Experimental Supplement to the Soda Can Sensor

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TRANSMISSION OF INFRARED LIGHT

As light interacts with a material it can be either reflected (as is the case between visible light and a mirror), transmitted (visible light through the air or through a glass) or absorbed by the material (your sunglasses absorb a portion of the incoming visible light). Infrared (IR) radiation, just like visible light, has similar interactions with matter. Different materials will either absorb, transmit or reflect infrared radiation. One crucial application of IR absorption is the greenhouse effect, believed to be the main mechanism by which humans are contributing to global warming. Carbon dioxide and other gases dumped on our atmosphere absorb the IR emitted by the Earth. As these gases absorb more and more of the Earth's energy, they start to heat up, causing global warming. In this experiment we will demonstrate how different gases and materials interact with the IR radiation, and we will review the crucial concepts to understand the greenhouse effect.

Materials and tools

- Socket with a 60 W light bulb (This will be our radiation source)
- At least 2 identical balloons
- 1 sheet of white paper
- Aluminum foil
- Black garbage bag
- Water
- SF_6 (optional)
- Balloon pump (optional)

Setup

Set the lamp and sensor about 1 1/2 feet separated from each other. Turn on the sensor and align it until you get a maximum measurement, change the calibration of the sensor if needed so that you get at least 6 V, but are not saturated. Once aligned, fix the sensor so that it wont move during the experiment, leave the lamp free to move. Fill one balloon with air and the other with water or a different gas (if available). Sulfur hexaflouride -SF_6- will be used for the demonstration. Fill the two balloons to approximately the same size.

Cut the black garbage bag into pieces about the size of the white sheet of paper (get at least 6 pieces), cut a piece of aluminum foil of the same size. You are now ready to start making some measurements.

Procedure

Turn on the sensor and the lamp. You will see the measurement of the sensor increasing with time, do not start the experiment until the sensor registers a stable measurement. While the lamp is reaching a stable point, remove the lamp from the line of sight of your detector. Measure the voltages you get from all the materials as labeled in the table provided. This will tell you about the background radiation that each material is emitting. Once you measure them, move the lamp back in line with the detector, make sure that you are getting at least 6 volts and fix the lamp so it does not move during the experiment. Make a measurement placing each of the materials between the lamp and the detector. Why are you getting the different voltages? What is happening to the IR energy coming from the light bulb?

Object	Voltage **with no** heat source	Voltage **with** heat source
No material		
Paper		
Aluminum		
Plastic bag		
Air Balloon		
SF_6 Balloon / Water		

When no material is present between the lamp and the detector, you are measuring the amount of energy as transmitted through the air from the lamp. As you place different objects you see how much of the energy is being blocked by each material. The balloon filled with air, tells you the absorption by the balloon's plastic. When you replace the air balloon with the balloon filled with SF_6(or water), you get a different measurement. What does this imply? Is the SF_6 absorbing more or less of the energy compared to the air?

A final experiment is to verify how does the radiation reaching the detector changes as we increase the quantity of an absorber. To do this section of the experiment, first place one plastic bag layer between the detector and the light bulb, and record the voltage. Repeat the procedure with additional plastic bag layers. Does every layer drop the voltage by the same amount? You can use the table below to record your results.

Plastic bag layers	Voltage	Plastic bag layers	Voltage	Plastic bag layers	Voltage
0		3		6	
1		4		7	
2		5		8	

Discussion

The Earth emits infrared radiation all the time (any object emits "radiation"). Imagine the light bulb in the experiment is the Earth and the balloons are the atmosphere. You saw that some of the radiation emitted by the light bulb (Earth) is lost in the balloon (atmosphere), either absorbed or reflected back. If we change the composition of our atmosphere by placing heavy absorbers of infrared radiation (like SF_6, which is about 16000 times more potent as a greenhouse gas than CO_2), then more radiation will be absorbed. We observed this with our SF_6 balloon, compared to the air balloon. Since the infrared energy is trapped inside the planet, the Earth tends to heat up, and this is the basic concept of global warming. However, as you saw in the last experiment, there is a limit to how much absorption can happen, if you add too many absorbers (too many plastic bags), there will be a point when you block all the radiation and adding more absorbers does not change anything.

You can experiment with other materials and substances to see if they transmit infrared radiation! You can try with glass, if you find a thin enough glass that transmits IR, you can experiment with different liquids (water, coke, milk). Some interesting questions: While starting the experiment the sensor measured an increasing voltage, why is this? If you turn off the light bulb, is there a way of knowing when it is safe to touch it? Be careful here, the top of the bulb will be different from the side of the bulb. Let the balloons with air, and SF_6(or water) sit near the light bulb for 10 minutes, then remove the light bulb and measure the emissions from the different balloons. What does this show?

MEASURE THE ABILITY OF MATERIALS TO REFLECT IR

Since the sensor's output is related to the amount of infrared energy it receives. This experiment is designed to study the reflectivity of IR radiation of different objects. This experiment shows the change in sensor output as different media is used to reflect the IR energy.

Materials

- Heat source(light bulb or candle)
- Soda Can Sensor
- Multi-meter
- Base or support to hold items in place
- Mirror
- Card Board
- Aluminum
- White Paper

Setup

- Insert the multi-meter leads into the corresponding outputs of the can (red into red, black into black).
- Align the soda can sensor and the heat source in 90 degree angle.
- Place the base at the point where the two 90 degree lines meet at a 45 Degree angle.

Procedure

1. Turn on Soda Can Sensor, light bulb and multi-meter (turn to the right where it says 20), let the sensor facing light bulb till the output is stable.
2. Set up the Mirror/Card Board/Aluminum/Paper on the base in sequence, spin the sensor within +/- 5 degree, trying to get maximum output, record the output of the multi-meter in the following table.

Object	Output	Object	Output
Mirror		White Paper	
Card Board		Other	
Aluminum		Other	

3. Turn off the multi-meter and the soda can sensor

Discussion

- Did the items reflectivity match what you expected?
- What can be inferred from this data?

INTENSITY V. DISTANCE

We often look up at the stars at night and wonder how fast they are moving or how far away from us are they. By studying how the brightness of a star changes with distance, we can answer these questions. In this science project, you'll create a model of starlight and use a multi meter to discover the key relationship between brightness and distance.

Objective

To determine how the intensity of light changes with distance from a point source. Do you love looking at the stars? No, not the Hollywood kind – the ones in the sky! For thousands of years, people have looked up at these faithful pinpoints of light and wondered about those "diamonds in the sky." Stars have been used as centerpieces of religions, as fuel for legends and myths, as tools for navigation, and as predictable calendars for planting crops. In 1584, though, Giordano Bruno suggested that the stars were objects, much like the Sun, just farther away. This idea upset a lot of people, and he was actually killed for this and for other beliefs. It would take more than 250 years for people to accept that Bruno was right and take their first distance measurement from Earth to a star.

To find out just how far away a star is, scientists first had to figure out how the brightness or intensity of a point source of light, like a star, changes with distance. They experimented and predicted that the relationship between brightness and distance would follow an inverse-square law. This means that as the distance from a light source doubles, its brightness decreases by a factor of four, (which is the square of the distance). This is illustrated in the drawing below, where the red dot, the point source of light, has a brightness we'll name L0 for this example, at one unit (it could represent any unit) away from the light; but as you double the distance to two units away, the brightness goes down by a factor of four. At three units away, the brightness goes down by a factor of nine, and so on.

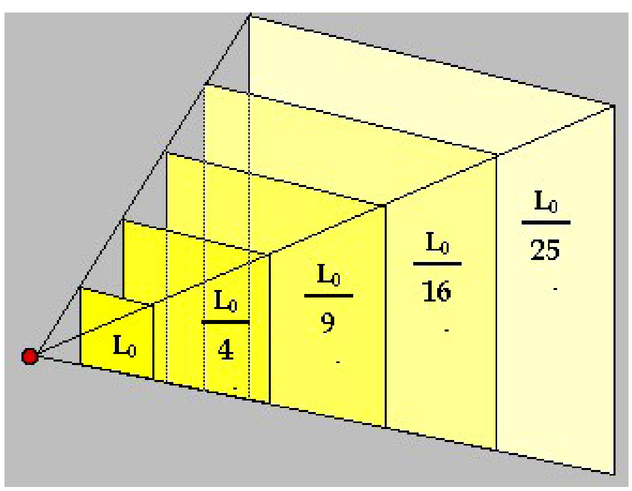

Figure 1: This drawing shows how light follows an inverse square law. Notice that as the distance increases from the light source (the red dot), the light must spread out over a larger surface area, and the surface brightness decreases by the distance squared. (NASA, 2006.)

In this science project, we will set up an experiment that will allow us to test whether light from a point source, like a star, follows the predicted inverse-square law.

Terms, Concepts, and Questions to Start Background Research

Intensity, Point source, Inverse-square law, Square, Factor, Linear, Inverse

Questions

- Why do you think stars are approximated as point sources, even though they are much bigger than Earth?
- Based on this research, how is it possible to measure distance to stars from changes in the brightness of a point source?
- Can you think of any other laws that follow an inverse-square relationship?

Materials and Equipment

- Multi-meter
- Measuring tape
- Lamp with a round light bulb (any wattage)
- Room that can be darkened well and cleared of objects in a 6-foot x6-foot area
- Lab notebook
- Graph paper

Setting Up Your Experiment

1. Clear the table and make enough space for the 1 meter ruler
2. Remove any shining or reflecting surfaces that might interfere with the experiment.
3. Place the lamp with the light bulb on a smooth table.
4. Place the sensor you have just constructed some distance away from the light bulb.
5. Adjust the sensor to point directly at the light bulb by maximizing the output voltage.
6. Place a measuring tape or a measuring rule between the light stand and the sensor.

Testing How Light Intensity Changes with Distance

1. Turn on the light bulb and wait for it to get heated (about 5–10 minutes)
2. Create a data table in your lab notebook, like the one below.
3. Position the sensor at the 8-inch mark on the measuring tape.
   (a) Place the legs of the sensor directly over the mark on the measuring tape.
   (b) Feel free to start at a closer initial starting point if you are able to physically get closer to the light source.
4. Take a measurement from the multi-meter meter and record your measurement in your lab notebook.
   (a) Be sure you, and any other people around, are standing behind the sensor when you take your measurement. You don't want any people or shadows between the light source and the sensor that might affect your measurement.
   (b) Wait about 10 seconds (sec.) for the multi-meter to settle down to a final value.
   (c) If it is oscillating between one or two values, then choose the higher one.

Table 1: Light Intensity Data Table

Distance from light source (ft.)	Trial 1	Trial 2	Trial 3	Average of trials

5. Move the sensor back 4 inches. Make sure to adjust the pointing to maximize the sensor output voltage.
6. Take a measurement from the multi-meter.
7. Repeat steps 5-6 until the sensor legs are at the 3-ft. mark.
8. Repeat steps 3-7 two more times for a total of three trials. By running a few trials, you will ensure your results are repeatable and accurate.

Analyzing Your Data Table

1. Calculate the average light intensity for each distance from the three trials and record your calculations in the data table.
2. Make a line graph that plots the distance (in feet) on the x-axis and the average light intensity on the y-axis.
3. Look at your graph.
   (a) Is it linear? Or, does it look like a curve?
   (b) If it looks like a curve, does the average light intensity increase or decrease with distance?
   (c) If it looks like a curve, is the average light intensity equal to a constant divided by the distance?
   (d) Does it follow an inverse relationship? Or, is the average light intensity equal to a constant divided by the distance squared?
   (e) Do you think light intensity follows an inverse-square law?

SENSOR DEPENDENCE ON TEMPERATURE FOR COOLING WATER

There are many satellites that orbit the earth for scientific purposes. Some of these are used for weather prediction. Meteorological satellites have different channels which enables them to record a variety of weather parameters. One channel on board these satellites is the InfraRed (IR). The IR channels on weather satellites can be used to show scientists the temperature of cloud tops, which is related to the cloud height. If used in series IR images can show clouds growing vertically which is a sign of convective activity, a necessity for hail, thunderstorms, tornadoes, and other kinds of severe weather.

The satellite sensors work in a similar fashion as the one used in this experiment. They record infrared radiation from a source and turn it into something readable by scientists. The purpose of this experiment is to study a form of passive remote sensing as it relates to temperature changes of an object. This experiment shows the change in sensor output as water cools. The sensor's output is related to the amount of infrared light it receives. Because of this one can derive an experimental relationship between water temperature and infrared emission.

Materials

- Soda Can Sensor and Multi-meter
- Thermometer
- Ring stand (or something able to hold the can in the same position over a period of time)
- Stop watch (online or hand held, clock with a second hand can work too)
- Plastic cup
- Cold water $\sim$ 2 cups or so (varies with dish depth)
- Hot water $\sim$ 1/2 cup
- Baking dish ($\sim$ 2–3 inches deep)
- About 1 cup of ice
- Computer with a data analysis program (Excel, Minitab, Matlab, etc).

Setup: PHYSICAL EXPERIMENT

1. Get hot water and fill the plastic cup 2-3 inches.
   ****SAFETY:: Don't touch the hot water with your fingers. It may be hotter than you think and could cause burning*****
2. Place cup into empty baking dish
3. Get ice and cold water, Don't pour it in the dish yet
4. Connect leads to the multi-meter. Red goes in the middle and black goes to either side.
5. Insert the multi-meter leads into the corresponding outputs of the can (red into red, black into black)
6. Clamp the soda can into the ring stand with the leads facing up and the sensor facing down and parallel with a flat surface. **Be careful not to crush the can**

Procedure: DATA RECORDING

1. Turn on Soda Can Sensor and multi-meter (turn to the right where it says 20, 3 clicks for the orange ones used at HU)
2. Place thermometer in the hot water.
3. Lower the sensor so it is no higher than 2 inches above the cup. If the can is inside the cup it can still work, but condensation could occur throwing off all the data.
   MAKE SURE THE SENSOR DOES NOT TOUCH THE WATER
4. Reset the stopwatch to 0s
5. Read the voltage and temperature and record the values in the 0s row in the spreadsheet. Start the stop watch.
   BE CAREFUL WHEN READING THE DATA, IF YOU GET TOO CLOSE OR BREATHE ON THE SENSOR IT CAN THROW OFF THE VALUE OF THE MULTIMETER
6. Pour cold water and ice into the dish.
   Be careful not to pour so fast that it moves the cup
7. Take voltage and temperature data every 20s in the corresponding rows,
   ONCE THE EXPERIMENT IS STARTED DO NOT MOVE OR ADJUST THE SODA CAN SENSOR OR THE CUP/ICE BATH, THEY NEED TO STAY THE SAME FOR CONSISTENCY
   20s can go pretty quickly so be careful that you are paying attention to when data needs to be recorded

Time (S)	Temperature(C)	Voltage(V)
0		
20		
40		
60		
80		
100		
120		
140		
160		
180		
200		
220		
240		
260		
280		
300		

8. Once all the data rows are filled turn off the multi-meter and the soda can sensor

Analysis: COMPUTER SETUP

(using excel, could be different for other programs)

1. Open up Microsoft Excel
2. Create 3 column headers: A1) Time (s); B1) Temp (C or F); C1) Voltage (V)
3. Insert times to record in Column A (Time) starting at 0 in 20s intervals to 300
   Quick way to do this: input 0, 20, 40, 60, highlight those values from top to bottom, A2-A5 (not the title), move cursor to the bottom right corner of A5 until it turns into a black bold + sign, when it does that click, hold, and drag the cursor down to the desired time amount, let go and the cells will be automatically filled with 20 second intervals

Analysis: PLOTTING

Voltage vs Temp

1. Highlight all of the Temperature and Voltage data with one selection, do not include the labels.
2. Go to Insert, Chart, XY (scatter), points only, NEXT
3. It should default to ”series in columns”, click Next
4. Write your title and X and Y labels. X should be Temperature and Y should be Voltage, Next
5. Finish

Temp and Voltage vs Time

1. Highlight all the data (Time, Temp, Voltage) including the labels
2. Go to Insert, Chart, XY (scatter), Points and Lines, NEXT
3. Data in columns
4. Write your title and X and Y labels. X is Time, Y is Temperature
5. Finish
6. Right click on the Voltage data point/line, format data series, axis, secondary Y axis

Questions

- Are there any patterns shown in the data? (temp v time, voltage v time, voltage v temp, etc)
- What can be inferred from this data?
- What other information is needed to be able to use the Soda Can Sensor to remotely measure the temperature of a distant object?