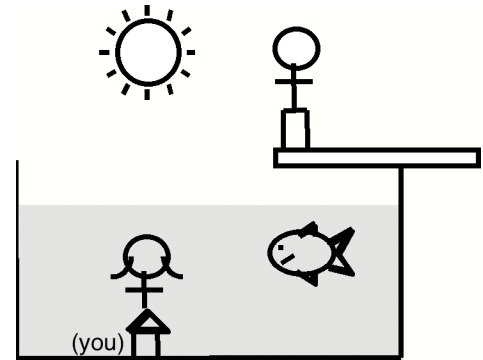


Questions/Problems

- Geometrically demonstrate using the law of reflection that you only need a mirror half your height to see your whole image (from head to toe) if the mirror is held vertically and placed at the correct elevation. Draw where your image is and its size. Why would standing at different distances from the mirror make a difference (or not)?

- Consider the following scenario. You are standing on the bottom of a pool looking *directly up*. You consider the fact that you can only see an object if light rays from that object reaches your eyes. Based on the properties of reflection and refraction, describe in words which of the following objects you could see, and *where they would appear to be to you* (see figure at right):

- The sun
- The person on the diving board
- The fish in the water

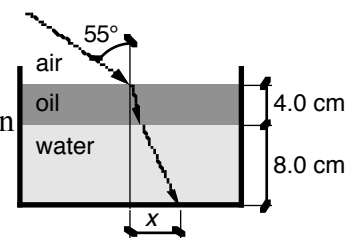


- Now consider the perspective of the person on the diving board. For the fish, the underwater person, and the sun, determine if you will be able to see each object, and if so, where the object will appear to be. (see figure in problem 2)

- The "Invisible Man" in H. G. Wells' story was a scientist who invented a process to alter the molecules in his body to have an index of refraction to nearly unity.

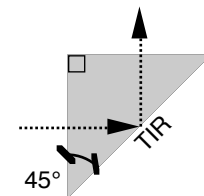
- Discuss how having an $n \approx 1$ ensures "invisibility."
- If he went swimming, would he still be invisible? Explain.

- A flat bottomed container is filled with water ($n = 1.33$) to a depth of 8.0cm. A 4.0cm layer of oil ($n = 1.47$) floats on the water. A light ray in air approaches the oil at an angle of incidence of 55° with respect to the normal. Find the horizontal distance x , where the light ray hits the



bottom of the container.

- As an FNT you solved the following problem:
What is the minimum index of refraction needed for total internal reflection to occur in this plastic block, shown at right, surrounded by air?



- What would the minimum index of refraction have to be if this block were instead immersed in water? ($n_{water} = 1.33$)
- What would the minimum index of refraction have to be if angle labeled 45° was instead 30° ?

- Light of a certain wavelength λ is incident in air at an angle of 0° with respect to the normal on a very thin sheet (thickness $t = 110\text{nm}$) of plastic ($n = 1.5$). Part of this light ray is reflected upwards by the top surface of this sheet; another part of this light ray is

reflected upwards by the bottom surface of this sheet. Air surrounds the top and bottom of the plastic sheet.

- (a) What is the path length difference between the light rays reflected by the top and bottom surfaces of the plastic sheet?
- (b) What is the wavelength of the light ray while it is traveling through plastic, compared to the wavelength of the light ray while it travels through air?
- (c) What is wavelength that this visible light would have in air that will constructively interfere for these reflected beams?

Q/P Comments

1. Remember that in order to see your whole body that you need to be able to see the top of your head and the bottoms of your feet.
2. (a) The light from sun, directly above you, hits along the normal line.
(b) The light from the person on the diving board bends when it hits the water. Determine if the light bends toward or away from normal. You know the light will not travel in a path directly from the diving board person to your eyes—determine where the light ray that successfully takes the path hits the water's surface.
(c) The fish can be seen directly in the water. You may also be able to see a fish from light that has reflected off the water's surface.
3. You can see the sun's reflection off the water's surface (determine where, exactly), the underwater person appears at less depth, and the fish cannot be seen from the diving board.
4. (a) The very fact that the Invisible Man even has an index of refraction means that light will be able to travel through him (at some speed dependent on his value of n), so he is going to be transparent. However, this by itself does *not* insure invisibility. The index of refraction of air is approximately equal to unity. Since the Invisible Man also has an $n \approx 1$, then any light ray going from air into him, or from inside him back out into air will not change direction. Since the light rays are not deflected, they will not give any evidence that they passed through him, so the Invisible Man is indeed invisible. If you dropped a glass slide into a beaker of water, then it is almost invisible. You can barely tell that the slide is in the beaker by carefully looking for its edges, because the indices of refraction for the slide and the water are almost the same. If they were exactly the same, then you couldn't tell that the slide was in the beaker of water just by looking.
(b) If the Invisible Man went for a swim at the Rec Pool, then his $n \approx 1$ body would become visible, as it would then be surrounded by the $n = 1.329$ water. Remember, air bubbles are perfectly transparent, yet are visible underwater because of the difference of the indices of refraction between the air and water; the Invisible Man would most likely resemble a man-shaped bubble underwater.
5. The trick here is to take it step by step. You should find the angle of the ray in the oil to be 33.9° from the normal, and the angle of the ray in water to be 38° from the normal. From these, you can figure out the distances. The total distance moved should be 8.94cm.
6. Use the Law of Refraction. (Answer: $n_1 = 1.88$ when the prism is surrounded by water. $n_1 = 2$ for 30-60-90 triangle)
7. Remember that the wavelength of light as it travels through plastic is *not* the same as its wavelength in air! If you take this into account properly, you should be able to find that the visible wavelength of light that will reflect and interfere constructively will linearly depend on the index of refraction of plastic.