Topics: Light, Color, Filters, Waves

Materials List

- ✓ A small box in which 2 windows can be cut that is several times longer than wide
- ✓ A round object with a diameter that is more that half the width of the box
- ✓ Polarizing filter material
- ✓ Dark paper or paint
- ✓ Tape
- ✓ Scissors
- ✓ Ruler

This activity can be used to teach:
Next Generation Science Standards:

- Light and vision (Grade 1, Physical Science 4-3, Grade 4, Physical Science 4-2)
- Waves: Amplitude, wavelength, energy (Grade 4, Physical Science 4-1)
- Waves are reflected, absorbed, or transmitted (Middle School, Physical Science 4-2)
- Science and Engineering Practices (Grades 3-12)

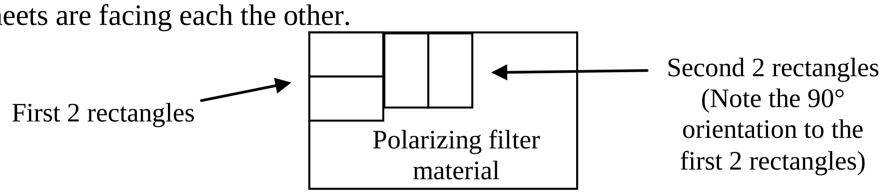
Polarizing Filter Illusion

The wall that never was!

Create a mystifying illusion based on polarized light that will fool the eye and engage students' curiosity and interest!

Assembly (Warning – do not look at the Sun through the polarizing material!)

1. Cut a rectangular opening into 2 opposing long sides of a thin cardboard box with edges that are, roughly, equally far from the surrounding sides. See above.
2. Cut 2 rectangles of polarizing filter material with the same orientation, see illustration below. Cut to a size that will overlap the top and bottom of an opening, but only a little wider than **half** the length of the opening, as above.
3. Attach each rectangle to a half of each opening, on the same end, so that the 2 sheets are facing each the other.



4. From the same polarizing material cut 2 rectangles with the same dimensions as in step 2, but cut **90° to the first 2 rectangles.** See the illustration above.
5. Attach the second set of rectangles over the remaining half of each opening.
6. The illusion will be more convincing if the interior of the box is a dark color or can be covered with dark paper or paint.

To Do and Notice

1. When looking through the polarizing filter covered openings does there appear to be an almost black wall down the middle of the box?
2. Place a round object, cylinder or sphere that can roll from end to end into the box.
3. Tilt the box to make the round object roll. Does the object pass through the wall?
4. If a pencil, hand, or other object is inserted into an opening in the end of the box, the object inserted will appear to pass unhindered through the "wall"!

The Science Behind the Activity

Light demonstrates both particle and wave properties. Ocean waves, until they break, essentially move up and down as they move forward. Light waves, however, can be moving up and down, sideways, and in every direction in between while moving forward. Light waves are sometimes modeled by shaking a rope back and forth so waves are created that travel along the rope. A polarizing filter is often modeled by imagining a rope running between the stakes in a picket fence. The fence (the filter) only allows waves going up and down, in line with the gap in the fence, to pass through. Waves made by shaking the rope side to side would be blocked by the stakes in the fence. While the model is correct, to an extent, the rope/fence model would appear to indicate that only a small fraction of the light waves, only a wave going exactly up and down, will pass through the filter, while the other 99+% of the light is blocked. That is clearly not the case as a polarizing filter seems to only slightly dim the image seen through the filter material. A light wave can be thought of as having

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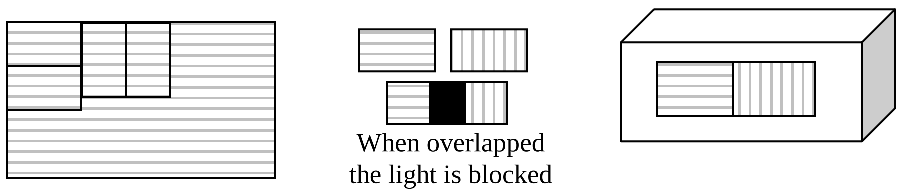
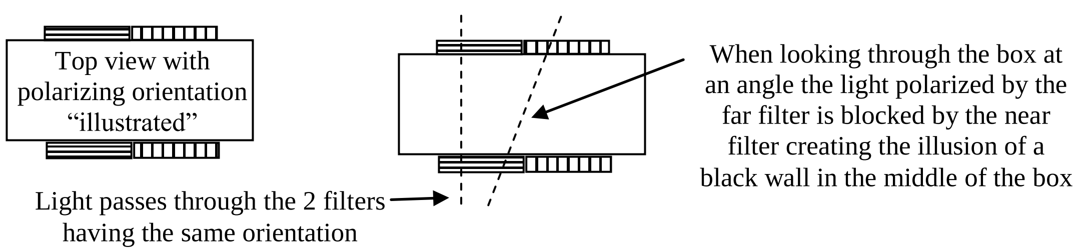
an up and down component and a sideways component that when added together create the specific orientation of the light wave. A light wave with only a sideways component would be fully blocked by the polarizing filter (the "fence") that is oriented to allow only up and down light waves to pass. The filter will absorb the light waves traveling sideways. For all of the other possible orientations of the light waves the sideways orientation would still be blocked but the up and down component of each wave would be able to pass through the filter. See **Web Resources** for additional details, illustrations, and more.

When two polarizing filters are overlapped and the polarizing orientations of one is oriented 90° to the other, one section allows only the sideways component (for example) of the light waves to past through while the second filter blocks the sideways components. The result is that, effectively, no light can pass through the area where the polarizing filters are overlapped. No polarizing filter material can absorb (or block) 100% of the light passing through the material. A small fraction of light having the "filtered" orientation will still be able to pass through.

The following illustrations have parallel lines added to indicate the invisible orientation of the polarized light when light passes through the material. Notice the left and right filter sections on the box opening are oriented 90° to each other.



The wall illusion, as illustration below, is due to the blocked light waves appearing as a dark/black area within the box. When viewed from different angles the dark rectangle is interpreted by the brain as a solid surface.



The web sites listed under **Web Resources** below contain much more detailed information plus graphics, animations, and interactive animations that will better explain what is happening when light is polarized. Additional information is also provided on the science behind polarized sunglasses and other polarizing experiments.

Taking it Further

See the RAFT idea sheet ***Color-Changing Disks*** for another polarizing filter activity.
Is a rainbow polarized?

Web Resources

(Visit www.raft.net/raft-idea?isid=560 for more resources!)

- Teacher information & activities – http://www.arborsci.com/CoolStuff/New_CoolStuff_Articles/cool28.aspx
- Interactive animations & more, for students – http://www.colorado.edu/physics/2000/polarization/index.html