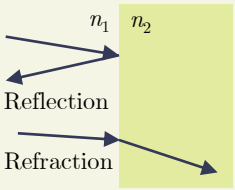
11 Light – Ray Optics

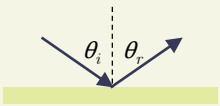
Ray Model of Light

- Light travels along straight lines at speed $v = c/n$, where n is the *index of refraction*. The light continues forever unless it interacts with matter; two common ways to interact are *reflection* and *refraction*.
- An object is a source of light rays.
- The ray model is valid when lenses, mirrors, and apertures are larger than about 1 mm.



Reflection

The law of reflection states that the reflected angle is equal to the angle of incidence. All angles are measured with respect to the normal.



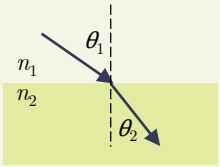
Refraction

The law of refraction states that

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

If $n_2 < n_1$, total internal reflection (TIR) occurs when θ_1 is greater than the critical angle,

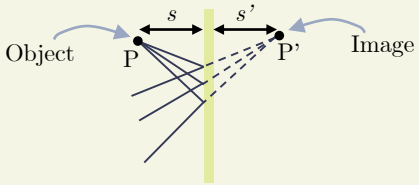
$$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right).$$



Plane Surfaces

Reflection

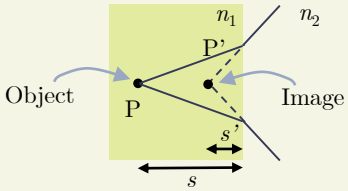
A virtual image is formed at P' with an image distance s' equal to the object distance s.



Refraction

A virtual image is formed at P', where the image distance s' is related to the object distance s by

$$s' = -\frac{n_2}{n_1}s.$$



Spherical Surfaces

Spherical Mirrors

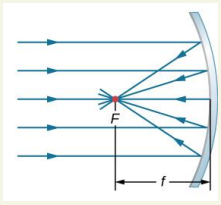
A spherical mirror can form a *real* or *virtual* image with location s' given by the *mirror equation*,

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f},$$

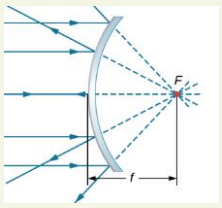
where $f = R/2$ is the focal length and R is the radius of curvature. The lateral magnification is given by

$$m = -\frac{s'}{s}$$

Sign conventions: R and f are positive for a concave mirror. s' is positive for a real image.



Concave mirror



Convex mirror

Refraction

A spherical surface can form a *real* or *virtual* image, with object and image distance related by

$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}.$$

Thin Lenses

A *thin lens* can form a *real* or *virtual* image with location s' given by

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}.$$

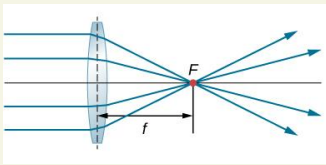
The lateral magnification is given by

$$m = -\frac{s'}{s}$$

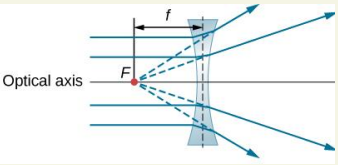
The focal length f is given by the lens maker's equation,

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

Sign conventions: R is positive for a surface convex toward the object. f is positive for a converging lens. s' is positive for a real image.



Converging lens



Diverging lens