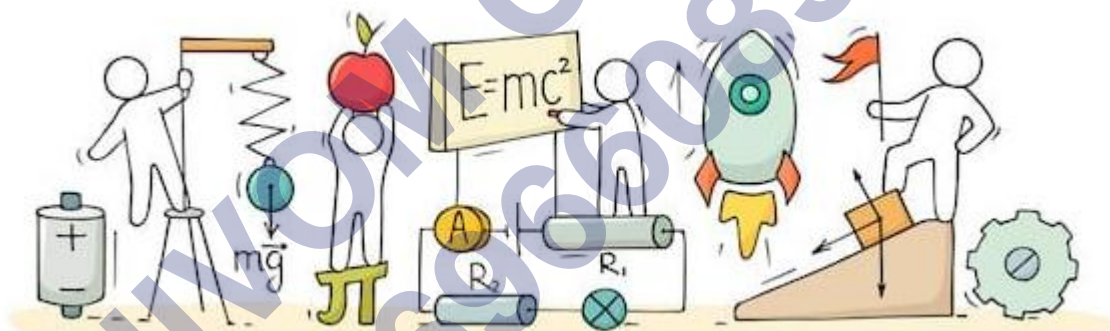


PHYSICS

CHAPTER 9: RAY OPTICS AND OPTICAL INSTRUMENTS



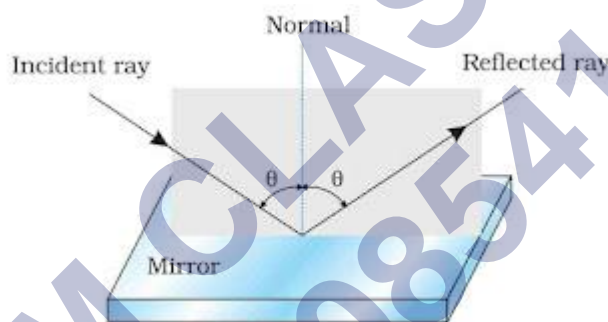
RAY OPTICS AND OPTICAL INSTRUMENTS

Ray Optics or Geometrical Optics:

In this optics, the light is considered as a ray which travels in a straight line. It states that for each and every object, there is an image.

Reflection of Light:

The phenomenon in which a light ray is sent back into the same medium from which it is coming, on interaction with a boundary, is called reflection. The boundary can be a rigid surface or just an interface between two media.



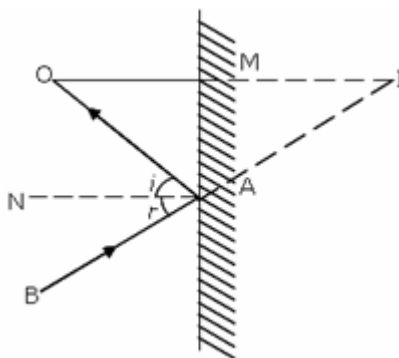
Law of reflection:

The angle of reflection equals the angle of incidence $\angle i = \angle r$.

The incident ray, reflected ray, and the normal to the reflecting surface at the point of incidence lie in the same plane.

Formation of Image by the Plane Mirror:

The formation of image of a point object O by a plane mirror is represented in figure.



The image formed I has the following characteristics:

- The size of image is equal to the size of object.
- The object distance = Image distance i.e., $OM = MI$.
- The image is virtual and erect.
- When a mirror is rotated through a certain angle, the reflected ray is rotated through twice this angle.

Spherical Mirrors:

A spherical mirror is a part of sphere. If one of the surfaces is silvered, the other surface acts as the reflecting surface. When convex face is silvered, and the reflecting surface is concave, the mirror is called a concave mirror. When its concave face is silvered and convex face is the reflecting face, the mirror is called a convex mirror.



- **Centre of curvature:** Centre of curvature is the center of sphere of which, the mirror is a part.
- **Radius of curvature:** Radius of curvature is the radius of sphere of which, the mirror is a part.
- **Pole of mirror:** Pole is the geometric center of the mirror.
- **Principal axis:** Principal axis is the line passing through the pole and center of curvature.
- **Normal:** Any line joining the mirror to its center of curvature is normal.

Reflection of Light from Spherical Mirror:

1. A spherical mirror is a part cut from a hollow sphere.
2. They are generally constructed from glass.
3. The reflection at spherical mirror also takes place in accordance with the laws of reflection.

Refraction of light:

Refraction is the bending of a wave when it passes from one medium to another. The bending is caused due to the differences in density between the two substances.

“Refraction is the change in the direction of a wave passing from one medium to another.”

Laws of Refraction:

Two laws of refraction are given as below:

- The incident ray, refracted ray and the normal to the refracting surface at the point of incidence lie in the same plane.
- The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for the two-given media. This constant is denoted by n and is called the relative refractive index.

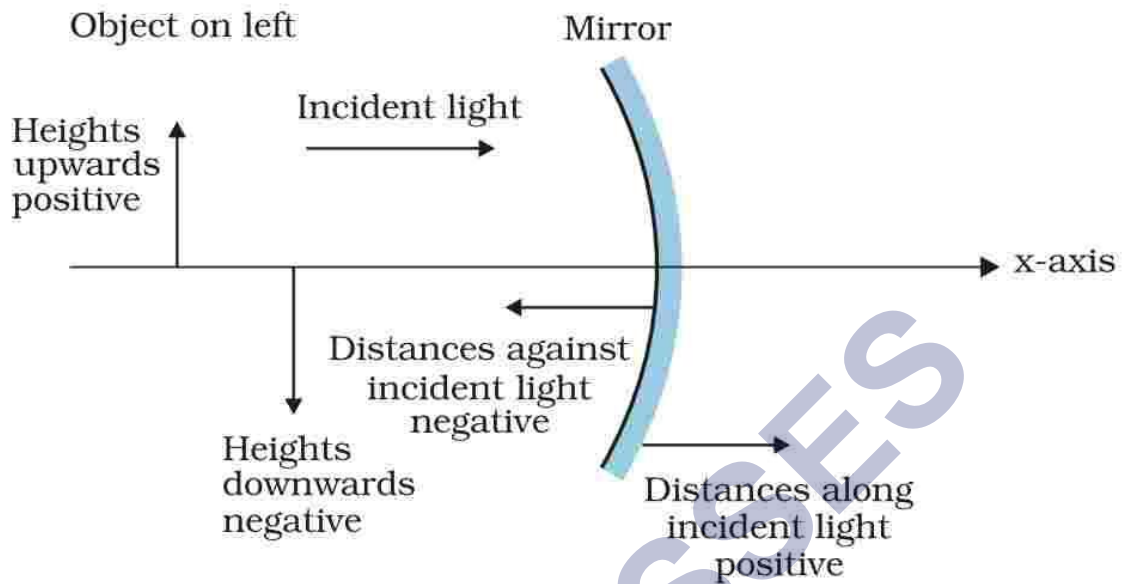
$$n = \frac{\sin i}{\sin r} \text{ (snell's law)}$$

where, n is refractive index of the second medium when first medium is air.

Sign Convention:

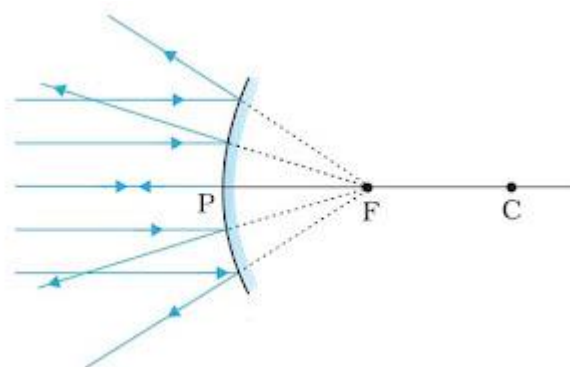
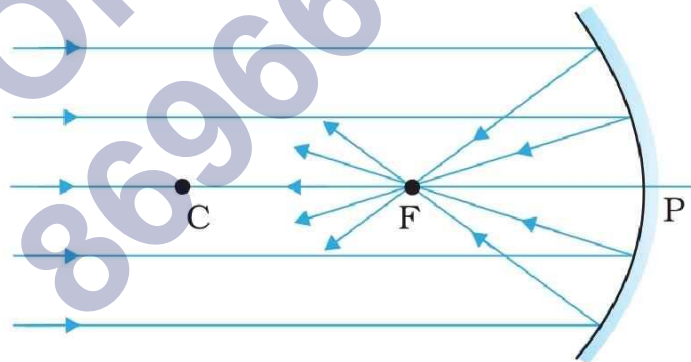
Following sign conventions are the new cartesian sign convention:

- All distances are measured from the pole of the mirror & the distances measured in the direction of the incident light is taken as positive. In other words, the distances measured toward the right of the origin are positive.
- The distance measured against the direction of the incident light are taken as negative. In other words, the distances measured towards the left of origin are taken as negative.
- The distance measured in the upward direction, perpendicular to the principal axis of the mirror, are taken as positive & the distances measured in the downward direction are taken as negative.



Focal Length of Spherical Mirrors:

When a parallel beam of light is incident on a concave mirror, and a convex mirror. The rays are incident at points close to the pole P of the mirror and make small angles with the principal axis. The reflected rays converge at a point F on the principal axis of a concave mirror. For a convex mirror, the reflected rays appear to diverge from a point F on its principal axis.



The point F is called the principal focus of the mirror. The distance between the focus F

and the pole P of the mirror is called the focal length of the mirror, denoted by f.

If, R be the radius of curvature of the mirror then relation between R and f is given by

$$f = \frac{R}{2}$$

Principal Axis of the Mirror:

The straight line joining the pole and the centre of curvature of spherical mirror extended on both sides is called principal axis of the mirror.

Mirror Formula:

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

Where u = distance of the object from the pole of mirror

v = distance of the image from the pole of mirror

f = focal length of the mirror

$f = \frac{R}{2}$ Where R is the radius of curvature of the mirror.

Lens:

Lens is a transparent medium bounded by two surfaces of which one or both surfaces are spherical.

Lens Formula:

Lens formula relates the distance of object from the lens with distance of image from the lens. It is given by.

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

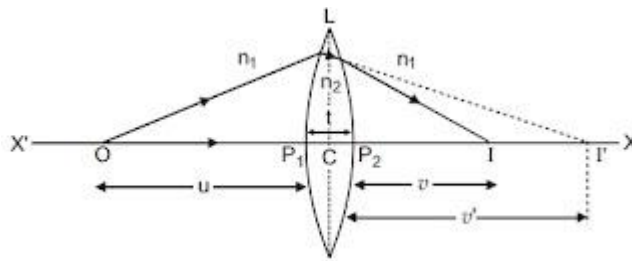
Where, u = object distance

v = image distance

f = focal length

Lens Maker's Formula:

Lens Maker's formula gives the focal length of a lens in terms of the nature of the surfaces by which the lens is bounded and the nature of material of the lens.



Let us consider the situation shown in figure. C_1 and C_2 are the centers of curvature of two spherical surfaces of the thin lens. O is the object and I' is the image due to first refraction. Let radii of curvature be R_1 and R_2 .

For the first refraction at image distance is v_1 . From the formula for refraction at a curved surface, we get

$$\frac{n_2}{v_1} = \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \dots (i)$$

Final image position is I , which is also the image due to second refraction. Let this image distance be v . For the second refraction, v_1 becomes the object distance. Hence we get,

$$\frac{n_1}{v} = \frac{n_2}{v_1} = \frac{n_1 - n_2}{R_2} \dots (ii)$$

Adding (i) and (ii), we get

$$\left(\frac{n_1}{v} - \frac{n_1}{u}\right) = (n_2 - n_1) \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right) \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{v} - \frac{1}{u} = (n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

According to the definition of the focal length f

$$\frac{1}{f} = (n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

This is called the "Lens Maker's formula".

Power of Lens:

The ability of a lens to converge or diverge the rays of light incident on it is called the power of the lens.

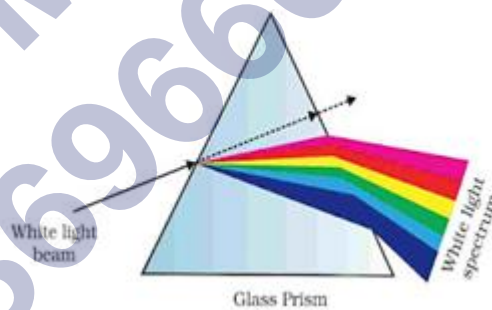
$$P = \frac{1}{f(\text{in m})}$$

SI unit of power lens = dioptre (D) = m^{-1}

Prism:

prism, in optics, piece of glass or other transparent material cut with precise angles and plane faces, useful for analyzing and reflecting light. An ordinary triangular prism can separate white light into its constituent colors, called a spectrum. Each color, or wavelength, making up the white light is bent, or refracted, a different amount; the shorter wavelengths (those toward the violet end of the spectrum) are bent the most, and the longer wavelengths (those toward the red end of the spectrum) are bent the least. Prisms of this kind are used in certain spectrosopes, instruments for analyzing light and for determining the identity and structure of materials that emit or absorb light.

Dispersion: When white light is incident on a prism, different colors having different wavelengths suffer different deviations. The phenomenon of splitting of light into its component colors is known as dispersion. The pattern of color components of light (VIBGYOR) is called the spectrum of light. The deviation produced by a thin prism depends on the refractive index.



Angular Dispersion: Angular dispersion produced by a prism for white light is the difference in the angles of deviation for two extreme colors i.e., violet and red. It is given by.

$$\theta = \delta_V - \delta_R$$

$$\theta = (n_V - n_R)A$$

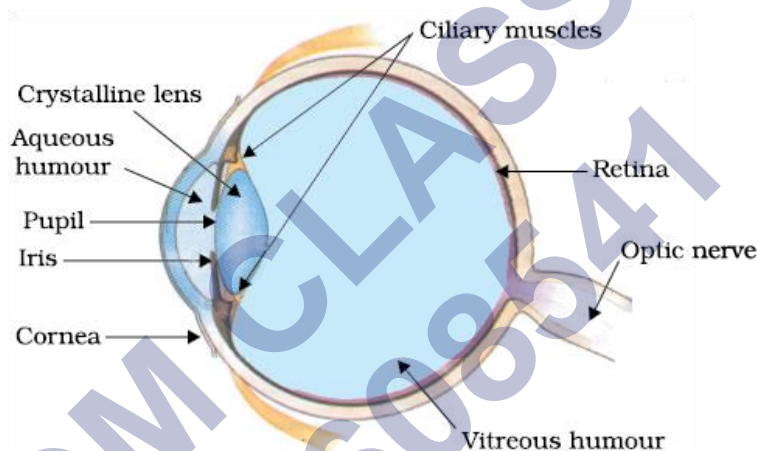
Dispersive Power: Dispersive power of a prism is defined as the ratio of angular dispersion to the mean deviation produced by the prism.

$$\omega = \frac{\delta_V - \delta_R}{\delta_Y}$$

Optical Instruments:

Optical instruments are the devices which help human eye in observing highly magnified images of tiny objects, for detailed examination and in observing very far objects whether terrestrial or astronomical.

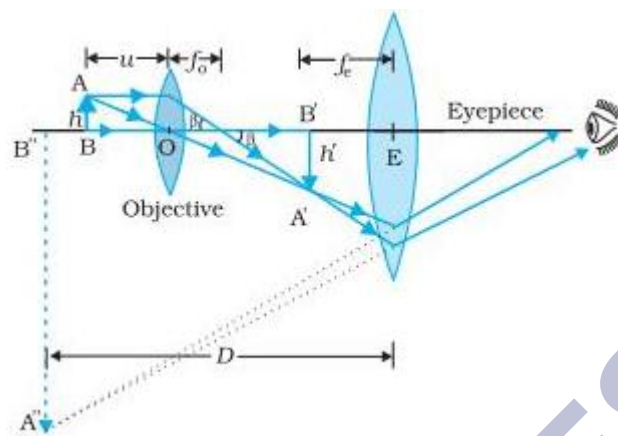
The Eye: Light enters the eye through cornea a curved front surface. It passes through the pupil which is the central hole in the iris. The size of pupil can change under control of muscles. The light is further focused by the eye lens on the retina. The retina is a film of nerve fibers covering the curved black surface of the eye. The retina contains rods and cones which sense light intensity and color respectively and transmit electrical signals via the optic nerve to the brain.



The shape (curvature) and therefore the focal length of the lens can be modified somewhat by ciliary muscles. So, images are formed at the retina for objects at all distances. This property of the eye is called accommodation.

The closest distance for which the eye lens can focus light on the retina is called the least distance of distinct vision or the near point. The standard value for normal vision is taken as 25cm (Symbol D). If the object is too close to eye; the lens cannot curve enough to focus the image on the retina, and the image is blurred.

The microscope: A simple magnifier or microscope is a converging lens of small focal length. The lens nearest the object, called the objective, forms a real, inverted, magnified image of the object. This serves as the object for the second lens, the eyepiece, which functions essentially like a simple microscope or magnifier, producing an enlarged virtual final image.

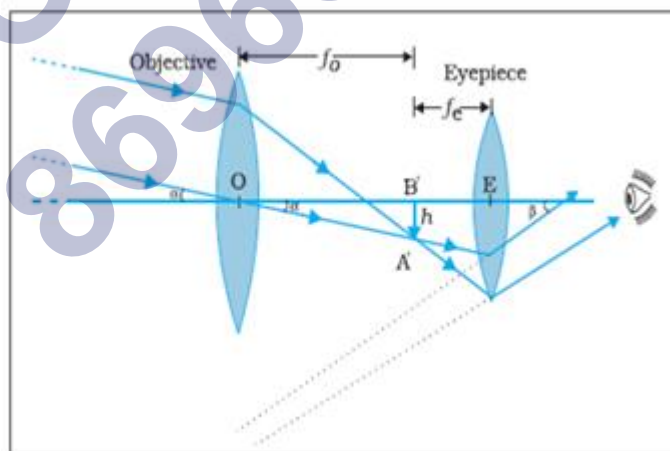


The first inverted image is thus near (at or within) the focal point of the eyepiece, at a distance appropriate for final image formation at infinity, or a little closer for image formation at the near point. Clearly, the final image is inverted with respect to the original object.

Magnification power is given by

$$m = \frac{v_0}{u_0} \left[\frac{D}{v} + \frac{D}{f_e} \right]$$

Telescope: This device is used to observe objects which are far away. However, a telescope has an objective lens of large aperture and considerable focal length and eye lens that with a small aperture and focal length.

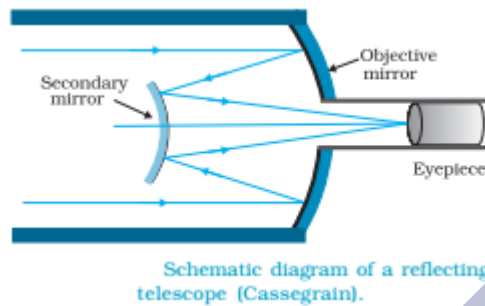


Magnifying power is given by

$$m = -f_0 \left[\frac{1}{f_e} + \frac{1}{v} \right]$$

Reflecting Telescope (Cassegrain telescope):

In such telescope, one objective lens is replaced by a concave parabolic mirror of large aperture, which is free from chromatic and spherical aberrations.



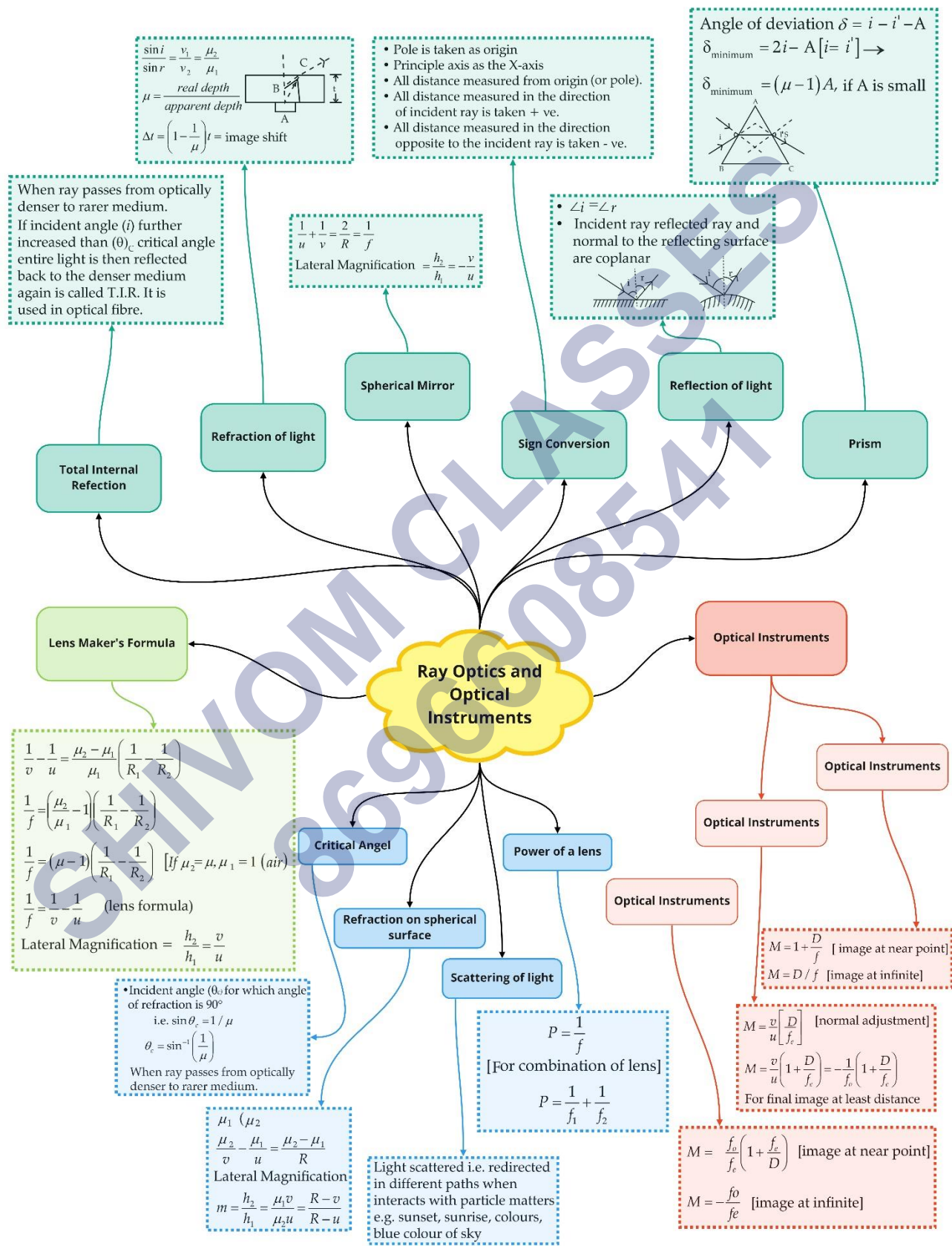
In normal adjustment, magnifying power

$$m = \frac{f_0}{f_e} = \frac{R}{2f_e}$$

Advantages of taking mirror objectives are:

- There is no chromatic aberration in a mirrors.
- If a parabolic reflecting surface is chosen, spherical aberration is also removed.
- Mechanical support is much less of a problem since a mirror weighs much less than a lens of equivalent optical quality and can be supported over.
- Entire back surface not just over rim unlike lens.

Class : 12th Physics
Chapter- 9 : Ray Optics and Optical Instruments



Important Questions

Multiple Choice questions-

- For a total internal reflection, which of the following is correct?
 - Light travels from rarer to denser medium.
 - Light travels from denser to rarer medium.
 - Light travels in air only.
 - Light travels in water only.
- Critical angle of glass is θ_1 and that of water is θ_2 . The critical angle for water and glass surface would be ($\mu_g = 3/2$, $\mu_w = 4/3$).
 - less than θ_2
 - between θ_1 and θ_2
 - greater than θ_2
 - less than θ_1
- Mirage is a phenomenon due to
 - refraction of light
 - reflection of light
 - total internal reflection of light
 - diffraction of light.
- A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will
 - become zero
 - become infinite
 - become small, but non-zero
 - remain unchanged
- Which of the following forms a virtual and erect image for all positions of the object?
 - Concave lens
 - Concave mirror
 - Convex mirror
 - Both (a) and (c)
- Two lenses of focal lengths 20 cm and -40 cm are held in contact. The image of an object at infinity will be formed by the combination at
 - 10 cm

- (b) 20 cm
- (c) 40 cm
- (d) infinity

7. Two beams of red and violet color are made to pass separately through a prism (angle of the prism is 60°). In the position of minimum deviation, the angle of refraction will be

- (a) 30° for both the colors
- (b) greater for the violet color
- (c) greater for the red color
- (d) equal but not 30° for both the colors

8. Which of the following colours of white light deviated most when passes through a prism?

- (a) Red light
- (b) Violet light
- (c) Yellow light
- (d) Both (a) and (b)

9. An under-water swimmer cannot see very clearly even in absolutely clear water because of

- (a) absorption of light in water
- (b) scattering of light in water
- (c) reduction of speed of light in water
- (d) change in the focal length of eye lens

10. An astronomical refractive telescope has an objective of focal length 20 m and an eyepiece of focal length 2 cm. Then

- (a) the magnification is 1000
- (b) the length of the telescope tube is 20.02 m
- (c) the image formed of inverted
- (d) all of these

Very Short:

1. When light undergoes refraction at the surface of separation of two media, what happens to its frequency/wavelength?
2. Define the refractive index.
3. What is the distance between the objective and eyepiece of an astronomical telescope in its normal adjustment?
4. Name the phenomenon responsible for the reddish appearance of the sun at sunrise and sunset.

5. What are the two main considerations that have to be kept in mind while designing the 'objective' of an astronomical telescope?
6. Under what condition does a biconvex lens of glass having a certain refractive index act as a plane glass sheet when immersed in a liquid? (CBSE Delhi 2012)
7. Write the relationship between the angle of incidence 'i', angle of prism 'A' and angle of minimum deviation for a triangular prism. (CBSE Delhi 2013)
8. Why can't we see clearly through the fog? Name the phenomenon responsible for it. (CBSE AI 2016)
9. How does the angle of minimum deviation of a glass prism vary if the incident violet light is replaced by red light? Give reason. (CBSE AI 2017)
10. The objective lenses of two telescopes have the same apertures but their focal lengths are in the ratio 1: 2. Compare the resolving powers of the two telescopes. (CBSE AI 2017C)

Short Questions:

1. The aperture of the objective lens of an astronomical telescope is doubled. How does it affect
 - (i) the resolving power of the telescope and
 - (ii) the intensity of the image? (CBSE Sample Paper 2018-19)
2. How does the resolving power of a compound microscope change on (a) decreasing the wavelength of light used, and (b) decreasing the diameter of the objective lens?
3. The layered lens shown in the figure is made of two kinds of glass. How many and what kinds of images will be produced by this lens with a point source placed on the optic axis? Neglect the reflection of light at the boundaries between the layers.
4. Monochromatic light is refracted from air into a glass of refractive index n . Find the ratio of wavelengths of the incident and refracted light.
5. Draw a labelled ray diagram to show the image formation in a compound microscope.
6. A ray of light while travelling from a denser to a rarer medium undergoes total internal reflection. Derive the expression for the critical angle in terms of the speed of light in the two media.
7. Draw a labelled diagram for a refracting type astronomical telescope. How will its magnifying power be affected by increasing for its eyepiece (a) the focal length and (b) the aperture? Justify your answer. Write two drawbacks of refracting type telescopes. (CBSE Sample Paper 2018-19)

8. Draw a labelled ray diagram of a Newtonian type reflecting telescope. Write any one advantage over refracting type telescope.

Long Questions:

1. Draw a labelled ray diagram to show the image formation in a refracting type of astronomical telescope. Obtain an expression for the angular magnifying power and the length of the tube of an astronomical telescope in its 'normal adjustment' position. Why should the diameter of the objective of a telescope be large?
2. Draw a ray diagram to show the formation of an erect image of an object kept in front of a concave mirror. Hence deduce the mirror formula. (CBSE 2019C)

Assertion and Reason Questions:

1. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

- a) Both A and R are true and R is the correct explanation of A.
- b) Both A and R are true but R is not the correct explanation of A.
- c) A is true but R is false.
- d) A is false and R is also false.

Assertion: If optical density of a substance is more than that of water, then the mass density of substance can be less than water.

Reason: Optical density and mass density are not related.

2. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

- a. Both A and R are true and R is the correct explanation of A.
- b. Both A and R are true but R is not the correct explanation of A.
- c. A is true but R is false.
- d. A is false and R is also false.

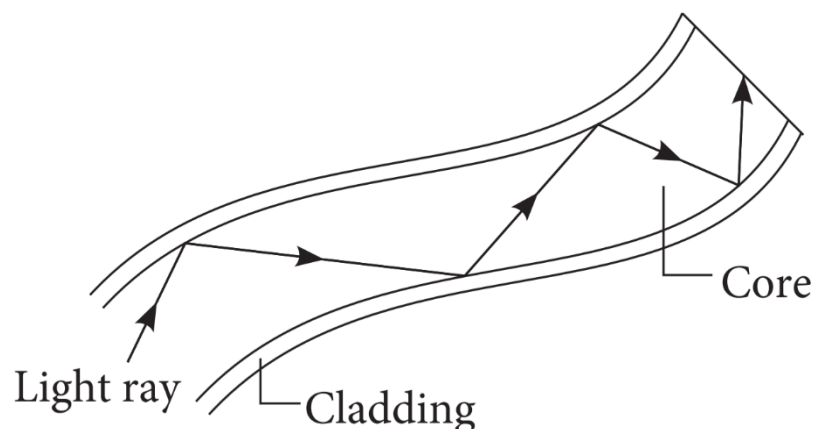
Assertion: A single lens produces a coloured image of an object illuminated by white light.

Reason: The refractive index of the material of lens is different for different wavelengths of light.

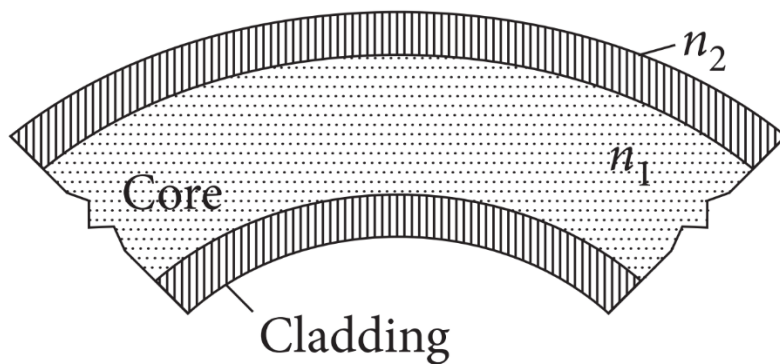
Case Study Questions:

1. An optical fibre is a thin tube of transparent material that allows light to pass through, without being refracted into the air or another external medium. It make use of total internal reflection. These fibres are fabricated in such a way that light

reflected at one side of the inner surface strikes the other at an angle larger than critical angle. Even, if fibre is bent, light can easily travel along the length.



- (i) Which of the following is based on the phenomenon of total internal reflection of light?
- Sparkling of diamond.
 - Optical fibre communication.
 - Instrument used by doctors for endoscopy.
 - All of these.
- (ii) A ray of light will undergo total internal reflection inside the optical fibre, if it.
- Goes from rarer medium to denser medium.
 - Is incident at an angle less than the critical angle.
 - Strikes the interface normally.
 - Is incident at an angle greater than the critical angle.
- (iii) If in core, angle of incidence is equal to critical angle, then angle of refraction will be.
- 0°
 - 45°
 - 90°
 - 180°
- (iv) In an optical fibre (shown), correct relation for refractive indices of core and cladding is:



- a. $n_1 = n_2$
- b. $n_1 > n_2$
- c. $n_1 < n_2$
- d. $n_1 + n_2 = 2$

(v) If the value of critical angle is 30° for total internal reflection from given optical fibre, then speed of light in that fibre is:

- a. $3 \times 10^8 \text{ms}^{-1}$
- b. $1.5 \times 10^8 \text{ms}^{-1}$
- c. $6 \times 10^8 \text{ms}^{-1}$
- d. $4.5 \times 10^8 \text{ms}^{-1}$

2. An astronomical telescope is an optical instrument which is used for observing distinct images of heavenly bodies like stars, planets etc. It consists of two lenses. In normal adjustment of telescope, the final image is formed at infinity. Magnifying power of an astronomical telescope in normal adjustment is defined as the ratio of the angle subtended at the eye by the angle subtended at the eye by the final image to the angle subtended at the eye, by the object directly, when the final image and the object both lie at infinite distance from the eye. It is given by, $m = \frac{f_o}{f_g}$. To increase magnifying power of an astronomical telescope in normal adjustment, focal length of objective lens should be large and focal length of eye lens should be small.

- (i) An astronomical telescope of magnifying power 7 consists of the two thin lenses 40cm apart, in normal adjustment. The focal lengths of the lenses are
 - a) 5cm, 35cm
 - b) 7cm, 35cm
 - c) 17cm, 35cm
 - d) 5cm, 30cm
- (ii) An astronomical telescope has a magnifying power of 10. In normal adjustment, distance between the objective and eye piece is 22cm. The focal length of objective lens is:
 - a) 25cm

- b) 10cm
 - c) 15cm
 - d) 20cm
- (iii) In astronomical telescope compare to eye piece, objective lens has:
- a) Negative focal length.
 - b) Zero focal length.
 - c) Small focal length.
 - d) Large focal length.
- (iv) To see stars, use:
- a) Simple microscope.
 - b) Compound microscope.
 - c) Endoscope.
 - d) Astronomical telescope.
- (v) For large magnifying power of astronomical telescope.
- a) $f_0 \ll f_e$
 - b) $f_0 \ll f_e$
 - c) $f_0 \ll f_e$
 - d) None of these.

✓ Answer Key:

Multiple Choice Answers-

1. Answer: b
2. Answer: c
3. Answer: c
4. Answer: b
5. Answer: d
6. Answer: c
7. Answer: a
8. Answer: b
9. Answer: d

10. Answer: d

Very Short Answers:

1. Answer: There is no change in its frequency, but its wavelength changes.
2. Answer: The Refractive index of a medium is defined as the ratio of the speed of light in a vacuum to the speed of light in the given medium.
3. Answer: Distance between objective and eyepiece of telescope = $f_o + f_e$
4. Answer: Atmospheric refraction.
5. Answer: Two main considerations are
 - Large light gathering power
 - Higher resolution (or resolving power)
6. Answer: When the refractive index of the liquid is equal to the refractive index of a glass of which the lens is made.
7. Answer: $2i = A + \delta_m$
8. Answer: Because it scatters light. Scattering of light.
9. Answer: It decreases as $\delta_m \propto \frac{1}{\lambda}$
10. Answer: Same as resolving power does not depend upon the focal length of lenses.

Short Questions Answers:

1. Answer:

The resolving power of a telescope is given by the expression $\frac{D}{1.22\lambda}$.

(i) When the aperture of the objective lens is increased, the resolving power of the telescope increases in the same ratio.

(ii) The intensity of the image is given by the expression $\beta \propto D_2^2$, thus when the aperture is doubled, the intensity of the image becomes four times.

2. Answer:

The resolving power of a microscope is given by the expression $RP = \frac{2n\sin\theta}{\lambda}$

(a) If the wavelength of the incident light is decreased, the resolving power of the microscope increases.

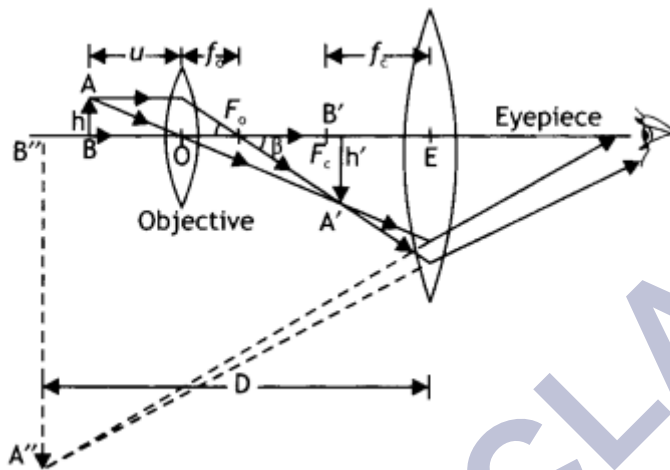
(b) There is no effect of the decrease in the diameter of the objective on the resolving power of the microscope.

3. Answer: Two images will be formed as the lens may be thought of, as two separate lenses of different focal lengths. The images will be surrounded by bright halos.

4. Answer: Using the relation $\lambda_1 n_1 = \lambda_2 n_2$ we have

$$\frac{\lambda_1}{\lambda_2} = n$$

5. Answer: The labelled diagram is as shown.



6. Answer:

Snell's law can be used to find the critical angle. Now Snell's law, when the ray moves from denser medium 'b' to rarer medium 'a', is given by

$${}_b n_a = \frac{\sin i_c}{\sin 90^\circ} \quad \dots(1)$$

$$\text{But } {}_a n_b = \frac{1}{{}_b n_a}$$

Therefore, the above equation can be

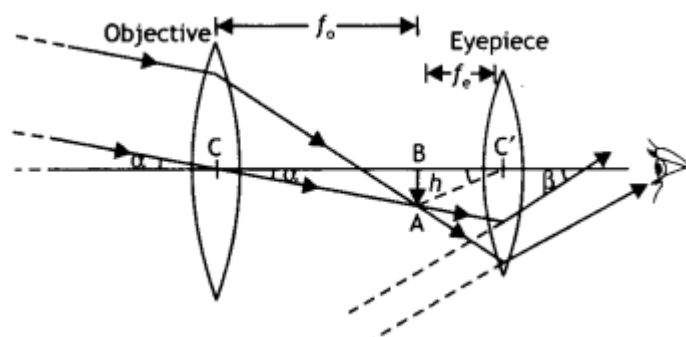
$$\text{written as } \frac{1}{{}_a n_b} = \frac{\sin i_c}{\sin 90^\circ} \quad \dots(2)$$

$${}_a n_b = \frac{1}{\sin i_c} \quad \dots(3)$$

Now we know that $n = \frac{c}{v}$, substituting in the above relation we have

$$\frac{c}{v} = \frac{1}{\sin i_c} \text{ or } \sin i_c = \frac{v}{c}$$

7. Answer: The labelled diagram of the telescope is as shown in the figure.



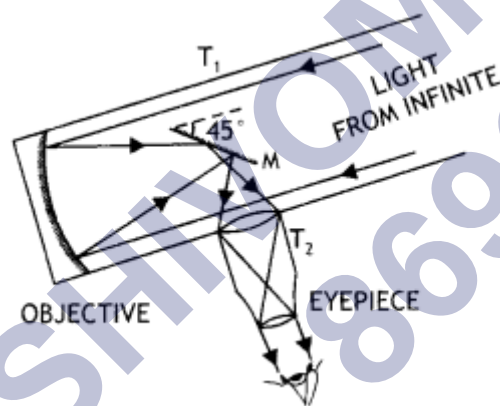
(a) The magnifying power of a telescope is given by $M = \frac{f_o}{f_e}$. If the focal length of the eyepiece is increased, it will decrease the magnifying power of the telescope.

(b) Magnifying power does not depend upon the aperture of the eyepiece. Therefore, there is no change in the magnifying power if the aperture of the eyepiece is increased.

Drawbacks:

- Large-sized lenses are heavy and difficult to support.
- Large-sized lenses suffer from chromatic and spherical aberration.

8. Answer: The labelled diagram is shown below.

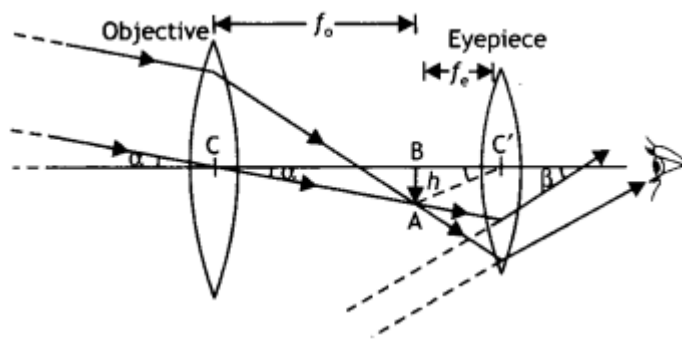


Due to the large aperture of the mirror as compared to a lens the image formed is much brighter than that formed by a refracting type of telescope.

Long Questions Answers:

1. Answer:

A labelled diagram of the telescope is shown in the figure.



The object subtends an angle at the objective and would subtend essentially the same angle at the unaided eye. Also, since the observers' eye is placed just to the right of the focal point f_2 , the angle subtended at the eye by the final image is very nearly equal to the angle β .

Therefore, $M = \frac{\beta}{\alpha} = \frac{\tan \beta}{\tan \alpha} \dots(1)$

From right triangles ABC and A'B'C' as shown in figure, we have

$$\tan \alpha = \frac{AB}{CB} = \frac{-h}{f_o} \text{ and}$$

$$\tan \beta = \frac{A_1B_1}{C'A} = \frac{-h'}{f_e}$$

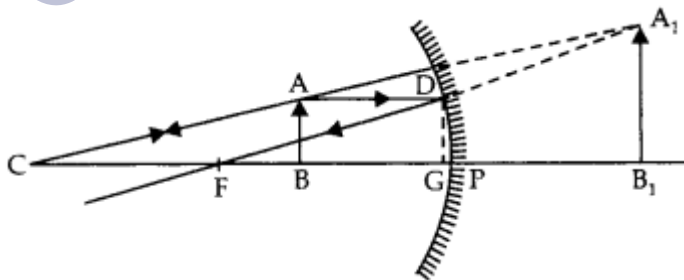
substituting the above two equations in equation (1), we have

$$M = \frac{\beta}{\alpha} = \frac{-h'}{f_e} \times \frac{f_o}{-h} = \frac{f_o}{f_e}$$

The length of the telescope is the distance between the two lenses which is $L = f_o + f_e$. The diameter of the objective of a telescope should be large so that it can collect more light and image of distant objects is formed clear.

2. Answer:

An object AB is placed between P and F. The course of rays for obtaining erect image A₁B₁ of object AB is shown in the figure.



Draw $DG \perp$ on the principal axis.

Triangles DGF and A₁B₁C are similar

$$\therefore \frac{DG}{A_1B_1} = \frac{GF}{FB_1}$$

$$\text{or } \frac{AB}{A_1B_1} = \frac{GF}{FB_1} \quad [\because DG = AB] \quad \dots(i)$$

Again triangles ABC and A_1B_1C are similar

$$\therefore \frac{AB}{A_1B_1} = \frac{CB}{CB_1} \quad \dots(ii)$$

From Eqs. (i) and (ii), we have

$$\frac{GF}{FB_1} = \frac{CB}{CB_1}$$

Since Point G is close to P, so $GF = PF$

$$\therefore \frac{PF}{FB_1} = \frac{CB}{CB_1}$$

Using sign conventions, we get

$$\frac{PF}{PF + PB_1} = \frac{PC - PB}{PC + PB_1}$$

$$\text{or } \frac{-f}{-f + v} = \frac{-2f + u}{-2f + v}$$

Multiplying and dividing both sides by uvf , we get

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

Assertion and Reason Answers:

1. (a) Both A and R are true and R is the correct explanation of A.

Explanation:

Optical density and mass density are not related to each other. Mass density is mass per unit volume. It is possible that mass density of an optically denser medium be less than that of an optically rarer medium (optical density is the ratio of the speed of light in two media). e.g., turpentine and water. Mass density of turpentine is less than that of water but its optical density is higher.

2. (a) Both A and R are true and R is the correct explanation of A.

Explanation:

Due to the variation of the refractive index of the material of the lens, the focal length also varies accordingly. Now as white light is composed of different colours of light, each colour will produce its own image based on the focal length for that colour. This particular phenomenon for a single lens is known as chromatic aberration.

Case Study Answers:

1. Answer :

(i) (d) All of these.

Explanation:

Total internal reflection is the basis for following phenomenon:

- Sparkling of diamond.
- Optical fibre communication.
- Instrument used by doctors for endoscopy.

(ii) (d) Is incident at an angle greater than the critical angle.

Explanation:

Total internal reflection (TIR) is the phenomenon that involves the reflection of all the incident light off the boundary. TIR only takes place when both of the following two conditions are met: The light is in the more denser medium and approaching the less denser medium.

The angle of incidence is greater than the critical angle.

(iii) (c) 90°

Explanation:

If incidence of angle, $i =$ critical angle C , then angle of refraction, $r = 90^\circ$

(iv)(b) $n_1 > n_2$

Explanation:

In optical fibres, core is surrounded by cladding, where the refractive index of the material of the core is higher than that of cladding to bound the light rays inside the core.

(v) (b) $1.5 \times 10^8 \text{ms}^{-1}$

Explanation:

From Snell's law, $\sin C = {}_1n_2 = \frac{v_1}{v_2}$

Where, $C =$ critical angle $= 30^\circ$ and v_1 and v_2 are speed of light in medium and vacuum, respectively. We know that, $v_2 = 3 \times 10^8 \text{ms}^{-1}$

$$\therefore \sin 30^\circ = \frac{v_1}{3 \times 10^8}$$

$$\Rightarrow v_1 = 3 \times 10^8 \times \frac{1}{2}$$

$$\Rightarrow v_1 = 1.5 \times 10^8 \text{ms}^{-1}$$

2. Answer :

i. (a) 5cm, 35cm

Explanation:

$$m = \frac{f_0}{f_e} = 7$$

$$f_0 = 7f_e$$

In normal adjustment, distance between the lenses,

$$f_0 + f_e = 40$$

$$7f_0 + f_e = 40 \Rightarrow f_e = \frac{40}{8} = 5\text{cm}$$

$$f_0 = 7f_e = 7 \times 5 = 35\text{cm}$$

ii. (d) 20cm

Explanation:

$$m = -10; L = 22\text{cm}$$

$$\text{As, } m = \frac{-f_0}{f_e} \Rightarrow -10 = -\frac{f_0}{f_e}$$

$$f_0 = 10f_e$$

$$\text{As, } L = f_0 + f_e$$

$$22 = 10f_e + f_e = 11f_e$$

$$\text{or } f_e = \frac{22}{11} = 2\text{cm}$$

$$f_0 = 10f_e = 20\text{cm}$$

iii. (d) Large focal length.

Explanation:

Objective lens has larger focal length than eye-piece.

iv. (d) Astronomical telescope.

Explanation:

Astronomical telescope is used to see stars, sun etc.

v. (c) $f_0 \ll f_e$

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