POLARIZATION OF LIGHT

Light waves are electromagnetic waves consisting of both an oscillating electric field and an oscillating magnetic field. These two oscillations sustain each other and allow light to propagate independently, even through a vacuum. The electric field and magnetic field waves are both transverse waves where the oscillating fields are perpendicular to the direction of wave travel. In addition, the electric field oscillation is perpendicular to the magnetic field oscillation. Working with both of these perpendicular oscillations is complex. As a result, light waves are often simplified as a single transverse wave involving only the electric field oscillation.

Because the oscillating electric field occurs in a set plane, light waves are **polarized**. The poles of the oscillation are the crests and troughs of the electric field wave, which maintain their orientation as light waves propagate. The plane in which the electric field oscillates is known as the **plane of polarization**. In Figure 17.7, the electric field is oscillating in the x-y plane and this electromagnetic wave is polarized along the y-axis.

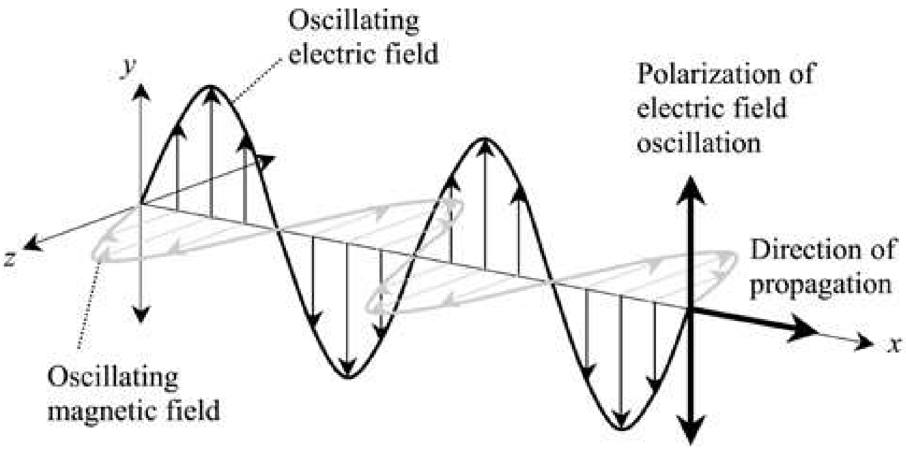

Figure 17.7. Electromagnetic wave

Light waves can be polarized in any direction. Light arriving from the Sun consists of countless waves, each polarized in random directions. When treated together, all of these random polarizations cancel each other. So the light from the Sun, as well as light from other conventional light sources, is unpolarized. The diagrams in Figure 17.8 are simplified by showing the polarization of light for two light waves coming directly out of the page. Figure 17.8(a) is polarized in the *y*-direction only. Figure 17.8(b) consists of waves polarized in a variety of directions and is an example of unpolarized light.

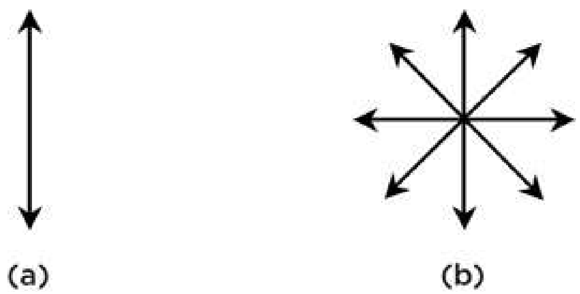

Figure 17.8. Polarized (a) and unpolarized (b) light

If unpolarized light passes through a **polarizing filter**, it will become polarized. A polarizing filter contains a transparent sheet imbedded with long, organic molecules oriented in only one direction. It is similar to the bars of a jail cell, where some things can pass through and others cannot. Only the light rays oscillating in one direction will pass through the polarizing filter. Light oscillating in all other directions is blocked.

Unfortunately, polarization is often shown incorrectly in diagrams in order to simplify the concept for beginning students. Figure 17.9 is the simplified, incorrect example. It shows unpolarized light passing through a polarizing filter where the organic molecules are aligned in the *y*-direction.

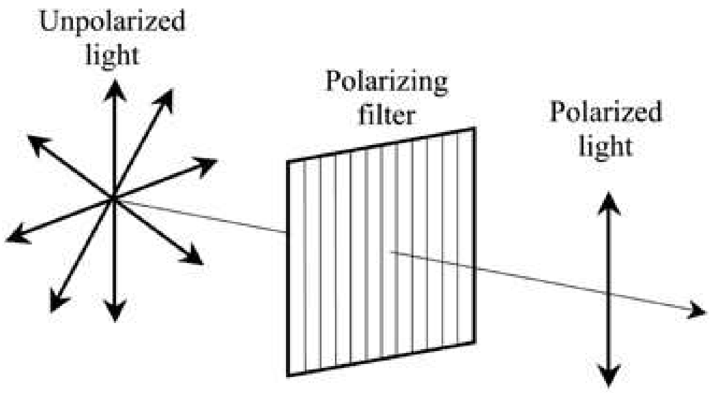

Figure 17.9. Simplified but incorrect example of polarization

Figure 17.9 seems logical, but the reality is a bit more complex. As light passes through the polarizing filter, the oscillating electric field causes the electrons in the organic molecules to vibrate. This transfer of energy absorbs the light polarized in the direction matching the alignment of the organic molecules. The light that actually transmits through the filter is the light perpendicular to the strands of organic molecules, as shown in Figure 17.10.

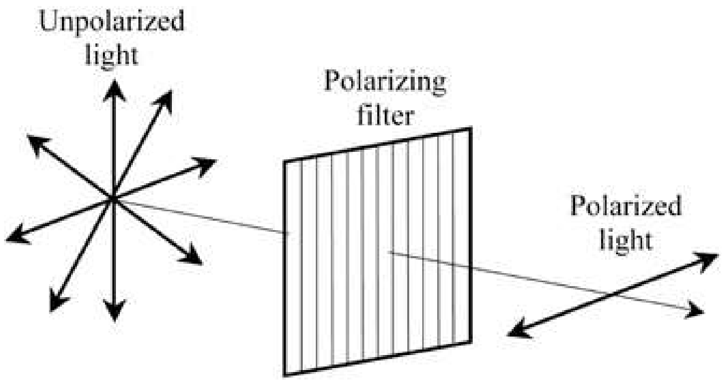

Figure 17.10. Correct example of polarizing light

Exams are more likely to focus on the fact that a single polarizing filter allows light waves oscillating in only one direction to pass through. You should also note that this phenomenon experimentally demonstrates that light is a transverse wave. In addition, exams will often test the effect of two polarizing filters used together, as shown in Figure 17.11.

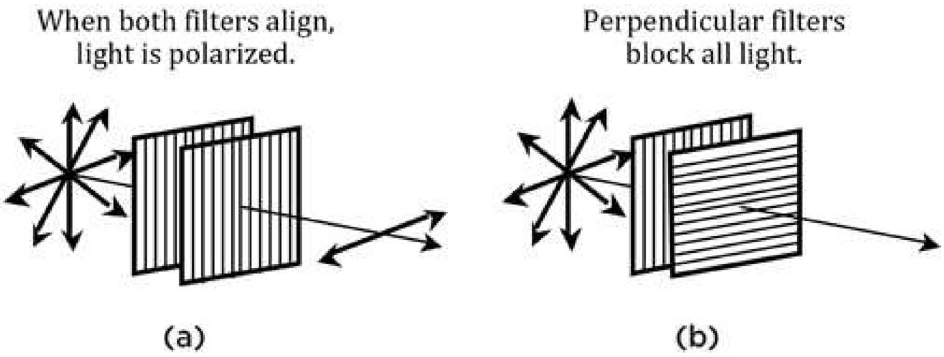

Figure 17.11. Effect of two polarizing filters

Polarization demonstrates that light is a transverse wave.

When two polarizing filters have the same orientation, light is polarized in the same manner as if only one filter is present. When two polarizing filters are perpendicular, they block all waves in any orientation. No light passes through. If the filters start in the position shown in Figure 17.11(a) and one filter is turned about the axis of propagation, the light passing through will become dimmer and dimmer. When the filter has turned 90°, all light will be blocked. Polarizing filters are used in 3-D glasses to view movies. A 3-D movie is actually two polarized movies superimposed on the screen. One lens of the 3-D glass allows vertically polarized light to pass through, and the other lens allows horizontally polarized light to pass through. Each eye is watching a different movie. The brain interprets the resulting images as three dimensional.

Light reflecting off of surfaces is partially polarized. The direction of this polarization matches the surface from which the light is reflected. When sunlight reflects off of the ocean, lakes, and the hoods of cars, it is slightly polarized in the horizontal direction. This type of polarization is commonly referred to as reflected glare. Polarized sunglasses are actually polarizing filters oriented to block this horizontally polarized reflected glare.