Name: _____ Date: _____

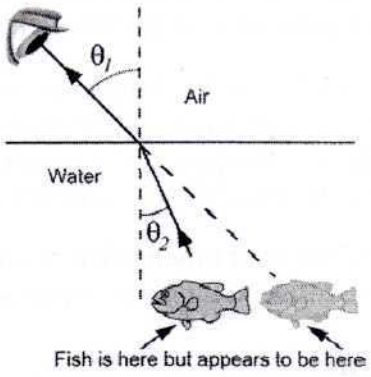
PRACTICE 112m = 4 sec 23.2

Refraction

When light rays cross from one material to another they bend. This bending is called **refraction**. Refraction is a useful phenomenon. All kinds of optics, from glasses to camera lenses to binoculars depend on refraction.

READ

If you are standing on the shore looking at a fish in a stream, the fish appears to be in a slightly different place than it really is. That's because light rays that bounce off the fish are refracted at the boundary between water and air. If you are a hunter trying to spear this fish, you better know about this phenomenon or the fish will get away.



Why do the light rays bend as they cross from water into air?

A light ray bends because light travels at different speeds in different materials. In a vacuum, light travels at a speed of 3×10^8 m/sec. But when light travels through a material, it is absorbed and re-emitted by each atom or molecule it hits. This process of absorption and emission slows the light ray's speed. We experience this slowdown as a bend in the light ray. The greater the difference in the light ray's speed through two different materials, the greater the bend in the path of the ray.

The *index of refraction* (n) for a material is the ratio of the speed of light in a vacuum to the speed of light in the material.

$$\text{Index of refraction} = \frac{\text{speed of light in a vacuum}}{\text{speed of light in a material}}$$

The index of refraction for some common materials is given below:

Vacuum	1.0
Air	1.0001
Water	1.33
Glass	1.5
Diamond	2.42

PRACTICE 1

1. Could the index of refraction for a material ever be less than 1.0? Explain.
2. Explain why the index of refraction for air (a gas) is smaller than the index of refraction for a solid like glass.
3. Calculate the speed of light in water, glass, and diamond using the index of refraction and the speed of light in a vacuum (3×10^8 m/sec).
4. When a light ray moves from water into air, does it slow down or speed up?
5. When a light ray moves from water into glass, does it slow down or speed up?

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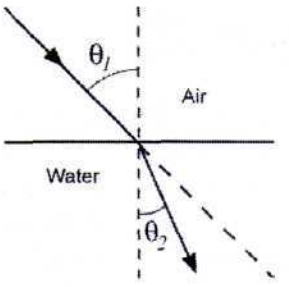
Which way does the light ray bend?

Now let's look at some ray diagrams showing refraction. To make a refraction ray diagram, draw a solid line to show the boundary between the two materials (water and air in this case). Arrows are used to represent the incident and refracted light rays. The normal is a dashed line drawn perpendicular to the boundary between the surfaces. It starts at the point where the incident ray hits the boundary.



As you can see, the light ray is bent *toward* the normal as it crosses from air into water. Light rays always bend toward the normal when they move from a low-*n* to a high-*n* material. The opposite occurs when light rays travel from a high-*n* to a low-*n* material. These light rays bend away from the normal.

The amount of bending that occurs depends on the difference in the index of refraction of the two materials. A large difference in *n* causes a greater bend than a small difference.

PRACTICE 2

1. A light ray moves from water (n = 1.33) to a transparent plastic (polystyrene n = 1.59). Will the light ray bend toward or away from the normal?

2. A light ray moves from sapphire (n = 1.77) to air (n = 1.0001). Does the light ray bend toward or away from the normal?

3. Which light ray will be bent more, one moving from diamond (n = 2.42) to water (n = 1.33), or a ray moving from sapphire (n = 1.77) to air (n = 1.0001)?

4.

Helium	1.00004
Water	1.33
Emerald	1.58
Cubic Zirconia	2.17

The diagrams below show light traveling from water (A) into another material (B). Using the chart above, label material B for each diagram as helium, water, emerald, or cubic zirconia.