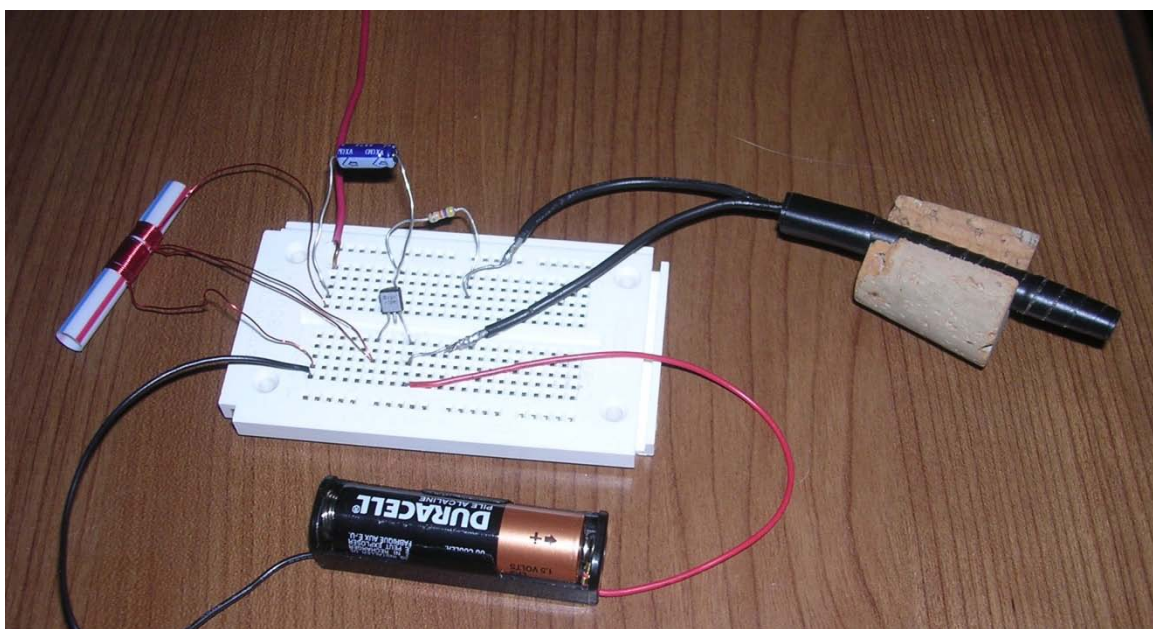


## **Modeling Remote Sensing with a Student Built Transmitter**

What does “remote sensing” mean? How do the remote sensors on satellites work? How does the concept of reflectivity help us to understand how remote sensors on satellites observe and measure things on the Earth and in the heavens? With about five dollars in simple electronic parts, students can build a working model of a simple remote sensor. The sensor can then be used to measure reflected light. By adding color filters, the reflectance in red, green, and blue wavebands can be determined separately and the results graphed with computer software such as Microsoft Excel.

This circuit and original lesson were designed by Duane Laursen for his students in the La Puente High School Academy of Science & Engineering and presented at the Satellites & Education Conference in 2003. The current lesson format was prepared by Pete Arvedson and presented at conferences in 2006 and 2007.

The complexity and depth of information explored by the students depends on the intended lesson context. For some classes, simply completing the construction of a working model brings great personal reward. For others, the theory of light, color, and reflectivity can be explored along with basic electronics and radio theory. Once the sensor is constructed and tested, it should be used in an experiment to determine the intensity of red, green, and blue light reflected from various reflective surfaces. Glossy red, green, blue, and white papers can be used as controls while sand or dirt, grass, and other natural materials are used as experimental surfaces. The experimental results generally vary depending on selection of reflective materials, the light source, and the amount and quality of ambient room light present during measurements. A sample data set with analysis is included here.



Developed by Duane Laursen and Pete Arvedson, La Puente High School Academy of Science & Engineering, La Puente, California. Presented to the Satellites & Education Conference, 2003, 2006, 2007

## **Construction**

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### **Construction Step 1: Gather the parts**

The Radio Shack prices listed on the “Parts Lists” page are subject to change without notice. An on-line order can be made through Kelvin at the address and URL below the parts list. Radio Shack may be more convenient for many. Kelvin is less expensive and offers greater variety and volume.

### **Construction Step 2: Identify Components**

Use the attached “What’s That?” reference sheet to help students identify each electronic component. You may wish to pre-sort the parts and distribute them to each student in a zip-lock type plastic bag with the student’s name written on the bag with a marker. Caution students to handle each part with care. Do not drop any part on the floor or table top.

### **Construction Step 3: Wind the Coil**

Use the instruction sheet “Winding the Coil” as reference if needed.

### **Construction Step 4: Read the Schematic – Assemble the Parts on the Breadboard**

The schematic diagram is included on the sheet “Satellite Remote Sensing Model Using Student Built Transmitter.” Students should take time to consider how to assemble the parts – what connects to what. Soldering requires a low wattage soldering iron for electronic use, lead-free solder for electronic use, and the patience to teach students to solder. Once assembled, soldered models cannot be disassembled and are given to the students to take home. With the breadboard, models can be disassembled and parts reused or replaced. If needed, refer to “Sensor Construction with Breadboard Module” for assembly hints. Caution students to correctly identify the emitter, collector, and base on the transistor and not rely on the assembly sketch on the breadboard reference sheet.

## Parts List

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### Radio Shack Parts List for Model Sensor Project

Catalog No.	Description	Pkg	Price
278-1345	Magnetic wire, 3 spools, 315 ft total	pkg	4.99
276-1617	NPN Transistor, 2N2222	15/pk	2.59
270-401	Battery holder, single AA, with hook wire	ea	0.99
272-1012	4.7 uf polarized electrolytic capacitor, axial leads	ea	0.99
271-1342	47K ohm resistor, 1/4 watt	5/pk	0.99
276-1657	CdS photoresistor, assortment	5/pk	2.79
278-1215	Hook up wire, 22 AWG, solid, 100 ft	ea	4.99
23-885	AA Enercell alkaline battery, 40 pack	40/pk	19.99
276-175	Modular IC breadboard socket	ea	8.99

**Lower prices and more variety available from  
Kelvin, 280 Adams Blvd., Farmingdale, NY 11735  
<http://www.kelvin.com>**

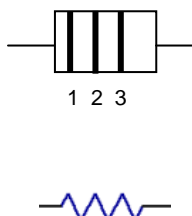
Additional items:

---	Soda straw	---	---
---	Sand paper	---	---
---	Safety pin	---	---
---	Glossy paper – white, red, green, blue	---	---
---	Color filters, monochromatic – red, green, blue	---	---
---	FM radio receiver	---	---
---	Light source such as LED flashlight	---	---
---	Vernier LabPro Interface	---	---
---	Vernier Microphone	---	---
---	Vernier Logger Pro software	---	---

**Vernier Software & Technology  
13979 SW Millikan Way  
Beaverton, Oregon 97005-2886  
888-837-6437  
<http://www.vernier.com>**

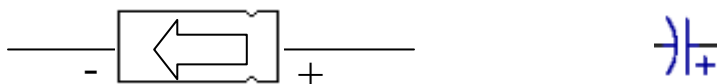
## What's That?

**Resistor** = device to slow down electrons in an electronic circuit. Resistance is measured in Ohms.

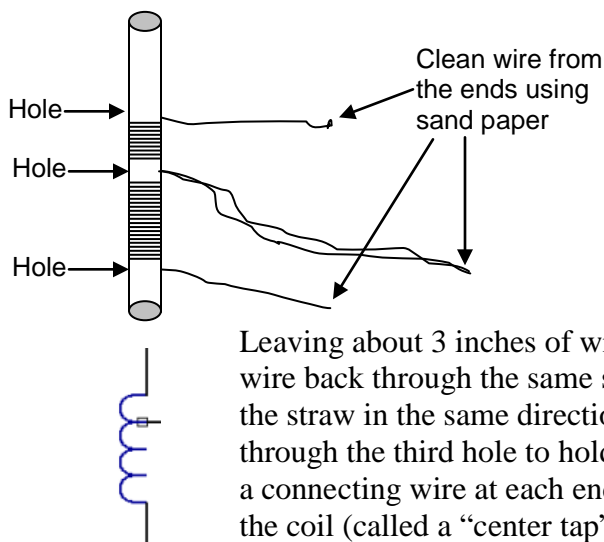


Resistor Color Code				
1st & 2nd Color Band		3rd Color Band	4th Color Band	
Black	0	Black	x1	Tolerance:
Brown	1	Brown	x10	Gold 5%
Red	2	Red	x100	Silver 10%
Orange	3	Orange	x1k	None 20%
Yellow	4	Yellow	x10k	
Green	5	Green	x100k	
Blue	6	Blue	x1 meg	
Violet	7	Silver	/100	
Gray	8	Gold	/10	
White	9			

**Capacitor** = device to store static electric charge in an electronic circuit. Capacitance is measured in Farads. Charge is stored and then discharged across the capacitor plates at regular intervals depending on the value of the capacitor. Electrolytic capacitors have an electrolyte between the plates where the charge is stored and then continuously leaked in very small amounts of current between discharges.



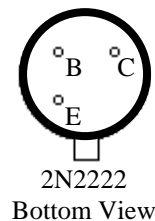
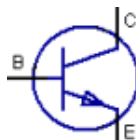
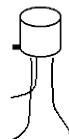
**Inductor** = device to store electric charge in a magnetic field. Varying an electric current in a coil produces a changing magnetic field that induces voltages in the same circuit or



in a nearby circuit is called. Inductance is measured in henrys. You will build your own inductor by winding lacquered wire around a coil form (section of soda straw). Using the safety pin, carefully poke three holes all the way through the straw as indicated. Pass the wire through the first hole to hold the wire in place. Wind the wire around the straw 10 times and pass through the second hole.

Leaving about 3 inches of wire extended through the second hole loop the wire back through the same second hole. Continue winding the wire around the straw in the same direction as before for another 20 turns. Pass the wire through the third hole to hold it in place. The result is a coil of 30 turns with a connecting wire at each end and a connecting wire 1/3 of the way through the coil (called a "center tap"). Use the sand paper to carefully clean the lacquer from about 1/2 inch of the end of each of the wire leads.

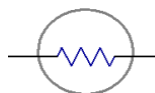
**Transistor** = “A semiconductor device commonly used as an amplifier or for an electrically controlled switch.” (Wikipedia) The three leads from the transistor case are the **base (B)**, **emitter (E)**, and **collector (C)**.



**Battery** = An enclosed storage container for a chemical reaction (dry cell) that supplies a source of electrons to move in a circuit (current) and the electromotive force (voltage) to move them. Electrons move out of the negative pole and into the positive pole of the battery.



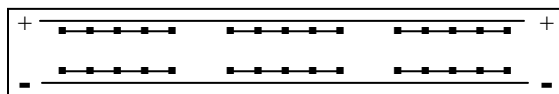
**Photoresistor** = “An electronic component whose resistance decreases with increasing incident light intensity.” (Wikipedia)



**Antenna** = “A transducer designed to transmit or receive radio waves (electromagnetic waves). Antennas convert radio frequency electrical currents into electromagnetic waves and vice versa.” (Wikipedia)

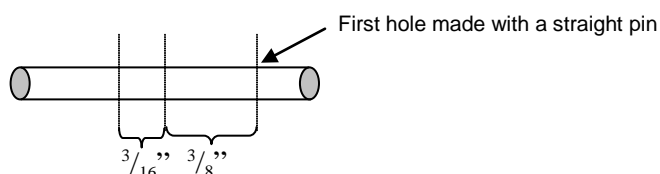


**Breadboard** = A board with connection points where electronic components can be arranged in a trial circuit with temporary connections. In the breadboard diagram below, each dot is a connection point. Five points are connected together internally as indicated by the lines joining the points in the diagram.

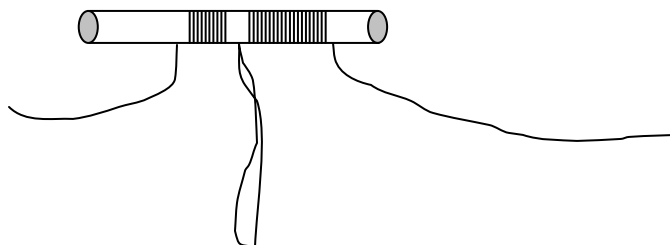
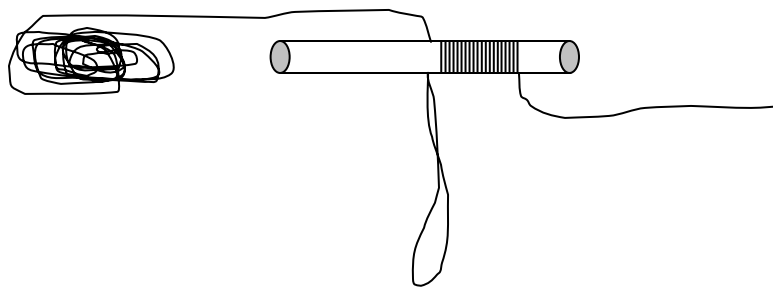


## Winding the Coil

1. Cut a section of plastic soda straw about 1½" long.
2. Measure ¼" from one end of the straw and poke a hole all the way through both sides of the straw with a straight pin. **Do not push the pin into your finger!**
3. Measure ⅜" from the first hole and make a second hole in the straw.
4. Measure ⅜" from the second hole and make a third hole in the straw.



5. Magnetic wire is copper wire that has a coating of lacquer instead of vinyl insulation. It is used in making coils that produce a magnetic field when the coils are used as inductors. When working with magnetic wire it is very important to **avoid kinks in the wire**.
6. Carefully thread one end of your magnetic wire through the first hole so that the wire goes all the way through the straw. Pull about 3" of wire through the hole for connecting the coil in the circuit later.
7. Hold the 3" wire lead in place and neatly wrap the wire carefully and tightly around the straw until you have exactly twenty turns around the straw. Then thread the other end of the wire through the second (middle) hole until the wire goes all the way through the straw. Gently, pull the wire snug so the 20 turns of coil stay in place. **Do not deform the straw** while pulling the wire taut.
8. Double back and thread the end of the wire through the second hole again in the reverse direction leaving about 3" of doubled wire sticking out.
9. Now continue to wrap the wire around the straw until you have exactly 10 more turns of wire.
10. Thread the end of the wire through the third hole and gently pull the wire so that the additional 10 turns stay in place.
11. You can cut the excess wire leaving at least 3" for connecting the coil in the circuit later.
12. With sand paper, carefully clean the lacquer from the about ½" of the end of each of the three connecting wires. Leave the lacquer on all turns of the coil. Gently twist together the doubled wire from the second hole.



## Building the Remote Sensing Model

### Purpose:

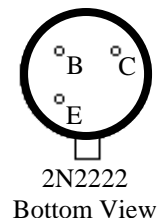
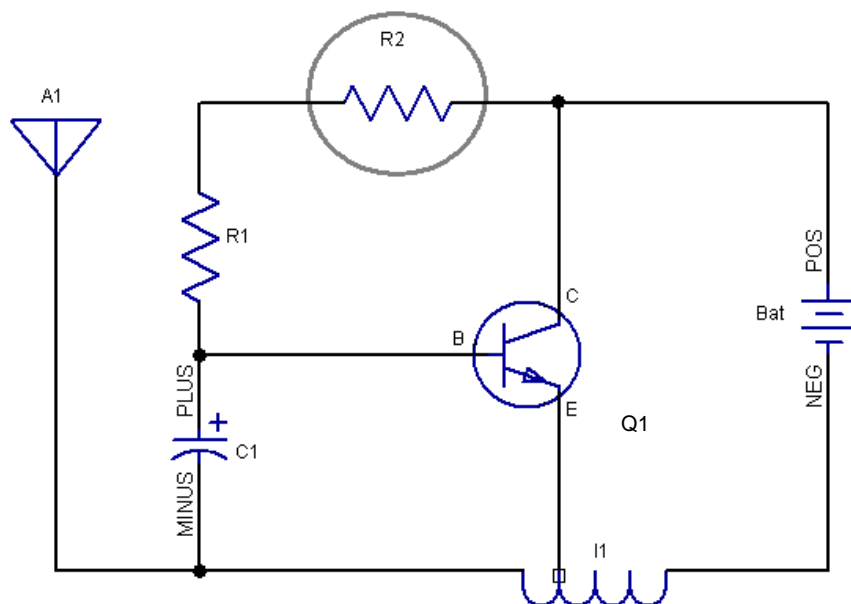
To build a photo sensitive transmitter in order to simulate the identification of Earth's surface materials by a satellite using various frequencies of the electromagnetic spectrum

### Materials:

Transmitter: Q1 2N2222 transistor, NPN  
 I1 Inductor: 30 winds tapped 1/3 of the way from one end  
 Bat 1.5 VDC, "AA" battery in battery holder with leads  
 C1 4.7  $\mu$ f polarized electrolytic capacitor  
 R1 47 K resistor, carbon film, 1/4 watt  
 R2 Photo resistor  
 A1 Antenna, hook up wire, app. 12 in.

### Procedure:

1. Check to be sure all parts are present and they are the correct parts.
2. Make the inductor: Cut a piece of plastic tubing about 1 inch long and about 40 inches of magnetic wire. Wind 20 turns of the coil then 10 more turns with a connector protruding from the coil between turns 20 and 21.
3. Carefully place all parts in order following the circuit diagram. Give particular attention to polarity. Determine which transistor lead is the emitter (**E**), the base (**B**), and the collector (**C**) using the diagram at right.
4. Do not allow any wire component leads to make connection where no connection is shown in the circuit diagram.
5. Connect each component by soldering, or with a crimp connector, or on a breadboard. If soldering, protect the component from excess heat during soldering with a heat sink.



# Sensor Construction with Breadboard Module

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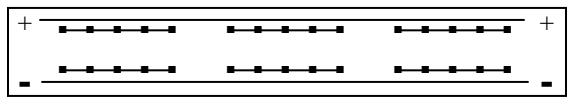


Diagram A: Breadboard Socket Internal Connections

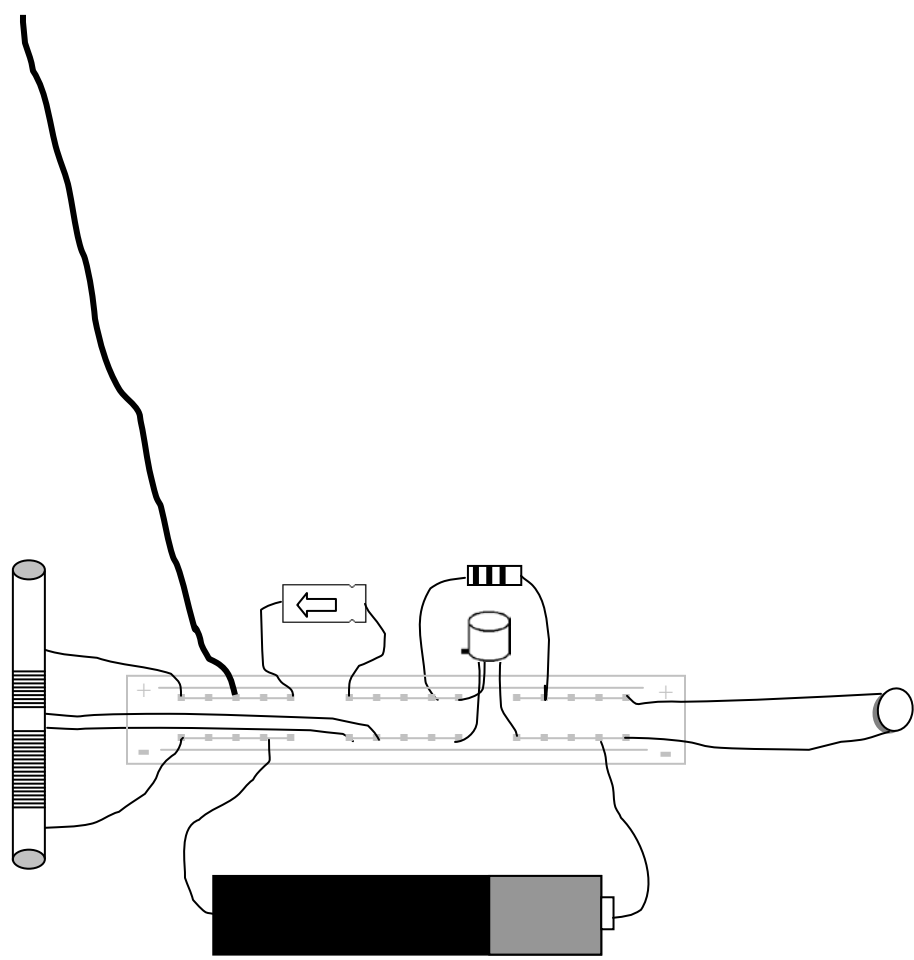


Diagram B: Layout of Sensor Components when Connected to Breadboard

## Gathering Reflectance Data

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### Experiment Step 1:

Set up your sensor with the photoresistor in a dark plastic tube to reduce the amount of ambient light reaching the photoresistor. A soda straw wrapped in black, vinyl tape works well.

### Experiment Step 2:

Adjust the end of the photoresistor to 5-10 cm from the white glossy paper reflective sample. The actual distance is not as critical as consistency from measurement to measurement. Arrange the light source so the light enters the photoresistor tube from the reflective surface and not from the light source directly.

### Experiment Step 3:

Set up the computer with the Vernier LabPro interface with microphone and Logger Pro software for the Physics experiment called "Sound Frequency and Beats." (Alternatively, other probeware and software can be used.) Set the sampling rate at 10,000 samples per second and a collection time of 1.00 second. Tune a standard FM broadcast radio receiver to a frequency with little or no station broadcasting so the clicking of the pulses from the transmitter can be heard clearly. Place the microphone close to the radio speaker.

### Experiment Step 4:

Trigger the software to begin data collection. Sound data will be ingested from the radio receiver through the microphone for 1.0000 second. When the graph is displayed, each click is apparent as a major peak. The minor peaks are background noise and static.

### Experiment Step 5:

Using the software tools, determine the average time between major click peaks (seconds/pulse) and record this number.

### Experiment Step 6:

Repeat Steps 4-5 using a colored filter (red, green or blue) in front of the sensor so that the sensor receives only light of that color. Repeat this with each color of filter. Analysis of these data should provide a good profile of how the sensor will respond in each, major visible light waveband.

### Experiment Step 7:

Repeat Steps 4-6 using red glossy paper as a reflective surface. Repeat the same sequence again for green and blue surfaces.

### Experiment Step 8:

Repeat Steps 4-6 again with various natural reflective surfaces such as sand, dirt, green leaves, concrete or asphalt, and so on. Repeat again using each color filter.

## Analysis of Data – Sample Data and Analysis

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The goal is to produce a graph of relative reflectance for each sample where higher relative reflectance numbers correlate to greater intensity of light reflected from the surface material. In the sample data below, the time between pulses in Table A varies in the opposite direction: the greater the time between pulses, the lower the reflected light intensity. Some manipulation of the raw data is necessary to produce relative reflectance numbers that vary appropriately.

The sample data were collected by students with the model sensor pictured on page 1. They were processed and graphed using Microsoft Excel. Table A contains the time between click peaks in seconds/pulse for each filter and surface combination. Each value is an average of three measurements. Table B converts these numbers to relative reflectance values using the formula  $[(1/(\text{sec/pulse})) * 1000]$  and rounding off to the nearest integer. The relative reflectance values were graphed in an x-y scatter graph with connecting lines. The graph properties were adjusted for color and ease of interpretation.

**Table A**

**Number of Seconds/Pulse**

(sampled at 10,000 points per second)

Reflective Substance	Filter			
	None	Blue	Green	Red
White surface	0.088	0.092	0.087	0.091
Blue surface	0.091	0.092	0.096	0.093
Green surface	0.090	0.094	0.091	0.092
Red surface	0.090	0.091	0.093	0.087
Unknown: Sand	0.090	0.093	0.092	0.090

**Table B**

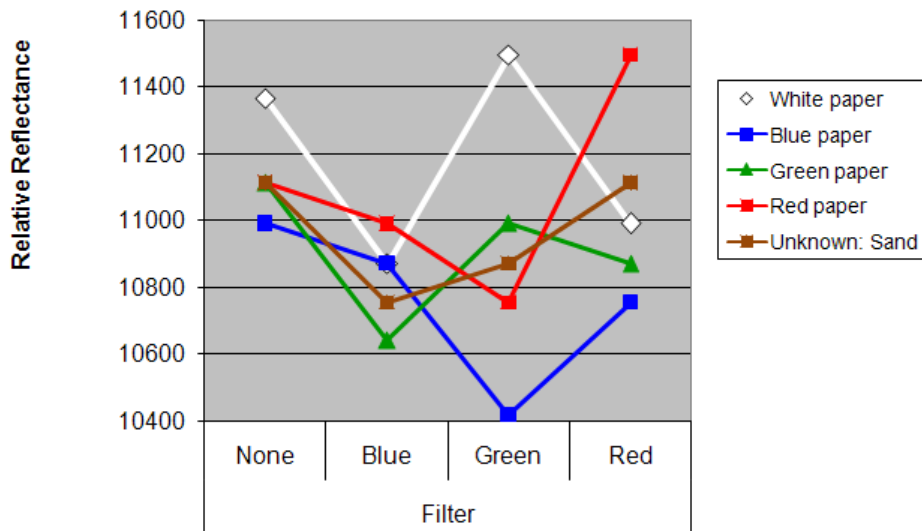
**Relative Reflectance**

$[(1/(\text{sec/pulse})) * 1000]$

Reflective Substance	Filter			
	None	Blue	Green	Red
White surface	11364	10870	11494	10989
Blue surface	10989	10870	10417	10753
Green surface	11111	10638	10989	10870
Red surface	11111	10989	10753	11494
Unknown: Sand	11111	10753	10870	11111

By following the each line on the resulting graph, conclusions such as “the blue surface reflects more blue light than green light” can be reached. More discipline is required to reach such conclusions as “more blue light is reflected from the blue surface than from the green surface.” While a column graph would be more useful here, the x-y scatter graph with connecting lines was chosen because it is the same type of reflectance graph generated by MultiSpec software (<http://cobweb.ecn.purdue.edu/~biehl/MultiSpec/>) when analyzing multispectral Landsat data. Leading or following the sensor project with MultiSpec tutorials from the G.L.O.B.E Program (<http://www.globe.gov>) can take students from the realm of a model in a class project to the real world of remote sensing and Earth observations.

Relative Reflectance of Various Materials



Relative Reflectance of Various Materials

