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PHYSICS

Class-12 (Part-II)

For the Students of Rajasthan Board of Secondary Education

By

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Preface

We are extremely pleased to present this book according to latest syllabus of NCERT. The book has been written in easy and simple language so that students may assimilate the subject easily. We hope that students will get benefitted from it and teachers will appreciate our efforts. In comparison to other books available in market, this book has many such features which make it a unique book :

1. Theoretical subject-material is given in adequate and accurate description along with pictures.
2. The latest syllabus of NCERT is followed thoroughly.
3. Complete solutions of all the questions given at the end of the chapter in the textbook are given in easy language.
4. Topic wise summary is also given in each chapter for the revision of the chapter.
5. In every chapter, all types of questions that can be asked in the exam (Objective, Fill in the blanks, Very short, Short, Numerical and Long answer type questions) are given.
6. At the end of every chapter, multiple choice questions asked in various competitive exams are also given with solutions.

Valuable suggestions received from subject experts, teachers and students have also been given appropriate place in the book.

We wholeheartedly bow to the Almighty God, whose continuous inspiration and blessings have made the writing of this book possible.

We express our heartfelt gratitude to the publisher – Mr. Pradeep Mittal and Manoj Mittal of Sanjiv Prakashan, all their staff, laser type center and printer for publishing this book in an attractive format on time and making it reach the hands of the students.

Although utmost care has been taken in publishing the book, human errors are still possible, hence, valuable suggestions are always welcome to make the book more useful.

In anticipation of cooperation!

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CHAPTER 9

Chapter Overview

9.1 Introduction

Newton believed that "light energy is concentrated in small particles, which are called corpuscles by him and he proposed that light energy is concentrated in these corpuscles. He also imagined that corpuscles are massless elastic particles." The speed of light in vacuum is highest, whose value is $c = 3 \times 10^8$ m/s and light travels in a straight line. Since the wavelength of light is very small compared to the size of ordinary objects, the light wave can be said to travel along a straight line from one point to another. This path is called a light ray and the group of rays is called a light beam.

We represent the light ray by a straight line and indicate its direction of propagation by placing an arrow on it. In this way the ray indicates the direction in which light energy is transmitted, this is the meaning of ray optics. In this chapter, we will discuss the phenomena of reflection, refraction and dispersion of light using the ray form of light. Using the basic laws of reflection and refraction, we will study the formation of images by plane and spherical reflecting and refracting surfaces, after that we will explain the functions and working of some important optical instruments including the human eye.

9.2 Reflection of Light

When light falls on a plane, some part of it is absorbed by the plane and some part passes through the plane into another plane or medium. Some part is returned back to the same medium again. How much part of the incident light returns, how much part goes into another medium and how much part is absorbed by the surface, all this depends on the surface. "When a light ray travelling through a medium and incident on a boundary (a boundary separating two mediums) returns to the same medium, then this phenomenon is called reflection of light."

Points to be Remember

(i) After reflection, the speed, wavelength and frequency of light remain unchanged while the intensity changes according to the nature of the plane.

(ii) If a light ray is incident normally on a surface, then after reflection it returns back to its incident path.

9.2.1 Reflection at Plane

For reflection of light on a plane, we will get information about the phenomenon of reflection of light on both plane and rough surfaces.

Regular reflection : When sunlight or light from any other source falls on a plane mirror, all the reflected rays return in a particular direction according to the law of reflection. Therefore, when we place the eye in the path of these reflected rays, the mirror appears bright to us, but apart from this, when viewed from other directions, it appears less bright or not visible to us. This reflection is called regular reflection. As shown in Fig.

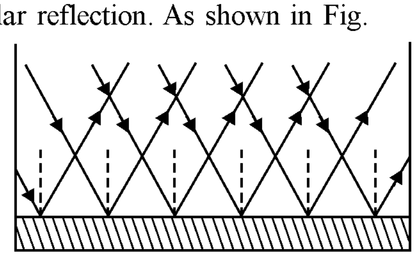


Fig. : Regular reflection

Diffused reflection : When sunlight falls on a rough surface, it travels in all directions. The effect of spreading light evenly around a rough surface is called diffused reflection. Mostly we see objects only through diffused light because of dust and smoke in the atmosphere, the particles keep scattering light.

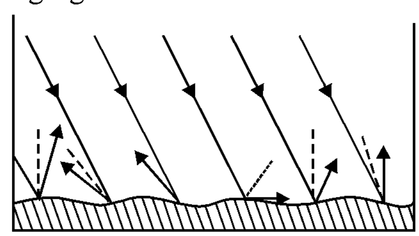


Fig. : Diffused reflection

The blue colour of the sky is also the effect of reflected light due to the atmosphere, whereas when astronauts come out of the Earth's atmosphere the sky appears completely black.

9.2.2 Laws of Reflection of Light

Reflection of light from a surface occurs according to the following two laws. These are called laws of reflection.

(1) The incident ray, the normal at the point of incidence and the incident ray all lie in the same plane.

(2) The angle of reflection is always equal to the angle of incidence, *i.e.* $\angle r = \angle i$

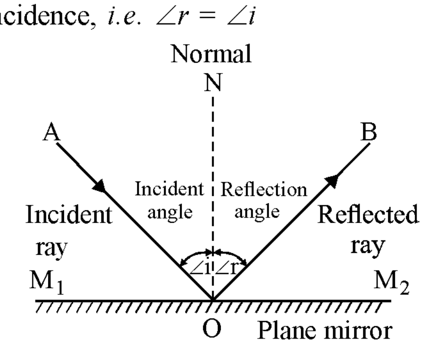


Fig.

Points to be Remember

(i) If we make any change in the direction of the incident ray, the direction of the reflected ray also changes.

(ii) Even if we rotate the mirror in its plane while keeping the direction of the incident ray constant, the reflected ray does not deviate from its direction.

(iii) The law of reflection of light is valid for every point on any reflecting surface, whether surface plane or curved.

(iv) If light is reflected from a denser medium, it gets changed in π phase. This is also called Stokes' rule.

9.2.3 Image in Plane Mirror

When we place an object (image) in front of a mirror, the shape of that object is formed in the mirror. This shape is called the 'image' of the object. Its definition can be given as follows :

"If the rays of light travelling from a point on an object meet at another point after reflection or appear to come from another point, then this second point is called the image of the first point."

(i) Lateral change : The size of image in plane mirror is equal to the size of object and the shape is also the same. But the change in shape of image is necessary. Reversible change in the shape of the image to the right in the image of an object in a plane mirror is called lateral change.

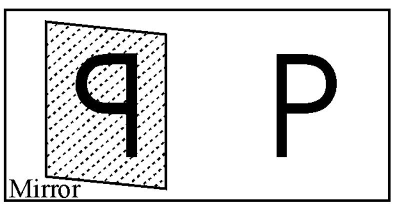


Fig. : Side change

(ii) Position of the image : In a plane mirror, the image is formed at exactly the same distance behind the mirror as the object is placed in front of the mirror.

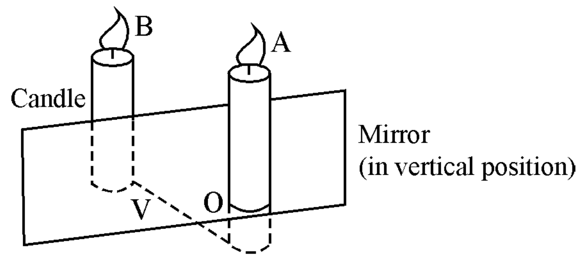


Fig. : Position of image

(iii) Nature of image (virtual) : The image formed in a plane mirror is always virtual. We cannot obtain a virtual image on any screen, because the rays of light are unable to reach the image.

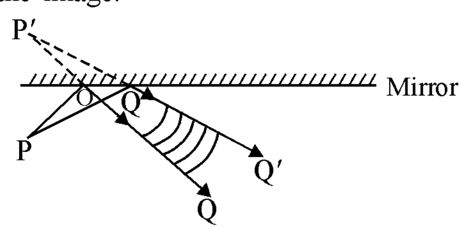


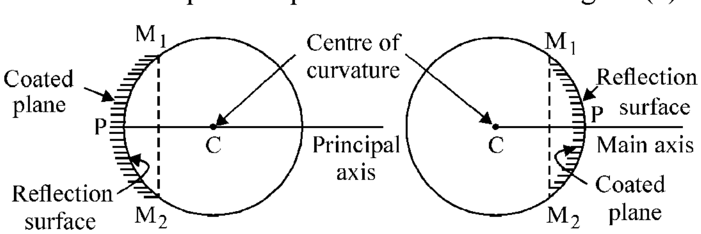
Fig. : Nature of image in plane mirror (virtual)

9.3 Reflection of Light by Spherical Mirror

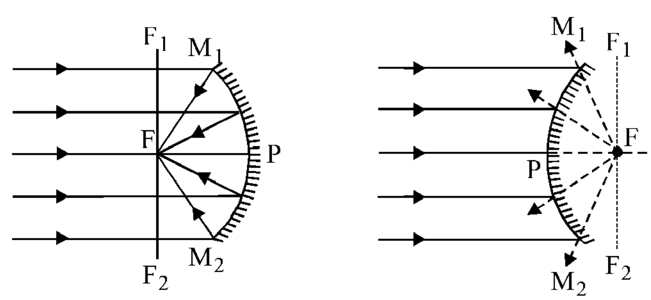
If a hollow sphere is cut and one part of its surface is polished, then the surface on the other side becomes a reflective plane. Such mirrors are called spherical mirrors. These are of two types : (i) Concave mirror, (ii) Convex mirror.

Concave Mirror : It is a mirror in which reflection occurs from the depressed side, *i.e.*, the inner surface of the sphere is reflective. In this the polished is placed towards the outside of the circle. As shown in figure (a).

Convex Mirror : It is a mirror in which reflection occurs from the convex plane of the sphere, *i.e.*, the outer plane of the sphere is the reflecting plane. In this, the inner bottom of the sphere is polished. As shown in figure (b).



(a) Concave (b) Convex



(c) Concave mirror (d) Convex mirror

Fig. : Reflection in concave and convex mirrors

Points to be Remember

The laws of reflection of light are the same for spherical mirrors as for plane mirrors. It is emphasized here that in spherical mirrors, the line joining the center of curvature of the mirror to a point is always normal to that point.

Some Important Definitions related to Spherical Mirrors :

(i) Pole : The mid-point of the reflecting plane of the mirror is called the 'pole' of the mirror. In the figure P is the pole.

(ii) Aperture : The diameter of the reflecting plane of the mirror perpendicular to the principal axis is called the aperture of the mirror, the dotted line (M_1M_2) in the figure is the aperture.

(iii) Center of Curvature : The center of the hollow sphere from which a spherical mirror is cut is called the 'centre of curvature' of the mirror. It is on the other side of the reflecting plane in a convex mirror and on the side of the reflecting plane in a concave mirror. In the figure, C is the center of curvature.

(iv) Radius of Curvature : The radius of the sphere of which the mirror is a part is called 'Radius of Curvature' of the mirror. In the figure, distance PC = radius of curvature.

(v) Principal Axis : The line joining the pole of the mirror and the center of curvature is called the 'principal axis' of the mirror. Line PC is the principal axis in the figure.

(vi) Focus and Focal Length : After reflection from the mirror, the rays travelling parallel to the principal axis meet the principal axis at the point (in a concave mirror) or appear to emerge from it (in a convex mirror), that point is called the focus of the mirror.

In figures (c) and (d), F is the focus. It is clear from figures (c) and (d) that the focus of a concave mirror is real and in front of the mirror, whereas the focus of a convex mirror is virtual and behind the mirror. The distance from the pole of the mirror to the focus of the mirror is called the focal length of the mirror. In the figure PF = focal length.

(vii) Focal Plane : The plane perpendicular to the principal axis and passing through the focus is called focal plane. In figures (c) and (d), plane F_1FF_2 is the focus plane.

(viii) Angular Aperture : The angle formed by the diameter of the mirror at the center of curvature, is called the 'angular aperture'.

(ix) Marginal Rays : The light rays incident on the parts of the edges of the mirror away from the principal axis are called marginal rays.

(x) Paraxial Rays : Light rays incident on the central part of the mirror near the principal axis are called paraxial rays.

9.3.1 Relation between Focal Length and Radius of Spherical Mirrors

Concave mirror : Let C be the center of curvature of the mirror. Consider a light ray parallel to the principal axis which hits the mirror at M. CM is the normal to the mirror at point M. Let θ is the angle of incidence and MD is perpendicular to the principal axis from point M. Then,

$\angle MCP = \theta$ and $\angle MFP = 2\theta$

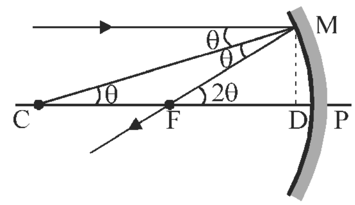


Fig. : Concave spherical mirror

Now, in right angled ΔCDM, $\tan\theta = \dfrac{MD}{CD}$ and in right angled ΔFDM,

$$\tan 2\theta = \frac{MD}{FD} \qquad ...(1)$$

For small values of θ, which is true for paraxial rays, $\tan\theta \approx \theta$, $\tan 2\theta \approx 2\theta$

∴ From eqn. (1)

$$\frac{MD}{FD} = \frac{2MD}{CD}$$

or
$$FD = \frac{CD}{2} \qquad ...(2)$$

Now for small θ, the point D is very close to the point P. Therefore, FD = f and CD = R. Hence eq. (2) gives

$$\boxed{f = \frac{R}{2}} \qquad ...(3)$$

Hence in concave spherical mirror focal length is half of radius of curvature (R).

Concave spherical mirror : In right-angled ΔCDM,

$$\tan\theta = \frac{MD}{CD}$$

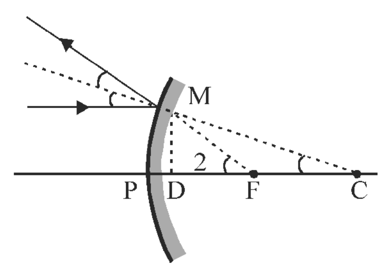


Fig. : Geometry of reflection of incident ray on convex spherical mirror

In right-angled ΔFDM,

$$\tan 2\theta = \frac{MD}{DF}$$

For small values of θ, which is true for paraxial rays, $\tan\theta \approx \theta$, $\tan 2\theta \approx 2\theta$

$$\therefore \quad \frac{MD}{DF} = \frac{2MD}{CD}$$