5/10–Ray Optics

1. A light ray enters an aquarium tank (from air to glass to water). The angle from air into the glass is 50° relative to the normal. What is the angle from the glass to the water? (Given $n_{glass} = 1.5$ and $n_{water} = 1.33$).

2. A diver holds a light source under the water and shines it toward the surface.

   (a) One ray from the light hits the surface at an angle of 35° with respect to the normal. What angle does that ray make (wrt the normal) in the air?

   (b) What happens if the angle in the water is 60°? This is called total internal reflection.

   (c) What is the cut-off angle in water (called the critical angle) for total internal reflection for a water-air interface?

3. A diverging (concave) lens:
   We haven't done this one in class yet–so let me give you two pieces of information: First, for a concave lens, we say the focal length is negative–this is because the rays diverge on the outgoing side of the lens, but you could trace them back so that they focus on the incoming side. So we call that negative for focal length. Second, draw the ray that starts parallel very carefully. Think about which way it should bend when it hits the lens, and therefore which of the two fs you should use. Hint: you can trace the ray back to first focal length! The incident parallel ray must bend away from the axis. An object 12cm tall is placed 30 cm in front of a concave lens with focal length of -15 cm.

   (a) Locate the image by ray tracing. Clearly draw all three rays.

   (b) Describe the image: real or virtual, upright or inverted?

   (c) Now locate the image using the Thin Lens Equation. Don't forget the sign conventions!

(d) What is the magnification?

(e) Are the two methods consistent?

4. Is it possible to have a real image with a diverging/concave lens? Why or why not?

5. A convex lens (with the object inside the focal length):
An object 6cm tall is placed 10 cm in front of a convex lens with focal length of 15 cm.

   (a) Locate the image by ray tracing. Clearly draw all three rays.

   (b) Describe the image: real or virtual, upright or inverted?

   (c) Now locate the image using the Thin Lens Equation. Don't forget the sign conventions!

   (d) What is the magnification?

   (e) Are the two methods consistent?

6. A system of two lenses:
Whenever you have a two (or more) lens system, the image of the first lens becomes the object for the second lens! And then you can use all the same rules for ray tracing and the thin lens equation twice. Once for each lens. Two lenses, one of focal length 10 cm and one of focal length -15 cm are 30cm apart. An object 6cm tall is placed 20cm in front of the first lens (with $f = 10$cm).

   (a) Locate the first image using the Thin Lens Equation.

   (b) What is the magnification from the first lens?

   (c) Now use the image from the first lens as the object from the second. (I strongly advise making a sketch to find the position of the image of the first lens relative to the second lens.) Where is the final image?

   (d) What is the magnification of the second lens? What do you think you do to get the final magnification? Do that.

   (e) Draw a ray diagram for this system. Are the two methods consistent?