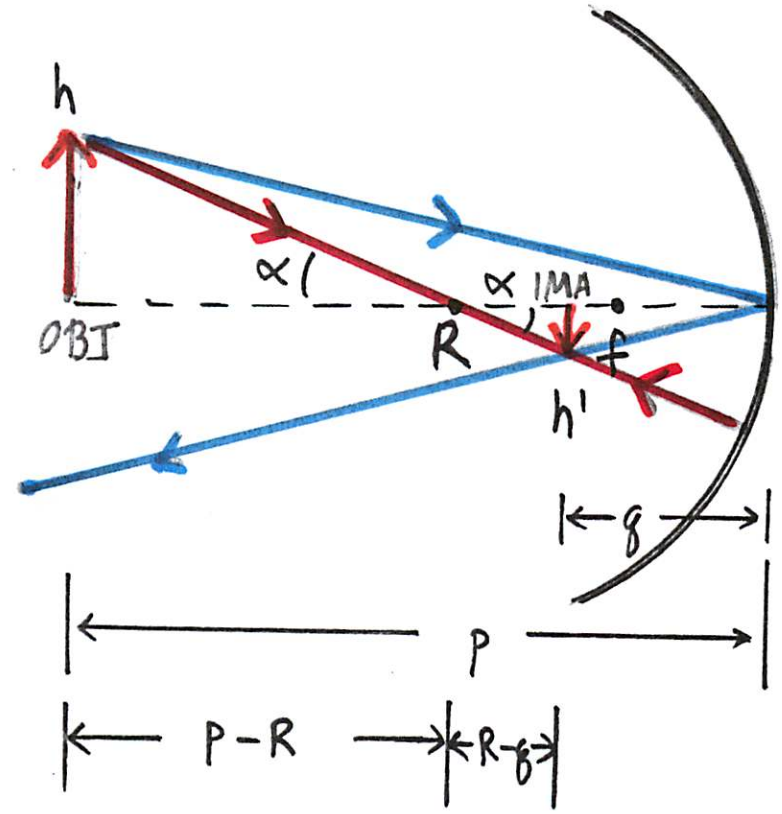


$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R} = \frac{1}{f}$$

$$M = \frac{h'}{h} = -\frac{q}{p}$$

Plane Mirrors: The image is *virtual* and $q = -p$. The magnification $M = -q/p$ is equal to 1.

Spherical Mirror, Concave: The image can be real or virtual. The focal distance $f = R/2$, where R is the radius of curvature of the mirror. The equation

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

determines any one of the quantities if the other two are known. *Any calculation should be checked by drawing a ray diagram... you only need* **two** *rays.* To avoid confusion always indicate the position of the observer of the image on the ray diagram!

Spherical Mirror, Convex: The image is always virtual. Very confusing sign conventions are common. Quantities are given a minus sign when they represent something that is opposite from the standard case, which is not helpful to anyone who does not know what the "standard case" is.

$$M = \frac{h'}{h} = -\frac{q}{p}.$$

f is taken positive for a concave mirror and negative for a convex mirror. ALWAYS draw a ray diagram to check your result.

Thin Lenses: The same equations can be used for thin double-convex or double-concave lenses. For the first case the focus is positive, for the second case it is negative. ALWAYS draw a ray diagram to check your algebra and numerical work.

Thick Lenses, Lensmaker's Equation:

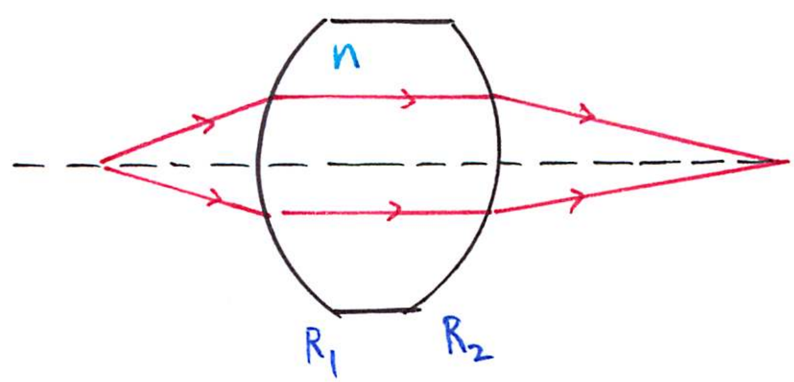
$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R}, \text{ one surface.}$$

$$\frac{1}{p} + \frac{1}{q} = [n - 1]\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f},$$

where R_1 is for the front surface and R_2 is for the back surface.

Aberrations, the Eye, the "diopter," compound microscopes, refracting telescopes, reflecting telescopes.

Lens power in diopters is $1/f$ where f is in meters.



Mirror and Lens Examples:

A concave mirror gives an image with $M = -2$. What are p and q in terms of f?

Answer: $p = (3/2)f$, $q = 3f$.

A convex mirror gives an image with $q = -p/4$. What is its focal distance?

Answer: $f = -p/3$.

A double-convex thin lens has $f = p/4$. Where is the image?

Answer: $q = p/3$.

A double-concave thin lens has $f = -10$ cm and $q = -2$ cm. What is p?

Answer: $p = 2.5$ cm.