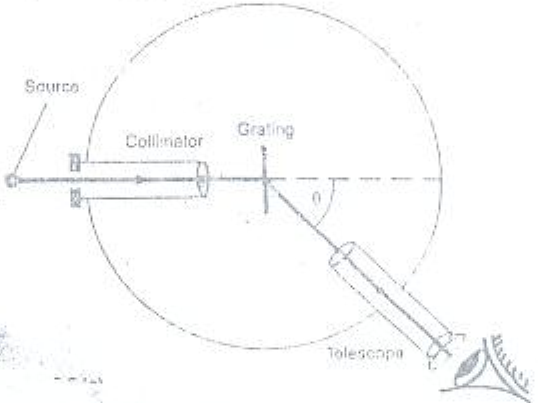
Construction

The essential components of spectrometer are

(i) Collimator

(ii) Turn Table

(iii) Telescope



Collimator

It consists of a fixed metallic tube with a convex lens at one end and an adjustable slit at the other end which can be slided in and out of the tube. When the slit is just at the focus of the convex lens, then the rays of light coming out of lens become parallel. For this reason, it is called a collimator.

TURN TABLE

It is a circular table which can rotate about a fixed vertical axis. A prism or grating is placed on it. Turn table can be raised or lowered with the help of levelling screws. A circular scale is attached with it usually graduated in half degrees for measurement of angle.

TELESCOPE

An ordinary refracting telescope is attached with a vernier scale and can be rotated about the same vertical axis as that of turn table.

ADJUSTMENTS IN SPECTROMETER

Before using a spectrometer, following adjustments must be made.

(i) Collimator is so adjusted that parallel rays of light emerge out of its convex lens.

(ii) The telescope is so adjusted that the rays of light entering it are focussed at the cross-wires near the eye-piece

(iii) The refracting edge of the prism must be parallel to the axis of rotation of telescope so that the turn table is levelled.

(iv) The collimator, telescope and turn table are so adjusted that they must lie in the same horizontal plane.

USES OF SPECTROMETER

It has following uses

(i) It is used to study the spectra from different sources of light.

(ii) It is used to determine the refractive index of the material of the prism accurately.

(iii) It can measure the wavelength of light by using a diffraction grating.

SPEED OF LIGHT

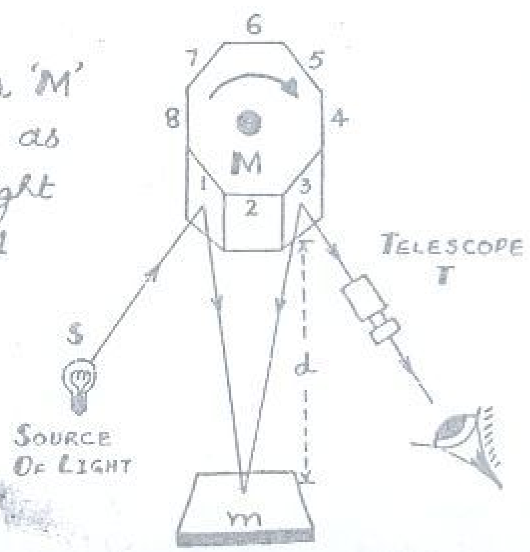
Galileo was the first person which tried to measure the speed of light but he could not succeed. Speed of light accurately measured by Michelson. He used rotating mirror method to measure speed of light, this method is known as MICHELSON'S EXPERIMENT.

EXPERIMENTAL ARRANGEMENT

An eight-sided polished mirror 'M' is mounted on the shaft of a motor whose speed can be changed. A plane mirror 'm' is placed at a distance 'd' from the mirror 'M' as shown in figure. A telescope 'T' is also placed at a certain position to see the reflected light from mirror 'M'.

WORKING

Consider that mirror 'M' is stationary in the position as shown in figure. A beam of light from source 'S' falls on face 1 of the mirror 'M'. After reflection from 'M', light falls on plane mirror 'm'. This beam of light



again reflected back from plane mirror 'm' and falls on face 3 of the mirror 'M'. On reflection from face 3, light enters the telescope 'T'.

Consider that the mirror 'M' is rotated clockwise with certain speed. Initially, the source of light 'S' will not be visible through the telescope 'T' and when the mirror 'M' gains a certain speed, the source 'S' becomes visible. This happens when the time taken by light in moving from M to m and back to M is equal to the time taken by face 2 to move to the position of face 3. In this condition, the light covers a distance of 2d,

As

$$\left.\begin{array}{l}\text{Total angle subtended by the eight}\\ \text{sided mirror M in one revolution}\end{array}\right\} = 2\pi$$

So

$$\left.\begin{array}{l}\text{Angle subtended by any side of}\\ \text{the eight sided mirror M}\end{array}\right\} = \frac{2\pi}{8}$$

Let

Frequency of mirror $M = f$

When source S is visible through the telescope T, then time taken by the mirror M in one revolution or rotate through an angle 2π is $1/f$.

So, the time taken by the mirror M to rotate through an angle $2\pi/8$ is given as

$$\omega = \frac{\theta}{t} \Rightarrow t = \frac{\theta}{\omega}$$

Where 'ω' is angular speed of mirror M and it is given as

$$T = \frac{2\pi}{\omega} \Rightarrow \omega = \frac{2\pi}{T} = 2\pi\left(\frac{1}{T}\right) = 2\pi f$$

and $\theta = \dfrac{2\pi}{8}$

$$\therefore \quad t = \frac{\theta}{\omega} = \frac{2\pi/8}{2\pi f}$$

or $$t = \frac{1}{8f} \longrightarrow (1)$$

Now, time taken by light to cover distance '2d' from mirror M to m and back to M is

$$\text{Time} = \frac{\text{Distance}}{\text{Speed}}$$

or $$t = \frac{2d}{c} \longrightarrow (2) \quad (\because \text{Speed of light} = c)$$

These two times are equal, so comparing equation (1) and (2), we get

$$\frac{1}{8f} = \frac{2d}{c}$$

or $$c = (8f)(2d)$$

or $$\boxed{c = 16fd} \longrightarrow (3)$$

Michelson used this equation to find the speed of light. Presently accepted value for the speed of light in vacuum is

$$\boxed{c = 2.99792458 \times 10^{8}\ m s^{-1}}$$

or $$\boxed{c = 3.00 \times 10^{8}\ m s^{-1}}$$

The speed of light depends upon the nature of the medium. Its value for vacuum is c and for other mediums is always less than c. However, the speed of light in air is approximately equal to that in vacuum.

Introduction To Fibre Optics

For hundreds of years, man uses flashes of reflected light from sun by day and lanterns by night for communications. During periods of radio-silence, navy signalmen uses powerful blinker lights to transmit coded signals to other ships. Alexander Graham Bell invented a device known as 'PHOTO PHONE' shortly after his invention of telephone. With the help of this device, Bell was able to communiate his voice signal via a beam of light This idea was used for many years. During the recent past the transmission of light through thin optical fibres has been revived and is now being used in communication technology.

The use of light as transmission carrier wave in fibre optics has several advantages over radio wave carriers due to their much wider bandwidth capability and immunity from electromagnetic effect.

Advantages of optic fibres are given as

1. It is used to transmit light around corners and into inaccessible places

2. The fibre optic tools are used in industry.

3. The fibre optic diagnostic tools are used in medicine.

4. Thousands of telephone conversations, several television programs and number of data signals between stations are transmitted through one or two flexible hair-thin threads of optical fibre.

5. An optical fibre with its protective case is almost 6.0 mm in diameter can replace a 7.62 cm diameter bundle of copper wires to carry the same amount of signals.

STRUCTURE OF OPTICAL FIBRE

Optical fibre consists of two parts

(i) Core

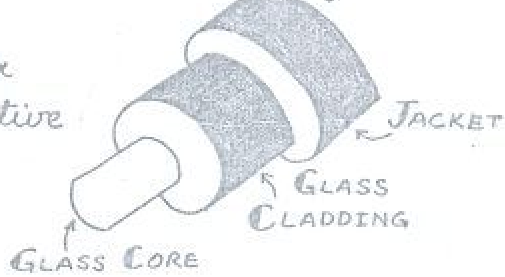
(ii) Cladding

CORE

The central portion of the optical fibre is called core. It is made of silica or SiO_2. Its refractive index is greater than the cladding.

CLADDING

The core is wrapped by a cover, called cladding. Its refractive index is less than the core. Cladding is covered by a jacket.



FIBRE OPTIC PRINCIPLES

Propogation of light in an optical fibre requires that the light should be totally confined within the fibre. This may be done by two ways.

(i) Total Internal Reflection

(ii) Continuous Refraction

(i) TOTAL INTERNAL REFLECTION

One of the qualities of any transparent material is the speed at which light travels within material. It depends upon the refractive index 'n' of the material.

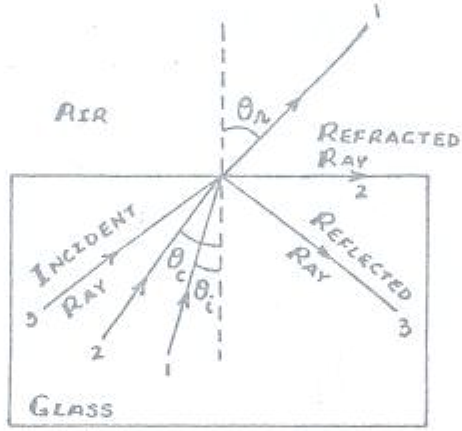
REFRACTIVE INDEX

It is defined as the ratio of the speed of light 'c' in vacuum to the speed of light 'v' in that material. It is denoted by 'n'

$$n = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in material}} = \frac{c}{v}$$

CRITICAL ANGLE

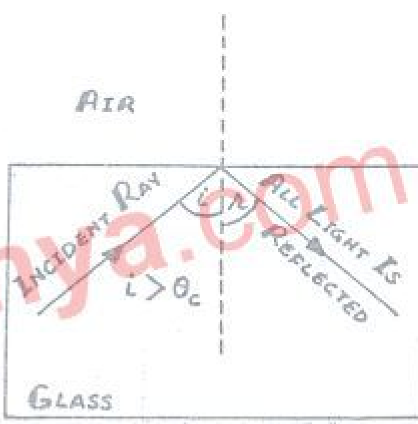
When light enter from a denser to a rarer medium, then it bends away from the normal. In this case, the angle of refraction is always greater than the angle of incidence. If we increase the angle of incidence then the corresponding angle of refraction will also increase until at some angle of incidence the angle of refraction becomes 90°. Hence the angle of incidence for which the angle of refraction is 90°, called critical angle (θ_c).



(CRITICAL ANGLE)

TOTAL INTERNAL REFLECTION

When light enter from a denser to a rarer medium, then if the angle of incidence becomes greater than the critical angle, then light did not refract but reflection takes place from the boundary of two media. This phenomenon of light is called as total internal reflection.



(TOTAL INTERNAL REFLECTION)

The conditions for total internal reflection are

(i) The incident ray should enter from denser to rare medium.

(ii) The angle of incidence should be greater than critical angle.

TOTAL INTERNAL REFLECTION USED IN FIBRE OPTICS

For incidence angles equal or greater than the critical angle, the glass-air boundary will act as a mirror and no light escapes from the glass.

Using Snell's law to find the critical angle 'θ_c' for glass-air boundary as

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Where

n_1 = Refractive index of glass = 1.5

n_2 = Refractive index of air = 1.0

θ_1 = Angle of incidence
θ_2 = Angle of refraction

By the definition of critical angle

If $\theta_1 = \theta_c$

then $\theta_2 = 90°$

Putting these values in Snells law, we have

$$n_1 \sin\theta_c = n_2 \sin 90°$$

or $$n_1 \sin\theta_c = n_2(1) \qquad (\because \sin 90° = 1)$$

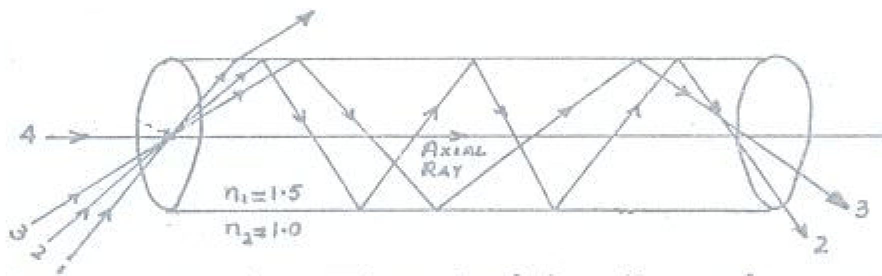
or $$\sin\theta_c = \frac{n_2}{n_1}$$

or $$\sin\theta_c = \frac{1.0}{1.5} = 0.66$$

or $$\theta_c = \sin^{-1}(0.66)$$

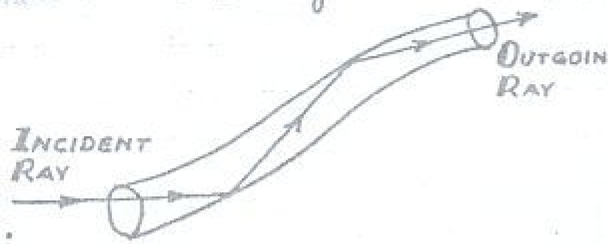
or $$\boxed{\theta_c = 41.8°}$$

Now consider that the glass is formed into a long, round rod. As we know that all the light rays striking the internal surface of the glass at angles greater than critical angle 41.8° will be reflected back into the glass while those rays with angles less than 41.8° will escape from the glass as shown.



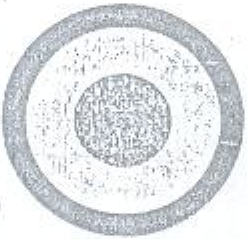
Let ray 1 is entered into the glass rod and strikes the glass - air boundary at about 30°. As this angle is less than the critical angle, it will escape from the glass rod and then lost. Ray 2 strikes the glass - air boundary at 42°, so it will be reflected back into the rod, as will ray 3 at 60°. Since the angle of reflection equals the angle of incidence, these two rays will continue to move down the rod as shown. Ray 4 is called an axial ray since its path is parallel to the axis of the rod. Axial rays will travel directly down this straight rod.

However, in flexible glass fibre they will be subjected to the laws of reflection.



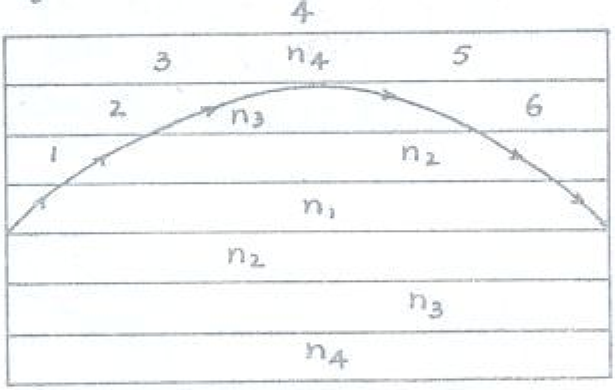
(ii) CONTINUOUS REFRACTION

There is another method of propogation of ligh through optical fibres in which light is continuousl refracted within the fibre. For this purpose centr core has high refractive index and over it is a layer of a lower refractive index. This layer is called cladding. Such type of fibre is called mu -mode step index fibre whose cross-sectional vie is shown in figure.



Now-a-days, a new type of optical fibre is used in which the central core has high refractive index and its density decreases gradually towards the periphery. This type of fibre is called multi-mode gradded index fibre.

In both these fibres, the propogation of light signal is through continuous refraction. When a ray pass fr a denser to a rarer medium it bends away fr the normal and vice-versa. In step index or gradded index fibre, a ray of light entering th optical fibre is continuously refracted through steps and is reflected from the surface of t outer boundary. Hence light is transmitted by continuous refraction and total internal reflection.



MODE

The method by which light is propogated within the fibre is called mode. Mode is the various paths that light can take in travelling down fibre.

TYPES OF OPTICAL FIBRES

There are three types of optical fibre

(i) Single-mode step index fibre.

(ii) Multi-mode step index fibre.

(iii) Multi-mode gradded index fibre.

SINGLE-MODE STEP INDEX FIBRE

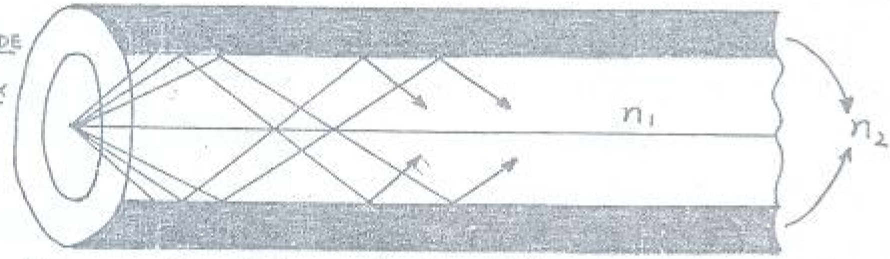
The diameter of the core of this fibre is very thin of about 5 μm and it has a relatively large cladding of glass or plastic. Since it has very thin core, a strong monochromatic light source i-e; a Laser source is used to send light signals through it. It can carry more than 14 TV channels or 14000 phone calls.

MULTI-MODE STEP INDEX FIBRE

The diameter of the core of this fibre is relatively large of about 50 μm and it has comparatively smaller cladding. It is used for carrying white light but due to dispersion effects, it is useful for short distance only. The fibre core has a constant refractive index 'n_1' such as 1.52 from its centre to boundary with the cladding as shown in figure.

SINGLE-MODE STEP INDEX FIBRE

MULTI-MODE STEP INDEX FIBRE

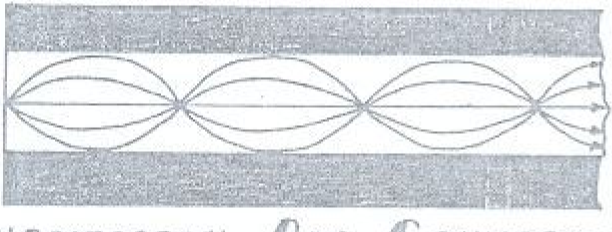


The refractive index then changes to a lower value 'n_2' such as 1.48 which remains constant throughout the cladding.

MULTI-MODE GRADED INDEX FIBRE

The diameter of the core of this fibre ranges from 50 μm to 1000 μm. It has a core of relatively high refractive index and the refractive index decreases gradually from the middle to the outer surface of the fibre. There is no definite boundary between core and the cladding. This type of fibre is useful for long distance applications in which white light is used

MULTI-MODE GRADED INDEX FIBRE



SIGNAL TRANSMISSION AND CONVERSION TO SOUND

The signal transmission through optical fibre consists of three major components given as

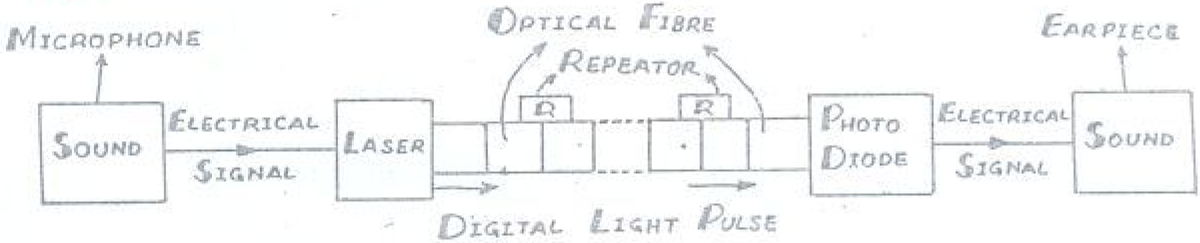
(i) A TRANSMITTER ⟹ That converts electrical signals into light signals.

(ii) AN OPTICAL FIBRE ⟹ It is used for guiding the signal

(iii) A RECEIVER ⟹ That receive the light signals at th other end of the fibre and reconverts them to electrical signals.

The light signal in the transmitter may be a semiconductor laser or a light emitting diode (LED). With either device, the light emitted is an invisible infra-red signals of wavelength is about 1.3 μm. Such a light will travel faster through optical fibres than will either visible or ultra-violet light.

The lasers and LED's used in this case are tiny units less than half the size of the thumbnail in order to match the size of the fibres. To transmit information by light waves, it is necessary to modulate the light signals. For this, we use digital modulation in which laser or LED is flashed on and off at an extremely fast rate. A pulse of light represents the number 1 and absence of light represents zero. So, instead of flashes of light travelling down the fibre, Ones (1s) and zeros (0s) are moving down the fibre.



The receiver is programmed to decode the 1s and 0s. It receives into sound or pictures or data as required. Digital modulation is expressed in bits or megabits (10^6 bits) per second where a bit is a 1 or a 0.

Despite the ultra-purity of the optical fibre (99.99% glass), the light signals eventually become dim and must be regenerated by devices called repeators. Repeators are placed about 30 Km apart, but in the newer system they may be placed 100Km apart.

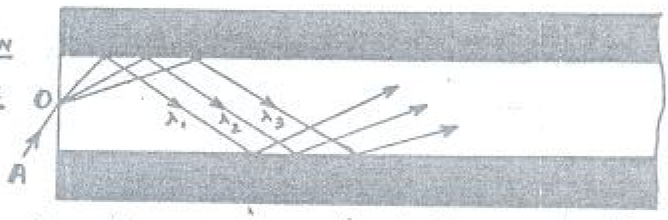
At the end of the fibre, a photodiode converts the light signals into electrical signals, which are then amplified and decoded.

Losses Of Power

When a light signal travels along optical fibres through multiple reflection, some light is absorbed due to glass impurities and some of it is scattered by groups of atoms formed at places such as joints when fibres are joined together. Careful manufacturing of optical fibres can reduce the power loss by absorption and scattering. Hence, the information received at the other end of the fibre can be faulty due to absorption and scattering of the light signal.

If the light signal is not perfectly mono-chromatic, then in such a case, a narrow band of wavelengths are refracted in different directions when the light signal enters the optical fibre and the light signal spreads. Consider a light signal when enters the optical fibre spreads into three different wavelengths λ_1, λ_2 and λ_3 as shown in figure.

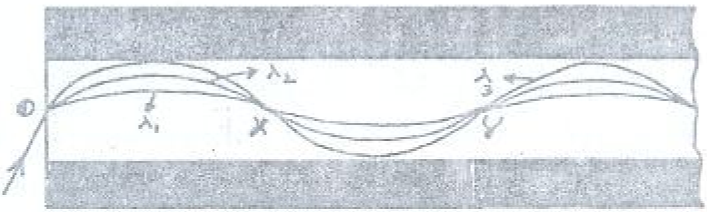
Light Paths In Step Index Fibre



Ray λ_1 meets the core - cladding at the critical angle and λ_2, λ_3 at slightly greater angles than λ_1. All the rays travelling along the fibre by multiple reflections but light paths have different lengths. So light of different wavelengths reaches the other end of the fibre at different times. Hence, the light signal received is therefore faulty or distorted.

This disadvantage of step-index fibre can be reduced by using a graded index fibre as shown in figure. It is clear from figure that the

LIGHT PATH IN GRADED INDEX FIBRE



different wavelengths will take different paths and are totally internally reflected at different layers, but still they are converged at the same point like X and Y etc. It is possible because the speed of light is inversely proportional to the refractive index. Hence, the wavelength λ_3 travels a longer path than λ_1 and λ_2 but at a greater speed. So, inspite of different dispersions, all the wavelengths reach at the other end of the fibre at the same time.

With a step-index fibre, the overall time difference may be about 33 nS per Km length of the fibre. By using a graded index fibre, the time difference is reduced to about 1 nS per Km of the fibre.

Fsc Part 1 Chapter 10

SHORT QUESTIONS & ANSWERS

10.1 What do you understand by linear magnification and angular magnification? Explain how a convex lens is used as a magnifier?

Ans. Linear magnification is the ratio of the size of the image to the size of the object.
Angular magnification is the ratio of the angles subtended by the image as seen through the optical device to that subtended by the object at the unaided eye.
A convex lens of short focal length can be used as a magnifier when the object is placed very close to it i.e., when the object is in between the lens and its focus. The image then formed is virtual, erect and magnified.

10.2 Explain the difference between angular magnification and resolving power of an optical instrument. What limits the magnification of an optical instrument?

Ans. Angular magnification or magnifying power of an optical instrument means how large or magnified is the image formed by the instrument. But the magnification alone is of no use unless we can see the details of the object distinctly. The resolving power of an instrument is its ability to reveal the minor details of an object under examination. The magnification of the optical instruments is limited due to defects of the lenses such as chromatic and spherical aberrations. The image does not remain well defined and details of the object are not seen distinctly.

10.3 Why would it be advantageous to use blue light with a compound microscope?

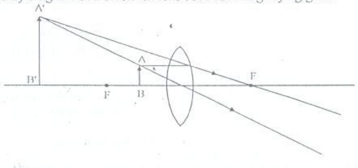
Ans. If blue light is used to see the object in the compound microscope, it increases its resolving power and more details of the object can be studied easily.

10.4 One can buy a cheap microscope for use by the children. The images seen in such a microscope have coloured edges. Why is this so?

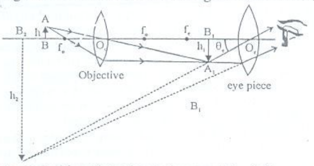
Ans. The image seen in the cheap microscope have coloured edges due to defect of the lenses known as chromatic aberration. This is because of the prism like formation of the lens, which causes dispersion of the white light and makes the edges of the image coloured.

10.5 Describe with the help of diagrams, how (a) a single biconvex lens can be used as a magnifying glass. (b) biconvex lenses can be arranged to form a microscope.

Ans. (a) Ray diagram of a biconvex lens used as a magnifying glass



(b) Ray diagram of two biconvex lenses arranged to make a microscope

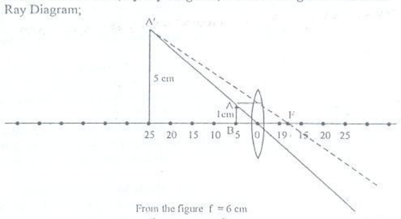


10.6 If a person was looking through a telescope at the full moon, how would the appearance of the moon be changed by covering half of the objective lens.

Ans. Still he will see the full image of the moon but its brightness is reduced as less light is transmitted by the half covered objective lens.

10.7 A magnifying glass gives a five times enlarged image at a distance of 25cm from the lens. Find, by ray diagram, the focal length of the lens.

Ans. Ray Diagram;



From the figure f = 6 cm

10.8 Identify the correct answer.

(i) The resolving power of a compound microscope depends on;
- **(a) The refractive index of the medium in which the object is placed.**
- **(b) The diameter of the objective lens.**
- **(c) The angle subtended by the objective lens at the object.**
- **(d) The position of an observer's eye with regard to the eye lens.**

(ii) The resolving power of an astronomical telescope depends on;
- **(a) The focal length of the objective lens.**
- **(b) The least distance of distinct vision of the observer.**
- **(c) The focal length of the eye lens.**
- **(d) The diameter of the objective lens.**

(i) The resolving power of compound microscope, lens of diameter ' D ' is given by;

$$\alpha_{min} = 1.22\frac{\lambda}{D}$$

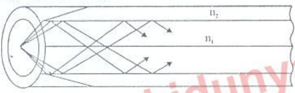
Hence, the correct answer is statement 'b'.

(ii) The correct answer is statement 'd'.

10.9 Draw sketches showing the different light paths through a single-mode and a multi-mode fibre. Why a single-mode fibre preferred in telecommunications?

Ans. (a) Light path through a single-mode fibre

(b) Light paths through a multi-mode fibre



Modern communication systems are digital and use monochromatic laser as source of signals. Transmission is free from dispersion defects and can carry more than 14 TV channels or 14000 phone calls simultaneously.

10.10 How the light signal is transmitted through the fibre?

Ans. An optical fibre communication system consists of three major components:

(i) a transmitter that converts electrical signals into light signals

(ii) an optical fibre for guiding the signals by total internal reflection and continuous refraction

(iii) a receiver at the other end, which converts light signals to electrical signal.

To convert audio or video information by light signals, the waves are modulated. The most common method is digital modulation in which a laser is flashed on and off at an extremely fast rate. A pulse of light represents number 1 and the absence of light represents 0. Any information can be represented by a particular pattern or code of these 1s and 0s and at the receiving end these are decoded to reconstruct the original information.

10.11 How the power is lost in the optical fibre through dispersion? Explain.

Ans. If the source of the light signals is not trimly monochromatic, the light is dispersed while propagating through the core of the optical fibre into different wavelengths λ_1, λ_2 and λ_3 etc as shown in figure. As shown, λ_1 meets the core cladding at the critical angle and λ_2 and λ_3 at slightly greater angles. The light paths have thus different lengths.

So the light of different wavelengths reaches the other end of the fibre at different times and the signal received is distorted or faulty.