LAB #8 - The Herschel Experiment

Work with your lab partner and hand in one copy of the lab per group. All group members are expected to contribute equally.

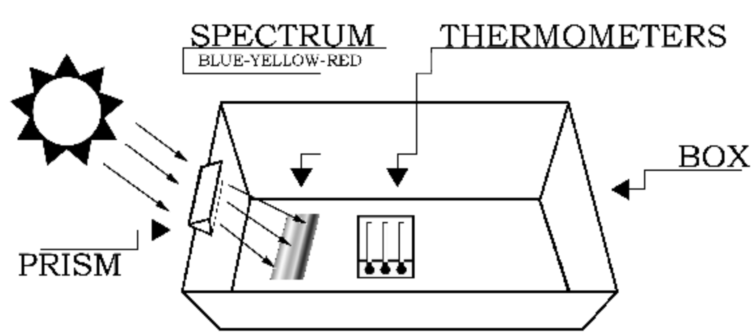
Purpose: To measure the amount of light emitted by the sun at different wavelengths (or colors) using a prism and thermometers, i.e. to obtain a rudimentary solar spectrum.

Materials: A glass prism, 3-4 thermometers covered in black paint, a cardboard box, a white sheet of paper, a watch or timer, and a sunny day!

Introduction: Light from the sun can be dispersed by a prism into different colors in the same way that water molecules in the atmosphere cause rainbows to appear. All those colors are being emitted by the sun at the same time, and our eyes perceive the combination of all the colors to be a yellowish white. When that white light passes through a prism (or a water molecule), it is deflected - i.e. its direction changes. The amount of deflection depends on the wavelength of light, so that when the light exits the prism it is separated into different colors. In this lab, you will measure how much light the sun is emitting at each wavelength. In the next class, you'll see that by doing this we can actually determine the temperature of the gas inside the sun (spoiler: it's very hot!).

A) Setup:

The experiment should be conducted outdoors on a sunny day. Variable cloud conditions, such as patchy cumulus clouds or heavy haze will diminish your results. The setup for the experiment is depicted in the figure below. Begin by placing the white sheet of paper flat in the bottom of the cardboard box. The next step requires you to carefully attach the glass prism near the top (Sun-facing) edge of the box. The cutout notch should hold the prism snugly, while permitting its rotation about the prism's long axis. Slide the prism into the notch cut from the box, and rotate the prism until the widest possible spectrum appears on a shaded portion of the white sheet of paper at the bottom of the box.



The Sun-facing side of the box may have to be elevated (tilted up) to produce a sufficiently wide spectrum (a book or binder is useful for this, or you can use the box lid).

1. Place the thermometers in the shade inside the box (well away from the spectrum and any sunlight) to record the ambient air temperature. Leave the thermometers in the shade for a couple of minutes then record the temperature for each thermometer on the first row of the table on the next page.

2. Compare your values for each thermometer. Are they the same? Do you expect them to be the same? Name a couple of reasons why it's important to measure the shade temperature for each thermometer before measuring the solar spectrum.

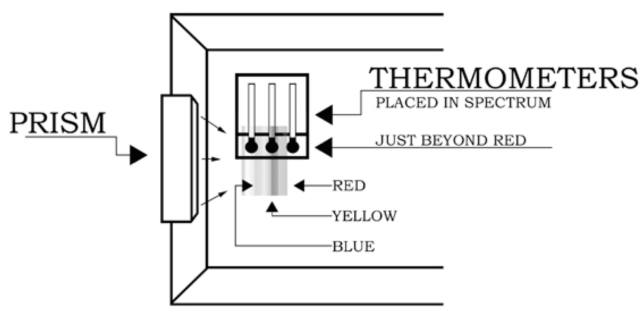
3. The thermometer bulbs in your setup are covered in black paint - why do you think that is? (hint: think of what happens to black car seats on a sunny day).

4. In the next step, you will use the thermometers to measure the temperature of the different colors of the spectrum. As you saw during setup, the location of the spectrum on the box depends on the relative angle between the prism and the sun. If it takes 5-10 mins to do this experiment, do you expect the location of the spectrum to change? Why/why not?

B) Procedure:

Read all the instructions in section B) before starting your measurements.

1. Once you've obtained a shade measurement for each thermometer, you should place the thermometers in the spectrum, such that one bulb is in the shade <u>just beyond the red region</u> (this will be your "control" thermometer), and the other thermometers are measuring different colors in the spectrum (see figure). You should try and sample the colors evenly (e.g. one in violet/blue, one in yellow/green, and one in the red). If the thermometers are mounted too far apart or too close together, adjust the width of the spectrum so that the thermometers are spanning the entire spectrum. In the table, record which color each thermometer is measuring in the second row (remember that one of the end thermometers must be in the shade - enter "control" in the color row).



2. Write down a prediction for what you think will happen to <u>each thermometer</u>. Will their temperature increase or not? Which color will increase the most/least? Try to keep the thermometers on that same color for the next 5 minutes (i.e., if the spectrum is moving slowly, try to adjust the location of the thermometers so that each thermometer is always measuring the same color). <u>Important: make sure the control thermometer is always in the shade</u>.

3. Once you place the thermometers in the spectrum, it will take about six minutes for the temperatures to reach their final values. Take readings for each thermometer every 2 minutes until the temperatures are stabilized and record the temperatures in the table. Do not remove the thermometers from the spectrum or block the sunlight while reading

	Therm #1	Therm #2	Therm #3	Therm #4
Initial (Shade) Temperature, T				
Color Measured				
Temperature after 2min				
Temperature after 4min				
Temperature after 6min, T				
ΔT = T				

the temperatures.

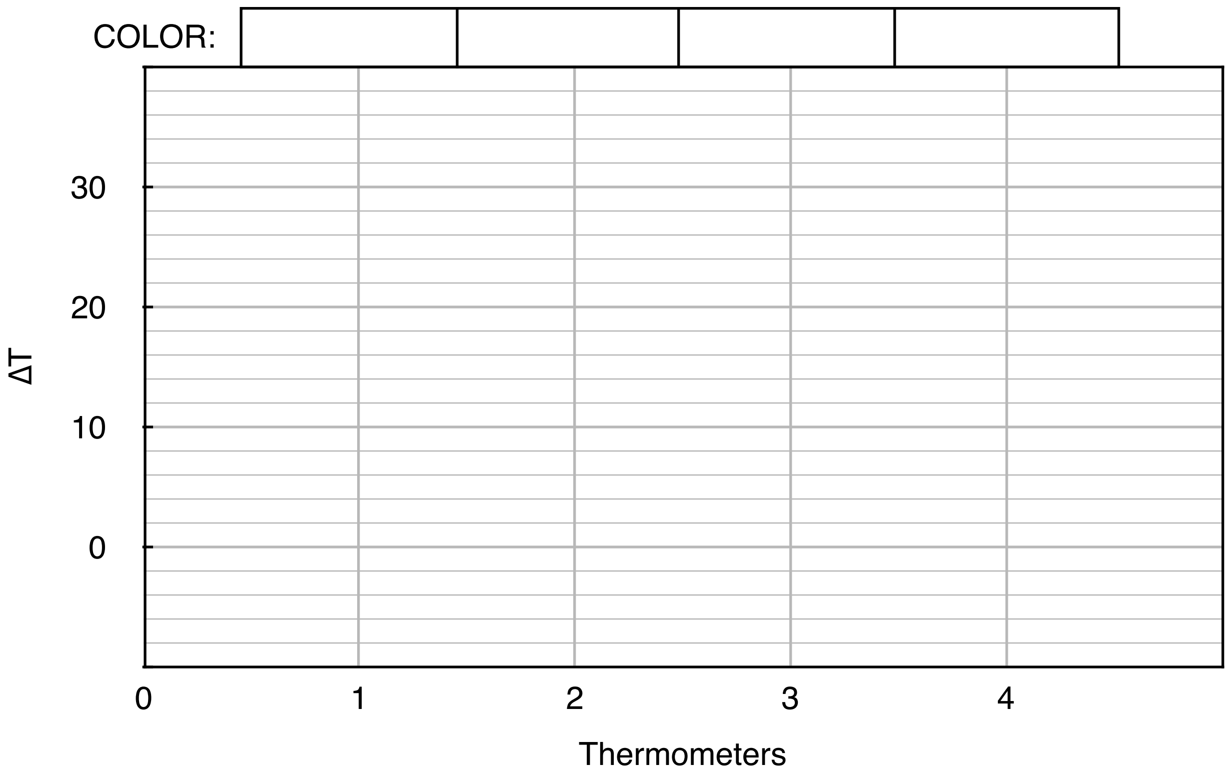
C) Analysis and Interpretation

1. Compute the difference between the final temperatures, T_F, and the initial shade temperatures from the first row, T_i, for each of the thermometers and enter them in the last row of the table.

2. Plot your temperature difference values (ΔT) for each thermometer in the graph on the next page. Label each thermometer with the corresponding color in the top panel and make sure to include your control thermometer, and label it as "control". This is your solar spectrum - the amount of light emitted by the sun as a function of wavelength.

3. What does the graph you just plotted tell you? Did you observe any trends? Which thermometers had the largest/smallest temperature increase? Did this match your prediction from section B?

4. What happened with your control thermometer during the experiment? Was the temperature constant, or did it change? Is this what you expected to happen? Why/why not? Write down <u>at least two</u> possible causes for the behavior you observe, and how you would go about testing these hypotheses, then check your reasoning with your instructor.


COLOR:
30
20
10
0
ΔT
0
1
2
3
4
Thermometers