1. This lecture is concerned with the formation of images by thin lenses. The key points to remember are
   a. **Real** images are formed by light rays which pass through the image points.
   b. **Virtual** images are formed by light rays which emanate from image points.
   c. **Magnification** is simply the ratio of the height or length of image to object.
   d. **Vergence** describes the curvature of a wavefront, positive or negative.
2. The fundamental concepts of imaging can be illustrated by first looking at images as formed by plane and spherical mirrors.
   a. **Plane mirror**: The image is virtual and erect, and appears to be as far behind the mirror as the object is in front of it. The magnification is
      \[ M = \frac{\text{image height}}{\text{object height}} = \frac{h'}{h} = 1 \] (i.e., image is unmagnified)
   b. **Spherical mirror**: There are several possible cases to be examined, depending on where the object is inside or outside the center of curvature (CC).
      i. **Object outside** the CC. Following the ray parallel to the axis, it must pass through the focal point.
      ii. **Object inside** the CC of a concave mirror. Again, following the same procedure, we follow the ray parallel to the axis of the system, and then the ray which passes through the center of curvature. The intersection of these two rays defines
      iii. **Object outside** the CC of a convex mirror. In this case, the rays all diverge from an image point behind the mirror. This image is virtual, because if you were to put a
3. Now let us consider how images are formed by a single refracting surface, a section of a sphere bounding an infinite half space. The radius of curvature of the sphere is \( R \).
   a. Light from the bright point \( A \) strikes the “len” surface at the point \( P \), making an angle \( i \) with respect to the surface normal. The axis of this optical system is defined by the line connecting \( A \) with the center of curvature of the “len” at \( C \). The light refracted at \( P \) intersects this axis at the point \( A' \).
   b. Now we want to write down some quantitative relationships among the various angles. To do so, we will use the Cartesian sign convention described in the text on page 29.
c. By invoking Snell’s law and the paraxial approximation for the single refracting surface, we can derive Gauss’s relation:

\[
\frac{n - n'}{s} + \frac{n'}{R} = \frac{n'}{s'} \Rightarrow V + P = V'
\]

where \( P \) is defined as the power of the surface.

7. Now let us consider how images are formed by lenses. This can be done by applying Gauss’s relation to a pair of refractive surfaces and neglecting what happens to the ray between the two surfaces. If we properly take account of the sign of the refractive-index difference, we arrive at the lens-makers equation and the Newtonian form of the lens-makers equation:

\[
P_{\text{lens}} = (n_{\text{lens}} - n_0) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \Rightarrow \frac{1}{s} + \frac{1}{f_2} = \frac{1}{s'}
\]