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Main features

Big Picture Science

The Science Newsletter for Montessori Teachers of 6-15 yr-olds #16 Feb. 2001

Interactions of Light and Matter

All wavelengths have the same kinds of interactions

First students can use visible light to see the ways in which light and matter interact. Then they can go on to apply what they have learned to other wavelengths of electromagnetic radiation.

Light and its behavior are perennially fascinating subjects. We are very visual creatures, so we like studies of things that we can see. Students can learn about the interactions of electromagnetic radiation and matter, starting with studies that use visible light, and then moving to activities with the invisible wavelengths.

Part of the electromagnetic spectrum is too energetic to use in the classroom. Students won't be able to experiment with the gamma ray and X-ray wavelengths, but they can work with near ultraviolet (with appropriate eye protection – see page 8), infrared, microwave, and radio wavelengths.

The first step is to observe and catalog the interactions of visible light with matter. On page 3, you will find a flow chart that lists interactions of light and matter. Further discussion of these interactions and the characteristics of the matter starts on page 2.

Students need some equipment for these light studies. I've listed some useful items and a supplier on page 7. You will also need to provide a relatively dark area in which students can work. This can be as simple as a large cardboard box on its side or a table, covered with a tablecloth, that is tall enough for students to sit under. It does not have to be totally dark, just dark enough for a light beam to show up well on a piece of white paper.

For studies with infrared light (see page 7), you can use a remote control and a suitable target devise (CD player, TV, etc.). If the only thing you have is a TV monitor, make sure it is set to a channel with no broadcast or disconnected from the antenna or cable to avoid classroom distractions. The students can observe how the invisible beam of the "remote" turns the sound off and on. Then they can place various materials between the remote and the detector. They will be able to tell opaque, transparent, and translucent materials for the infrared wavelengths used in remote controls.

Some of the activities I describe are basic, good for 6-9 year-olds. If older children have not done the basic activities, they should observe them at least briefly before moving on to more advanced activities.

Light is indeed a huge subject. In spite of running over to 8 pages, I ran out of room to address optics, the refraction of light that we use for eyeglasses, microscopes, cameras, and some telescopes. That will have to wait for a future issue. ❖

Big Picture News

The past few months have been a busy time for me. I have been working on an update for botany studies. I am pleased to offer you a current and, I hope, stimulating view of botany. Shortly I will be publishing a (real!) book entitled ***Plant Lessons: Introducing Children to Plant Form and Function***. It will have about 90 pages, illustrations, and will come in a three-ring binder.

As another first, I am offering the book on CD-ROM (in pdf format) as well as the printed version.

If you would like to pre-order this book, send me your name and shipping address along with $35 for the printed version or $20 for the CD-ROM. I expect to start shipping by May 1.
Thanks!

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Light Meets Matter and Lots of Things Can Happen

Take a few minutes to look at the diagram on page 3. It shows the main interactions that occur when light meets matter. The number codes in the boxes appear below with further descriptions. Remember that it is very rare for matter to have only one type of interaction with light. In almost all instances, there are multiple interactions going on at the same time.

Matter absorbs light (1). When a ray of light enters a material and transfers its energy to the material, we say that it has been absorbed. The oscillations of electrical and magnetic fields that constitute a light ray are gone. The atoms of the material may react in a number of ways, depending on what kind of atoms there are and how they are arranged or bonded to one another.

Heating up (2). When light is absorbed and the energy simply makes the atoms vibrate or move more rapidly, the material heats up. Some heating occurs in all interactions of light and matter, since energy is lost as a consequence of the second law of thermodynamics. Students can readily relate to the transformation of light to heat if they have worn dark clothing on a sunny day.

A light-to-heat experiment. Students can experiment with steel food cans that have been painted various colors. Save several identical cans and make sure that there are no sharp points of metal at the openings. Paint one can glossy white and another flat black. For the others, you can use whatever other colors you have available or that students want to try. Use a graduated cylinder or other accurate measuring devise to add the same volume of water to each can. Arrange the cans so that they are all in full sunlight. At intervals, measure and record the temperature of the water in each can. You will get a more accurate reading if you stir the water before you take its temperature. You will have to experiment with the time intervals, since the rate of heating will depend on the water volume and on air temperature.

Boosting electrons. If the wavelength of light is short enough – if there is enough energy per photon – the light energy may boost outer electrons of atoms in the material to a higher orbital or even knock them free of the atom. There has to be enough energy to push the electrons all the way to the next orbital or free them entirely. Electrons can't hang around between energy levels. The light that is needed differs from atom to atom and from molecule to molecule. Once the electron has taken on the energy and moved further from the atom's nucleus, it may cause a variety of changes depending on the nature of the material.

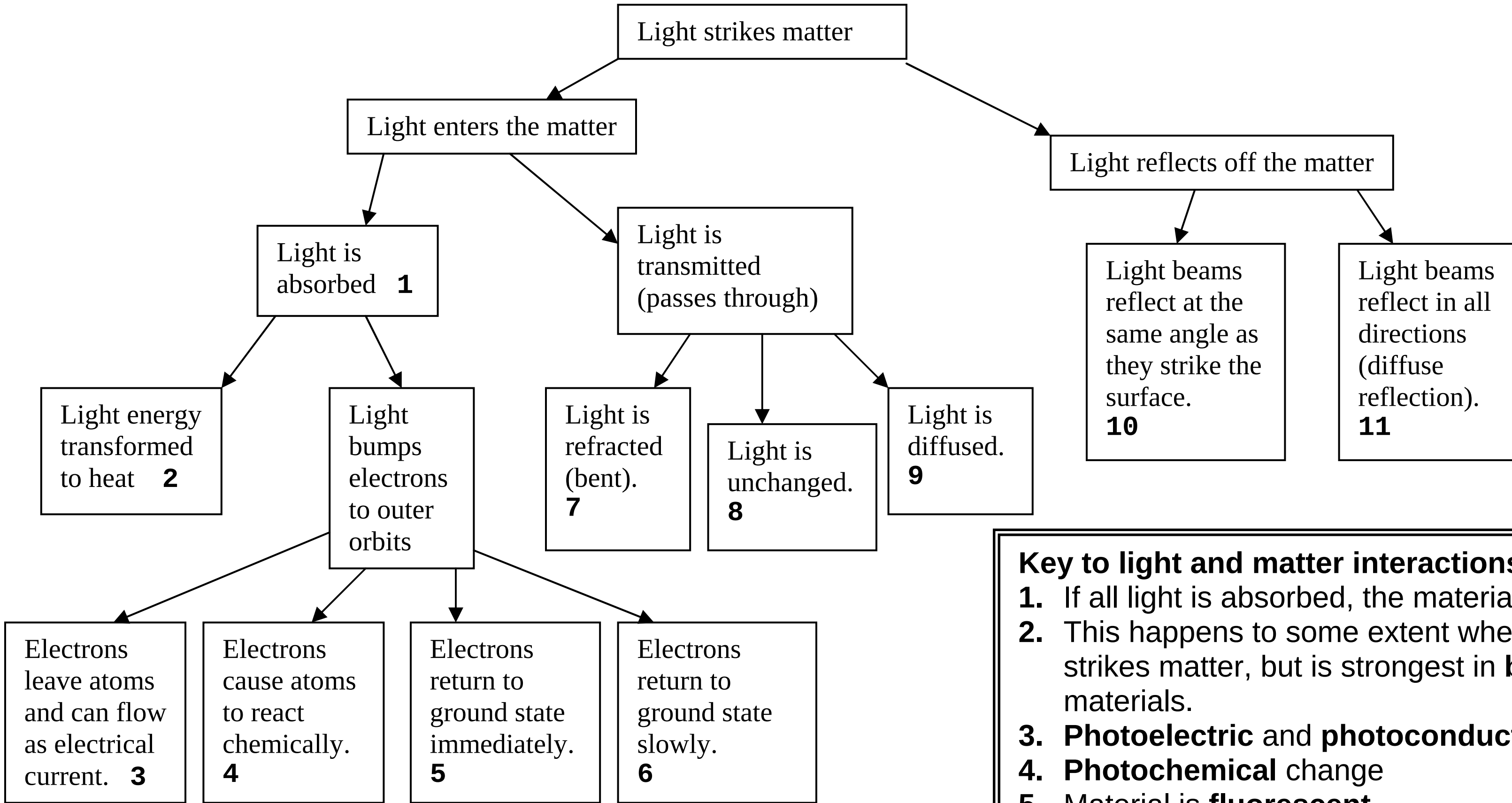
Photoelectric effect (3). In metals, some metalloids, and some other molecules, light causes electrons to leave the atoms and flow as electrical current. Light can also cause materials to conduct more easily, a phenomenon called photoconductivity. We use materials that have a photoelectric effect in a wide variety of applications. They are part of electric eyes, light meters for photography, photocopiers, and light detection systems in devices such as CD players and drives, infrared remote receivers, and digital cameras. Photovoltaic cells use silicon with small amounts of arsenic and boron to generate electrical current from light. You can find information about how many of these devices work in an encyclopedia or in a "how things work" type book or website.

Photochemical changes (4). Light energy can transfer to electrons and produce chemical changes in materials. All film photography depends on this phenomenon. In black and white photography, the light causes a silver compound to break down and release free silver atoms. These show up on the negative as the black areas. When colors fade in sunlight, the dye molecules undergo photochemical changes that cause them to decompose. A most important photochemical change happens when the pigment chlorophyll absorbs sunlight. The light energy causes an electron to become energized and starts the process of photosynthesis. In our eyes, light strikes a molecule called rhodopsin in the rod cells of our retinas. The energy causes the rhodopsin to change shape, which triggers changes in the membrane that send a signal through an adjacent neuron and, after all that, we see light.

The next two changes are part of a larger category, **luminescence,** which is the emission of light caused forms of energy other than heat. (In comparison, light produced when materials are heated is incandescent light.) It is sometimes called cold light. Beams of electrons can cause luminescence. So can compressing some types of crystals – seen when you crush a wintergreen lifesaver in the dark and see flashes. Fireflies show bioluminescence, the production of light by chemical reactions in living organisms.

Fluorescence (5). In some materials, electrons that light boosts to a higher energy level fall back immediately and release the energy as photons of light. The light the material gives off has a longer wavelength (less energy per photon) than the light that boosted the electrons. Fluorescent minerals show this property. If you shine an ultraviolet light on them, they glow with light in the visible range. This shift to a longer wavelength happens because energy is always lost in the process, so you can't get out light (continued on page 4)

What happens when light strikes matter? There are several possibilities. All or part of them can happen.



Key to light and matter interactions diagram

1. If all light is absorbed, the material is **opaque.**
2. This happens to some extent whenever light strikes matter, but is strongest in **black** materials.
3. **Photoelectric** and **photoconductive** effects
4. **Photochemical** change
5. Material is **fluorescent.**
6. Material is **phosphorescent.**
7. This happens whenever light passes between two materials with **different refractive indices**.
8. Material is **transparent.**
9. Material is **translucent.**
10. **Mirror** surface
11. Surface of any **object we can see** that is not highly polished.

Some specialized materials and their interactions with light

Polarizing materials allow only light waves that are oriented in one plane to pass.

Photochromic materials change color when light shines on them.

Diffraction gratings have many tiny parallel lines. Light is disbursed into a rainbow when it passes through and is diffracted.

Fiber-optic materials

Light Meets Matter, cont.

with as much energy as you put in. Fluorescent colors like you might see on poster board absorb ultraviolet light and emit in the visible range. Optical brighteners in laundry products do this as well. Fluorescent lights have a small amount of mercury vapor inside. The electrical current ionizes the mercury atoms and they give off ultraviolet light. It strikes the coating inside the glass tube, called the phosphor, which fluoresces. The glass tube absorbs any extra UV light. The color of the light depends on the phosphors used to coat the tube.

Phosphorescence (6). (from Greek, means "light carrier") The electrons that are boosted to a higher energy level take some time to return to their ground state in phosphorescent materials. Children have seen this property in "glow-in-the-dark" materials. Note that the visible light most of them give off is the same greenish color. This says that the electrons drop the same amount of energy as they return to the ground state.

Matter that transmits light. Materials usually transmit some light, depending on the material and its thickness. Light will even pass through gold leaf, even though thicker pieces of the metal block it very effectively. There are three main categories of materials with respect to transmission of light. "**Transparent**" means "to show through", and that is what images do through transparent materials **(7).** The light rays pass through without change, except that a few are absorbed. If the material is colored, then it is transparent to only some wavelengths and it absorbs others. "**Translucent**" means "to shine through". Light travels through translucent material **(8)**, but the rays are scattered and the image is lost or blurred. "**Opaque**" comes from a Latin word for dark, and these materials transmit no light (**1)**. Students can gain further insight about transparent and translucent materials if they look at samples of each with a hand lens (5-10X) or dissecting microscope (about 20X). In translucent filters, there are many of textures that scatter light.

Students may wonder about **translucent liquids**, such as dilute milk. Whenever a solution is transparent, it contains only ions or molecules that are smaller than 1 nanometer across. If the particles are 1-1000 nanometers across, they won't settle out by the pull of gravity. They will, however, scatter a beam of light and you can see the beam shining through the liquid. You can show this with gelatin. Just shine a flashlight through a solution or solid gelatin (in a darkened room). Particles that behave like this are called colloids. As particles get larger, they scatter light even better and, instead of a solution, you have a suspension. When a microbiologist places bacteria in a test tube of broth, she can tell that they have grown when the broth gets cloudy. The bacteria (1000-3000 nanometers across) are scattering the light and making the broth translucent. (It takes about a million bacteria per milliliter to do this!) The tiny water droplets of fog similarly scatter light and make the atmosphere translucent. Milk has tiny protein clusters that reflect light.

When light passes from one transparent medium to another, it may be **refracted (9).** This word means "break against" and refers to the bend in the light beam's path. When the two materials have exactly the same refractive index the light beam does not bend. The bending happens because light moves at different speeds in different media. The speed of light that is commonly given (186,000 miles per second) is its speed in a vacuum, where nothing slows it. As you might think, light travels at the same speed in materials with the same refractive indices. There are various analogies to explain this bending. See the reference books for more information and many demonstrations of refraction. All lenses work by refracting light. I will save the topic of lenses for a future newsletter – and try to finish what I have started here. (Continued on page 5.)

Classifying types of light transmission.

This activity will help students mentally picture what happens when invisible wavelengths pass through materials.

Materials: Transparent materials (such as a glass microscope slide or a clear plastic lid – these can be colored, but they can't diffuse the light.)

Translucent materials (such as the frosted end of a microscope slide, wax paper, or plastic from a milk carton). The set of 100 colored filters from Edmund Scientifics (see p. 6) may have translucent filters included (check for filter numbers 100-160; what is included in each set has varied at times).

Opaque materials (such as poster board, aluminum foil or other metals).

A light source (such as a lamp, a flashlight, or light coming through a window).

The student looks through the material at the light source and records if the image is visible and if so, if the details of the image are clear. Then she/he lays the material on a printed page and slowly lifts it. The print will remain readable through the transparent materials. The print is readable through thin sheets of a translucent material that lies directly on the text, but the letters quickly blur as the observer lifts the material off the page. The student records her observations and states whether the material is transparent, translucent, or opaque. Give lower elementary students a container of materials to classify.

More Light Meets Matter – Reflection

When light does NOT enter a material, it **reflects** - bounces off the outside. It would be impossible for us to see an object that reflects no light at all. We all know about reflections in mirrors. There we see a clear image, but we don't see an image reflected from most objects. Since they both reflect light, what is the difference? It lies in the smoothness of the surface. A mirror has a very smooth surface. The light rays that strike it all bounce off at the same angle they strike, preserving the image. Light that bounces off ordinary objects gets scattered in all directions by the roughness of the surface. We call this "diffuse reflection" because the rays are scattered. See the experiment books listed on page 8 for activities with reflection. Don't forget to provide a hand lens (10X) or dissecting microscope so that students can look at mirrors and compare their surfaces to those of a white card or other non-reflective material.

Note that **there must be some reflection from a light beam before we can see it**. When you shine a beam of light in water, you need to add a little milk to see the path of the beam. Reflection from smoke or dust particles allows you to see a beam of light in air, so one experiment book suggests lighting an incense stick near experiments.

Reflection study is an exercise in geometry. One "must do" activity is a demonstration to show that **the angle of incidence is equal to the angle of reflection**. You need a way to produce a single beam of light to follow what happens. You can make a ray box (see books) or buy one (see p.6). You can even tape cardboard with a slit over a flashlight. Delta Education (1-800-442-5444) offers the Osmiroid light box.

Students enjoy reflection activities with curved mirrors. Show them how to project a real image with a magnifying mirror, which has a concave surface. (The image you see in a flat mirror is a virtual image. You can't touch it or project it onto a surface because it is formed in your brain. You can project a real image.) If you stand in front of window and hold the mirror so that it faces the window and reflects an image below the window on the wall, you can move the mirror back and forth until you have focused an upside down image of the scene outside.

Light Meets Special Kinds of Matter

So far I have been discussing the interactions of light with ordinary objects. There are several engineered materials that have unusual interactions with light. Here are some of them.

Photochromic materials turn darker when light shines on them and lighten when they are in more dimly lit places. They are used to make combination sunglasses and indoor eyeglasses. Photochromic materials have a special type of photochemical reaction. For an explanation of how they work, see Amato's book, *Stuff*.

Diffraction gratings bend light in a different way than refraction. These materials have many (500-1000 or more per millimeter!) tiny parallel grooves. As light passes through them, the light waves bend. The red wavelengths bend more than the blue wavelengths and the light disperses into a spectrum. Whenever a wave passes through an opening that is small compared to the wavelength, it spreads out (diffracts). You can find a diagram of this in World Book or another encyclopedia. Diffraction gratings are used in scientific instruments to separate light into wavelengths. You see a spectrum when light reflects and diffracts off a CD disk.

Fiber-optic materials use a special type of reflection to carry light over long distances and around curves. If a light beam strikes the boundary between two materials, it can be refracted (bent) and reflected. If the angle of the light is right and the refractive index of the second material is less than the first, the light will all be reflected. This is called total internal reflection. See the *Optics Book* and *Light Action*, chapter 6, for demonstrations. Fiber-optic cables transmit light signals just like copper wires transmit electrical ones. They are used in medical instruments and communications. Your students will enjoy working with fiber optics – see page 7 for ordering information.

Polarizing materials are special kinds of filters. They pass only light waves that are vibrating in one plane. With one filter, things look a bit darker. If you have two polarizing filters and you look through them as you rotate one, there will be a position where the filters look very dark, nearly black. This is the "crossed polars" position. You have rotated the filters until the planes in which they transmit waves are at right angles. If you insert test objects between the two filters, and if the test objects rotate polarized light, you will see colors coming through the two filters. This is how the polarized light microscopes that image minerals and crystals work. They have a polarizing filter above and below the specimen. The crystals rotate the polarized light and appear in brilliant colors. Your students will enjoy seeing this effect. You can order polarizing materials (See p. 7.) or use polarizing lenses from sunglasses. The *Optic Book*, *Light Action*, and the *Magic Wand* have activities with polarizing filters. Materials that you can place between crossed polars to see colors include cellophane packaging, acrylic lenses, and clear plastic forks.

Why don't microwaves come through the holes in the microwave oven door?

In the infrared light experiment on page 7, students see that IR won't pass through two or more layers of metal screening. They may have wondered why there can be holes in the door of the microwave oven that allow visible light through, but apparently are opaque to microwaves. Here's one more demonstration and an explanation.

You need a small radio. I use a pocket-sized weather-band radio, available at Radio Shack stores, which has the advantage of not distracting with music. You also need a cylinder of aluminum foil that will fit over the radio when its antenna is extended about 4 inches or less. Turn on the radio and have it picking up some signal, even if it isn't getting full reception. Set it on a level surface, but don't touch it, since your body will act as an antenna and spoil the demonstration. Lower the aluminum foil to cover the radio and you should block the signal entirely. (If you can't block it, try another radio or adjust the antenna.) Next, lower a cylinder of aluminum window screening over the radio. It, too, should block the signal. For the grand finale, lower a cylinder of chicken wire or other large mesh wire over the radio. It also blocks the signal. By now the students will want to know what is going on.

When an electromagnetic wave strikes the metal, it causes the electrons to move. If the holes in the metal mesh are smaller than the wavelength of the radiation, the electron movement around the hole sets up a counter field that causes the electromagnetic wave to reflect, just like a solid metal surface reflects light. For more information, see the microwave section of Louis Bloomfield's website, How Things Work, http://rabi.phys.virginia.edu/HTW/

The key is that the holes must be smaller across than the wavelength of the electromagnetic radiation. We don't see metal with holes blocking visible light, because the holes would be so small that it would take an electron microscope to see them. Now you know why satellite dishes can be made of mesh instead of solid metal and why microwaves (about 12 cm wavelength) don't pass through the small holes in the metal mesh in the oven door.

The remote entry system for cars and garage door openers use radio waves, but I have been unable to develop a blocking demonstration with wire mesh. I think this is because the radio waves can travel through your body. Have you noticed that the keyless entry button for your car works as well behind you as in front of you?

Materials to purchase for experiments with light and matter.

From Edmund Scientifics (1-800-728-6999 or www.scientificsonline.com). Prices are approximate:

Optics discovery kit – #CR39-140. This kit includes a number of useful items such as polarizing filters, optical fiber, and a diffraction grating, as well as acrylic lenses and ideas for what to do with it all. $15

Colored and translucent filters – Book of 100 different filters - #CR39-417. This set of filters included a variety of translucent filters when I ordered it a few months ago. $8

Mira – transparent mirror - #CR81-730. This plastic mirror allows easy tracking of light rays and is good for symmetry exercises. It shows the combination of transparency and reflection. $5

Polarizing disks (set of two) with protective mounting - #CR38-605. These disks have the polarizing filters mounted between layers of glass. Their diameter is about 10 cm. $30

Polarizing filters, experimental quality - #CR37-349. These 7 X 7 ½ inch sheets are $7 each.

Fiber optic light wand - #CR31-771. This has a bunch of optical fibers mounted at the end of a flashlight. In a dark room, you can see how the fibers carry the light. It has been used as an impressionistic model of the electrons around an atom – twirl it to see this effect. $5

Lucite rod - #CR36-863. This shows light transmission by internal reflection. It carries light around a curve. $25

Ray box - #CR38-597. This is a battery-operated ray box that would work well in reflection studies. It comes with some lenses as well. $45.

What about UV photography? While UV photography doesn't require a special film (a slow speed black and white one is fine), it does require some special lenses. Modern multi-coated lenses block it. You need an older camera with uncoated or single coated lenses. The professionals use expensive quartz lenses. The camera doesn't focus UV in the same setting as it does visible light and the light meter won't work. Those pictures of the UV absorbing areas on flowers aren't as easy to get as you might think.

Experimenting with infrared light

In this exercise, students determine what materials are transparent, translucent, and opaque to infrared light.

Materials: an electronic device with a remote control (see page 1 for suggestions); a measuring tape that is about 20 ft. long; materials to test, including some of the following. Styrofoam, paper, colored (opaque) plastic object, aluminum screening like you would use for a screen door – provide several squares about 4" or 10 cm on a side, a drinking glass filled with water, blue food color, aluminum foil, brown glass objects. Invite students to test other materials that they find in the classroom or bring from home (within limits of common sense, of course).

What you do. Place the electronic device at the end of a long hall if possible. There needs to be some distance between the receiver and the control. Try the control and see how far away you can get and still turn the devise off and on. This is analogous to shining a flashlight across a room. At some point the light gets too dim to trigger a photocell or work a light powered calculator. (This might be a good time to introduce the inverse squared law if you haven't already. See the references on p. 8 for help.) When you have the farthest distance or you are as far away as the room or hall allows, measure the distance. You will use this measurement to determine how much the materials have decreased the intensity of the infrared light that comes from the control.

For younger students, you may wish to do a more qualitative experiment and just see if the material blocks the infrared beam when you stand 10 feet away and one foot away. Some materials will block at 10 feet, but not at one foot.

Stand near the farthest limit that your control works. Hold a test material in front of the control and press the button to see if the infrared beam reaches the receiver. If it does not, step closer and try again. Record the type of material and the farthest distance to the receiver that the control works. Nothing but air between the control and the devise is the control for this experiment. Leave space to note whether the materials are transparent, translucent, or opaque to infrared.

For the glass of water, record the distance from the receiver that the control works when you shine it through plain water, then add a generous amount of blue food coloring and try again. The distance was about the same when I tried this, showing that the food color is largely transparent to infrared.

For the screening, try shining the control through one thickness of screen. Then add a second and third layer, with the squares not aligned, so that the holes are effectively smaller. The smaller holes should block the IR beam. For an explanation, see page 6. For paper, see how many layers it takes to stop the beam.

Evaluating the results. It may help students see what is happening if they shine a Mini-Mag light or other small flashlight through transparent and translucent materials and observe what happens to the light. They will see that materials that diffuse the light – translucent materials – cut the intensity of the beam so that it only shines a short distance. For each material they tested with the IR control, the students should state whether it is transparent (the control works at the maximum distance), translucent (control works only if closer), or opaque to infrared.

Advanced students may wish to do more mathematical work. They can determine the thickness of styrofoam, for instance, that cuts the intensity of the infrared beam to one fourth its original strength. That's what it would be you had to stand half the distance to the receiver to switch it when the styrofoam is in front of the beam. They may wish to determine what fraction of the IR beam's intensity each material has absorbed.

What you should see: I found that most materials transmitted some IR. The only total blockers were aluminum foil (I think any solid metal should block), two or more thicknesses of aluminum screening, and a brown glass bottle.

More fun. Let students address more questions. Can you bounce the infrared beam off a mirror? Try your set-up with visible light first to see if you have the mirror aligned properly. Can you pass the infrared beam through a prism? How does it effect the beam?

Infrared photography gives a really different view of the world. Show your students black and white photographs that have been taken on infrared film. You can find these in photography books or references such as the manual I list on page 8. The sky appears dark, and foliage is white in these pictures. Ask students to describe why things appear as they do. They should answer in terms of IR transmission and reflection. Color IR photos are harder to understand because they are false color, so stick with black and white at least at the beginning. If you want to take your own IR photos, try a digital camera with a filter that excludes visible light. The filter you need is #87. The camera will record IR without the filter, but visible wavelengths may hide the effect. If you take a picture of the remote control as someone pushes a button, you can tell if your camera is imaging the IR. You should image a flash of light from the control.

Resources for studying interactions of light and matter

Dewey decimal numbers: Light – 535 and thereabouts; Infrared photography – 778.34.

Books

Amato, Ivan. 1997. ***Stuff: The Materials the World is Made of.*** Avon Books. ISBN 0-380-73153-3. More information about photochromic glass and a myriad of other materials. MS-adult.

Cobb, Vicki and Josh Cobb. 1993. ***Light Action: Amazing Experiments with Optics***. Harper Collins. ISBN 0-06-021437-6. A great collection of light experiments of all kinds. Just don't use paint thinner for the refractive index activity "Lose a glass in a glass" – there are safer alternatives. LE-UE

Day, Trevor. 1998. ***Light***. Science Projects series. Raintree Steck-Vaughn Publishers. ISBN 0-8172-4943-5. This includes how to make a ray box and explorations with reflection and refraction. LE-UE.

Doherty, Paul and Don Rathjen. 1995. ***The Magic Wand and Other Bright Experiments on Light and Color.*** Exploratorium Snackbook Series. John Wiley & Sons, Inc. ISBN 0-471-11515-0. There are good activities with polarized light, critical angle, and Fresnel lenses. LE-UE

Gardner, Robert. 1995. ***Experiments with Light and Mirrors***. Enslow Publishers. ISBN 0-89490-668-2. A good listing of activities on reflection and other light phenomena. LE-UE

Lauber, Patricia. 1994. ***What Do You See and How Do You See It? Exploring light, color, and vision***. Crown Publishers, Inc. ISBN 0-517-59390-4. Has a good explanation of diffuse reflection and pictures taken with IR. LE

Levine, Shar and Leslie Johnstone. 1998. ***The Optics Book: Fun Experiments with Light, Vision & Color***. Sterling Publishing Co., Inc. ISBN 0-8069-9947-0. Another collection of activities. LE-UE

Tomecek, Steve. 1995. ***Bouncing and Bending Light***. Phantastic Physical Phenomena series. W. H. Freeman & Co. ISBN 0-7167-6541-1. Children will enjoy this lively view of light and the history of its study. LE-UE

White, Laurie. 1996. ***Infrared Photography Handbook***. Amherst Media, Inc. ISBN 0-936262-38-9. This book has all the technical details if you are interested. It offers a variety of infrared photographs that will help your students see what absorbs and reflects near infrared wavelengths.

Internet resources

There is a great website from University of Colorado called Physics 2000: http://www.colorado.edu/physics/2000/cover.html

Photoelectric effect: http://www.colorado.edu/physics/2000/quantumzone/photoelectric.html

The polarizing filters page lets you rotate filters and see what effect this has on light transmission: http://www.colorado.edu/physics/2000/polarization/index.html

Compton's online encyclopedia on photoelectric devices: http://www.comptons.com/encyclopedia/ARTICLES/0125/01439232_A.html

Information about UV light and children's eyes: http://www.tsbvi.edu/Outreach/seehear/fall99/ultraviolet.htm

What about experiments with ultraviolet light?

Before you do anything in the classroom with UV light, **make sure you have the right safety glasses to protect children's eyes**. Polycarbonate safety glasses or goggles are what you need. You can buy them from many scientific suppliers. Carolina (1-800-334-551) has child-sized safety spectacles, order #CE-64-6713, for $2.50. Consult an ophthalmologist for further information. The website above has more information.

With eye safety addressed, your students will enjoy seeing minerals fluoresce under a "black light". They can also look for optical brighteners in laundry products. When you have a mineral or other object that fluoresces under UV, you can try a variety of materials to see if they effect the transmission of UV light, like you did with the IR experiment. Use long wavelength UV when possible. Germicidal lamps should not be in a classroom – they are far too damaging.

Children may have experienced a photochemical reaction with UV light at the dentist's office. The special materials that are used as protective coatings on teeth are often "cured" (solidified) with UV light. There are many industrial adhesives that solidify with UV exposure.