PHYS 242   BLOCK 12 NOTES

Sections 34.1, 34.2, and 34.4.

Plane and Spherical Mirrors, Thin Lenses

An **object** is a source of light. We will usually consider **real objects**—objects from which the light rays *really* do diverge. **Please learn all the conventions in these notes so you can excel.**

CONVENTION: We will always place the real object to the left of the mirror or lens.

For a **real image**, the light rays from each object point *really* do converge to an image point (then diverge from that point if allowed). **Only real images can be projected on a surface.** (For example, our eyes form real images on our retinas.) The first real image point shown in our text is point *P´* in Figs. 34.10, page 1115.

For a **virtual image**, the light rays from each object point only *appear* to be diverging from an image point. Figures 34.2 and 34.4 show a real *object* point *P* and the virtual *image* point *P´* formed by reflection from a plane mirror. In Fig. 34.3, the virtual image point is formed by refraction. Figure 34.6 shows a real object *PQ* and the virtual image *P´Q´* formed by a plane mirror. (Standing in front of a plane mirror, you see a virtual image of yourself of your same height and at the same distance behind the mirror as you are in front of the mirror.)

The **object distance** *s* is the distance from the object to the mirror or lens.

CONVENTION: *s* is + for real objects and *s* is – for virtual objects.

The **image distance** *s´* is the distance from the image to the mirror or lens.

CONVENTION: *s´* is + for real images and *s´* is – for virtual images.

Figures 34.5 have real point objects (positive *s*) and virtual point images (negative *s´*).

For spherical mirrors and thin lenses:

All incident rays that are both parallel to the axis and near to that axis *really* do reflect from *concave* mirrors or *really* do refract through *converging* lenses to all arrive together at a *real* **focal point** *F*. (See Figures 34.13a and 34.28a.) On the other hand, all incident rays that are both parallel to the axis and near to that axis reflect from *convex* mirrors or refract through *diverging* lenses, then spread out as if *virtually* originating from a *virtual* focal point. (See Figures 34.17a and 34.31a).

The distance along the axis from a focal point to the mirror or lens is *f*, the **focal length**.

CONVENTION: *f* is + for the real focal points of concave mirrors and converging lenses and *f* is – for the virtual focal points of convex mirrors and diverging lenses.

CONVENTION: A radius of curvature *R* is + when the center of curvature *C* is on the side where the light *really* goes after reflection from a spherical mirror or after refraction through a thin lens (and *R* is – otherwise). In other words, a radius *R* is + when its center *C* is on the side of the *outgoing* light. Thus ***R* is + for all concave mirrors and *R* is – for all convex mirrors**. That is, *R* and *f* have the same sign for spherical mirrors (as seen in the first equation below).

Using geometry, trigonometry, and small-angle approximations, the text shows $\boxed{f = \frac{R}{2}}$ *for spherical mirrors only*. Also, $\boxed{\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}}$ *for both spherical mirrors and thin lenses***.** The distances are usually in cm.

The **lateral magnification** m is defined as the ratio of the image height y' to the object height y. Thus m has no unit. Figures 34.14 and 34.29 show $m \equiv \frac{y'}{y} = -\frac{s'}{s}$ *for both spherical mirrors and thin lenses***.**

If m is +, the image is erect (because then y' and y have the same sign). Thus for real objects (s is +), *all* virtual images (s' is –) formed by a spherical mirror or a thin lens are erect.

If m is –, the image is inverted (because then y' and y have opposite signs). Thus for real objects (s is +), *all* real images (s' is also +) formed by a spherical mirror or a thin lens are inverted.

If $|m| > 1$, $|y'| > |y|$ so *the image is enlarged.*

If $|m| = 1$, $|y'| = |y|$, so *the image has the same* |*height*| *as the object.*

If $|m| < 1$, $|y'| < |y|$, so *the image is reduced.*

The radius of curvature of a plane (that is, flat) surface is infinity. Thus for plane mirrors, $R = \infty$, so $f = R/2 = \infty$. Also, since $1/\infty = 0$, $1/s + 1/s' = 1/f$ gives us $s' = -s$. Then $m = -s'/s = +1$. You should now be able to state from these signs and numbers that *all* plane mirrors form an erect, virtual image of a real object at the same distance behind the mirror and the image has the same height as the object. See Fig. 34.6 again.

There are an infinite number of rays leaving the point of a real object arrow, but only a few special **principal rays**. *See Figures 34.19 and 34.20 for the four principal rays used with spherical mirrors.*

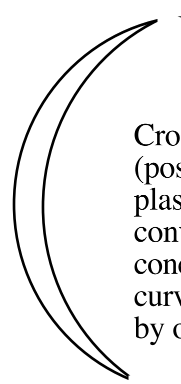
A thin lens has *two* focal points, each a distance $|f|$ from the center of the lens. The text derives the "lensmaker's equation" for the focal length f of a thin spherical lens by using the image from the first surface as an object for the second surface. *For a thin spherical lens in air or vacuum,* $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

n is the index of refraction (no unit) of the lens material.

R_1 is the radius of curvature of the 1st surface the light hits (that is, the left surface).

R_2 is the radius of curvature of the 2nd surface the light hits (that is, the right surface).

By our conventions, **a radius R is + if its center of curvature is to the right of the lens (and is – if to the left of the lens**).



Cross section of a converging (positive focal length) glass or plastic lens in air. Its left side is convex and its right side is concave, but the two radii of curvature are also both positive by our sign convention.

Consider a prism or lens with a higher index of refraction than its surroundings. Light rays refracting through it bend toward the thickest part of that prism or lens (except for a ray through the center of a thin lens). **Thus, any such converging lens is thickest at the center and has a positive f, while any such diverging lens is thinnest at the center and has a negative f** (see Fig. 34.32). Therefore, f is positive for the lens shown in cross section above (for which R_1 and R_2 are also both positive).

See Figures 34.36 and 34.37 (except (f) with its virtual object) for the three principal rays used with thin lenses.

Cover up the answers and try Examples 34.1 to 34.4 and 34.8 to 34.11.