III. Light and optics:

While light color spectrum wavelength frequency dispersion reflection refraction critical angle – total internal reflection. Lasers –types- focal length-magnification power- spherical and chromatic aberrations – filters- spectrometer- principle and parts- applications- microscopes. Types of microscopes- simple – compound – phase contrast-polarizing – fluorescent- dark field-electron microscope-parts and care of the microscope.

DISPERSION THROUGH A PRISM

A beam of white light, when it passes through a prism is split up in to the constituent colours. This phenomenon is called *dispersion*. The coloured band obtained on the screen is called *spectrum*. It is found that the violet colour is deviated more than the red. Hence the refractive index of glass is greater for violet than for red. Thus as the wavelength increases, the refractive index decreases. If δ be the angle of deviation of certain colour (spectrum), A be the angle of prism and *n* be the refractive index, then $\delta = (n - 1)$ A. Dispersive power (ω) is the ratio of the angular dispersion to the deviation of the mean ray.

Geometrical optics deals with the phenomena which is based on the assumption that light travels through a homogeneous medium in a straight line

The angle of incidence is the angle between the incident ray and the normal to the interface between two media at the point of incidence. *The angle of reflection* is the angle between this normal and the reflected ray. *The angle of refraction* is the angle between the normal and the refracted ray.

When a ray is incident on the interface between two media the angle of incidence is equal to the angle of reflection. The incident ray, the normal and the reflected ray all lie in the same plane. The magnitude of reflection is characterised by the reflection coefficient (ρ) which is equal to the ratio between the energy flux in the reflected wave and the incident wave.

Refractive index (n) is the ratio of sine of the angle of incidence to the sine of the angle of refraction of second medium with respect to first medium. $n = \dfrac{\sin i}{\sin r}$

When the light ray is incident from one medium to other and as the angle of incidence increases to a certain angle called critical angle then the refracted light ray travel at the interfaces between two medium such that critical angle $\theta_c = \sin^{-1}\left(\dfrac{n_2}{n_1}\right)$.

Any light ray which is incident at an angle greater than critical angle to the normal of incidence will be reflected back in to the same medium. This phenomenon is called is called *total internal reflection.*

LASERS

Introduction

We know current can be amplified by vacuum tube or transistor amplifier. Similarly light waves can also be amplified and is termed as LASER (Light Amplification by Stimulated Emission of Radiation)The fact that there are two kinds of emission , namely spontaneous and stimulated was first predicted by Albert Einstein in 1917. He made this prediction based on the thermodynamic equilibrium between atoms and the radiation field. He further proved that both spontaneous and stimulated emissions are necessary to obtain Planck's quantum radiation law. Charles Towner demonstrated stimulated emission for the first time at microwave frequencies and Theodore Maiman demonstrated it at optical frequencies in a ruby laser in 1960. Within a few months of operation of this device, Javan and his fellow workers constructed the first gas He – Ne Laser . The semiconductor laser was invented in1962. Since then laser action has been obtained in a variety of materials like liquids, ionized gases, dyes, etc.,

Characteristics

Directionality

Ordinary light spreads in all directions and its angular spread is 1m/m. But, it is found that laser is **highly directional** and its angular spread its 1mm/ meter. For example the laser beam can be focused to very long distance with a few divergence (or) angular spread.

Divergence (or) Angular spread is given by $(\phi) = (r_2 - r_1) / (d_2 - d_1)$ degrees

Where d_1 & d_2 are any two distances from the laser source emitted and r_1, r_2 are the radii of the beam spots at a distance d_1 & d_2 respectively

Intensity

Since an ordinary light spreads in all directions, the intensity reaching the target is very less. But in the case of laser, due to high directionality the intensity of laser beam reaching the target is of **high intense beam.** For example, 1mW power of He – Ne laser appears to be brighter than the sunlight

Monochromatic

Laser beam is **highly monochromatic** (i.e.,) the wavelength is single, whereas in ordinary light like mercury vapour lamp, many wavelengths are emitted.

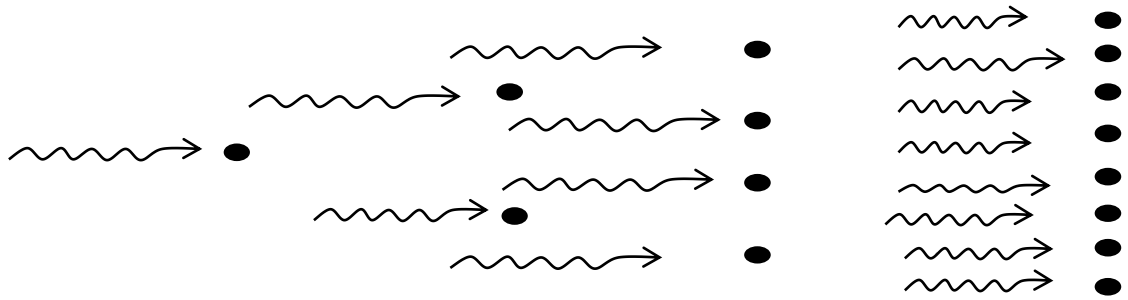
Coherence

In lasers the wave trains of same frequency are in phase (i.e) the radiation given out is in mutual agreement not only in phase but also in the direction of emission and polarization. Thus it is a **Coherent beam.**

Concept of Laser

The photon emitted during stimulated emission has the same energy, phase, frequency and direction as that of the incident photon. Thus, we have two coherent photons in the above case. These photons now incident on two other atoms in the state E_2. This will result in induced emission of two more photons. Now there are four coherent photons of same energy. These four photons may induce further transitions with four other atoms in the energy state E_2. This gives rise to stimulated emission of eight coherent photons of same energy.

If the process continues in a chain, we will ultimately be able to increase the intensity of coherent radiation enormously. Stimulated emission is multiplied through a chain reaction. The multiplication of photons through stimulated emission leads to coherent, powerful, monochromatic, collimated beam of light. This light is known as LASER. Laser requires stimulated emission exclusively. This can be achieved by population inversion



Population inversion

Population inversion creates a situation in which the number of atoms in higher energy state is more than that in lower energy state. Usually at thermal equilibrium, the number of the atoms in the higher energy state N_2 is much smaller than the population of atoms at lower energy state N_1. i.e., $N_1 > N_2$.

The phenomenon of making the number of the atoms in the higher energy state greater than that of the lower energy state is called population inversion.

Condition

- There must be two energy levels
- There must be a source to supply the energy
- The atoms should be continuously raise to excited state

- **Types of laser**

Based on the type of active medium, laser systems are broadly classified as follows:

Sl.No	Type of laser	Examples
01.	Solid state laser	Ruby laser, Nd-YAG laser
02.	Gas laser	He - Ne Laser,Co_2 laser, Ar- ion laser
03.	Liquid laser	$SeOCl_2$ laser.
04.	Dye Laser	Rhodamine 6G laser
05.	Semiconductor laser	GaAs Laser, GaAsP laser

SPHERICAL AND CHROMATIC ABERRATIONS

The deviations from the actual size, shape and position of an image is called aberration. The aberration produced by the variation in the refractive index with wavelength of light is called chromatic aberration. The failure of a lens to form a point image of a point object on the axis is called spherical aberration.

SPHERICAL ABERRATION IN A LENS

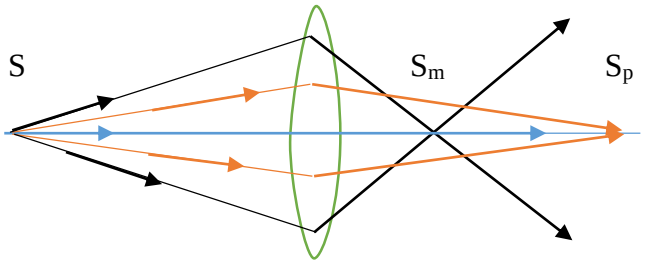
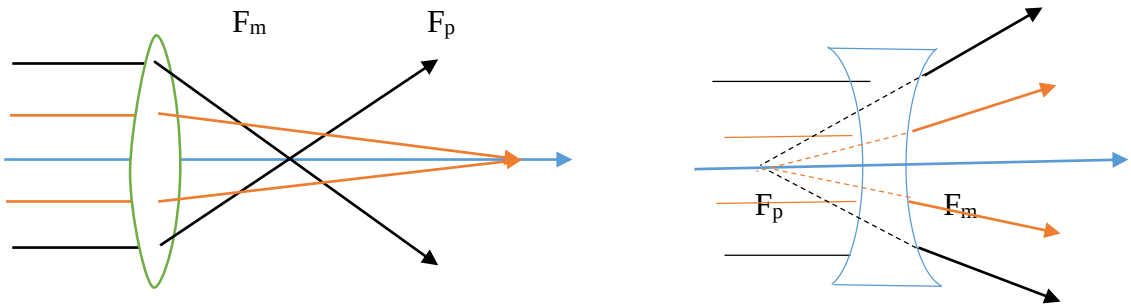


Fig. 3.1

This aberration is due to large aperture of the lenses. The lens of large aperture may thought to be made up of zones. The marginal and paraxial rays forms the images at different places. Figure 3.1 shows a monochromatic point source S on the axis. S_m and S_p are the images formed by marginal and paraxial rays respectively. Thus the point object is not imaged as point and the focus of marginal and paraxial rays do not coincide. The distance S_m, S_p on the axis measures longitudinal spherical aberration. Here spherical aberration of a convergent lens is taken as positive while for diverging lens is negative



Methods of minimising spherical aberration

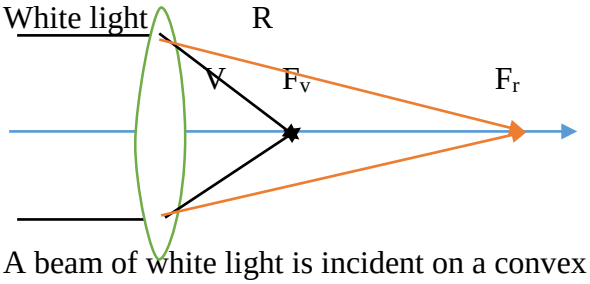
- By using the two lenses separated by a distance

- By using an aplanatic lens
- By using crossed lens

CHROMATIC ABERRATION IN A LENS

The focal length of a lens is given by $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ Since n changes with the colour of light, f must be different for different colours. This change of focal length with colour is responsible for chromatic aberration. It is classified in to two types:

(a) Longitudinal chromatic aberration



A beam of white light is incident on a convex lens parallel to principal axis. The dispersion of colours takes place due to prismatic action of light. Violet is deviated most and red as least. Red is brought to focus at a point farther than the violet. Hence The difference $f_v - f_r$ is a measure of the axial chromatic aberration of a lens for parallel rays.

Hence $f_v - f_r = \omega f_y$

(b) Lateral chromatic aberration

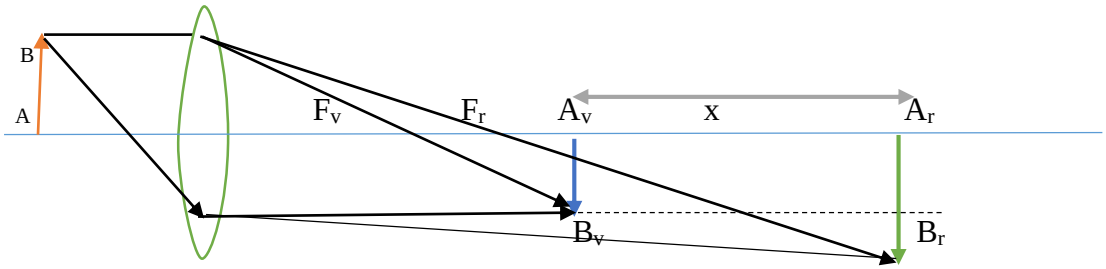


Figure shows a convex lens and n object placed in front of the lens. The lens forms the image of white object AB as B_v A_v and B_r A_r in violet and red colours respectively. The images on other colours lie in between the two. Evidently the size of red image is greater than the size of the violet image. The difference is a measure of lateral chromatic aberration.

MAGNIFYING POWER OF A TELESCOPE

M = Diamter of the objective / Diameter of the exit pupil

= limit of proportionality of the eye / limit of the resolution of the telescope

THE SPECTROMETER

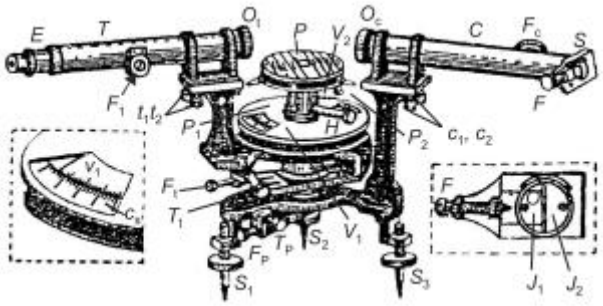
The instrument is normally used to study spectra and to measure refractive indices. It has a following essential parts:

(i) **Collimator (C)** It consists of a horizontal tube with a converging achromatic lens at one end of the tube and a vertical slit S of adjustable width at the other end. The slit can be moved in or out of the tube by a rack and pinion arrangement F_c and its width can be adjusted by tuning the screw F. The collimator is rigidity fixed to the main part of the instrument and can be made exactly horizontal by two screws C_1 and C_2 below it. When properly focussed, the slit lies in the focal plane of the lens O_c. Thus the collimator provides a parallel beam of light.

(ii) Prism Table (P) it is a small circular table and capable of rotation about a vertical axis. It is provided with three levelling screws as P_1, P2 and P_3. On the surface of the prism table, a set of parallel, equidistant line parallel to the line joining two of the levelling screw, is ruled. Also, a series of concentric circles with the centre of the table as their common centre is ruled on the surface. The screw H fixes the prism table to the two verniers V_1 and V_2 and also keep it at a given height. These two verniers rotate with the table over a circular scale are graduated in fraction of a degree. The angle of rotation of the prism table can be recorded by these two verniers. The screw F_1 fixes the prism table and the screw T_p is the tangent screw for the prism table by which a smaller rotation can be imparted to it. It should be noted that a tangent screw functions only after the corresponding fixing screw is tightened.

(iii) Telescope (T): It is a small astronomical telescope with an achromatic doublet as the objective O_t and the Ramsden type eye-piece E. The eye-piece is fitted with cross-wires and slides in a tube which carries the cross-wires. The tube carrying the cross wires in turn, slides in another tube which carries the objective. The distance between the objective and the cross-wires can be adjusted by a rack and pinion arrangement F_1. The Telescope can be made exactly horizontal by two screws t_1 and t_2. It can be rotated about the vertical axis of the instrument and may be fixed at a given position by means of the screw F_t slow motion can be imparted to the telescope by the tangent screw T_t.

Circular Scale (*C.S.*): It is graduated in degrees and coaxial with the axis of rotation of the prism table and the telescope. The circular scale is rigidly attached to the telescope and turned with it. A separated circular plate mounted coaxially with the circular scale carries two verniers, V_1 and V_2, 180° apart. When the prism table is clamped to the spindle of this circular plate, the prism table and the verniers turn together. The whole instrument is supported on a base provided with three levelling screws S_1, S_2, and S_3. One of these is situated below the collimator.



ADJUSTMENT OF THE SPECTROMETER

The following essential adjustments are to be made step by step in a spectrometer experiment:

(i) Leveling

Levelling the apparatus means making (a) the axis of rotation of the telescope vertical, (b) the axis of the telescope and that of the collimator horizontal, and (c) the top of the prism table horizontal. The following operations are performed for the purpose.

(a) Levelling of telescope: Place a spirit level on the telescope tube T making its axis parallel to that of the telescope. Set the telescope parallel to the line joining the levelling screw S_1 and S_2. Bring the air bubble of the spirit level halfway towards the centre by turning the screw S_1 and S_2 by equal amounts in the opposite direction. Next bring the bubble at centre by turning the levelling screw t1 and t2 below the telescope by equal amounts in opposite directions.

Now rotate the telescope through 180° so that it is placed to its first position on the other side. Bring the air bubble at centre as before, i.e. half by the screws S_1 and S_2 and the other half by t_1 and t_2. Repeat the operations several times so that the bubble remains at the centre for both positions of the telescope. Next place the telescope in the line with the collimator and bring the air bubble of the spirit level at the centre by turning the screw below the collimator, i.e. S_3 check the first adjustment after this second one is made. The axis of the rotation of the telescope has thus become vertical and the axis of the telescope has become horizontal.

(b) Levelling of collimator: Remove the spirit level from the telescope. Place it on the collimator along its length. Bring the air bubble of the spirit level at the centre by adjusting the levelling screws C1 and C2 below the collimator. This makes the axis of the collimator horizontal.

(c) Levelling of the prism table: Place a spirit level at the centre of the prism table and parallel to the line joining two of the levelling screw of the prism table. Bring the air bubble of the spirit level at the centre by turning these two screws in the opposite directions. Now place the spirit level perpendicular to the line joining the two screws and bring the bubble at the centre by adjusting the third screw. This makes the top of the prism table horizontal.

(ii) Alignment of the source

Place the Bunsen burner at a distance of 15 to 20 cms from the slit in such a way that the axis of the collimator passes through the centre of the flame. Soak the asbestos wound round the iron or copper ring in a concentrated solution of sodium chloride. Place the ring round the flame at such a height that the brightest part of the flame lies opposite to the slit.

Now place a screen with an aperture between the source and the slit so that light from the source can reach the slit without obstruction while, at the same time, stray light is prevented from reaching the observer's eyes directly.

(iii) Focussing the cross-wires:

Rotate the telescope towards any illuminated background. On looking through the eye-piece, you will probably find the cross-wires appear blurred. Move the eye-piece inwards or outwards until the cross-wire appear distinct.

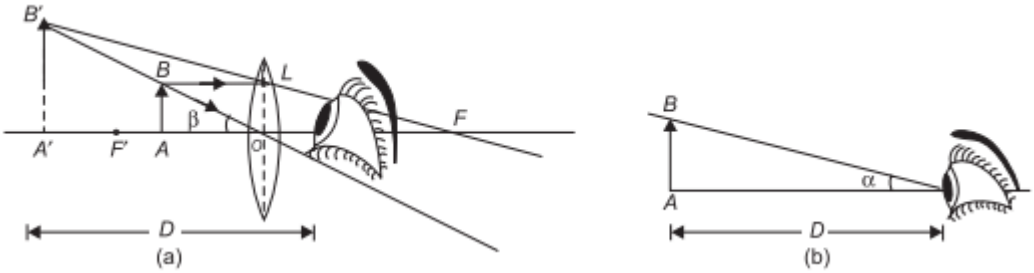
(iv) Adjustment of the Slit

Place the telescope in line with the collimator. Look into the eye-piece without any accommodation in the eyes. The image of the slit may appear blurred. Make the image very sharp by turning the focussing screw of the telescope and of the collimator, if necessary. If the

images does not appear vertical, make it vertical by turning the slit in its own plane. Adjust the width of the slit so that its image may have a breadth of about one millimetre.

SIMPLE MICROSCOPE

A microscope is an optical instrument which forms large image of a close and minute object. In the simplest form a simple microscope or magnifying glass is just a thin, short-focus convex lens carrying a handle. The object to be seen is placed between the lens and its focus and the eye is placed just behind the lens. Then, the eye sees a magnified, erect and virtual image on the same side as the object. The position of the object between the lens and its focus is so adjusted that the image is formed at the least distance of distinct vision (D) from the eye. The image it is then seen most distinctly.



In Figure (a), AB is a small object placed between a lens L and its first focus F'. Its magnified virtual image A'B' is formed at distance D from the lens, the distance of the image A'B' from the eye is also D.

Magnifying Power: Let β be the angle subtended by the image A'B' at the eye [Fig. (a)] and α the angle subtended by the object AB at the eye when placed directly at a distance D from the eye [Fig. (b)]. Then, the magnifying power of the simple microscope is given by

$$M = \frac{\textit{angle subtended by the image at the eye}}{\textit{angle subtended by the object at the eye when placed}} = \frac{\beta}{\alpha}$$

$\beta = \tan\beta = AB / OA$; $\alpha = \tan\alpha = AB / D$

$$M = \frac{AB/OA}{AB/D} = \frac{D}{OA}$$

But OA = *u* (distance of the object from the lens)

$$\therefore M = \frac{D}{u}$$

The image A'B' is being formed at a distance D from lens. Hence, in the lens formula

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$. we shall put v = -D and u = - u, thus $\frac{1}{-D} - \frac{1}{-u} = \frac{1}{f}$ (or)

$\frac{1}{u} = \frac{1}{D} + \frac{1}{f}$ (or) $\frac{D}{u} = 1 + \frac{D}{f}$. Thus $M = 1 + \frac{D}{f}$

We shall substitute only the numerical values of D and *f*. Thus M is positive which means that an erect image is formed. It is also clear, that shorter the focal length of the lens, larger is the magnifying power.

If the eye is kept at the distance d from the lens, then v = – (D – d), and the magnifying power will be $M = 1 + \frac{D-d}{f}$

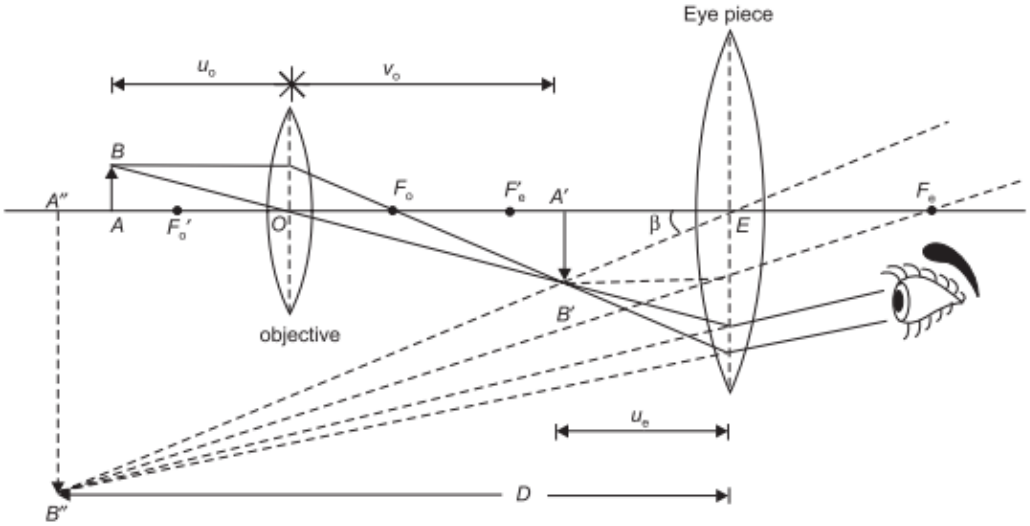
Thus, magnifying power is reduced. Hence to obtain maximum magnifying power, the eye must be very close to the lens. To see with relaxed eye, the image A'B' should be formed at infinity. In this case, the object AB will be at the focus of the lens, that is, u = f. Thus, $M = \frac{D}{f}$

COMPOUND MICROSCOPE

Construction: It consists of a long cylindrical metallic tube carrying at one end an achromatic convex lens O of small focal length and small aperture (Fig.). This lens is called the 'objective lens'. At the other end of the tube is fitted a smaller tube. At the outer end of this smaller tube is fitted an achromatic convex lens E whose focal length and aperture are larger than that of the objective lens. The lens E is towards the eye and is called the eye-piece. The entire tube can be moved forward and backward by rack and pinion arrangement.

Adjustment: First of all the eye-piece is moved forward or backward in the tube and brought in a position so that on seeing through it the cross-wire appear distinct. Then the object is placed just below the objective lens and the entire tube is moved by rack and pinion arrangement until the image of the object is formed on the cross-wire and there is no parallax between the image and the cross-wire. In this position the image of the object will be seen distinctly.

Formation of Image: Suppose AB is a small object placed slightly away from the first focus Fo' of the objective O (Fig.) which form a real inverted and magnified image A'B'. This image lies between the eye-piece E and its first focus Fe' and acts as an object for the eye-piece which forms a magnified, virtual final image A"B". To find the position of B", two dotted rays are taken from B". One ray; which is parallel to the principal axis passes, after refracting, through the second focus Fe of E. The other ray which passes through the optical centre of E travel straight. Both the refracted rays when produced backward meet at B". The image A"B" is generally formed at the least distance of distinct vision although it can be formed anywhere between this position and infinity. The rays by which the eye sees the image are clearly shown in the Fig.



Magnifying Power: Suppose the final image A"B" subtends an angle βat the eye-piece E. Since eye is very near to the eye-piece, the angle βcan also be taken as subtended by A"B" at the eye. Suppose when the object AB is at the least distance of distinct vision D, then it subtends an angle α at the eye. The magnifying power of the microscope is

$$M = \frac{\textit{angle subtended by the final image at the eye}}{\textit{angle subtended by the object, when placed at least distance of distinct vision}} = \frac{\beta}{\alpha}$$

Since β and α are very small. We can write

$\beta = \tan\beta = A'B' / EA'$; $\alpha = \tan\alpha = AB / D$

$$M = \frac{\beta}{\alpha} = \frac{A'B'/EA'}{AB/D} = \frac{A'B'}{AB}\left(\frac{D}{EA}\right)$$

If the distance of the object AB and the image A'B' from the objective O be u_o and v_o respectively, then from the magnification formula we have (taking proper sign)

$$\frac{A'B'}{AB} = \frac{+v_0}{-u_0}$$

Similarly, if the distance of *AB* from the eye-piece be u_e, then $EA = -u_e$. Therefore, from the above formula, we have

$$M = \frac{-v_0}{u_0}\left(\frac{-D}{-u_e}\right) = \frac{-v_0}{u_0}\left(\frac{D}{u_e}\right)$$

Now there are two possibilities:

(i) The final image is formed at the least distance D of distinct vision: If the distance of the final image A"B" from the eye-piece be D, then applying the lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ for the eye piece, we shall have $v = -D$, $u = -u_e$ and $f = +f_e$, where f_e is the focal length of the eye-piece. Now, we get

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

(or) $$\frac{1}{u_e}=\frac{1}{D}+\frac{1}{f_e}$$

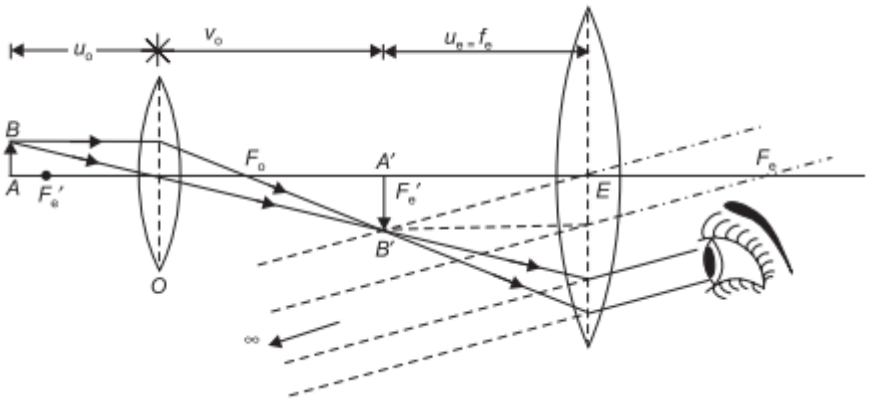
(or) $\frac{D}{u_e}=1+\frac{D}{f_e}$. Thus $$M=\frac{-v_0}{u_0}\left(1+\frac{D}{f_e}\right)$$

In this position the length of the microscope will be *v*o + *u*e.

(*ii*) *When the final image is formed at infinity:* To see with relaxed eye, the final image *A"B"* should
be formed at infinity (Fig). In this case the image *AB* will be at the focus *F*e of the eyepiece *E* i.e. *u*e = *f*e. Substituting this value in equation (*i*), we get the magnifying power of the relaxed eye, which is given by

$$M=\frac{-v_0}{u_0}\left(\frac{D}{f_e}\right)$$

In this position the length of the microscope will be *v*o + *f*e.



In formula (*ii*) and (*iii*) we shall substitute only the numerical values of *v*o, *u*o, *f*e and *D*. Negative sign shows that the final image is inverted. It is clear from these formula that in order to increase the magnifying power of microscope:
1. *u* should be small i.e. the object *AB* should be placed quite close to the objective *O*. But to obtain a real and magnified image of the object, the object should be placed beyond the focal length *f*o of the objective. Hence, for greater magnifying power of the microscope, the focal length of the objective should be small.
2. The distance *v*o of the image *AB* from the objective *O* should be large. For this, the object should be placed near the first focus of the objective.
3. The focal length *f*e of the eye-piece should be small. Thus it is clear that the magnifying power of the microscope depends upon the focal lengths of both the lenses. Hence by taking proper focal lengths the magnification can be increased.

DARK FIELD

In dark field microscopy the illuminating beam is prevented from entering the image-forming ray paths. The background of the field is dark, and only light scattered by optical discontinuities in the specimen is designed to appear in the image as bright lines or dots. Thus, contrast can become extremely high, and diffraction images can be detected as bright points or lines even when the diameter of the scattering object becomes vanishingly small compared to the microscope's limit of resolution.

For small objects that are not obscured by other light-scattering particles (a condition rather difficult to achieve) and are free in a fluid substrate, Brownian motion of the object and the time constant and sensitivity of the detector, rather than the object's absolute size, are more likely to set a lower limit to the size of the object that can be clearly visualized with dark field microscopy.

PHASE CONTRAST

Two light waves arise from the same points in object space but traverse regions that are spatially separated in the objective aperture plane, a phase plate introduced in that plane can be used to modify the relative phase and amplitudes of those two waves. The phase plate is configured to subtract (or add) a $\lambda/4$ phase to one wave relative to other so as to introduce a $\lambda/2$ (or zero) phase difference between the two and, in addition, to reduce the amplitude of the first wave so that it approximates that of the second wave. Thus, when the two waves come to focus together in the image plane, they interfere destructively or constructively to produce a darker or brighter in-focus image of the small, transparent object against a dark gray background (positive and negative phase contrast).

POLARIZING MICROSCOPES

The polarizing microscope generally differs from a standard transilluminating microscope by the addition of a polarizer before the condenser; a compensator slot and analyzer behind the objective lens; strain-free optics; a graduated, revolving stage; centrable lens mounts; cross-hairs in the ocular aligned parallel or at 45° to the polarizer axes; and a focusable Bertrand lens that can be inserted for conoscopic observation of interference patterns in the back aperture of the objective lens. In addition, the front element of the condenser can be swung into place for higher-NA conoscopic observations or swung out for low-NA orthoscopic observations of larger field areas.

FLUORESCENCE

Fluorescence microscopes (or attachments) use epi-illumination incorporating interchangeable filter cubes that are matched to the fluorochrome. The filter cube is placed in the collimated beam between the objective and a tube lens, at the intersection of the microscope axis and that of the excitation illuminator located on a side arm. The objective lens serves both as the condenser and the objective. A field diaphragm, and sometimes an aperture iris, is placed in the illuminating side arm together with the source collector at appropriate conjugate planes. The illuminating beam, commonly emitted by a xenon or mercury arc lamp, is filtered through a narrow band path interference filter and reflected down into the objective by a dichromatic beam splitter. The fluorescence imaging beam originating from the specimen passes straight through the dichromatic beam splitter and associated barrier filter and reaches the ocular or camera. Each fluorescence cube contains the appropriate excitation interference filter,

dichromatic beam splitter, and barrier filter so that they can be switched as a group, for example, to rapidly inspect specimens containing (or stained with) multiple fluorochromes.

ELECTRON MICROSCOPE

This microscope is used to see very minute particles distinctly. In this microscope an electron beam is used instead of light-rays. The electron-beam is focussed by magnetic and electric fields. It behaves as a wave of wavelength of the order of 1 Å; which is 5000 times smaller than the mean wavelength of visible light. Hence an electron microscope can resolve 5000 times compared to an optical microscope.

Principle

A stream of electrons is passed through the object and the electron which carries the information about the object is focused by electric and magnetic fields. The resolving power is inversely proportional to the wavelength, the electrons microscope has high Resolving power because of its shorter wavelength. Electrons have wavelength 10^5 times shorter than the visible light

Construction:

It consists of an electron gun to produce stream of electrons. In this type of microscope, Magnetic condensing lens are used to condense the electron, Objective lens is used to resolve the structure of the specimen and projector lens is used for enlargement view when viewed from eye piece. The whole arrangement is kept in a vacuum chamber to allow the passage of electron beam as shown in figure

Working:

Stream of electrons are ejected and accelerated by the electron gun. The electron beam is allowed to pass through the centre of doughnut shaped magnetic condensing lens. These electrons are made as parallel beam and focused on to object AB

The electrons are transmitted more in the less denser region of the object and absorbed by more denser region of the object. This transmitted electron beam falls over the magnetic objective lens which resolves the magnified real image of the object. Further it is magnified by the projector lens and image is fall on the fluorescent screen. To record this image a photographic plate is introduced

Advantages:

(i) The magnification as high as 1,00,000 X

(ii) We can vary the focal length of microscope

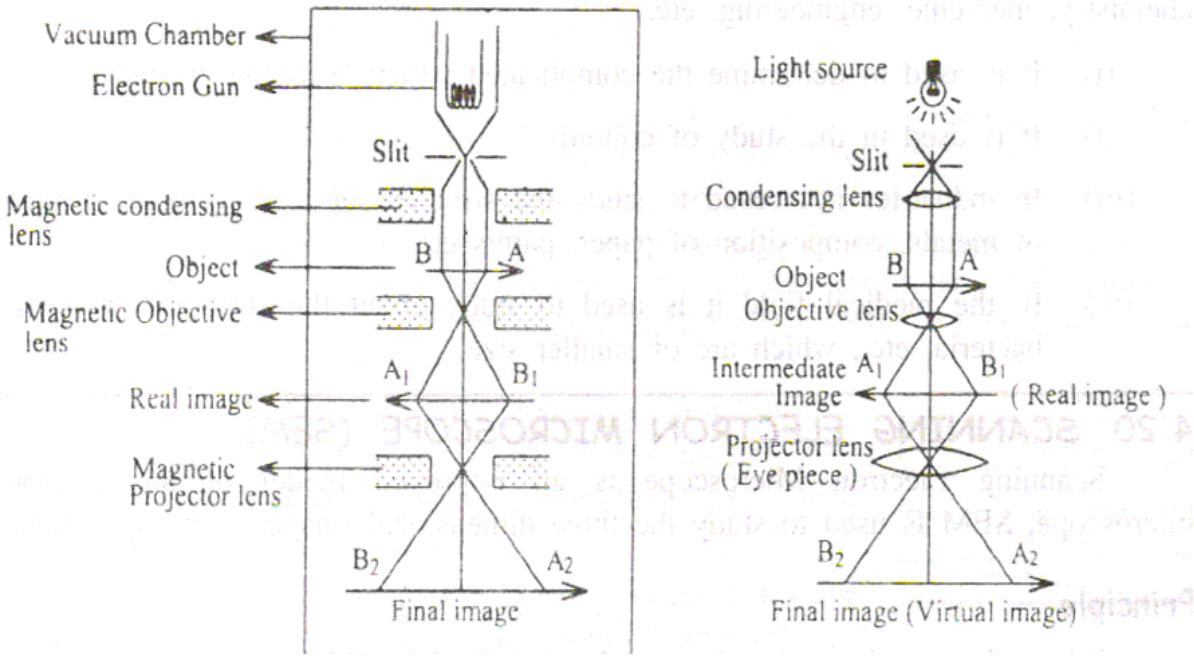
Applications:

(i) In material science, the surface details can be studied

(ii) It is used to determine the complicated structure of the crystal

(iii) In Nanotechnology, it is used to study the colloidal particles

(iv) In medical field, it is used to study the structure micro organisms



Types of electron microscope:

There are three types of microscopes. They are

(1) Scanning Electron Microscope

(2) Transmission Electron Microscope

(3) Scanning Transmission Microscope