Physics 1214 — Chapter 24: Geometric Optics — 03/15

---

1 Reflection at a Plane Surface

image or virtual image: the result of an object point P formed by a mirror; the apparent source of reflected rays.
object distance: s, the distance from the object to the mirror.
image distance: s', the distance from the virtual image to mirror.
real image: the image resulting from the outgoing rays that actually pass through an image point.

Sign rules for object and image distances

Object distance: When the object is on the same side of the reflecting or refracting surface as the incoming light, the object distances s is positive; otherwise, it is negative.
Image distance: When the image is on the same side of the reflecting or refracting surface as the outgoing light, the image distance s' is positive; otherwise, it is negative.

$$s = s' \quad \text{plane mirror}$$

lateral magnification

For object height y and image height y', the lateral magnification m is

$$m = \frac{y'}{y}.$$

For a plane mirror, the lateral magnification m is unity. In other words, when you look at yourself in a plane mirror, your image is the same size as the real you.

erect: when the object and image are in the same direction
inverted: when the object and image are in opposite directions
reversed: in a plane mirror, the orientation of the image versus the orientation of the object; the right side of the object "appears" to be the left side of the object thereby appearing reversed.

2 Reflection at a Spherical Surface

center of curvature: the center of the geometrical sphere of which the mirror is curved, C.
vertex: the center of a spherical mirror surface, V.
optic axis: the line through the object point, P, the center of curvature, C, and the vertex, V.

Sign rules for the radius of curvature

When the center of curvature C is on the same side as the outgoing (reflected) light, the radius of curvature R is positive; other wise, it is negative.

$$\boxed{\frac{1}{s} + \frac{1}{s'} = \frac{2}{R} \quad \text{spherical mirror}}$$

paraxial rays: rays from P that make sufficiently small angles with the optic axis and intersect P' after being reflected (and thus are close to the axis and nearly parallel to it) using ***paraxial approximation***.
focal point or focus: with an object distance very far from a spherical mirror, the incident rays after reflection converge to a point F given by $R/2$.
focal length: the distance, f from the vertex to the focal point; $f = R/2$

Focal point of a concave spherical mirror

1. Any incoming ray parallel to the optic axis is reflected through the focal point.
2. Any incoming ray that passes through the focal point is reflected parallel to the optic axis.

For spherical mirrors, these statements are true only for paraxial rays; for parabolic mirrors, they are *exactly* true.

$$\boxed{\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \quad \text{spherical mirror}}$$

$$\boxed{m = -\frac{s'}{s} \quad \text{spherical mirror}}$$

virtual focal point: the focal point for a convex mirror that appears to come from behind (or beyond) the mirror.

3 Graphical Methods for Mirrors

Definitions of principal rays for spherical mirrors

1. A ray parallel to the axis, after reflection, passes through the focal point F of a concave mirror or appears to come from the (virtual) focal point of a convex mirror.
2. A ray through, away from, or proceeding toward the focal point F is reflected parallel to the axis.
3. A ray alon the radius through, away from, or proceeding toward the center of curvature C strikes the surface normally and is reflected back along its original path.
4. A ray to the vertex V is reflected forming equal angles with the optic axis.

Once we have found the position of the real or virtual image point by means of the (real or virtual) intersection of any two of these four principal rays, we can draw the path of any other ray from the object point to the same image point.

4 Refraction at a Spherical Surface

5 Thin Lenses

thin lens: the simplest lens has two spherical surfaces close enough together that we can neglect the distance between them.
converging lens: a lens in which parallel rays incident on the lens converge to a real image point after passing through the lens.
diverging lens: a lens in which parallel rays incident on the lens diverge after refraction.

Thin-lens equation or lensmaker's equation

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

6 Graphical Methods for Lenses

Principal rays for thin lenses

1. *A ray parallel to the axis*, after refraction by the lens, passes through the second focal point F_2 of a converging lens or appears to come from the second focal point of a diverging lens.
2. *A ray through the center of the lens* is not appreciably deviated, because, at the center of the lens, the two surfaces are parallel and close together.
3. *A ray through, away from, or proceeding toward the first focal point* F_1 emerges parallel to the axis.

- When the **image is real**, the position of the image point is determined by the intersection of any two of the three principal rays.
- When the **image is virtual**, the outgoing rays diverge and the diverging rays are extended backward to their intersection point.

Once the image position is known, any other ray can be drawn from the same point.