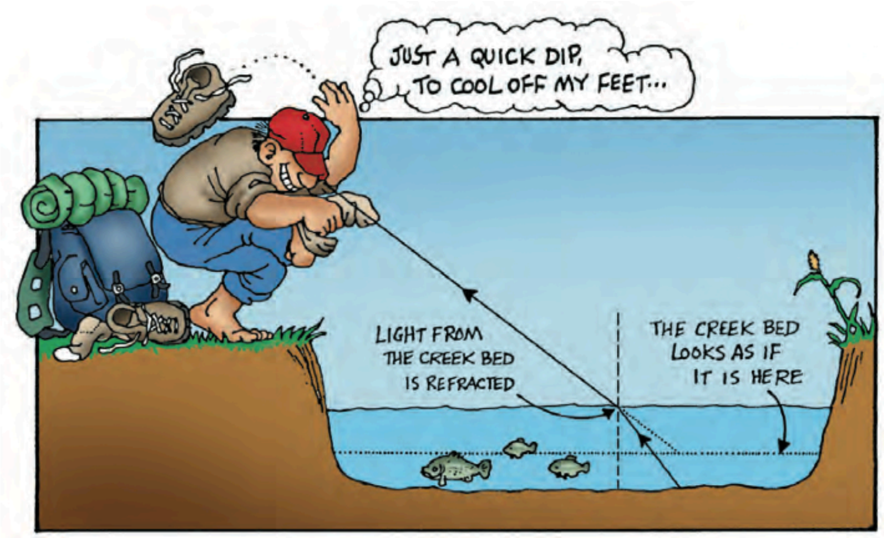
# Refractive Index and Wet Pants

Phew! It's a scorching day, and that creek looks very inviting to a hot, tired hiker. His feet are aching, and he's dying to slip off his stiff hiking boots and thick socks and wade in that nice cool water. In he goes, and . . . Splash! Instead of being up to this ankle, the water is up to his knees. Why was the water much deeper than it appeared – and how will the hiker dry his pants? If only he had paid attention in science class! Why? Because he would have known that the apparent depth of the water was an illusion. Look at the picture of the hiker. Can you see how the hiker's brain was tricked by refraction?




*The water is deeper than it looks. Knowledge of how light is refracted when it passes from water into the air might have saved this hiker the embarrassment of wet pants.*

## What causes refraction?

Light is refracted when it changes speed. Light changes speed when it passes from one transparent material into another. For example, light travels slower in water than in air – about three-quarters as fast. Light therefore bends when it passes from air into water. (Do you remember the pencil in water? Didn't it appear bent?) The difference between the speed of light in two transparent materials determines how much the light bends as it passes between them. The bigger the difference in the speed of light in the two materials, the more bending, or refraction, takes place when the light passes from one material into another.

Refraction between the air and this jar of water makes this student look distorted. What causes refraction?

## Refractive Index

Scientist find it useful to compare the light bending ability of different transparent materials. They make this comparison using something called refractive index. The refractive index of a transparent material is defined as the speed of light in a vacuum divided by the speed of light in the transparent material. Each transparent material has a different refractive index.

The slower the speed of light in a material, the higher its refractive index. In a vacuum-where there is no matter to slow down the light-light travels at its fastest speed. The refractive index of a vacuum is 1. This is the lowest refractive index. In glass, light travels much slower, about two-thirds-a refractive index of about 1.5. The table below shows refractive indices of a vacuum and of different transparent materials.

In which of these transparent materials does light travel the slowest?

| Transparent Materials | Refractive Index |
|---|---|
| Vacuum<br>(A vacuum contains no matter) | 1.00 |
| Air | Slightly higher than 1.00<br>(1.0002930 |
| Glass | 1.53 |
| Diamond | 2.42 |
| Transparent Plastic | 1.50 |
| Water | 1.33 |

## Birdbrains and fishy physics

If you know the refractive index of two materials, you can predict which way light will bend when it passes from one to another. Light passing from a material with a lower refractive index to one with a higher refractive index bends toward the normal (just as you observed when light passed from the air into the transparent plastic block).

What happens when light travels in the opposite direction? When light passes from a material with a higher refractive index into one with a lower refractive index (for example, from the transparent plastic block into the air), it is refracted in the opposite direction. The light ray bends away from the normal.

If the hiker had known, this, could he have avoided getting his pants wet? Look back at the picture of the soggy hiker. Light reflected from the creek bed travels from water into the air it was refracted away from the normal This made the water look shallow. The hiker was tricked by refraction!

Some birds that are expert fishers, such as the great blue heron, don't make the mistake the hiker made. They take refraction into account when they lunge underwater for their prey. They must lunge at the position deeper and at an angle different than where the fish appears to be.  Did you know that birdbrains were so good at physics?

Now imagine you're a fish looking up from the water into the air. You would have the reverse problem of the hiker or the heron. Light traveling from the air into the water is refracted in the opposite direction, toward the normal. From underwater, objects look farther way than they actually are.

Can you use refractive indices to predict how light will behave when it passes from water to glass? Will a ray of light be refracted toward or away from the normal?