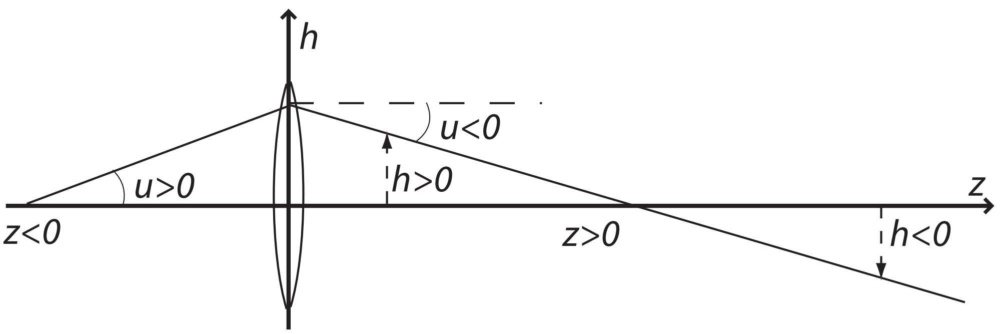
Sign convention

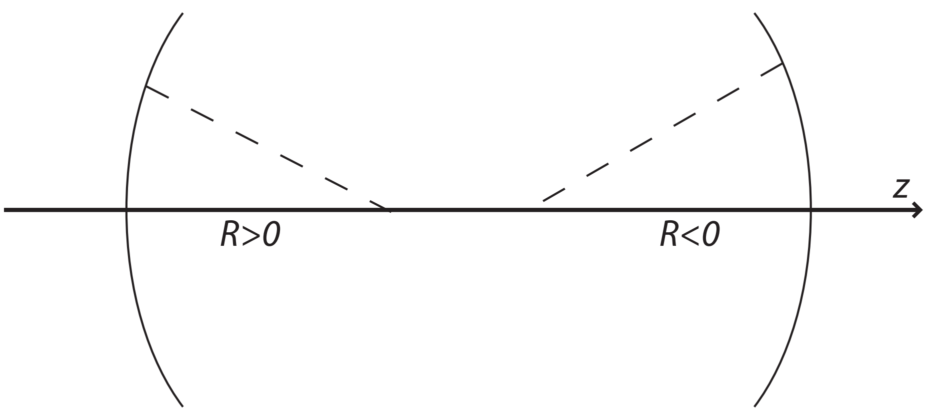
We use the normal sign convention for optical design, which differs from that in Hecht. This set of notes specifies the sign convention, and gives the formulae you already know from Hecht, but with sign adjustments.

As illustrated in Fig. 3, the sign conventions are:

- Axial distances z are positive along the optical axis ("to the right") and negative in the opposite direction ("to the left").
- Ray heights h are positive above the optical axis, and negative below.
- Angles u are positive if the ray has an upward slope (h increases along the ray), and negative if it has a downward slope (h decreases along the ray).
- Radii of curvature R are positive if the centre of curvature is to the right of the surface, and negative if the centre is to the left of the surface.



(a)



(b)

Figure 1: Sign conventions for (a) axial distances, ray heights, angles, and (b) radii of curvature.

Image distances and refractive power

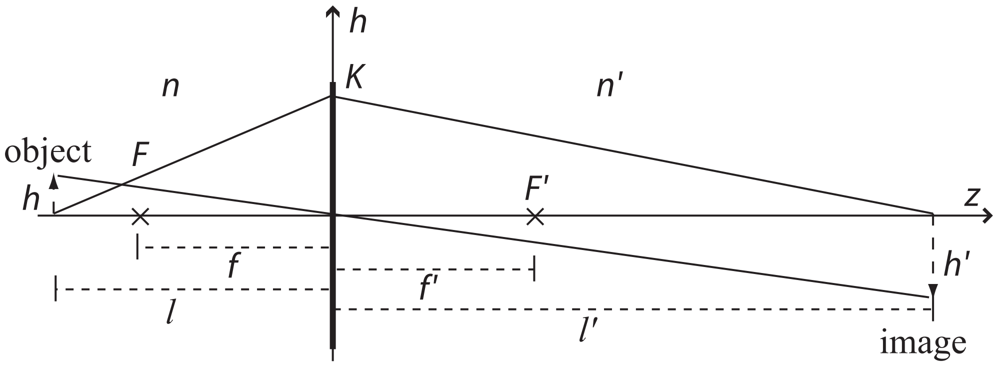


Figure 2: A single optical element of power K used to image an object.

The refractive power $K = n'/f'$ of the element, where f' is the second focal length, is related to the object and image distances l and l' and the object and image refractive indices n and n' as

$$K = \frac{n'}{f'} = \frac{n'}{l'} - \frac{n}{l}\,. \tag{1}$$

If the element is in air, $n = n' = 1$ and

$$K = \frac{1}{f'} = \frac{1}{l'} - \frac{1}{l}\,. \tag{2}$$

The magnification in air is $m = \frac{h'}{h} = \frac{l'}{l}$.

Single surface: $K = (n' - n)c$, where $c = \frac{1}{R}$ is the curvature.
Thin lens in air: $K = (n-1)(c_1 - c_2)$, where n is the refractive index of the lens material and c_1 and c_2 the curvatures of the first and second surfaces, respectively.

Principal planes and effective focal length

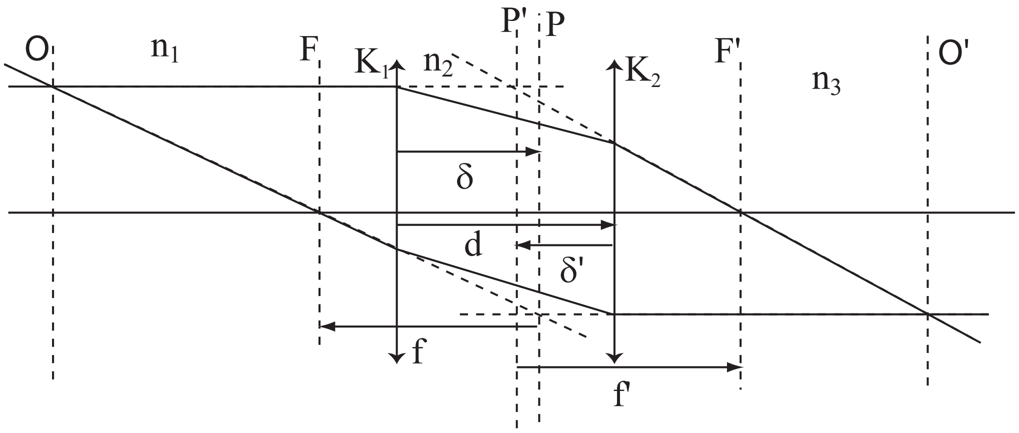


Figure 3: Two refractive elements of powers K_1 and K_2 combine their refractive powers.

Two refractive elements of power K_1 and K_2 are used simultaneously. They could be e.g. two lenses, two optical systems, or the two refractive surfaces of a thick lens. The refractive index before, in between, and after the lenses are n_1, n_2, and n_3 respectively. The distance between the two lenses is d.

The effective refractive power of the system is

$$K = K_1 + K_2 - \frac{dK_1K_2}{n_2} \,. \tag{3}$$

The distances between lenses and principal planes are

$$\delta = \frac{n_1}{n_2}\frac{K_2 d}{K} \tag{4}$$

$$\delta' = -\frac{n_3}{n_2}\frac{K_1 d}{K} \tag{5}$$

For a system in air, $n_1 = n_3 = 1$ and $\delta = \frac{1}{n_2}\frac{K_2 d}{K}$ and $\delta' = -\frac{1}{n_2}\frac{K_1 d}{K}$. All formulas on previous pages may be used, provided the object and image distances are replaced by $l = PO$ and $l' = P'O'$.