Living in a Red, White and Blue World

With the sun still low on the horizon of a new semester, teachers look into student faces still reddened from the summer break. Thus, it's apropos to investigate the red appearance of the sun when it's low on the horizon. Dawn begins with the eastern sky's red glow and then the sun loses its exotic appearance to become a yellow-white object by noon. By sun-down, the redness is back.

A glass of milky water helps explain this phenomenon.

Exploration phase. Divide the class into small groups. Ask a child in each group to bring a strong flashlight to class. Have one student fill a clear glass with water and another student use an eye dropper to add milk to the water.

Turn off the lights and pull the blinds to make the room as dark as possible. Place the flashlight on a table so that the light shines through the water and onto a sheet of white paper, which serves as a projection screen, about 10 cm behind the glass (see Figure 1).

Every time a drop of milk is added to the water, stir the solution and observe the paper. Slowly, the paper becomes yellow-orange-red.

Concept introduction. If possible, show photographs or a video of astronauts outside the shuttle or walking on the moon, along with pictures of the earth as seen from space. All images in these videos and/or photos are surrounded by stark darkness. Space has no color. Lunar astronauts look into the heavens that are without red sunsets, white clouds and a blue sky.

White light is composed of the colors red, orange, yellow, green, blue and violet. Before this heterogeneous palette from the flashlight splashes onto the paper as white light, some of the wavelengths disappear. The very diluted milk solution looks red-orange because the other colors are somehow dispersed.

In physics, the word scattering is used to describe what happens to light waves when they collide with and are momentarily absorbed by the air's component molecules (oxygen, nitrogen and water) and dust particles, and then are randomly re-emitted in many directions.

While their direction is random, there's a quantitative manner in which the colors are dispersed. Shorter wavelengths (blue) are scattered about seven times more easily than the longer red wavelengths; yellow wavelengths are scattered about three times more easily than red.

The following scale shows the relative ease at which different colors are scattered: purple -- 10, blue -- 7, yellow -- 3, orange -- 2, red -- 1. This is why, during the day, the sky appears to be blue most of the time. But wait just a second! Purple is scattered more than blue, so why isn't the sky purple? Easy. Because the retina is not as sensitive to that color.

When the sun is low on the horizon, the longer wavelengths -- yellow, orange and red -- penetrate the thick atmosphere while blue is seen in regions perpendicular to the line of sight. This dispersal of specific wavelengths is called selective scattering.

Figure 2 shows that when the sun or moon is on the horizon, their light travels through thicker air and more scattering and redness occurs.

Waves circle away from a stone dropped into a pond, and when they hit a cork, it bobs up and down with the same frequency as the passing ripples. The wave direction is slightly changed, too. This analogy explains how light waves journey through the atmosphere and encounter its component molecules and particulate matter. Following the collision, the light waves are sent off with the same frequency (just like the cork), but in a different direction (scattering).

This reddening phenomenon is often visible four times a day: sunrise and sunset, moonrise and moonset. Remember that when the moon shines, it's merely reflecting the sun's light, so the earth's satellite also looks orange as it apparently moves above the eastern horizon and again hours later when it's low in the western sky.

Same end result. The passage of sunlight and moonlight through the atmosphere is analogous to the flashlight's battery powered wavelengths passing through the milky water. But impurities are impurities, whether they're dust particles and water vapor in the atmosphere or milk fat clouding up a glass of water, so the end result is the same.

The oil well fires during the 1991 Gulf War also drove particulate matter high into the air and also resulted in an intense reddening of the skies at dusk and dawn An excellent reference with colorful diagrams can be found at this Internet web site: http://av.yahoo.com/bin/query?p=optics+%2B+sc attering&hc=O&hs=1

Figure 1: Shine a flashlight through milky water and see a sheet of white paper change color. This experiment helps explain why the sun and moon are orange-red when on the horizon.

Figure 2: Since the atmosphere is thicker when the sun is on the horizon, there's more scattering and redness.

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