

Practice Problem Answers

Table of Refractive Indices (n)

<i>material</i>	<i>n</i>
Air	1.0003
Water	1.33
Crown glass	1.52
Whale Oil	1.460

1. A ray of light in air is approaching the boundary with water at an angle of 52 degrees. Determine the angle of refraction of the light ray. Refer to the table of indices of refraction if necessary.

$$\begin{aligned} \sin \theta_1 (n_1) &= \sin \theta_2 (n_2) \\ \sin 52^\circ (1) &= \sin \theta_2 (1.33) \\ 0.79 &= \sin \theta_2 (1.33) \\ 0.59 &= \sin \theta_2 \\ 36^\circ &= \sin \theta_2 \end{aligned}$$

2. A ray of light in air is approaching a layer of crown glass at an angle of 42.0 degrees. Determine the angle of refraction of the light ray upon entering the crown glass and upon leaving the crown glass. Refer to the table of indices of refraction if necessary.

Entering the glass:

$$\begin{aligned} \sin \theta_1 (n_1) &= \sin \theta_2 (n_2) \\ \sin 42^\circ (1) &= \sin \theta_2 (1.52) \\ 0.67 &= \sin \theta_2 (1.52) \\ 0.44 &= \sin \theta_2 \\ 26^\circ &= \sin \theta_2 \end{aligned}$$

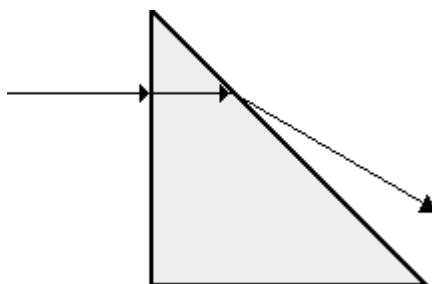
Entering the glass:

$$\begin{aligned} \sin \theta_1 (n_1) &= \sin \theta_2 (n_2) \\ \sin 26^\circ (1.52) &= \sin \theta_2 (1) \\ 0.67 &= \sin \theta_2 \\ 42^\circ &= \sin \theta_2 \end{aligned}$$

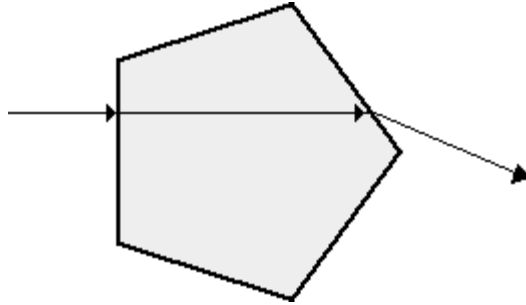
3. Cal Culator is performing an experiment to determine the index of refraction of an unknown material (in the shape of a 45-45-90 triangle). Cal determines that the light follows the path as shown on the diagram below. Use this path, a protractor, a calculator and Snell's Law to determine the index of refraction of the unknown material.

Measure angles to the normal with a protractor. The boundary where the light enters can be ignored since no refraction occurs. Examining the 2nd boundary:

$$\begin{aligned} \theta_1 &= 45^\circ \text{ and } \theta_2 = 75^\circ \\ \sin \theta_1 (n_1) &= \sin \theta_2 (n_2) \\ \sin 45^\circ (n_1) &= \sin 75^\circ (1.0) \\ 0.71 (n_1) &= 0.97 (1.0) \\ n_1 &= 1.37 \end{aligned}$$



4. The path of a light ray through an unknown material is shown in the diagram below. Make some measurements and determine the index of refraction of the material.



Measure angles to the normal with a protractor. Again, the boundary where the light enters can be ignored since no refraction occurs. Examining the 2nd boundary:

$$\begin{aligned}\theta_1 &= 35^\circ \text{ and } \theta_2 = 60^\circ \\ \sin \theta_1 (n_1) &= \sin \theta_2 (n_2) \\ \sin 35^\circ (n_1) &= \sin 60^\circ (1.0) \\ 0.57 (n_1) &= 0.87 (1.0) \\ n_1 &= 1.52\end{aligned}$$

5. What index of refraction should a fish have in order to be invisible to other fish?

It must be the same as water!

6. A light bulb is placed a distance of 45.7 cm from a double convex lens having a focal length of 15.2 cm. Determine the image distance.

$$\begin{aligned}\text{Using the lens equation: } d_o &= 45.7 \text{ cm} & f &= 15.2 \text{ so solving for } d_i \\ 1/d_i + 1/d_o &= 1/f \\ 1/d_i + 1/45.7 &= 1/15.2 \\ 1/d_i &= 1/22.7 \text{ or } 0.044 \\ \text{so } d_i &= 22.7 \text{ cm}\end{aligned}$$

7. A magnified, inverted image is located a distance of 32.0 cm from a double convex lens with a focal length of 12.0 cm. Determine the object distance and tell whether the image is real or virtual. Use a diagram to help!

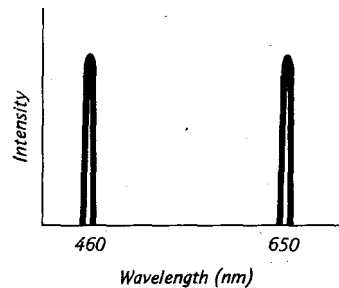
$$\begin{aligned}\text{Using the lens equation: } d_i &= 32.0 \text{ cm} & f &= 12.0 \text{ so solving for } d_o \\ 1/d_i + 1/d_o &= 1/f \\ 1/32 + 1/d_o &= 1/12.0 \\ 1/d_o &= 1/19.2 \text{ or } \\ \text{so } d_o &= 19.2 \text{ cm}\end{aligned}$$

The image is real, not virtual, because all inverted images are real.

8. Determine the focal length of a double concave lens that produces an image that is 16.0 cm behind the lens when the object is 28.5 cm from the lens.

Use the same equation as in 6 and 7. You should get an answer of 10.2 cm for the focal length.

9. A certain light has the intensity-distribution curve shown in the figure below. If this light shines on a white screen, what will be the hue and saturation of the illuminated region?



If the white light is RGB (for simplicity sake), using the table supplied in workshop and lab (spectroscopy),

10. White light passes first through a cyan filter, then a magenta filter. What color light results?

$$C = B + G - R$$

$$M = B + R - G$$

$$Y = R + G - B$$

So if the RGB light passes through a cyan filter, it will absorb the red, transmitting B and G. Then passing through a magenta filter, the G will be absorbed, allowing only B to be transmitted. Therefore, the light will be blue.

11. Just before the Battle of Midway in World War II, the U. S. submarine *Trigger* ran aground on a reef. The officers were wearing red goggles (in order to dark adapt). On their maps, the reefs were marked in red. Explain why they ran aground?

This is because the glasses only pass red light and absorb all others. The areas of the map that were white (RGB) would appear identical to those that were marked in red.

12. Water absorbs light weakly at the red end of the visible. This gives a drop of water a little bit of color. What color?

Well...if RGB light strikes a drop of water and it absorbs the red, it will transmit B and G, which make Cyan, thus giving the drop a hint of bluish color.

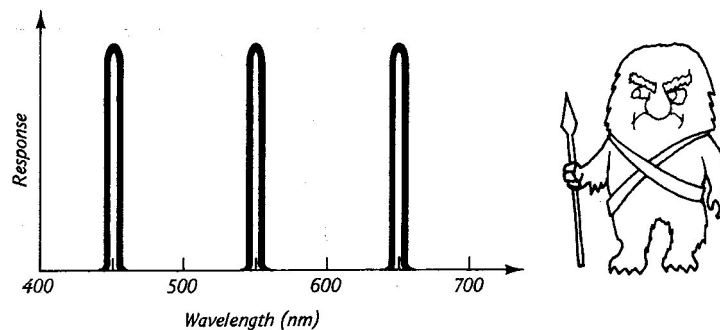
13. Water near a sandy beach on a bright, cloudless day often ranges in color from green near the shore to blue farther out. Explain why this is so.

One thing is that the sandy bottom is easily seen through the shallower water. It must mean that because the water is already absorbing red, the sandy bottom must be absorbing some blue! As for the deeper water, the sunlight doesn't penetrate through to the bottom and therefore appears cyan (or bluish).

14. Suppose we have two different beams of light, A and B that appear to be identical white lights. We don't know which is which, but we do know that one of them (we will call it 1) is made up of an additive mixture of two monochromatic sources with wavelengths 490 nm and 640 nm. The other, (we will call 2) consists of a more or less uniform distribution of intensities of all wavelengths between 400 nm and 700 nm. If you shine these two beams through a filter that absorbs all wavelengths between 500 nm and 600 nm (and no others), you find beam A remains white, while beam B looks purple. Identify the unknown beams A and B with the known distributions 1 and 2. Explain your answer.

A must be 1 and B must be 2. If 2 only has wavelengths between 400 and 700 nm, and you filter out wavelengths between 500 and 600, this leaves 2 with two narrow bands between 400-500 nm and 600-700 nm. Using your knowledge of wavelength and color, you would deduce that this would produce light in the blue and red range. Mixing blue and red produces magenta (or purplish) light.

15. A Martian (with color sensitive pigment cells - similar to our cone cells - as shown in the figure below) visits Earth and is watching a television show about street lights (on a normal Earth color TV set). Color televisions use the 3 primary colors of light (RGB) to produce the wide array of color we see. In the program the Martian is watching, one of the street lights described is the sodium light that emits light at a wavelength of 589 nm. The Martian is impressed by the effectiveness of this light in illuminating roads. That night, he rushes out to a country road that is illuminated only by sodium lights. To his dismay, everything appears dark -- it seems to him that the lights aren't even turned on! Explain why the Martian could see objects illuminated by sodium light on the TV but not on the country road.



Well it makes sense that he couldn't see the sodium street lights in person as his cone cells don't respond at all at 589nm (see figure above). Why could he see them on the TV? Well if you looked at the chart (from the spectroscopy lab), you will notice that his cones do respond to RGB light and with RGB light, one can generate almost any other color light (by mixing intensities).

violet	390 - 430 nm
blue	430 - 470 nm
blue-green	470 - 500 nm
green	500 - 530 nm
yellow-green	530 - 560 nm
yellow	560 - 590 nm
orange	590 - 620 nm
red	620 - 780 nm