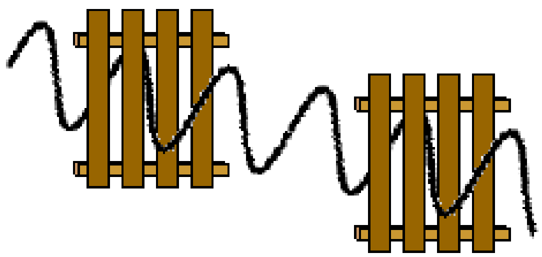
EXPLORING POLARIZATION

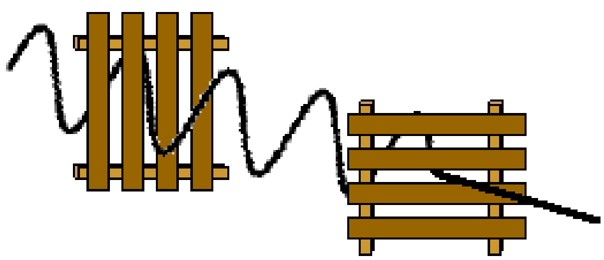
SOME BACKGROUND INFORMATION

As the figure shows, a transverse wave on a rope will pass through both fences when the slots in the fences are aligned, but will be blocked when the slots are at right angles to each other.

The Picket Fence Analogy

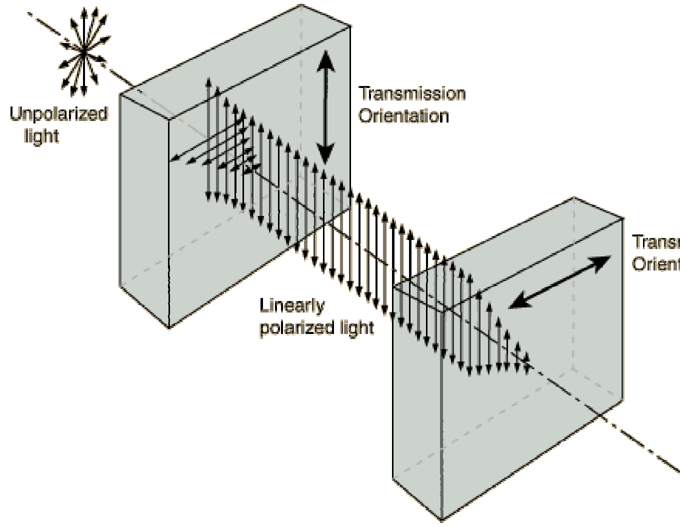


When the pickets of both fences are aligned in the vertical direction, a vertical vibration can make it through both fences.



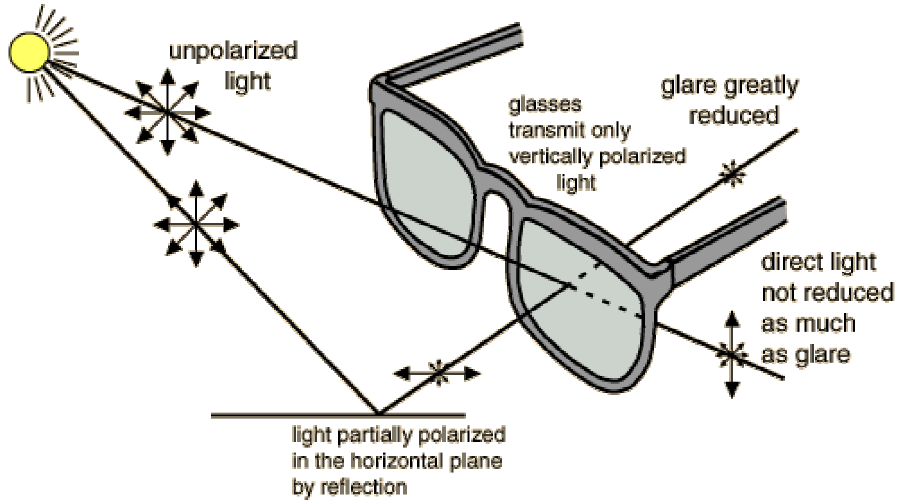
When the pickets of the second fence are horizontal, vertical vibrations which make it through the first fence will be blocked.

When light passes through a device called a polarizer, such as a Polaroid filter, only the waves vibrating in one direction pass through; all other light waves are absorbed. When a second polarizer, often referred to as an analyzer, is placed over the first, and slowly rotated, it is possible to totally block the light. Just as with the fence analogy, a wave that passes through one polarizer is absorbed by the second polarizer (see figure). This occurs because the transmission axes of the polarizers are "crossed," that is, at right angles to each other.

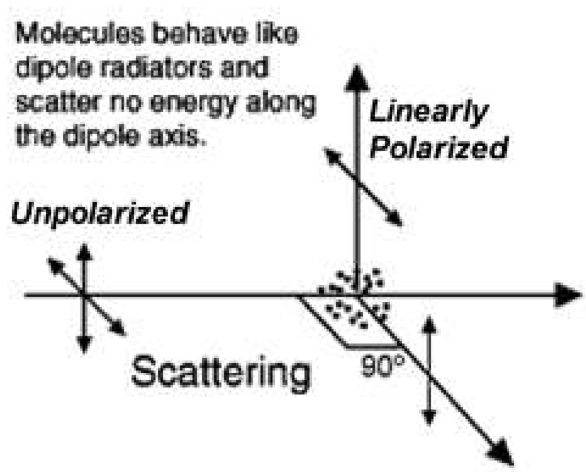


Polaroid filters contain long molecular chains that are arranged in parallel rows, like boards in a picket fence. As with a picket fence, open spaces, or molecular slots, separate the chains of molecules from one another. When light passes through a Polaroid filter, only the waves vibrating in one direction can pass through the openings between the long chains of molecules. All other light waves are absorbed.

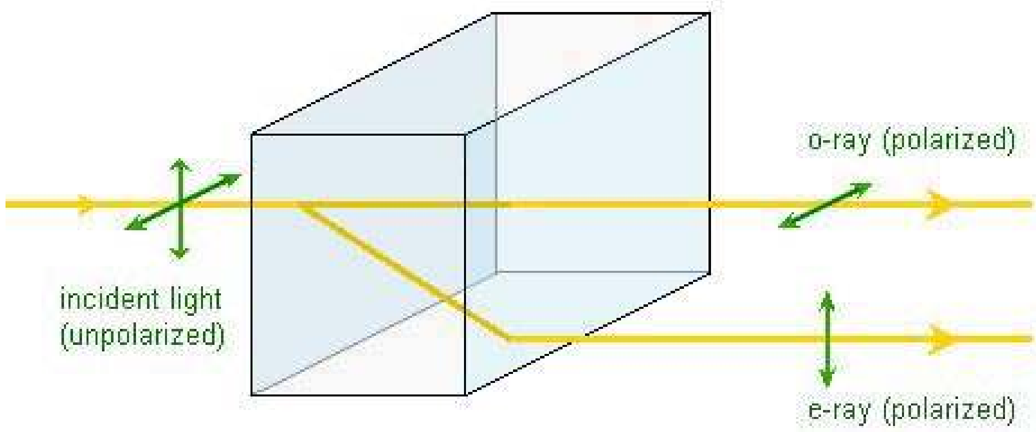
When light is reflected from a non-metallic surface, such as a tabletop, snow, or water, it becomes polarized in a plane parallel to the surface. In Polaroid sunglasses, the axes of polarization are vertical. The reflected glare, which is at least partially polarized in the horizontal direction, is reduced by the Polaroid sunglasses.



As sunlight passes through the atmosphere, it is scattered in all directions. Blue light is scattered more than red light. That is why the sky is blue. Atmospheric scattering also polarizes light. Looking at the sky with a Polaroid filter will convince you of this. The figure below illustrates the scattering process.



Crystals, such as calcite and quartz, are said to be birefringent ("two indices of refraction"). When unpolarized light enters a birefringent material, it divides into two rays. These rays have different speeds and are polarized at right angles to each other. Using a Polaroid filter to view the two rays as they emerge from the crystal, either ray can be extinguished while the other remains visible.



Inserting birefringent materials between two polarizers can produce brilliant colors. White light is composed of basically six colors: Red, Orange, Yellow, Green, Blue, and Violet. Birefringent materials rotate the direction of polarization of each color in the spectrum by a different amount. Clear plastic (on the left) and layers of cellophane tape (on the right) are birefringent. Placing these objects between crossed Polaroids produces rather colorful effects.

Optically active materials are also capable of rotating the plane of polarization. These materials include sugar solutions, corn syrup, turpentine, amino acids, and some crystals. When placed between two Polaroid filters, these substances cause the component colors in white light to separate (see below). As one filter is rotated, the colors of the spectrum are seen in turn.

Polarization Exploration

1. Direction of Polarization.

Overlap two sheets of Polaroid material. Look at a source of light through the filters while rotating one of the filters. Describe what you see. When the light is completely blocked by the overlapping filters, rotate them through 90 degrees. What do you observe now? Rotate the filters through an additional 90 degrees. Explain what is happening as you rotate the filters.

2. Polarization by Reflection.

Find a surface (e.g., tabletop, blackboard, etc.) from which the reflected light produces glare. Viewing the glare through a Polaroid filter, rotate the filter until you no longer see the reflected light. In this position, the filter's axis of polarization is vertical. Place a small piece of masking tape along the edge of the filter and indicate the axis of polarization with an arrow (↕). Rotate the filter to pass the maximum amount of light. Describe the orientation of the axis of polarization now.

Now view reflected light from a sheet of metal such as a piece of aluminum foil. Describe what happens this time as you rotate the filter. Compare the reflected light from a metallic surface to that reflected from a non-metallic surface.

3. Polarization by Scattering

If the weather permits, go outside and investigate skylight with a Polaroid filter. **DO NOT LOOK DIRECTLY AT THE SUN!** Slowly rotate the filter as you view a portion of the sky. Is it possible to reduce the brightness of the sky for certain orientations of the filter? Now examine other areas of the sky. Does the light in certain portions of the sky seem to be more polarized than others?

While you are outside, examine automobile windshields with your Polaroid filter. Describe what you see. Try to explain your observations.

If you can't go outside, observe the simulated sky produced by dissolving a small amount of powdered milk in water.

4. Birefringence

Place a calcite crystal on some printed material. How many images do you see? Now view the printed material after you have placed a Polaroid filter on top of the crystal. What do you see now? Can you extinguish one image at a time by rotating the filter? Why do you think this occurs?

When stressed, plastic and glass can become birefringent. Viewed between Polaroid filters, this birefringence appears as colored contours. Place a plastic fork, or other plastic object, between your filters to make the stress lines visible. If you are using a fork, squeeze the tines together. What happens to the colored stress lines?

5. LCD Display

Examine the LCD display on a watch, calculator, or laptop computer through a single Polaroid filter. Rotate the filter and note the effect. What does this tell you about light from liquid crystal displays?

6. Optically Active Substances

The corn syrup in the beaker on the overhead is optically active. Optically active substances rotate the plane of polarization of a beam of light. Note that there are Polaroid filters on the top and bottom of the beaker. Rotate the top filter and observe the color of the light. Can you produce all the colors of the spectrum?