Sensing the Invisible — Teacher Notes

3.1 What's This About?

Just as our ears cannot hear all wavelengths of sound, our eyes cannot see all wavelengths of light. Students build a photocell detector, and use it to detect different colors of light in a spectrum. Then they place the detector just outside the red region of the spectrum and see that the detector detects the presence of light there, even though there is no color visible. Students learn that "invisible light" exists and that we can detect this light with instruments other than our eyes. In a final part of the activity, students investigate the IR signals emitted by TV and VCR remote controls.

Suggested Grade Levels
7-12

Suggested Time Required
50 minutes

Suggested Learning Outcomes
After completing this activity, students will be able to:
- Describe a method for observing light using a photocell detector.
- Predict the color of light transmitted through a gel.
- Identify the infrared as a form of invisible light that is located next to the color red in the visible spectrum.

Student Prerequisites
- Students are assumed to be familiar with the visible spectrum and to have some knowledge of the electromagnetic spectrum, and how it relates to the visible spectrum.
- This activity assumes some familiarity assembling and working with electronic circuits.

The Activity

This activity assumes that students work with the materials in small groups. This requires the purchase of enough materials for each group to make their own photocell detector, in addition to each group needing its own overhead or slide projector. This activity can also be done as a teacher-led demonstration, with the teacher manipulating only one photocell detector and using only one overhead projector, or set up as an experimental station in the classroom.

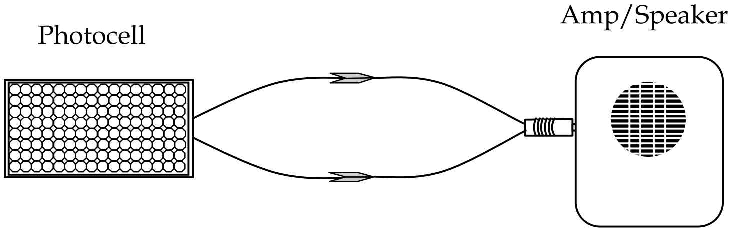
SOFIA SCIENCE

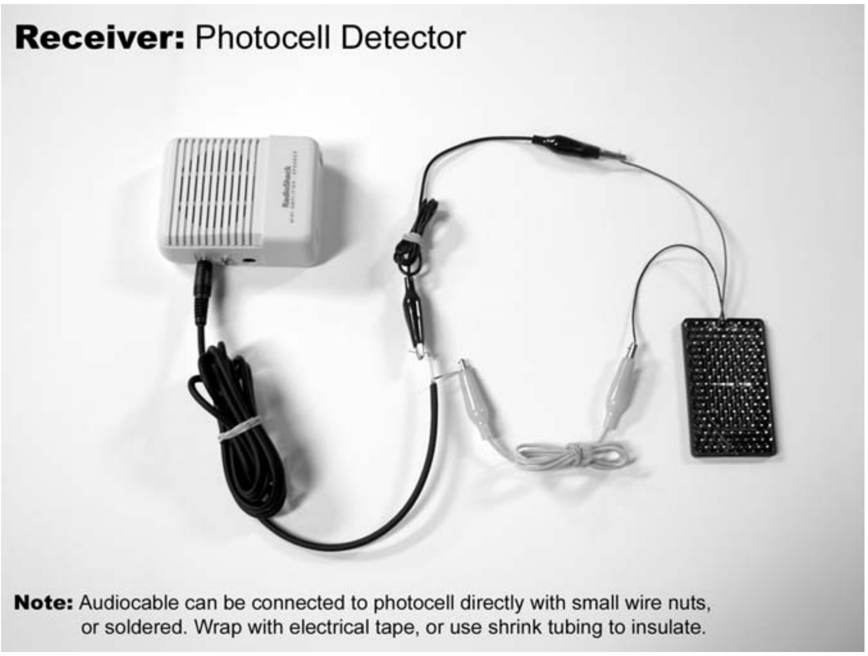
Flying at 41,000 feet, SOFIA will be above 99% of our atmosphere's obscuring water vapor that absorbs infrared radiation from the universe. The crew works in a commercial airliner environment for 8 or 9 hours at a time.

Part I - Hearing Light: *Students will use a detector to hear the presence of light.*

Since we cannot see infrared light, we must detect it with another of our senses. This activity leads students to "hear" infrared radiation via a photocell and speaker.. Students first consider how to tell, while blindfolded, if a cow is standing in a gym. Instead of the cow analogy, the instructor could also bring objects that have distinctive sounds and smells into the classroom and ask the students to close their eyes and identify them. Students then build a simple photocell detector, and see what happens when they move their hand back and forth in front of it. This same photocell detector is also used in the “Listening to Light” activity.

The photocell (or solar cell), connected as shown below, produces an electric current when exposed to light. Because of the way speakers are constructed, a changing current is needed to produce a sound in the speaker; a constant current will not produce a sound. When a constant light source illuminates the photocell, it produces a constant current and no sound is produced. Students should hear static, if anything, when a constant light source illuminates the photocell. When the light is continuously interrupted, or “chopped”, the current produced will continuously change and the speaker will produce a series of “pops” each time the light is chopped back on. NOTE: For best results, turn off any overhead fluorescent lights in the classroom. Fluorescent lights will generate a constant hum , which may interfere with students’ hearing sound from the visible spectrum.




Receiver: Photocell Detector

Note: Audiocable can be connected to photocell directly with small wire nuts, or soldered. Wrap with electrical tape, or use shrink tubing to insulate.

To make the photocell detector, use jumper cables to connect the photocell with the amplifier/speaker (requires a 9 volt battery). Clip one alligator clip from a jumper cable to one of the leads from the photocell, and clip the alligator clip at the other end of the jumper cable to one of the leads of the audio cable (which has its 1/8” mini-plug plugged into the “input” of the amp/speaker). Use a second jumper cable to connect the other lead from the photocell to the other lead of the audio cable.

This works best if you use an audio cable with a mini-plug on one end, and two exposed wire leads on the other. You can also use an audio cable with a mini-plug on both ends. In this case, connect the alligator clip from one jumper cable near the end of the mini-plug, and connect the alligator clip from the other jumper cable near the base of the mini-plug (next to the plastic piece that protects the rest of the audio cable). Be sure both alligator clips are in contact with metal parts of the mini-plug, and that they do not touch one another. Note that a Y-Adaptor Audio Cable will not work in this activity.

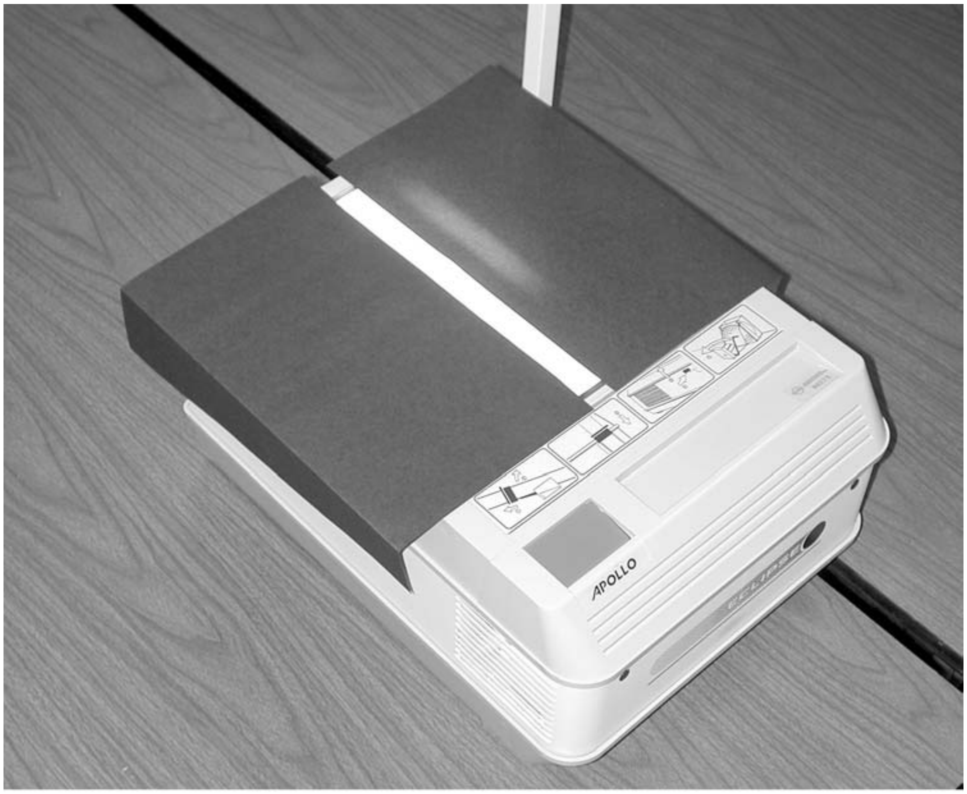
The chopper can be as simple as someone moving their hand back and forth in the beam of light, or as complicated as a fan placed in the light beam either before or after the diffraction grating. Since the chopper is required for so much of this activity, a fan is recommended. Be sure the fan used has spaces between the blades, to allow light to shine periodically through the fan.

Part II - The Visible Spectrum:

Students predict what portions of the spectrum are blocked by colored filters and then test their predictions. They recognize that some colors are not primary, but are the addition of several primary colors.

We recommend using a holographic diffraction grating to produce a visible spectrum using light from a slide projector or overhead projector. A holographic diffraction grating will produce a brighter, more spread out, color spectrum that students will find easier to use. A prism placed in a light beam will also produce a visible spectrum, but it will tend to be fainter, with the colors less dispersed, which makes it harder for students to make their measurements.

There are two ways you can generate a spectrum with a diffraction grating: with an overhead projector or a slide projector. If you use an overhead projector, place two pieces of 8” x 10” construction paper on the overhead, instead of a transparency, so that there is a slit about 1” wide on the base plate of the projector. Turn on the projector lamp and focus the projector on a white wall or screen. Place the diffraction grating (about 4 or 5 inches square) in front of the upper lens of the overhead, and rotate the grating until the spectrum appears on either side of the projected slit on the wall or screen. Note that this works best in a very dark room. You can place a fan in front of the diffraction grating to act as a chopper, or wave your hand back and forth.

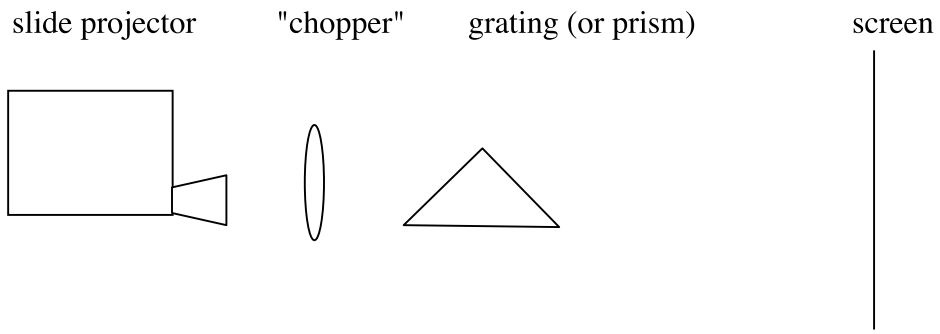


Overhead projector set up for EM spectrum projection using black construction paper. Slit width can be adjusted for best projection of visible and IR radiation. Recommended width is approximately 2.5cm.

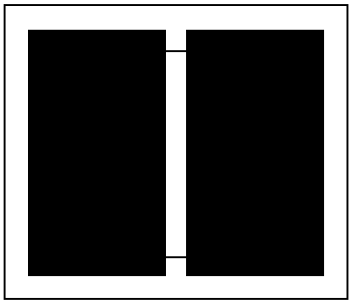
Overhead Projector Head with Holographic Grating attached

Note: The holographic grating is available pre-mounted between glass panes. This may reduce IR transmission.

Alternative method: *NOTE: Using a prism produces much narrower dispersion than using the holographic spectrum grating, and makes the experiments harder to conduct. It is included in the event that you do not have access to a holographic grating.* A slide projector can also be used to generate the spectrum as shown in the figure below.



The regular beam from a slide projector is too broad to generate a good spectrum. To limit the beam, you can make a slide using common undeveloped photographic film or pieces of black electrical tape. Mount two pieces of undeveloped film in a slide mount with a space between them, as shown in the figure below, to produce a line of light.



Place the slide with the mounted film in it in the projector, and turn on the projector's lamp. The slide should make a white vertical line on the screen or wall. Focus the projector. Place the diffraction grating in front of the projector lens. Rotate the grating until the spectrum appears on either side of the white line on the screen or wall. *Note that this works best in a very dark room.*

Once the spectrum is visible on a screen or wall where you want it, tell students not to move the projector and diffraction grating (or prism). When placing a gel into the beam of light, have students hold the gel between the diffraction grating and the screen or wall where the spectrum is displayed. It works best if they hold the gel close to the grating, so all of the light from the projector passes through the gel.

Theatrical gels are readily available from any theater supply store or can be ordered directly from the manufacturer (for more information, see the Materials Needed section below). We use the word "gel" instead of "filter" because filter can cause confusion. Some students may think that a red filter takes out the red, while others may feel that a red filter would allow only red to go through. It is clear from this activity that a red gel allows red to pass through while absorbing the other colors of the visible spectrum. Students will also see that a green gel allows some blue and yellow light to pass through it, in addition to the green. This is proof that green is not a primary color, like red, blue and yellow. *Note that theatrical gels are required for this activity; colored cellophane works poorly or not at all.*

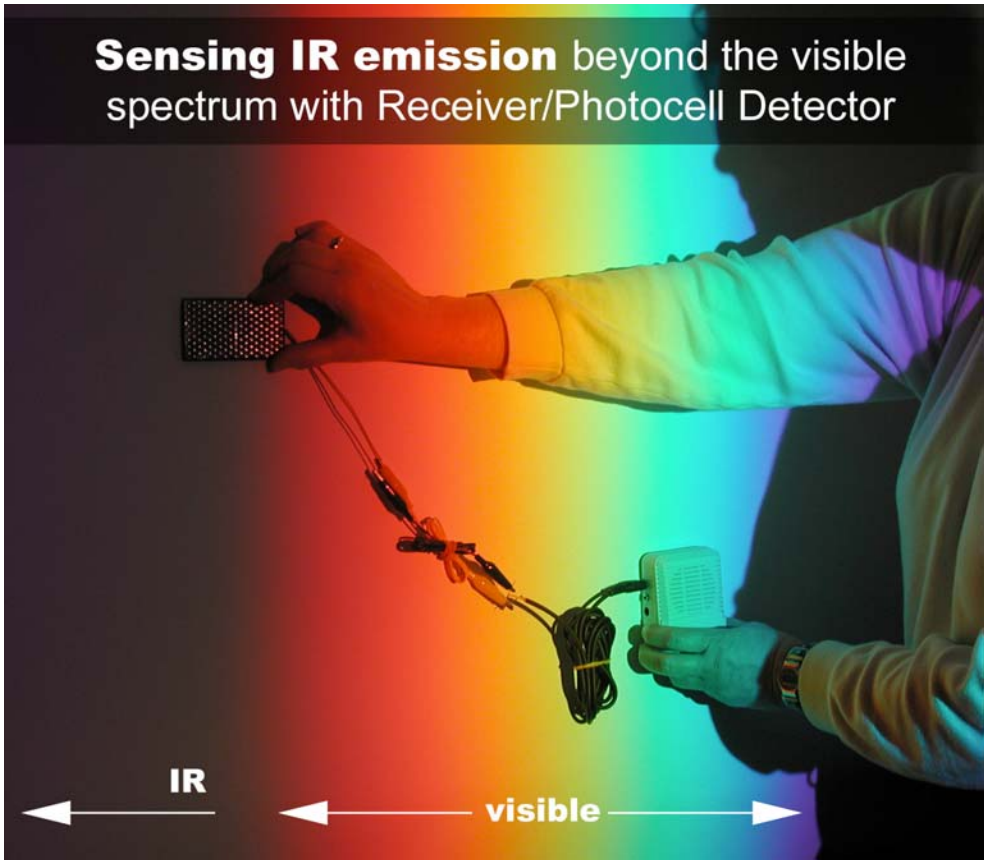
Part III - Where is the End of the Rainbow? *Students find that radiation exists beyond the red portion of the spectrum.*

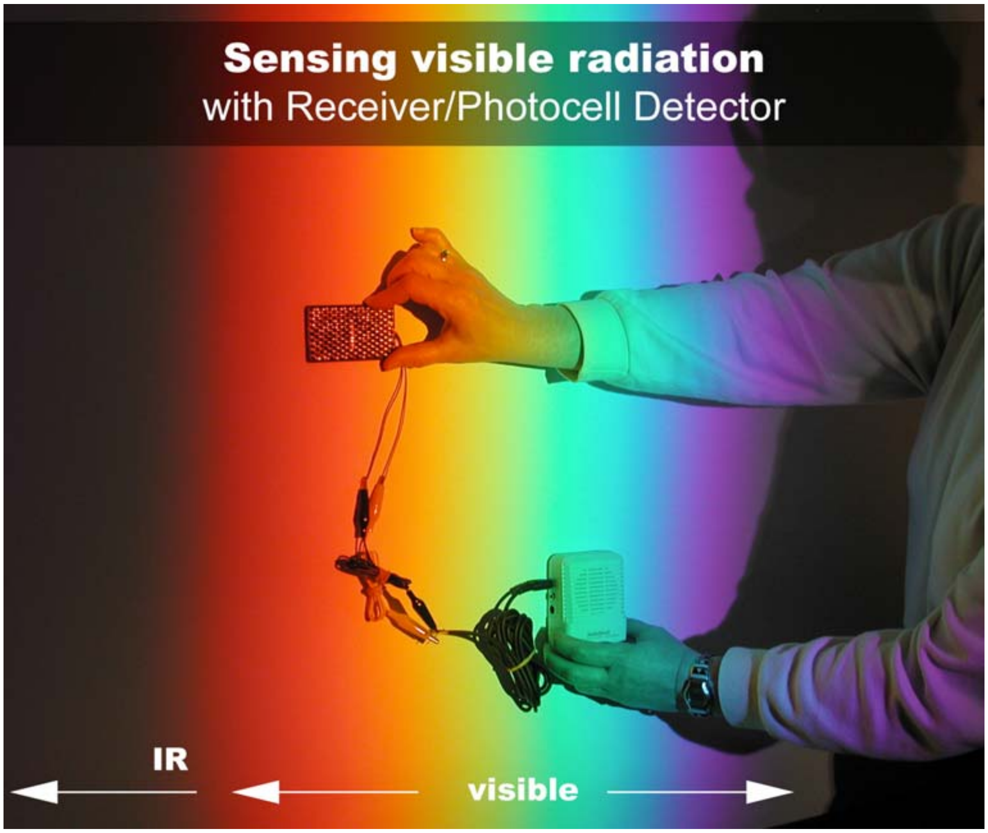
This activity emphasizes the use of gels. In the visible spectrum, a red gel allows only red light to pass through (transmit). The green gel allows green—plus some blue—light to go through. Both gels, however, should allow infrared light to pass through them to the photocell detector. If you look at the transmitted light curves for the two gels (given in the Materials Needed section below), you can see that both gels transmit more than 80% of light at infrared wavelengths.

The bulb in a slide projector or overhead projector generates infrared light as well as visible light. When the light passes through a diffraction grating (or prism), the infrared light is spread out, as are all of the constituent colors of the visible light. The sound generated by the photocell just beyond the red part of the spectrum is evidence of infrared light. Many slide projectors contain infrared-absorbing glass inside them, to absorb heat from the lamp and keep it from melting the slides. This may reduce the amount of infrared light available for students to detect. Even with the reduced infrared output, students should be able to “hear” infrared light with their photocell detector when no gels are used. However, they may have trouble detecting infrared light with the photocell when the gels are used, since the gels do reduce even further the amount of infrared light transmitted. The gels (especially the red and green gels together) may, therefore, cut the intensity of infrared light enough to drop it below the threshold for detection of the photocell. If this happens, explain to the students that if the detector was more sensitive, they would have detected an infrared signal even with both the red and green gel in the beam of light.

To ensure that students place the photocell in such a way as to detect the infrared, suggest students start by placing the photocell in the red. Then suggest they move it just outside the red and see if they still detect anything. Students can then move the detector slightly farther away from the red, continuing until they no longer detect any signal from the photocell. This helps students see that the infrared is a continuation of the visible spectrum.

This activity emphasizes that infrared is the same as visible light except that our eyes are not able to detect it. Stars, planets, comets, galaxies, interstellar dust and molecules all emit at many wavelengths. Some only emit radiation in the infrared and radio. Viewing objects in different regions of the electromagnetic spectrum through the use of filters and different kinds of telescopes gives astronomers more information about the universe.


Sensing IR emission beyond the visible spectrum with Receiver/Photocell Detector
IR
visible


Sensing visible radiation with Receiver/Photocell Detector
IR
visible

Part IV - The remote control: *Students investigate the IR signals used by TV remote control devices.*

This activity demonstrates one way in which students use infrared light in their everyday lives. They will hear different pitches and sounds when they aim remote controls from different manufacturers at the photocell. They may even hear different pitches and sounds when they press different buttons on a single remote control. For example, a remote control that controls both a VCR and a TV will produce different sounds from the photocell when you press the buttons that relate to the TV versus the buttons that relate to the VCR. These different pitches and sounds illustrate why a Sony remote control won't work on an RCA TV.

If printing costs are an issue, the instructions for this part of the lesson can be given verbally by the teacher or written on the board. Without the instructions for Part IV, the student handout is only four pages (two pages back-to-back). Students can then be instructed to write the results of their experiments with the remote controls on a separate piece of paper.

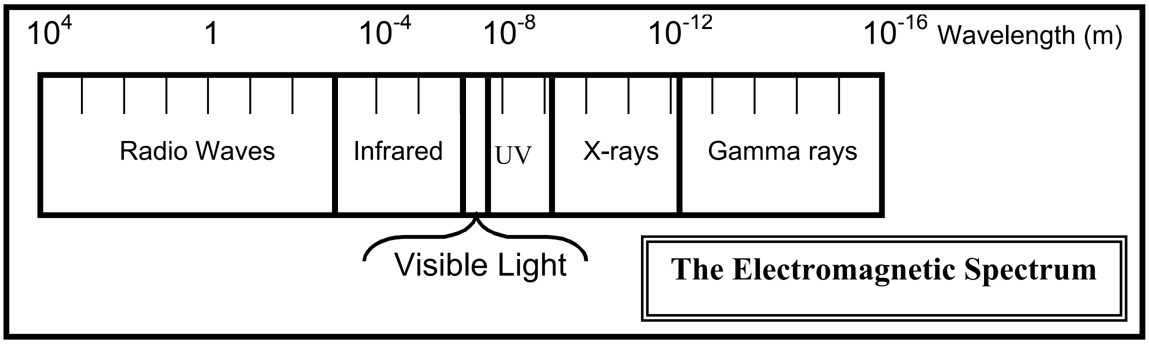
If you would like students to read more about infrared light, the following web sites contain appropriate material:

For the story of how Sir William Herschel discovered infrared light in 1800:
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/herschel_bio.html

For more information on how infrared light is used in our everyday world:
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/our_world_different_light/

Background Science

Visible light and infrared light are simply two different parts of the electromagnetic spectrum. The spectrum is composed of electromagnetic waves. Different parts of the spectrum correspond to different ranges of wavelengths. Radiation or light with wavelengths between 0.4μm (1μm = 10^{-6}m) and 0.7μm are visible to the human eye. Radiation or light with wavelengths between 0.7μm and 1.6 mm is called infrared light. Infrared waves are not visible to the human eye, but since they are the same type of waves as visible light, they exhibit the same properties. For example, like visible light, infrared light can reflect off a mirror.



Because of its longer wavelengths, infrared light is not absorbed by the gels students use in this activity (the gels are maximized to absorb certain visible wavelengths). As a result, it passes through the red and green gels and is detected by the photocell. The longer wavelengths also enable infrared light to pass through huge clouds of gas and dust between stars, which efficiently scatter and absorb visible light that tries to pass through them. Thus, astronomers can learn about what is happening in the centers of these clouds by observing in the infrared. Because of this, infrared astronomy has helped astronomers learn about the life cycles of very young stars, born in the centers of these huge clouds of gas and dust; the young stars cannot be seen in visible light.

The wavelengths of infrared light correspond to those of thermal radiation, or heat. Students sense infrared light every time they sit next to a campfire, hold their hand over the hot burners of a stove, or sit outside on a nice sunny day. Your skin is a good IR detector. Generally speaking, the warmer an object, the more infrared light it emits. For more information on infrared light, and its uses, see:

http://coolcosmos.ipac.caltech.edu/cosmic_classroom/ir_tutorial/

This web site includes background information on infrared light, as well as examples of ways in which people use infrared light, e.g., in meteorology, search and rescue, and environmental monitoring. For more classroom activities involving infrared light, including the same experiment done by Sir William Herschel in 1800 in which he discovered the existence of light outside the visible spectrum, see:
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/ir_activities.html

Solar Photo Cells: The solar cell used in this activity is known as a photovoltaic cell because it converts light (photo) into electricity (voltaic). When visible or infrared light strikes the solar cell, some of it is absorbed by the special material (usually silicon), called a semiconductor, out of which it is made. The energy of the absorbed light is transferred to the semiconductor material, knocking electrons in it loose. These loose electrons can then move freely throughout the material, resulting in an electric current. Most solar cells also have one or more electric fields in them which force the moving electrons to flow in one direction. By placing metal contacts at the top and bottom of the solar cell, the current flowing within it can be drawn off for use externally. In the case of this activity, the current generated by the light is sent to the amplifier/speaker, where it is converted into sound waves, which we can hear. For more detailed information about how a solar cell works, see: http://www.howstuffworks.com/solar-cell.htm

Speakers: Inside a speaker, a flexible cone (usually made of paper, plastic, or metal) vibrates rapidly in response to a changing electrical current. As it moves, it pushes the air molecules around it. Those air molecules, in turn, push the air molecules near them, and the vibration is transmitted through the air as a sound wave. Our ears detect the vibration of air molecules and convert them into an electrical signal that our brain interprets as music. Within the speaker, the flexible cone needs a changing current to vibrate. If the current is constant, the cone will not vibrate. For more information on how speakers work, see: http://www.howstuffworks.com/speaker.htm

Remote Controls:When you press the button of a remote control, an electrical connection is made that tells a computer chip inside the remote which button was pressed. The chip then produces a morse-code-like electrical signal that is different and distinct for each button. Transistors inside the remote control amplify the signal and send it to a Light-Emitting Diode, or LED, a kind of small light bulb. The LED converts the electrical signal into infrared light. Because the LED emits infrared light, which our eyes cannot detect, we do not see any light passing between the remote control and the TV (or VCR). But, the TV (or VCR) has a detector which can see infrared light. Depending on the exact nature of the signal (its wavelength, frequency, or intensity), the TV (or VCR) carries out the desired command. Note that many camcorders can also detect infrared light. If you aim a remote control at a camcorder and push a button, you should see infrared light flashing in the viewfinder. For more information about how remote controls work, see: http://www.howthingswork.com/inside-rc.htm

MATERIALS NEEDED

- Slide Projector or Overhead Projector
- Holographic diffraction grating or prism*
- Fan (optional)
- Masking tape
- 2 pieces of 8” x 10” construction paper
- Slide mount (if using slide projector)
- Undeveloped photographic film, or black electrical tape (if using slide projector)
- Photocell Detector (This device is also used in "Listening to Light.")
  - Solar cell*
  - Amplifier/Speaker*
  - Audio Cable with 1/8” mini-plug on one end*
  - 2 Jumper Cables with alligator clips on both ends*
  - 9 Volt Battery for Amplifier/Speaker
- red and green gels*
- Remote control devices (for TV, VCR, etc.) from several different manufacturers
- Philips screw driver

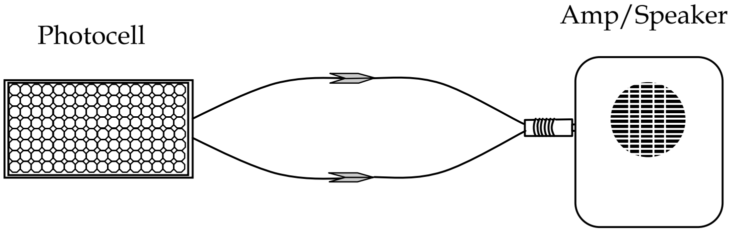
*see section 1.5 for details

3.2 PART I — HEARING LIGHT

Name________________________________ Date___________ Period__________

A. How can we tell that something is there if you can’t see it? Let's pretend that there is a cow standing in the middle of the school gym. You are blindfolded and put into the gym as well.

List several different ways that you could tell if the cow was also in the gym without taking off your blindfold.



B. A photocell uses light to generate an electric current. When transmitted through the wires to the speaker, this current can generate a sound. Make sure the photocell is connected to the speaker. Conduct the following experiments and record what you hear.

Receiver: Photocell Detector

Note: Audiocable can be connected to photocell directly with small wire nuts, or soldered. Wrap with electrical tape, or use shrink tubing to insulate.

Experiment	What do you hear?
Shine a flashlight directly on the photocell	
Move your hand back and forth so that you interrupt or "chop" the light	
Place an electric fan in the beam of light so that the blades of the fan chop the light	

Describe what must happen to “hear” light with a photocell.

PART II — THE VISIBLE SPECTRUM

As you know, white light can be split up into a spectrum of colors. Your teacher has set up a diffraction grating (or prism) in the beam of a projector to produce the visible spectrum on the wall. Place a strip of masking tape along the top or bottom of the spectrum, and mark the location of the red, yellow and green bands of light on the masking tape. Once the locations are marked, be careful not to move the equipment (projector, grating, chopper).

In the rest of this activity, we will be using "gels." A gel is a sheet of colored plastic, which your teacher will provide.

A. Predict what the spectrum will look like if a red or green gel is placed in the beam of the projector (either before or after the beam passes through the grating) and fill in the first line of the table below. Explain your reasoning. Then test your prediction by placing the gel in the beam. Fill in the rest of the table based on your observations.

Experiment	Red Gel	Green Gel
Predict what the spectrum will look like when you place a gel in the beam of the projector. Explain your reasoning.		
What color(s) of the spectrum does the gel allow to pass through?		
What color(s) of the spectrum does the gel block or absorb?		
What do you see at the location of yellow light in the spectrum?		
Predict what color(s) will appear on the wall when both a red and green gel are placed in the beam. Explain your reasoning and your results.	Put your prediction here	Record your observation here

PART III — WHERE IS THE END OF THE RAINBOW?

In Part I we found that we could hear light with a photocell, provided we "chop the light" to create a changing voltage in the photocell. You'll need to use a "chopper" between the light source and the wall for the remainder of this experiment, either an electric fan or a student moving their hand rapidly back and forth in the beam of light.

A. Leave the projector, grating, and chopper set up as in Part II. Hold the photocell in the red region of the spectrum on the wall. If the chopper is in place, you should "hear" the red light at this location. Predict what you will hear when you make the following changes to the beam, while holding the photocell in the same location on the wall. Then record your actual observations, and, in the column labeled “Conclusion,” explain why you think your observed results happened.

Experiment	Prediction	Observation	Conclusion
Place a red gel in the beam			
Place a green gel in the beam			
Place both a red and green gel in the beam			

B. Move the photocell to the dark region right next to the red part of the spectrum. Predict what you will hear when you make the following changes to the beam, while holding the photocell in the same location on the wall. Then record your actual observations, and, in the column labeled "Conclusion," explain why you think your observed results happened.

Experiment	Prediction	Observation	Conclusion
Hold the photocell in the dark region right next to the red part of the spectrum.			
Place a red gel in the beam.			
Place a red and green gel in the beam.			

The grating spreads white light out into a spectrum of colors. What do you think is interacting with the photocell to produce the sound in the dark region next to the red part of the spectrum? Explain your answer.

Astronomy is often like detecting the cow when you are blindfolded. Much like the red and green gels combined, interstellar dust can absorb all visible light sent in our direction by stars and other sources. Astronomers must then "look" for light from these sources in the invisible part of the spectrum to observe the obscured stars and other objects.

PART IV — THE REMOTE CONTROL

The invisible light near the red part of the spectrum is called infrared light (IR). Remote controls like those used with TVs and VCRs use IR signals to send commands to televisions, VCRs, etc.. Your instructor will provide several remote controls with which to experiment. Point a remote control at the photocell and push a button. Describe what you hear in the table below. Try different buttons on the same remote and different brands of remote controls, and describe what you hear in each case.

Indicate which button is pushed and which brand of remote control is used	**Describe what you hear.**

Explain why a Sony remote will not operate an RCA television.

3.3 PART I — HEARING LIGHT

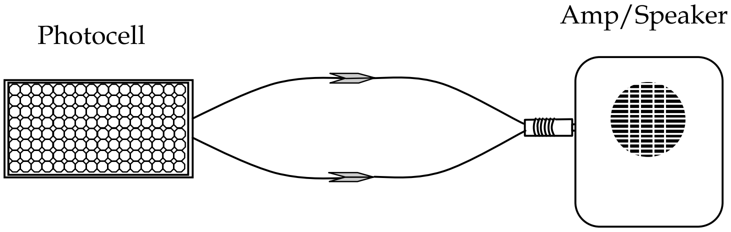
Name___________________________________ Date____________ Period__________

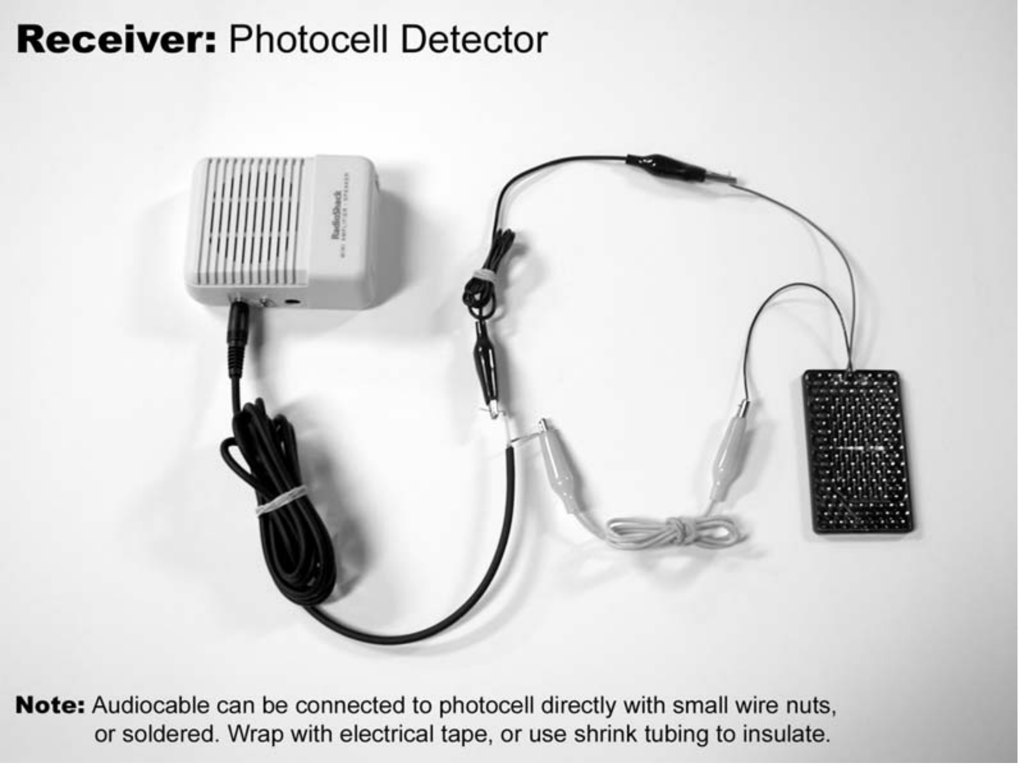
A. How can we tell that something is there if you can't see it? Let's pretend that there is a cow standing in the middle of the school gym. You are blindfolded and put into the gym as well.

List several different ways that you could tell if the cow was also in the gym without taking off your blindfold.

You would have to use your other senses. Listen for sounds (moo), smell the cow, walk around and touch it, although I doubt you'd want to taste it, you could.

B. A photocell uses light to generate an electric current. When transmitted through the wires to the speaker, this current can generate a sound. Make sure the photocell is connected to the speaker. Conduct the following experiments and record what you hear.





Receiver: Photocell Detector

Note: Audiocable can be connected to photocell directly with small wire nuts, or soldered. Wrap with electrical tape, or use shrink tubing to insulate.

Experiment	What do you hear?
Shine a flashlight directly on the photocell	*Nothing. Static.*
Move your hand back and forth so that you interrupt or "chop" the light	*A popping sound each time the light is chopped on.*
Place an electric fan in the beam of light so that the blades of the fan chop the light	*A more constant popping sound.*

Describe what must happen to "hear" light with a photocell.

Light cannot be constant. It has to continuously be turned on and off, or chopped, to hear it.

PART II — THE VISIBLE SPECTRUM

As you know, white light can be split up into a spectrum of colors. Your teacher has set up a diffraction grating (or prism) in the beam of a projector to produce the visible spectrum on the wall. Place a strip of masking tape along the top or bottom of the spectrum, and mark the location of the red, yellow and green bands of light on the masking tape. Once the locations are marked, be careful not to move the equipment (projector, grating, chopper).

In the rest of this activity, we will be using "gels." A gel is a sheet of colored plastic, which your teacher will provide.

A. Predict what the spectrum will look like if a red or green gel is placed in the beam of the projector and record your predictions in the first line of the table below. Explain your reasoning. Then test your prediction by placing the gel in the beam. Fill in the rest of the table based on your observations.

Experiment	Red Gel	Green Gel
Predict what the spectrum will look like when you place a gel in the beam of the projector. Explain your reasoning.	*Answers will vary.*	*Answers will vary.*
What color(s) of the spectrum does the gel allow to pass through?	*Red*	*Green and some blue*
What color(s) of the spectrum does the gel block or absorb?	*Everything except red*	*Everything except green, some blue, and maybe some yellow (depends on the gel)*
What do you see at the location of yellow light in the spectrum?	*Nothing*	Depending on the gel, there may be either some yellow or nothing
Predict what color(s) will appear on the wall when both a red and green gel are placed in the beam. Explain your reasoning and your results.	Put your prediction here *Answers will vary*	Record your observation here *No color should appear on the wall. The red gel only transmits red light, and the green gel absorbs red, (or vice versa) so no light gets through both*

PART III — WHERE IS THE END OF THE RAINBOW?

In Part I we found that we could hear light with a photocell, provided we "chop the light" to create a changing voltage in the photocell. You'll need to use a "chopper" between the light source and the wall for the remainder of this experiment, either an electric fan or a student moving their hand rapidly back and forth in the beam of light.

A. Leave the projector, grating, and chopper set up as in Part II. Hold the photocell in the red region of the spectrum on the wall. If the chopper is in place, you should "hear" the red light at this location. Predict what you will hear when you make the following changes to the beam, while holding the photocell in the same location on the wall. Then record your actual observations, and, in the column labeled “Conclusion,” explain why you think your observed results happened.

Experiment	Prediction	Observation	Conclusion
Place a red gel in the beam	*Answers will vary*	*Hear a popping sound as the light beam is chopped*	*Red light is being transmitted by the red gel and is being detected by the photocell*
Place a green gel in the beam	*Answers will vary*	*Should not hear anything*	*The green gel does not transmit any red light, so there is no light coming through to the red part of the spectrum for the photocell to detect.*
Place both a red and green gel in the beam	*Answers will vary*	*Should not hear anything*	*The red gel transmits only red light, while the green gel absorbs any red light transmitted (or vice versa), so no light gets through for the photocell to detect*

B. Move the photocell to the dark region right next to the red part of the spectrum. Predict what you will hear when you make the following changes to the beam, while holding the photocell in the same location on the wall. Then record your actual observations, and, in the column labeled “Conclusion,” explain why you think your observed results happened.

C.

Experiment	Prediction	Observation	Conclusion
Hold the photocell in the dark region right next to the red part of the spectrum.	*Answers will vary*	*Hear popping sounds as the light beam is chopped*	*Some kind of light that we cannot see is still getting through*
Place a red gel in the beam.	*Answers will vary*	*Hear popping sounds as the light beam is chopped, although the sound may be fainter*	*Some kind of light that we cannot see is still getting through. Since the red gel transmits only red light, students may assume the invisible light is related to red light.*
Place a red and green gel in the beam.	*Answers will vary*	*Hear popping sounds as the light beam is chopped, although the sound is probably much fainter than when there was no gel in light beam*	*"Invisible" light being detected can pass through some things that visible light cannot.*

The grating spreads white light out into a spectrum of colors. What do you think is interacting with the photocell to produce the sound in the dark region next to the red part of the spectrum? Explain your answer.

An "invisible" kind of light (that can pass through a combination of gels that stops visible light) is also spread out by the grating and is being detected by the photocell. OR "Colors" exist in the rainbow that we cannot see with our eyes.

Astronomy is often like detecting the cow with a blindfold on. Much like the red and green gels combined, interstellar dust can absorb or scatter all visible light sent in our direction by stars and other sources. Astronomers must then "look" for light from these sources in the invisible part of the spectrum to observe the obscured stars and other objects.

PART IV — THE REMOTE CONTROL

The invisible light near the red part of the spectrum is called infrared light (IR). Remote controls like those used with TVs and VCRs use IR signals to send commands to televisions, VCRs, etc.. Your instructor will provide several remote controls with which to experiment. Point a remote control at the photocell and push a button. Describe what you hear in the table below. Try different buttons on the same remote and different brands of remote controls, and describe what you hear in each case.

Indicate which button is pushed and which brand of remote control is used	**Describe what you hear.**
Answers will vary	*Students should describe different pitches of sound coming from the detector, with the sound "flickering" on and off at different rates*

Explain why a Sony remote will not operate an RCA television.

The Sony remote emits infrared light at a different pitch or rate than the RCA TV is looking for. Therefore, the RCA TV doesn't "see" the signal sent by the Sony remote.