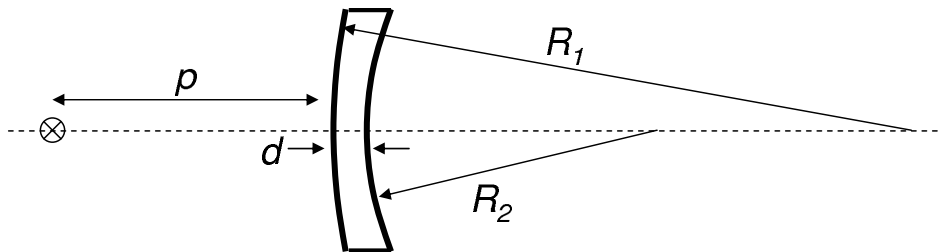


- (4 pts) A penny is sitting on the bottom of a swimming pool. The pool is filled with water to a depth of 1.67 meters. (a) How deep underwater does the image of the penny appear to be? (b) Does the image of the penny appear inverted or upright? (c) If the penny is 1.91 cm in diameter, what will the diameter of the image be?
- (4 pts) A fortune teller gazes into her crystal ball and sees a scene of sorrow and tragedy. The scene appears to be inside the ball 4.31 cm from the surface of the ball. But, of course she is really seeing the *image* of the scene of sorrow and tragedy. How far from the surface of the ball is the actual scene of sorrow and tragedy? The ball 30 cm in diameter is made of quartz with an index of refraction of 1.54.
- (5 pts) An object is placed a distance p in front of a lens, as shown below. The front surface of the lens has a radius of curvature R_1 , the back surface has a radius of curvature R_2 , and the two surfaces are separated by a distance d along the principle axis of the lens. The lens has an index of refraction n . (a) Imagine that the second surface doesn't exist — there is just the first surface followed by an infinite length of glass. How far to the right of the first surface will the image of the object form? (b) Now use the image formed by the first surface as the object for the second surface. Assuming that d is negligibly small (the thin lens approximation), how far to the left of the second surface will the object for the second surface be? (Remember, by convention, if the object is to the right of the surface, we think of it as being a negative distance to the left — i.e. it is a virtual object and p is negative.) (c) How far to the right of the second surface will the second image form? (d) What is the focal length of the lens?



- (3 pts) You have a clear rubber ball which is 4.22 cm in diameter. You make a thin lens by carefully slicing off an edge of the ball which is 2 mm thick (such that one side of the lens is completely flat). You measure the focal length of the lens and find that it is equal to 10.2 cm. What is the index of refraction of the rubber that the ball is made of? *Note that the lens makers' equation we just derived assumes a sign convention in which each radius is measured from the opposite side of the lens as the object.. The textbook uses the same convention, but the figure next to this equation in your text seems to label R_1 and R_2 as being measured from opposite sides. This is not in agreement with the equation. For example, if you had a curved piece of glass with the same curvature on each side such that at any point the two surfaces were parallel, you wouldn't expect it to focus light. If I use the correct convention, where both R s are measured from the far side of the lens, the lens makers' equation correctly gives me an infinite focal length.*
- (3 pts) When I place a glass lens 3.22 cm from an ant I find that the image of the ant is 3 times bigger than the ant. What possible focal lengths could the lens have?
- (5 pts) My camera has a lens which has a focal length of 50 mm. If I want to make an image of my wife (who is 1.73 m tall) which just fills the film (which is 35 mm tall), (a) should I try to make a real or a virtual image (b) how far should my lens be from the film, and (c) how far should my wife stand from the lens? (d) Will the image on the film be inverted or upright?

7. (6 pts) Draw ray diagrams for the following two situations. Draw at least 3 rays. In each case state whether the image is real or virtual: (a) An object is placed 20 cm in front of a lens with a focal length of 10 cm. (b) An object is placed 20 cm in front of a lens with a focal length of -10 cm. (c) Calculate the position of the image relative to the lens for the above two situations. Be sure to indicate whether the image is on the same side or the opposite side as the object. Make sure that your calculations agree with your diagrams!

Extra problems I recommend you work (not to be turned in)

- The magnification $M = -q/p$ that we discuss is the transverse (or lateral) magnification. What is the longitudinal magnification of the image made by a single thin lens equal to? In other words, if I make an image of an object which has a height h and a thickness t , the height of the image will be $M_T h$ and the thickness will be $M_L t$. What is M_L ?
- A cube which is 1 cm in length is placed 15 cm from a lens with a focal length of 2 cm. Draw what the image of the cube will look like.
- Explain what happens to the focal length of a lens when you flip it over, so that the first surface becomes the second surface. Back up your explanation using the lens makers' equation.