1/13/15 Ken Intriligator's Phys 4D Lecture outline

⋆ Reading: Relevant sections from Giancoli chapters 32 and 33.

• Last time: spherical refracting surface. Let object be distance d_0 from interface between index n_1 and n_2, where the interface has radius R. The image location d_i is determined, as before, from the condition that all rays take the same *time* (understand from Fermat), with $ct = n_1 L_1 + n_2 L_2$. Got

$$\frac{n_1}{d_o} + \frac{n_2}{d_i} = \frac{n_2 - n_1}{R}.$$

• Examples, including apparent depth of swimming pool, and spherical fishbowl with fish at center of sphere. Signs of R, d_i, etc.

• Put two spherical refracting surfaces together to obtain the thin lens formula:

$$\frac{n_o}{d_o} + \frac{n_o}{d_i} = (n_L - n_0)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \equiv \frac{1}{f}.$$

Also, geometry of rays shows that the magnification is $m \equiv (y_i/y_0) = -d_i/d_0$.

• Examples of converging and diverging lenses. Real vs virtual images. Upside down vs rightside up images. Various signs.

• Two lens systems. Lenses with f_1 and f_2, separated by distance L. Image of first lens, at location $d_{i,1}$ (found from the above equation with $n_0 = 1$ for air and $f = f_1$), becomes object of the second lens, at $d_{o,2} = L - d_{i,1}$. Then apply above equation, with $f = f_2$, to find final image location $d_{i,2}$. Note that all this works regardless of the signs of $d_{i,1}$ and $d_{o,2}$. The magnification of the combined lens system is $m_{total} \equiv h_{i,2}/h_{o,1} = (h_{i,2}/h_{o,2})(h_{i,1}/h_{o,1}) = m_1 m_2$, where we used that the image from lens 1 is the object for lens 2, so $h_{i,1} = h_{o,2}$. So the total magnification is the product of the separate magnifications of the two lenses, with $m_1 = -d_{i,1}/d_o$ and $m_2 = -d_{i,2}/d_{o,2} = -d_i/(L - d_{i,1})$. For example, if $d_{i,1} > 0$ and $L - d_{i,1} > 0$, then the image from the first lens has $m_1 < 0$, i.e. upside down, and the next lens has also $m_2 < 0$, so the image gets flipped upside down twice, and is back right side up.