PhyzGuide: Polarization

the magic behind fishing sunglasses and Honey, I Shrunk the Audience

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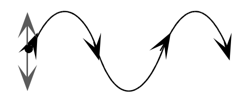
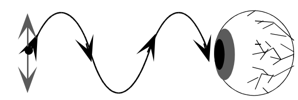
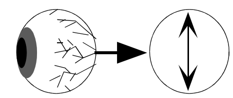
Our ideal vision of electromagnetic wave generation involves a charge oscillating vertically. Vertical oscillations in the electric field emanate horizontally to the left and right. This image is a simplification in a number of ways (which is OK; visualizing the accurate-to-the-nth-detail version is a delight reserved for the Einsteins, Feynmans, and Jearls of the world).

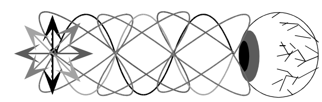


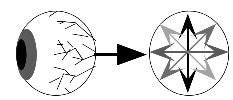
First, the electric field disturbances are propagating radially outward in the plane perpendicular to the oscillation of the charge, not just to the left and right.

Second, a typical source of electromagnetic radiation includes charges oscillating in multiple directions. So even along one direction away from the source, there are disturbances in the electric field in multiple directions. Consider the diagram of the idealized wave source to the right. As viewed from the position of the idealized (though tragically disembodied) eyeball, the disturbance in the electric field is vertical. Now consider the more realistic wave source and how the disturbance in the electric field appears to the eyeball. Multiple direction befuddlement. Reality is much worse; there are as many axes of electric field disturbances as there are electrons in oscillation. More than you can count before your 30th birthday.

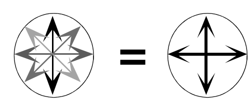






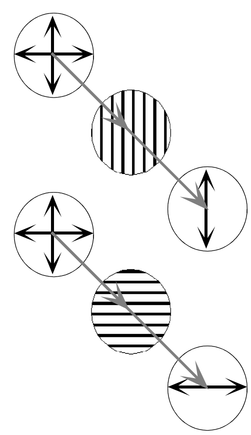


The point is this: electromagnetic radiation (including light) from ordinary sources involves waves oscillating in random orientations. Such waves are said to be **unpolarized**. We can use vector math to simplify unpolarized waves. Instead of the myriad orientations of oscillation represented in unpolarized light, think of the disturbance as having 50% vertical oscillation and 50% horizontal oscillation.



I'M SO EXCITED I COULD JUST YAWN

Gimme a second, here. The original idealized electromagnetic waves from the simple vertical oscillating charge are **polarized** because they oscillate in only one orientation. There are filters that can block out all waves except those oscillating in one particular orientation. They are aptly called *polarizers*. How they work is tricky; I won't go into it here. A polarizer allows 50% of incident radiation through. This is the radiation whose oscillations are aligned with the "optical grain" of the polarizer. The other 50% is reflected and therefore does not pass through the filter.

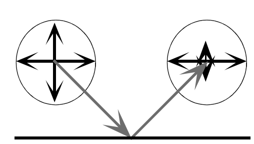


Two polarizing filters can be used to completely block out electromagnetic radiation. How?

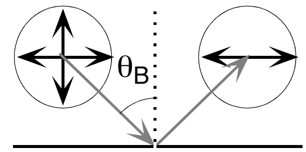
SO WHAT'S THIS GOT TO DO WITH SUNGLASSES?

When light is reflected from a nonconducting surface, it is polarized to some extent. Suppose unpolarized light is incident obliquely (at an angle) on a horizontal surface. (Remember to think of the light as 50% vertical and 50% horizontal.) The 50% of the light oscillating parallel to the surface reflects quite nicely. The other 50% does not. So the reflected light is highly polarized parallel to the reflecting surface.

A few details on polarization upon reflection. The reflecting surface must be a dielectric (nonconductor); metallic surfaces do not polarize reflected light.



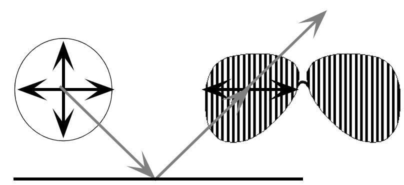
The incident light must be incident at some oblique angle; light incident at 0° is not polarized upon reflection. When light is incident at a great enough angle, the reflected light is completely polarized. This angle is called Brewster's Angle and varies from material to material. For transparent materials, the index of refraction is equal to the tangent of Brewster's Angle.



$n = \tan\theta_B$

There are perfectly good reasons for this apparent coincidence, but you'll have to take more physics to find out.

Glare is loosely defined as annoying specular reflection. It impedes good vision. This can be detrimental to the fishing enthusiast and outright hazardous to the driver. Since glare is reflected light, it is often partially or completely polarized. Therefore, it can be blocked out by a polarizing filter. This is the magic behind Polaroid™ sunglasses. Sunglasses with polarizing films are designed to block out glare. Ordinary sunglasses merely darken the scene, blocking an equal percentage of unwanted light and wanted light. (Some light must get through, or they'd be called "blindfolds.") Polarizing sunglasses darken the scene 50% and block out unwanted glare by up to 100%. They're "intelligent," blocking out more unwanted light than wanted light.

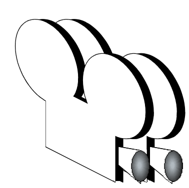


By blocking out glare, polarizing sunglasses allow fishing enthusiasts to see fish in shallow water despite reflections of the sky that would inhibit their vision if they weren't wearing the glasses. Drivers can see what's in front of them without annoying reflections from the dashboard, road, or hood to impede their vision.

WHERE DOES H,ISTA FIT IN WITH ALL THIS?

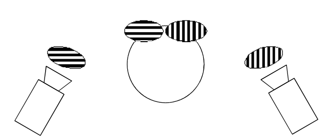
Three-dimensional vision is a wonderful thing. It requires that we see two slightly different views in our two slightly offset eyes. When watching TV or two-dimensional movies, one image is sent to both eyes. It is not possible to put two slightly offset images on the movie screen hoping that the right eye will focus on one while the left eye focuses on the other. (If you've ever removed your special 3-D specs during a 3-D movie, you know what I'm talking about.) What you see is a double-image blur.

Here's how polarization makes color 3-D movies possible.



1. When a 3-D movie is filmed, it must be filmed with a special two-film camera having stereoscopic lenses slightly offset from each other along a horizontal line (as our eyes are). So there is a right-eye image and a left-eye image. No polarizing filters are needed during the filming process.

2. The films are simultaneously projected on a metallic screen. Each image is polarized by the projection system. The right-eye image may be polarized vertically while the left-eye image is polarized horizontally.



TOP VIEW: looking down on 3-D moviegoer

3. Audience members wear glasses with polarizing filters. In front of the right eye lies a vertical filter and in front of the left eye lies a horizontal filter. So the right-eye image goes into the right eye and the left-eye image goes into the left eye. More importantly, the right-eye image is blocked out of the left eye and the left-eye image is blocked out from the right eye.