Physics 234
Homework 4 (Due Wednesday, February 10)
Lenses

Problem 1.
Claudius Ptolemy (A.D. 150) gave the following measured values for the angle of incidence, θ_i, and the angle of refraction, θ_R, for a light beam passing from air to water.

θ_i	θ_R
40°	29°
50°	35°
80°	50°

Are these data consistent with the law of refraction? If so, what index of refraction results? These data are interesting as perhaps the oldest recorded physical measurements.

Problem 2.
The formula

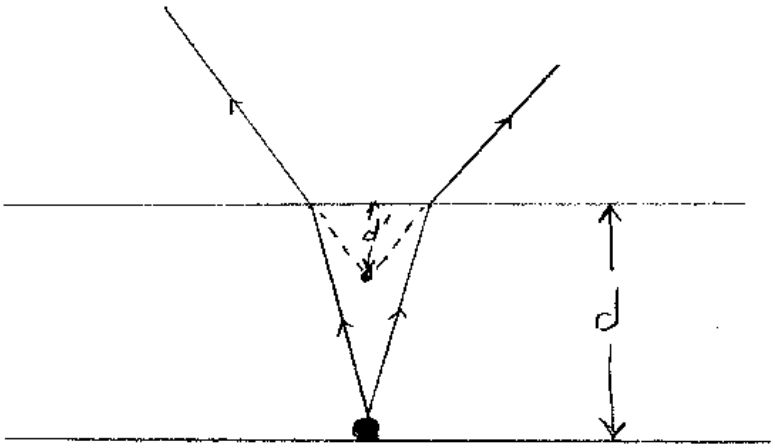
$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f} \tag{1}$$

is call the *Gaussian* form of the thin lens formula. Another form of this formula, the *Newtonian* form, is obtained by considering the distance x from the object to the first focal point and the distance x' from the second focal point to the image. Show that

$$xx' = f^2 \tag{2}$$

Problem 3.
Fill in the table below. Each column refers to a thin lens and a real object. Distances are in cm. If a number has no plus or minus sign in front of it, find the correct sign.

type	converging					
f(cm)	10	+10	10	10		
i(cm)						
o(cm)	+20	+5	+5	+5	+10	+10
m			> 1	< 1	+0.5	−0.5



Problem 4.
Show that the distance between a real object and its real image formed by a thin converging lens is always greater than or equal to four times the focal length of the lens.

Problem 5.
A penny lies at the bottom of a pool with depth d and index of refration n, shown in the figure. Show that light rays that are close to the normal appear to come from a point $d' = d/n$ below the surface. The distance d' is the apparent depth of the pool.