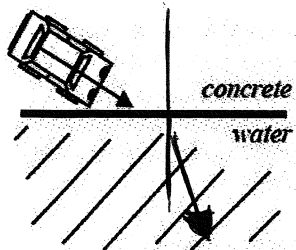


1. Imagine a car traveling on concrete hits a puddle of water.

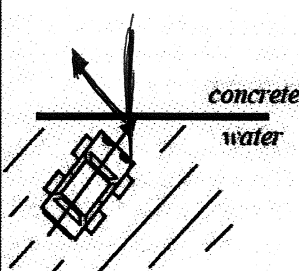
A. Will the car be faster on concrete or in the water?



- B. Draw the normal line perpendicular to the water where the car will enter.
- C. Which side of the car hits first? *Right*
- D. Use an arrow to draw the path of the car in the water.

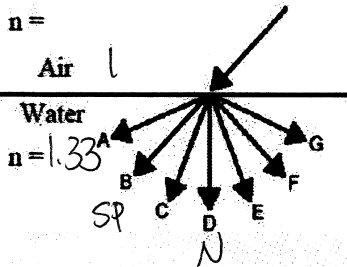
2. This time the car starts in the puddle.

A. Which side of the car gets out of the water first? *Left*



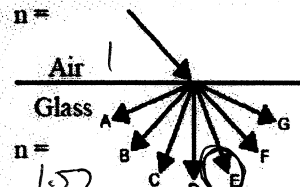
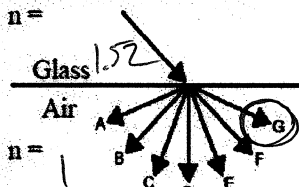
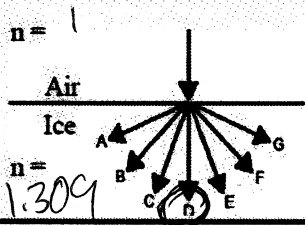
- B. Will the car speed up or slow down when it leaves the water?
- C. Draw the normal line.
- D. Draw the path of the car after it leaves the water.

3. A light ray passes from air into water, as shown.



- A. Find the indexes of refraction for both substance from the table on the front.
- B. In which substance does light travel faster? *Air*  
(Hint: notice the arrow on the left of the index of refraction table.)
- C. Looking from light rays point of view, which side of the light ray hits the water first: left or right? (If you have trouble seeing this, pretend the car is following the arrow: which wheel hits the water first?) *Right*
- D. Label the "straight path" as "SP" and the normal as "N".
- E. Which of the given paths will the light ray follow in the water? *C*
- F. Did the light ray bend toward or away from the normal? *toward*

4. Repeat the previous problem's for the three diagrams at the right. Then decide which path light will take in the second substance.



5. The index of refraction of a substance is 2. Calculate the speed of light in the substance.

$$n = \frac{c}{v} \Rightarrow v = \frac{c}{n} = \frac{3 \times 10^8 \text{ m/s}}{2} = 1.5 \times 10^8 \text{ m/s}$$

Notice that the speed is half that of the speed in a vacuum.

6. So, if the speed of light in a substance is  $1 \times 10^8$  m/s, what would its index of refraction be? (Without calculating.)

*3 or 1/3 the vel of light vacuum*

7. Two substances:  $n_A = 2.35$ ;  $n_B = 1.65$ . In which substance does light have the faster speed?

$$n_B = 1.65 < n_A = 2.35$$

8. Light travels at  $2.06 \times 10^8$  m/s in quartz. Calculate the index of refraction for quartz.

$$n = \frac{c}{v} = \frac{3 \times 10^8 \text{ m/s}}{2.06 \times 10^8 \text{ m/s}} = 1.45$$

9. Using the table on the front, calculate the speed of light in water.

$$v = \frac{c}{n} = \frac{3 \times 10^8 \text{ m/s}}{1.33} = 2.3 \times 10^8 \text{ m/s}$$

10. Light travels from a block of ice into air.

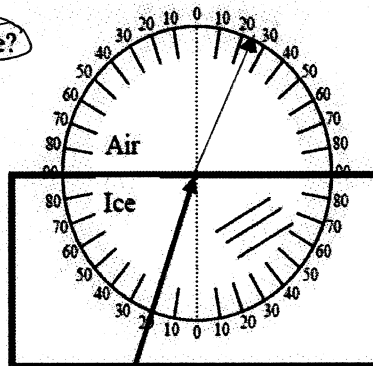
- A. Which is the first substance: air or ice?
- B. Calculate and draw the angle in air.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

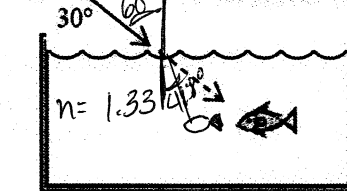
$$1.309 \sin 20^\circ = 1 \sin \theta$$

$$.4477 = \sin \theta$$

$$\theta = \sin^{-1}(.4477) = 26.6^\circ$$



11. A person thinks they see a fish at an angle of  $30^\circ$  to the surface of the water.



- A. Draw where the fish is really (approximately).
- B. Remembering that all angles are from the normal, calculate the actual angle of the fish in the water.

$$1 \sin 60^\circ = 1.33 \sin \theta$$

$$0.866 = 1.33 \sin \theta$$

$$\theta = \sin^{-1} \left( \frac{0.666}{1.33} \right) = 41.8^\circ$$