

Polarization of Light

Polarized light occurs everywhere in nature, from reflected sunlight, to minerals, to even molecules used for cooking. It is a phenomenon that few realize that they experience every day, when it is apparent all around us.

This lesson teaches what polarized light is, how it's made and can be filtered, as well as many instances in which it occurs both in nature, and purposely by people. Each idea comes with a demo, which are integral to this lesson. Since light is all around us, what better way to teach about it than using it and proving its characteristics.

Finally, I also ended with a demo showing how fiber optics work, just because I thought it was neat and wanted to show it. It has nothing to do with polarization, instead it uses the phenomenon of total internal reflection, but it's also a cool thing about light.

What is Polarized light?

Here's an applet showing polarized light as oscillating E and B fields. It will give you linear, elliptical, and circularly polarized light, depending on the phase of the E and B fields. I didn't use this applet, but you may want to.

<http://www.netzmedien.de/software/download/java/polarisation/>

Distribute small polarizing filters to the class and have them take out cell phones or digital watches to see what happens when the filter is placed in front of the display and rotated.

Then ask them what filters actually do – let certain stuff through, while blocking other stuff (light in this case).

So then ask what then a polarizing filter does, and they will say let through polarized light. Then show them two identical polarizers and cross them so that no light comes through (using an overhead projector). Try to get them to explain what's going on, and why the light can't get through.

When explaining a polarizing filter, I use the analogy that I learned in college of the filter like a picket fence. Only light waves traveling through in the same direction as the boards are able to pass through. All the other light rays get blocked.

Once they understand that, you can show them the mica sheet demo, and try to get them to tell you what's happening.

Mica Sheet

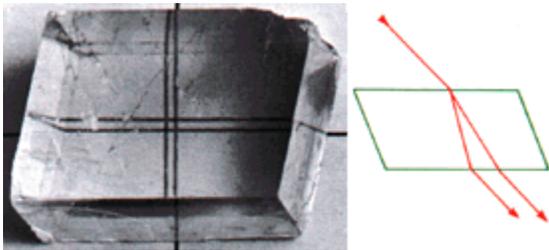
- Mica acts to change the orientation of polarized light by 90 degrees.
- Demo: Place a thin sheet of mica between two polarizers that are oriented 90 degrees to one another, so that no light can pass through. Then, you can orient the mica so that it rotates all of the polarized light coming through the first polarizer to be oriented the same way as the second polarizer, so that light can pass through again.
- You can also do it the opposite way, where both polarizers are oriented the same way, but the mica is the opposite way between them, so the light that makes it through the first polarizer, can't get through the second one, so it looks black.

Next, since Mica is a mineral found in nature, I went to the next natural occurring instance of polarization with the Calcite Crystal and birefringence. I made an overhead sheet that had a cross, a dot, and a phrase on it, I the double refraction from the crystal could best be seen with an s that was in my phrase, but you can use whatever works best. Also, depending on how much background the students have, you may have to do a quick introduction to refraction. My students had not learned refraction yet.

Birefringence

First show them the double image in the crystal and explain how it got there through the refraction and draw the picture shown below on the right. Next, I explained that these weren't just any regular refracted images, and I put the polarizer over the top of the crystal, and rotated it. They noticed that you could only see one of the images at a time, and I made them tell me why. All classes were able to figure it out.

- Birefringence happens when a light ray passes through a medium and the light is doubly refracted by the medium.
- The incoming ray of light is broken into two rays (called the ordinary and extraordinary rays), which travel through the crystal at different speeds. This is why you see two images.
- The polarization of the two light rays is different by 90° to one another.
- As you rotate the crystal, the ordinary ray remains stationary, while the extraordinary ray circles around.



picture credit:

http://webphysics.davidson.edu/alumni/MiLee/JLab/Crystallography_WWW/birefringence.htm

Stresses in Plastic

Next, I showed them a plastic fork and a plastic party cup sandwiched between two polarizers. The way that the plastic is stressed causes the different wavelengths of light to be rotated by different amounts as the polarized light passes through the plastic, so you see rainbow colors. They actually use polarizers in manufacturing to test products and make sure that there isn't too much stress on any part of a product that may cause it to break when it's not supposed to.

Next, I showed the students one of the coolest things that I've ever seen, it's simply Karo corn syrup. Place a polarizer over the overhead, and then set a glass beaker on top. While holding another polarizer above the beaker, slowly pour a bottle of corn syrup into the beaker. Watch as beautiful colors emerge and change as the depth of the corn syrup gets greater. Then when it's all been poured, also turn the top polarizer and again, you will see a rainbow of colors as you turn it in a complete circle. This demonstrates an optically active medium.

Optically Active Medium

- If a linearly polarized wave propagates through an optically active medium, it will remain linearly polarized but its polarization direction will rotate along the path
- Adding more syrup increases the path length, changing the transmitted color due to increased optical rotation. Also, rotating the polarizer also changes the color by changing the orientation of the light allowed to pass through the polarizer, and since the orientation of the light is dependent on wavelength, you see lots of colors as you rotate.
- Use corn syrup between two polarizers to show this color change – corn syrup is an optically active medium.
- Corn syrup is active medium because of the sugar crystals that make it.
- The angle of rotation of polarized light in an optically active medium is a function of wavelength.
- Sugar molecules are helical molecules that kind of look like rotini pasta that when the light hits it, it twists, and the amount of this twist is dependent on the wavelength of the light, so you get different colors, and the one that you see brightest is the one that is rotated the optimal amount for the depth of the corn syrup or the direction the polarizer is turned.

Next, we went outside, to see some more natural instances of polarization, from reflected sunlight. The sun's light is not polarized, but when it reflects off of objects, especially water, the reflected light is preferentially polarized along one direction. Therefore, by looking at an angle 90 degrees from the direction of the sun, the sky is polarized because of the light that's reflecting off of water molecules in the air. This actually works, but it must be a sunny day. Clouds ruin this effect (as we found out in my last period). In addition, we were lucky enough to be outside next to a puddle, and could see that the glare caused by reflected sunlight off of the water was also polarized. This is why you would want polarized sunglasses – they reduced glare! (but they don't work if you tilt your head sideways!).

Finally, was also talked about 3D vision as our last example of where polarization of light and polarizing filters are used. Whereas 3D movies and such used to use red and blue glasses to give you different perspectives and create a 3D image, now polarizing lenses are used, where the filter for one eye is directed vertically, and the other is directed horizontally, which again gives your eyes two different perspectives.

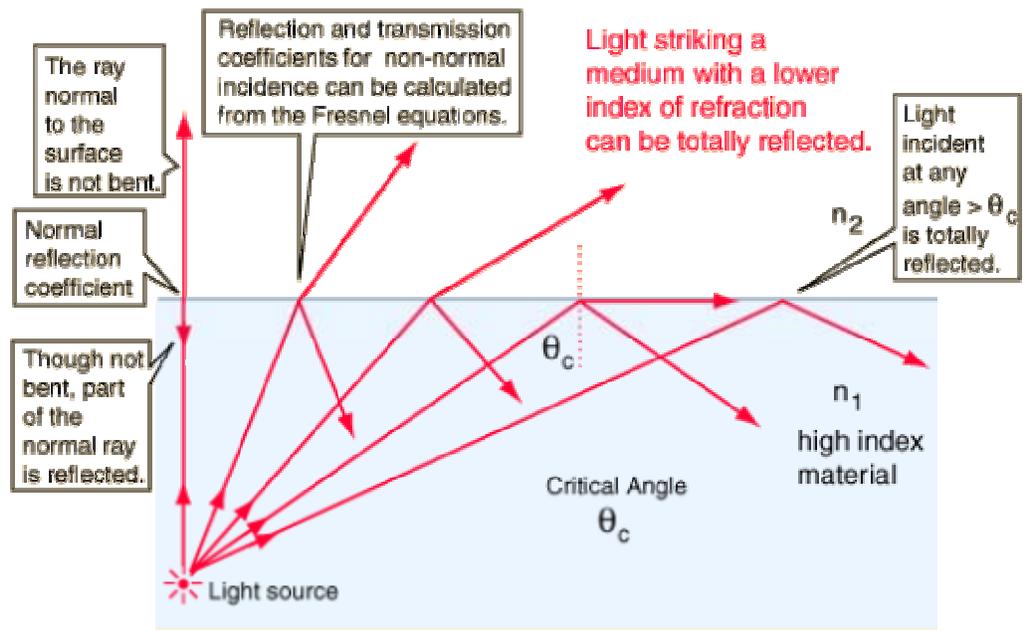
Last but not least, I showed them how fiber optics work, using total internal reflection.

Total Internal Reflection

Demo:

Plastic tube that curves around, so that light (laser) incident through one tube experiences total internal reflection all the way through the tube, and only comes out the other end, even though the tube winds around in a circle.

When light is incident upon a medium of lesser [index of refraction](#), the ray is bent away from the normal, so the exit angle is greater than the incident angle. Such reflection is commonly called "[internal reflection](#)". The exit angle will then approach 90° for some critical incident angle θ_c , and for incident angles greater than the critical angle there will be total internal reflection.



picture and explanation credit:

<http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/totint.html>

This is the same way that fiber optics work too. They're made of very tiny (about the size of a human hair) pieces of very pure glass, and transmit light because the light experiences total internal reflection.