Chapter 10

OPTICAL INSTRUMENT

LEARNING OBJECTIVES

At the end of this chapter the students will be able to:

Recognize the term of least distance of distinct vision.

Understand the terms magnifying power and resolving power.

Understand the working of spectrometer.

Describe Michelson rotating mirror method to find the speed of light.

Understand the principles of optical fibre.

Identify the types of optical fibres.

Appreciate the applications of optical fibres.

INTRODUCTION

In this chapter, some optical instruments that are based on the principles of reflection and refraction, will be discussed. The most common of these instruments are the magnifying glass, compound microscope and telescopes. We shall also study magnification and resolving powers of these optical instruments. The spectrometer and an arrangement for measurement of speed of light are also described. An introduction to optical fibres, which has developed a great importance in medical diagnostics, telecommunication and computer networking, is also included.

Q.1 Define least distance of distinct vision.

Ans. **LEAST DISTANCE OF DISTINCT VISION**

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

The distance is about 25 cm from the eye. It is denoted by 'd'. If the object is held closer to the eye than this distance the image formed will be blurred and fuzzy. The location of the near point however changes with age.

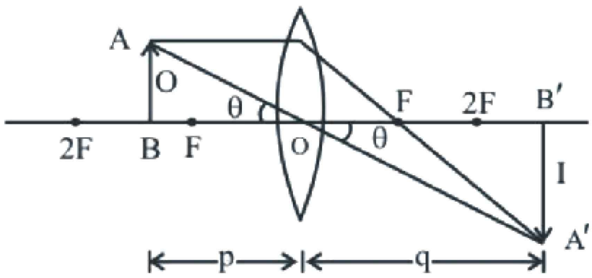
Q.2 Define linear magnification.

It is denoted by 'M'.

$$\therefore \qquad M = \frac{I}{O}$$

Q. Show that $M = \frac{I}{O} = \frac{q}{p} \left(\text{OR } M = \frac{q}{p} \right)$

Ans. When an object is placed in front of a convex lens at a point beyond its focus, a real and inverted image of the object is formed as shown in figure.



ΔABO and $\Delta A'B'O$ are similar triangles.

For similar triangles the ratio of the length of the corresponding sides is equal i.e.,

$$\frac{I}{O} = \frac{OB'}{OB}$$

$$\frac{I}{O} = \frac{q}{p} \qquad \left\{ \begin{array}{l} \because OB' = q = \text{image distance} \\ OB = p = \text{object distance} \end{array} \right.$$

As, $$M = \frac{I}{O}$$

$$\therefore \qquad M = \frac{I}{O} = \frac{q}{p}$$

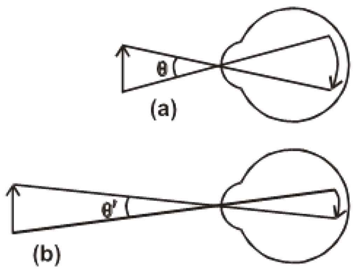


Fig. When the same object is viewed at a shorter distance, the image on the retina of the eye is greater; so the object appears larger and more details can be seen. The angle θ the object subtends in (a) is greater than θ' in (b).

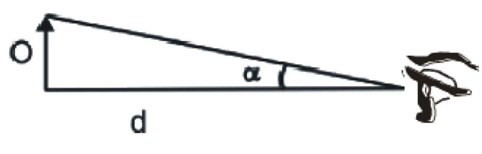
1. Visual Angle

The angle subtended by an object at the eye, is called visual angle.

The apparent size of an object depends upon its actual size and on the angle subtended by it at the eye. Thus the closer the object is to the eye, the greater is the angle subtended and larger appears the size of the object.

2. Object Angle

"When the object is placed at 'd', then the angle subtended at a naked (unaided) eye, by the object is called object angle".

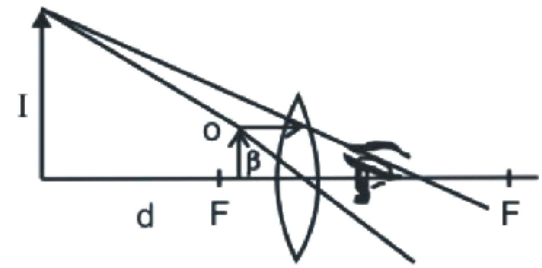


It is denoted by α.

3. Image Angle

"When the angle subtended by the image, formed at 'd', on the eye, is called image angle".

It is denoted by β.



Q.3 Define angular magnification.

Ans. **ANGULAR MAGNIFICATION**

"The ratio of the angles subtended by the image as seen through the optical device (aided eye) to that subtended by the object at the unaided eye, is called angular magnification".

It is also called magnifying power.

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

> **Tid-bits**
>
> If you find it difficult to read small print, make a pinhole in a piece of paper and hold it in front of your eye close to the page. You will see the print clearly.

Q.4 Define resolving power.

Ans. **RESOLVING POWER**

"The resolving power of an instrument is its ability to reveal the minor details of the object under examination."

Resolving power is expressed as the reciprocal of minimum angle which two point sources subtends at the instrument so that their images are seen as two distinct spots of light rather than one Raleigh showed that for light of wavelength 'λ', through a lens of diameter D, the resolving power

$$R = \frac{1}{\alpha_{min}} = \frac{D}{1.22\,\lambda}$$

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

$$\therefore \quad R = \frac{1}{1.22\,\lambda/D} = \frac{D}{1.22\,\lambda}$$

The smaller the value of α_{min} greater is the resolving power because two distant objects which one close together can be seen separated through the instrument.

In case of a grating spectrometer, the resolving power 'R' of the grating is defined as;

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

Thus we see that a grating with high resolving power can distinguished small difference in wavelength. If 'N' is the number on rulings of the gratings, it can be shown that the resolving power in the mth order (m) diffraction equals the product i.e., $N \times m$.

Q.5 What is simple microscope? Derive an expression for the magnifying power of simple microscope.

Ans. SIMPLE MICROSCOPE OR (MAGNIFYING GLASS) OR (MAGNIFIER)

Definition

"An optical instrument, which is used to see small objects distinctly, is called simple microscope."

Construction

It consist of a biconvex lens.

Principle

When the object is placed inside the focal point of the lens, then erect, magnified and virtual image is formed at 'd' (near point or 25 cm).

Magnification

The image formed by the object, when placed at 'd' on the eye as shown in Fig. 2 A lens is placed just in front of the eye and the object is placed in front of the lens, in such a way that a virtual image is formed at 'd', from the eye. The size of the image is now much larger than without the lens.

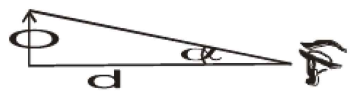


Fig 1

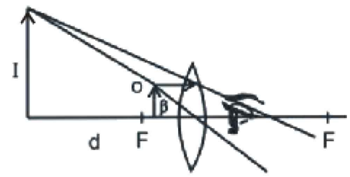


Fig 2

If 'β' and 'α' are the respective angles subtended by the object when seen through the lens and when viewed directly, then,

$$M = \frac{\beta}{\alpha} \qquad \text{......... (1)}$$

From Fig. 1

$$\tan\alpha = \frac{o}{d}$$

and from Fig. 2

$$\tan\beta = \frac{I}{d}$$

If α and β are very small then,

$$\tan\alpha \approx \alpha$$

$$\tan\beta \approx \beta$$

$$\therefore \qquad \alpha = \frac{o}{d}$$

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

Putting the values of 'α' and 'β' in equation (1).

$$\therefore \quad M = \frac{I/d}{o/d}$$

$$M = \frac{I}{d} \times \frac{d}{o}$$

$$M = \frac{I}{o}$$

As, $\frac{I}{o} = \frac{q}{p}$

$$\therefore \quad M = \frac{q}{p}$$

Since the image is at the least distance of distinct vision i.e., q = d.

$$\therefore \quad M = \frac{d}{p} \quad \ldots\ldots\ldots (2)$$

For Your Information

A seventeenth century microscope which could be moved up and down in its support ring (courtesy of the Museum of the History of Science Florence).

The lens formula is,

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

For virtual image

$$q = -q$$

$$\therefore \quad \frac{1}{f} = \frac{1}{p} - \frac{1}{q}$$

Since $q = d$

So, $\frac{1}{f} = \frac{1}{p} - \frac{1}{d}$

Multiply by 'd' both sides

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

$$\frac{d}{f} = M - 1 \qquad \left(\because \text{ from eq. (2) } M = \frac{d}{p}\right)$$

$$\therefore \quad M = 1 + \frac{d}{f}$$

It is clear for a lens of high angular magnification, the focal length will be small.

Ans. COMPOUND MICROSCOPE

Whenever high magnification is desired, a compound microscope is used.

Construction

It consists of two convex lenses, an objective lens (lens towards the object) of very short focal length and an eye piece (lens towards the eye) of comparatively longer focal length. The ray diagram is shown.

The object of height 'h' is placed just beyond the principal focus of the objective. This produces a real, magnified image of height 'h_1' at a place situated with in the focal point of the eye piece. The eye piece is used as a magnifying glass to see the image formed by the objective, which becomes object for eye piece. The final image seen by the eye through microscope is virtual and very much enlarged. In normal adjustment, the eye piece is positioned so that the final image is formed at the near point of the eye i.e., at 'd'.

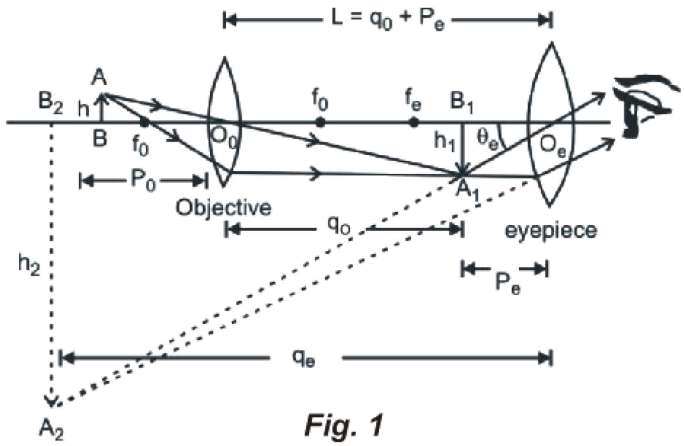


Fig. 1

Magnification

Here, $$M = \frac{\tan\theta_e}{\tan\theta}$$

Where 'θ_e' is the angle subtended by the final image 'h_2' and 'θ' is the angle subtended by the object at eye h, if placed at 'd'.

From Fig. '1' and '2'.

$$\tan\theta_e = \frac{h_2}{d} \quad \text{and} \quad \tan\theta = \frac{h}{d}$$

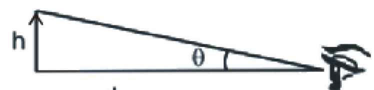


Fig2

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

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

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

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

Where '$\frac{h_1}{h}$' is the linear magnification 'M_1' of the objective and '$\frac{h_2}{h_1}$' is the magnification 'M_2' of the eye piece.

Since $M_1 = \frac{q_0}{p_0}$

and $M_2 = 1 + \frac{d}{f_e}$ ($\because$ eye piece is working as a simple microscope)

$\therefore \quad M = \frac{q_0}{p_0}\left(1 + \frac{d}{f_e}\right)$

Note Since the object is placed just beyond the principle focus of the objective.

$\therefore \quad P_0 \approx f_0$

As, $L = q_0 + p_e$

As the image h_1 is placed very closed to eye piece

$\therefore \quad p_e \approx 0$

$\therefore \quad L = q_0$

$\therefore \quad M = \frac{L}{f_0}\left(1 + \frac{d}{f_e}\right)$

The limit to which a microscope can be used to resolve details, 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.

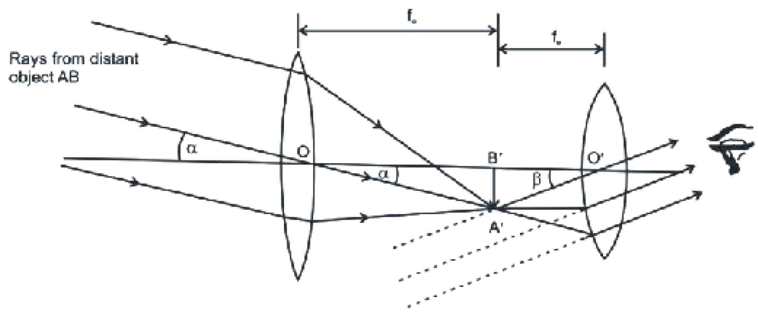
Q.7 What is astronomical telescope? Describe the construction and magnifying power of astronomical telescope.

Ans. **ASTRONOMICAL TELESCOPE**

"An optical device, which is used to see the heavenly objects like moon and stars."

It is a refracting telescope.

A simple astronomical telescope consists of two convex lenses, an **objective** of long focal length 'f_0' and an **eye piece** of short focal length f_e. The objective forms a real, inverted and diminished image $A'B'$ of a distant object AB. This real image $A'B'$ acts as object for the eye piece which is used as a magnifying glass.



The final image seen through the eye-piece is virtual, enlarged and inverted, as shown in the figure.

When a very distant object is viewed, the rays of light coming from any of its point (say its top) are considered parallel and these parallel rays are converged by the objective to form a real image $A'B'$ at its focus. If it is desired 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. The rays after refraction through the eye-piece will becomes 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 both the objective and eye–piece and the telescope is said to be in normal adjustment.

Magnification

The angle 'α' subtended at the unaided eye is practically same as subtended at the objective.

Consider $\Delta OA'B'$

$$\alpha = \tan\alpha = \frac{A'B'}{OB'}$$

$$\therefore \quad \alpha = \frac{A'B'}{f_0}$$

Considering $\Delta O'A'B'$

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

$$\therefore \quad \beta = \frac{A'B'}{f_e}$$

Hence magnifying power of telescope is

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

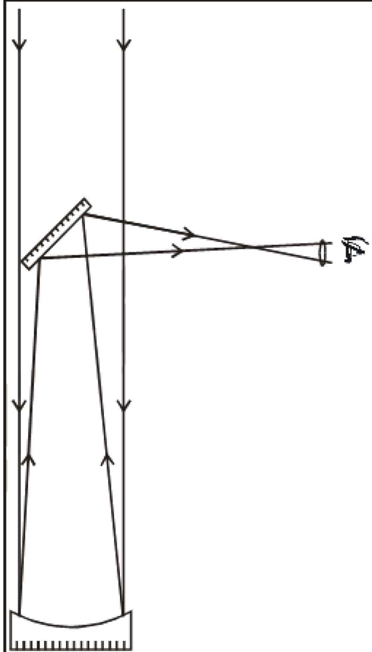
Putting values of 'α' and 'β'.

$$\therefore \quad M = \frac{A'B'/f_e}{A'B'/f_0}$$

$$M = \frac{A'B'}{f_e} \times \frac{f_0}{A'B'}$$

$$M = \frac{f_0}{f_e}$$

For Your Information



Reflecting Telescope

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

The length of telescope is the distance between objective and eye–piece of a telescope in normal adjustment.

$$\therefore \quad L = f_0 + f_e$$

Note: Besides having a high magnifying power another problem which confronts the astronomers while designing a telescope to see the distant planets and stars is that they would like to gather as much light form the object as possible. This difficulty is overcome by using the objective of large aperture so that it collects a great amount of light from the astronomical objects. Thus a good telescope has an objective of long focal length and large aperture.

Q.8 What is spectrometer? Also discuss its three parts.

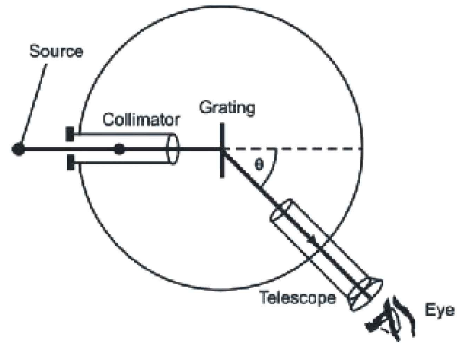
Ans. SPECTROMETER

Definition

"A spectrometer is an optical device used to study spectra from different sources of light."

Explanation

The essential components of a spectrometer are shown in the figure.



Collimator

It consists of a fixed metallic tube with a convex lens at one end and an adjustable slit at the other end.

The width of the slit can be adjusted. When the slit is just at the focus of the convex lens then the rays coming out of the lens become parallel.

Turn Table

A prism or a grating is placed on a turn table which is capable of rotating about a fixed vertical axis.

A circular scale graduated in half degrees is attached with it.

Telescope

A telescope is attached with a venire scale and is rotate-able about the same vertical axis as the turn table. A circular scale graduated in half degrees is attached with it.

The telescope is adjusted in such a way that the rays of light entering it, are focused at the cross wires near the eye–piece.

Note: *Before using a spectrometer, one should be sure that the collimator is so adjusted that parallel rays of light emerge out of its convex lens. The telescope is adjusted in such a way that the rays of light entering it are focused at the cross wires near the eye-piece. Finally, the refracting edge of the prism must be parallel to the axis of rotation of the telescope so that the turn table is levelled. This can be done by using the levelling screws.*

Q.9 Describe Michelson's experiment to determine the speed of light.

Ans. SPEED OF LIGHT

Light travels very fast and rapidly. Therefore, it is very difficult to measure its speed. Galileo was the first man who made an attempt to measure the speed of light but he got a failure in his attempt to measure the speed of light. Yet he agreed with the fact that light does take sometime to travel from one point to another. Michelson performed an experiment for the determination of the speed of light.

Michelson's Experiment

In this experiment, the speed of light was measured by measuring the time taken by light to cover a round trip between two mountains. The distance between two mountains was measure accurately. The experimental setup is shown in figure.

An eight sided polished mirror 'M' is mounted on the shaft of a motor whose velocity can be varied. Suppose the mirror is stationary in the position, shown in figure.

A beam of light from the face '1' of the mirror 'M' falls at the plane mirror 'm' placed at a distance 'd', from 'M'. The light is reflected back from the mirror 'm' and falls on the face '3' of mirror 'M'. On reflection from face '3', it enters the telescope.

If the mirror 'M' is rotated clockwise initially the source will not be visible through the telescope. When 'M' gains a certain speed the source 'S' becomes visible. This happens when the time taken by the 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 '1'.

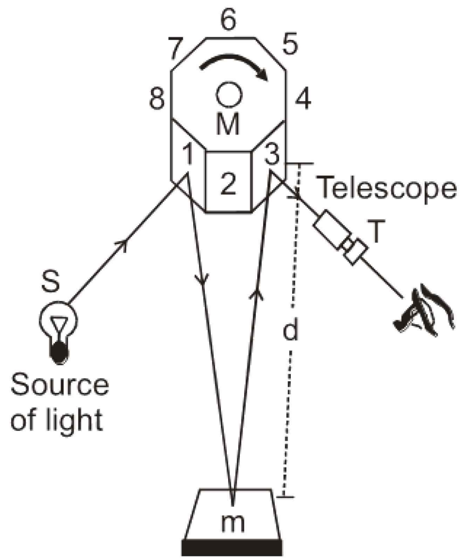


Fig. Michelson's method for measurement of speed of light.

Angle subtended by any side of eight sided mirror at the centre is $\frac{2\pi}{8}$. If 'f' is the frequency of the 'M' when the source 'S' is visible through the telescope, then the time taken by the mirror to complete 1 revolution $= \frac{1}{f}$.

Time to complete $\frac{1}{8}$ vibration $= \frac{1}{8f}$.

$$\therefore \quad t = \frac{1}{8f}$$

The time taken by the light from 'M' to 'm' and back to 'M' is;

Using $\quad S = Vt$

$$S = Ct \; (\because \; V = C)$$

$$2d = Ct$$

$$\therefore \quad t = \frac{2d}{C}$$

These two times are equal.

$$\therefore \quad \frac{2d}{C} = \frac{1}{8f}$$

$$C = 2d \times 8f$$

$$C = 16\,d\,f$$

$$C = 2.99792458 \times 10^{8}\ ms^{-1}$$

$$C = 3 \times 10^{8}\ ms^{-1}$$

As $\quad \theta = wt$

$$t = \frac{\theta}{w}$$

$$\therefore \quad w = 2\pi f$$

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

$$t = \frac{2\frac{\pi}{8}}{2\pi f}$$

$$t = \frac{1}{8f}$$

The speed of light in other materials is always less than C. In media other than vacuum, it depends upon the nature of the medium. However, the speed of light in air is approximately equal to that in vacuum.

Q.10 Write a note on the fibre optics.

Ans. **INTRODUCTION TO FIBRE OPTICS**

For hundred of years man has communicated using flashes of reflected sunlight by day and lanterns by night. Navy signalmen still use powerful blinder lights to transmit coded messages to other ships during periods of radio-silence. Light communication has not been confined to simple dots and dashes. It is an interesting but little known fact that Alexander Graham Bell invented a device known as "photo phone" shortly after his invention of telephone. Bell's photo phone used a modulated beam of reflected sunlight focused upon a Selenium detector several hundred metres away. With a device, bell was able to transmit a voice message via a beam of light. The idea remained dormant for many years. During the recent past the idea of transmission of light through thin optical fibres has been revived and is now being used in communication technology.

The use of light as transmission carries wave in fiber optics has several advantages over radio wave carries these advantages are (a) wide band-width capability and (b) immunity from electromagnetic interference.

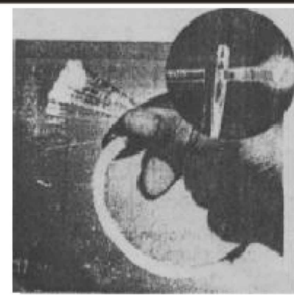
It is also used to transmit light around corners and into inaccessible places so that the formerly unobservable could be viewed. The use of fibre optic tools in industry is now very common, and their importance as diagnostic tools in medicine has been proved.

Recently the fibre optic technology has evolved into something much more important and useful and communication system of enormous capabilities.

One feature of such a system is its ability to transmit thousands of telephone conversations, several television programs and numerous data signals between stations through one or two flexible, hair thin threads of optical fibre. With the tremendous information carrying capacity called the bandwidth, fibre optic systems have undoubtedly made practical such services as two ways television which was too costly before the development of fibre optics. These systems also allow word processing, image transmitting and receiving equipment to operate efficiently.

In addition to give an extremely wide bandwidth, the fibre optic system has much thinner and light weight cables. An optical fibre with its protective case may be typically 6.0 mm in diameter, and yet it can replace a 7.62 cm diameter bundle of copper wire now used to carry the same amount of signals.

Point to Ponder



Each of the thin optical fibres is small enough to fit through the eye of a needle. Why is the size of the fibre important?

Fig. (a) Optical fibre image

Fig. (b) A precision diamond scalpel for use in eye surgery. The illumination is obtained by light passing through a fibre optic light guide.

Q.11 What are the basic principles of optical fibre? Explain then.

Total Internal Reflection

One of the qualities of any optically transparent material is the speed at which light travels within the materials, i.e., it depends upon the refractive index n of the material. The index of refraction is merely the ratio of the speed of light c in vacuum to the speed of light v in that material.

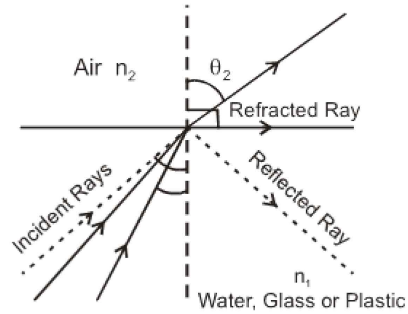


Fig. (a) If the angle of refraction in the air is 90^o the angle of incidence is called the critical angle.

Expressed mathematically,

$$n = \frac{c}{v}$$

The boundary between two optical media, e.g., glass and air having different refractive indices can reflect or refract light rays. The amount and direction of reflection or refraction is determined by the amount of difference in refractive indices as well as the angle at which the rays strike the boundary. At some angle of incidence, the angle of refraction is equal to 90^o when a ray of light is passing through glass to air. This angle of incidence is called the angle θ_c, shown in figure.

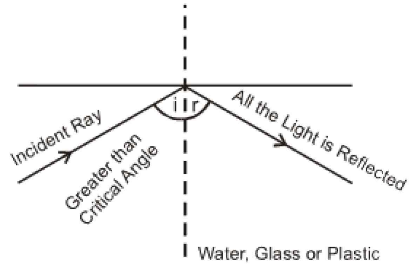


Fig. (b) For angles of incidence greater than the critical angle, all the light is reflected; none is refracted into the air.

We are already familiar with Snell's law;

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

From Fig.

when $\theta_1 = \theta_c$, $\theta_2 = 90^o$

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

For incident angles equal to or greater than the critical angle, the glass–air boundary will act as a mirror and no light escapes from the glass Fig. For glass–air boundary, we have

$$\sin \theta_c = \frac{n_2}{n_1} = \frac{1.0}{1.5} \quad \text{or} \quad \theta_c = 41.8^o$$

Let us now assume that the glass is formed into a long, round rod. We know that all the light rays striking the internal surface of the glass at angles of incidence greater than 41.8^o (critical angle) will be reflected back into the glass while those with angle less than 41.8^o will escape from the glass Fig. Ray 1 is injected into the rod so that it strikes the glass air boundary at an angle of incidence about 30^o.

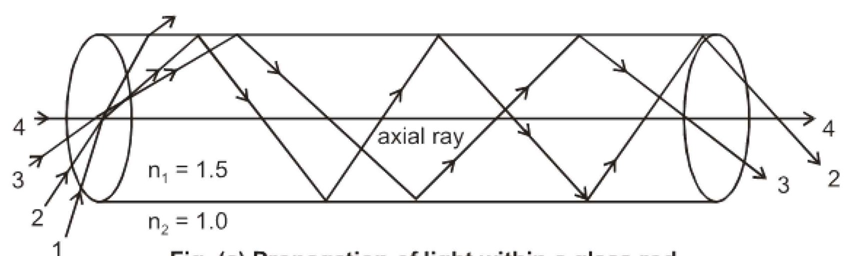


Fig. (a) Propagation of light within a glass rod.

Since this is less than the critical angle, it will escape from the rod and be lost. Ray 2 at 42^o will be reflected back into the rod, as will ray 3 at 60^o. Since the angle of reflection equals the angle of incidence, these two rays will continue to propagate down the rod, along paths determined by the original angles of incidence. 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 and rigid rod. However, in a flexible glass fibre they will be subjected to the laws of reflection figure.

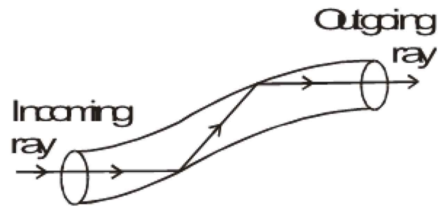


Fig. (b) Light propagation within a flexible glass fibre.

Optical fibres that propagate light by total internal reflection are the most wisely used.

Continuous Refraction

There is another mode of propagation of light through optical fibres in which light is continuously refracted within the fibre. For this purpose central core has high refractive index (high density). This layer is called cladding. Such a type of fibre is called multi-mode step index fibre whose cross sectional view is shown in figure.

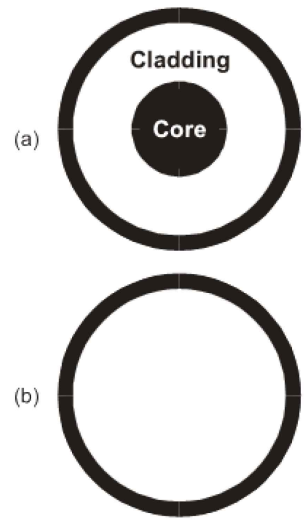


Fig. Cross sectional view of
(a) Multi-mode step index fibre
(b) Multi-mode graded index fibre

Now a days, a new type of optical fibre is used in which the central core has high refractive index (high density) and its density gradually decreases towards its periphery. This type of optical fibre is called a multi mode graded index fibre. Its cross sectional view is shown in Fig.

In both these fibres, the propagation of light signal is through continuous refraction. We already know that a ray passing a denser medium to a rarer medium bends away from the normal and vice versa. In step index or graded index fibre, a ray of light entering the optical fibre, as shown in Fig. is continuously refracted through these steps and is reflected from the surface of the outer layer. Hence light is transmitted by continuous refraction and total internal refraction.

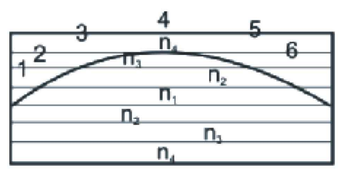


Fig. Light propagation within a hypothetical multi layer fibre.

Q.12 What are different types of optical fibre?

Ans. TYPES OF OPTICAL FIBRES

There are three types of optical fibres which are classified on the basis of the mode by which they propagate light. These are (i) single mode step index (ii) multi mode step index and (iii) multi

(i) Single Mode Step Index Fibre

Single mode or mono mode step index fibre has a very thin core of about 5 μm diameter and has a relatively larger cladding (of glass or plastic) as shown in the figure. Since it has a very thin core, a strong monochromatic light source i.e., a laser source has to be used to send light signals through it. It can carry more than 14 TV channels or 14000 phone calls.

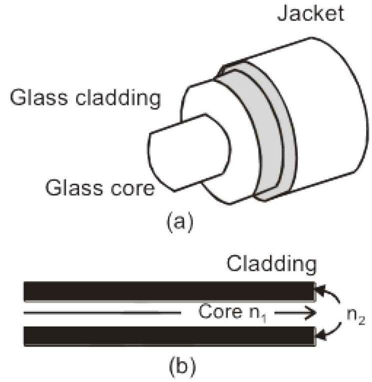


Fig. Single-mode step-index fibre.

(ii) Multi Mode Step Index Fibre

This type of fiber has a core of relatively larger diameter such as 50 μm. It is mostly used for carrying white light but due to dispersion effects, it is useful for a short distance only. The fibre core has a constant refractive index n_1; such as 1.52, from its centre of boundary with the cladding as shown in Fig. The refractive index then changes to a lower value n_2, such as 1.48, which remains constant through out the cladding.

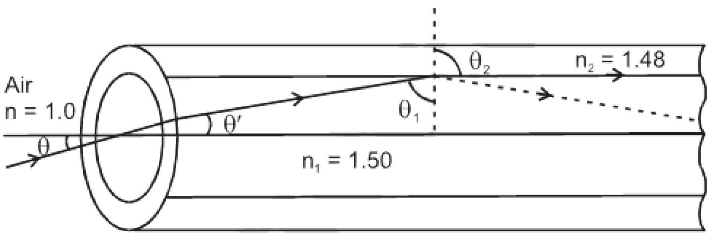


Fig. Light propagation through multi-mode step-index fibre.

This is called a step–index multimode fibre, because the refractive index steps down from 1.52 to 1.48 at boundary with cladding.

(iii) Multimode Graded Index Fibre

Multi mode graded index fibre has core which ranges in diameter from 50 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 noticeable boundary between core and cladding.

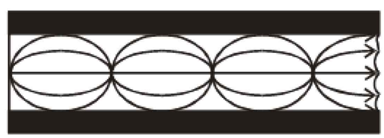


Fig Light propagation through multi-mode graded index fibre

This type of fibre is called multi mode graded–index fibre (Fig.) and is useful for long distance application in which white light is used. The mode of transmission of light through this type of fibre is also the same, i.e., continuous refraction from the surfaces of smoothly decreasing refractive index and total internal reflection from the boundary of the outer surfaces.

Q.13 Explain the signal transmission and conversion to sound in fibre optics.

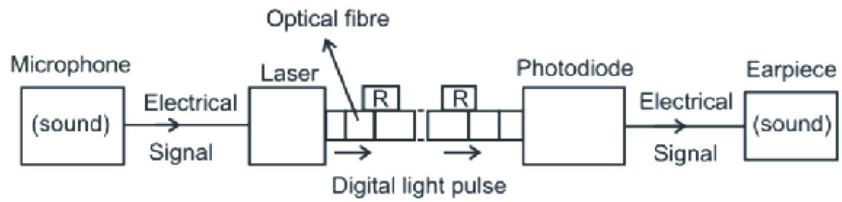
Ans. SIGNAL TRANSMISSION AND CONVERSION TO SOUND

A fibre optic communication system consists of three major components (i) a transmitter that converts electrical signals to light signals, (ii) an optical fibre for guiding the signals and (iii) a receiver that captures the light signals at the other end of the fibre and reconverts them to electric signals.

A light source in the transmitter can be either a semiconductor laser or a light emitting diode (LED). With either device, the light emitted is an invisible infrared signals. The typical wavelength is 1.3 μm.

Such a light will travel much faster through optical fibres than will either visible ultra–violet light. The lasers and LEDs used in this application are tiny units (less than half the size of the thumbnail) in order to match the size of fibres. To transmit information by light waves, whether it is an audio signal, a television signal or a computer data signal, it is necessary to modulate the light waves.

The most common method of modulation is called digital modulation in which the laser or LED is flashed on and off at an extremely fast rate. A pulse of light represents the number 1 and the absence of light represents zero. In a sense, instead of flashes of light traveling down the fibre, ones (1s) and zeros (0s) are moving down the path.



With computer type equipment, any communication can be represented by a particular pattern or code of these 1s and 0s. The receiver is programmed to decode the 1s and 0s, thus it receives, the sound, pictures or data as required. Digital modulation is expressed in bits (binary digit) or megabits (10^6 bits) per second, where a bit is a 1 or a 0.

Despite the ultra-purity (99.99 % glass) of the optical fibre, the light signals eventually become dim and must be regenerated by devices called repeaters. Repeaters are typically placed about 30 km apart, but in the newer systems they may be separated by as much as 100 km.

At the end of the fibre, a photodiode converts the light signals, which are then amplified and decoded, if necessary, to reconstruct the signals originally transmitted (figure).

Q.14 Explain how the power of light signals is lost by scattering and absorption during propagation?

Ans. LOSSES OF POWER

When a light signals travel along fibre by multiple reflection, some light is absorbed due to impurities in the glass. Some of it is scattered by groups of atoms which are formed at places such as joints when fibres are joined together. Careful manufacturing can reduce the power loss by scattering and absorption.

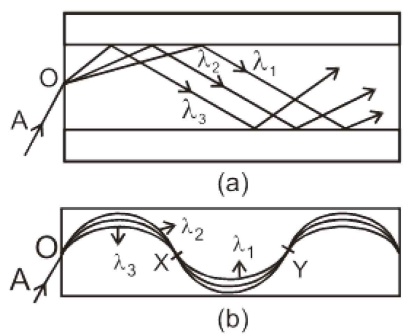


Fig. Light paths in (a) step-index and (b) graded-index fibre.

The disadvantage of the step-index fibre Fig. (a) can considerably be reduced by using a graded index fibre. As shown in the Fig. (b), the different wavelengths still take different paths and are totally internally reflected at different layers, but still they are focused at the same points like X and Y etc. It is possible because the speed is inversely-proportional to the refractive index. So the wavelength λ_1 travels a longer path than λ_2 or λ_3 but at a greater

Inspite of the different dispersion, all the wavelengths arrive at the other end of the fibre at the same time. With a step-index fibre, the overall time of difference may be about 33ns per km length of fibre. Using in a graded index fiber, the time difference is reduced to about 1ns per km.