



Laboratory Exercise
REFLECTION SPECTROMETER
Jie Ren

Purpose: To introduce students to use of a simple laboratory spectrometer, calibration, examination of several surfaces, plotting, and interpretation of results.

References:

J. B. Campbell, J.B., and R. H. Wynne, *Introduction to Remote Sensing*. Chapters 2 and 3.

Stein, Beth, J. McGee, and J. B. Campbell. *Collecting a Spectral Reflectance Curve*, VirginiaView (<http://virginiaview.cnre.vt.edu/education.html#Spectrometer>).

Treiman, Allan 2000. *ALTA Reflectance Spectrometer: Introduction and Classroom Lessons*. 2000. Lunar and Planetary Institute. Beaverton, OR. LPI Contribution 1071. 100 p.

Materials:

- ALTA II reflectance spectrometer
- White poster board
- Samples in black boxes large enough to completely cover the spectrometer's lamp array opening (located on the back of the instrument)
- Pencil with soft eraser (optional)
- Calculator (optional)
- Excel spreadsheet configured for use with spectrometer exercise
- Worksheets (used as an alternative or supplement for Excel spreadsheet, see pp. 6-8)

Teacher's laboratory preparation notes:

- Students organize into groups of two or three students, one group for each spectrometer. If the number of spectrometers is small relative to class size, organize such that students can be divided into several cohorts that can alternate the spectrometer activity with another exercise, then cohorts can exchange activities.
- Prepare small boxes (ea. approximately 12 in by 8 in or 30 cm x 20 cm), lined with black construction paper (perhaps at least two for each spectrometer).
- Fill each box with a different sample and label the box with the sample's name. For convenience, each box can include paired samples, such as live and dry leaves, deciduous and evergreen leaves/needles, etc. We suggest pairing samples to provide a selection of differences that will require students to apply concepts presented in text or lectures (live and dry leaves, wet and dry soils, etc.).
- Prepare copies of student handouts (pp, 6-8) for each group. Provide copies of "Data Table" for each group. If there is no computer in the classroom, prepare copies (according to the number of samples each group will do) of "Data Table with Reflectance Calculating" and "Graph Paper: Percent Reflectance vs. Color" for each group.
- For each group, ideally, each student will have a task. One student should instruct the group on the procedure, one should use the ALTA II and read out the measurements, and

another should record the measurements on the data table. We recommend that students switch tasks between samples.

- One ALTA II and one white poster board for each group.
- Sample boxes are prepared as above, and each group measures 2-4 samples.

About the ALTA II Spectrometer:

The ALTA II spectrometer is designed for educational applications to demonstrate concepts and applications in spectroscopy and remote sensing.

The ALTA II spectrometer measures reflectance corresponding to radiation at eleven specific wavelengths, from blue to infrared; seven are in the visible range, and four are outside in the invisible range. The 11 buttons on the front panel of the instrument correspond to each band, e.g., the *Blue* button corresponds to the blue region, the *Green* button corresponds to the green region, etc. Each button also corresponds to one of the lamps found in a circular hole on the rear of the instrument. These lamps emit energy corresponding to each wavelength, and the sensor that detects the energy reflected is in the middle of this circle. When a button is pressed, the instrument emits energy and measures the amount of energy reflected back. The front panel of the instrument screen indicates how much of the energy (in millivolts) is reflected back.

The spectrometer's display value is usually not zero when there is no light on the sensor - the display value is usually between zero and 150 — this value is called the “dark voltage,” or “dark current.” This value is derived entirely from the sensor itself, not from light hitting the sensor. Each ALTA II unit will have a slightly different reading for the dark voltage, and the reading may change over time due to temperature variations. Dark voltage is instrument noise, created within the spectrometer itself, which must be subtracted from voltages displayed when the instrument is used to observe a target. Thus, before each sample measurement, you need to take and record a dark voltage reading.

For remote sensing applications, the preferred measure is usually the reflectance of a surface (i.e., the proportion of total brightness) because it isolates characteristic spectral features of a surface from its overall brightness. The raw spectrometer reading does not directly provide a real reflectance value. To calibrate the ALTA II, users need to measure the amount of light reflected by an object with known reflectance values as a standard and compare that measurement to their sample measurements. As an approximation, white poster board, which reflects about 85–90% of the incident light, serves to illustrate basic concepts. For research applications, scientists often use a white material called “Spectralon,” manufactured to have uniform brightness over a broad range of wavelengths (at a cost of about \$670 for a 2 inch square!). To estimate a genuine reflectance value, you need to subtract the dark voltage from the measured voltages, and then divide the adjusted sample value by the adjusted standard and convert to a percent value. The percent reflectance of each sample is calculated as follows:

$$\% \text{ Reflectance} = \frac{(\text{sample voltage}-\text{dark voltage})}{(\text{standard voltage}-\text{dark voltage})} \times 100$$

See also: <http://www.vernier.com/products/sensors/spectrometers/alta/>
<http://www.lpi.usra.edu/education/products/spectrometer/>
<https://itunes.apple.com/us/book/nasa-tour-electromagnetic/id567540768?mt=11>
<http://speclab.cr.usgs.gov/spectral-lib.html>
https://landsat.usgs.gov/tools_spectralViewer.php

Student Procedure:

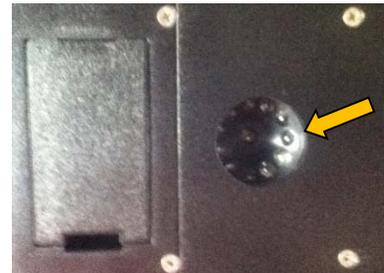
If your laboratory or classroom has a computer at hand, students may record spectrometer readings directly on the spreadsheet. Otherwise, they can record readings on the paper worksheet (pp 6 – 8).

Depending upon specific circumstances, you can use the paper data table (p. 6) to record data as an intermediate step prior to entering data into the Excel spreadsheet. If no computer is available, the paper worksheet (pp. 7-8) can be used to record and plot your spectral data.

1. **Turn the spectrometer on by pressing the “ON/OFF” button on the front of the instrument.**



2. Hold the instrument so that your group can see inside the lamp/sensor array on the back of the instrument. **BE CAREFUL NOT TO PLACE ANYTHING INSIDE THIS OPENING.** Press and hold the blue button on the front of the instrument. You should see the blue lamp glow as long as you continue to press the blue button. When you release pressure the lamp shuts off.

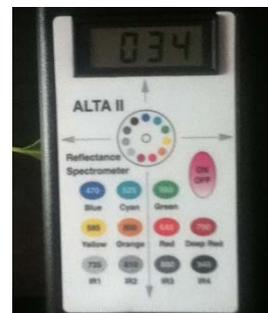


Still holding the spectrometer in your hand, look at the display panel. The reading on the display will be “1” when no lamps are lit and the instrument is not lying on a flat surface. This means too much light is reaching the sensor. In this condition, the instrument will not provide a valid reading.

3. **Place the spectrometer, lamp side down, on a leaf so that it completely covers the lamp/sensor array opening.** Note the display number (presented in millivolts) when you are not pressing any buttons on the color switch pad and no ALTA lamps are on.

The side of the vegetation that would normally face the sun should now face the lamps. The top side of the leaf is facing up as you look down at the instrument.

4. Wait for the display to stabilize. This reading is the ‘**dark voltage**’ (‘dark current’), which is instrument noise created within the spectrometer. The value is usually between zero and 150. **Record this value in the data table.**



5. **Turn the blue lamp on by pressing the number on the blue pad with a pencil.** Continue to press until the display number remains nearly constant. Record this value in your data table in the “Blue” row and “Sample1/Sample” column. (Readings obtained while



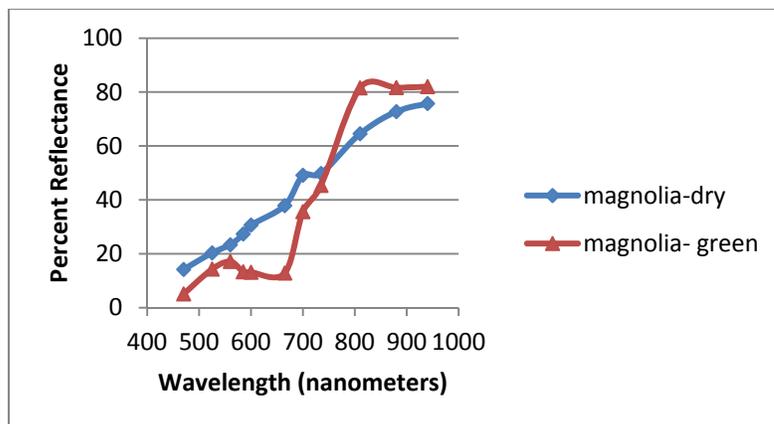
pressing a color button should always be higher than the dark voltage.)

6. **Working from left to right, press each remaining pad and record its value in the same column.** The green lamp is more sensitive and tends to drift. Record the highest value you observe for the green lamp when the readings begin to stabilize.
7. **Repeat Steps 3-6 using different samples.**
8. **Repeat steps 3-6 using the white poster board.** Record these values under “Standard White Poster” column.
9. **Calculation of Reflectance.** This lab assumes that the white poster board yields the maximum amount of the light that strikes it. **For each recorded reading, use the following formula.** This value is called the *percent reflectance*.

$$\% \text{ Reflectance} = \frac{(\text{sample voltage} - \text{dark voltage})}{(\text{standard voltage} - \text{dark voltage})} \times 100$$

10. **Enter data** from your data table into either the **Excel spreadsheet**, or the **paper worksheet**. The Excel spreadsheet will calculate reflectances as described above, and provide a spectral curve for each object using scatter plot option, as shown below. If the Excel spreadsheet is not available, the paper worksheets provide the basis for recording data so you can make calculations and plots later.

Using Excel: To create a spectral curve, on the toolbar at the top of the spreadsheet, left click *Insert*, then *Scatter with Smooth Lines and Markers*, then there is a blank chart box. Right click the chart box and left click *Select Data*, then a “Select Data Source” box pops up. Click *Add*, select sample name as *Series name*, select 11 wavelength values as *Series X values*, and select 11 voltage values of the sample as *Series Y values*, then click *OK*. Add the other sample with the same steps, then click *OK*. Under *Layout*, click *Axis Titles* to add horizontal and vertical axis titles.

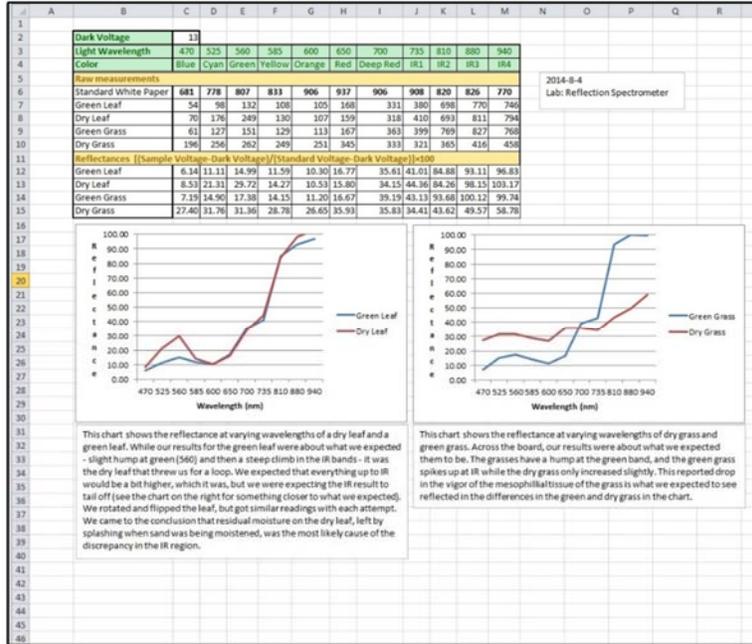


Example of screenshot of spectral curve prepared from spectrometer data.
(X-axis shows wavelength (nm); Y-axis shows percent reflectance).

If there is no computer available, use the worksheets mentioned previously (pp. 7-8) to prepare and plot the spectral data you have collected. **Manually enter data** on “Data Table with Reflectance Calculating” and calculate the percent reflectance. **Record the**

value under “% Reflectance” column. **Graph** your results on “Graph Paper: Percent Reflectance vs. Color”.

11. Follow your instructor’s instruction to present your interpretations of these spectral curves.



Example of Excel spreadsheet with reflectance calculations, spectral plots, and student’s interpretation.

Data Table

		Dark Voltage (mV):				
		Voltage (mV)				
Color	Light Wavelength	Standard White Poster:	Sample1:	Sample2:	Sample3:	Sample4:
Blue	470 nm					
Cyan	525 nm					
Green	560 nm					
Yellow	585 nm					
Orange	600 nm					
Red	645 nm					
Deep Red	700 nm					
Infrared 1	735 nm					
Infrared 2	810 nm					
Infrared 3	880 nm					
Infrared 4	940 nm					

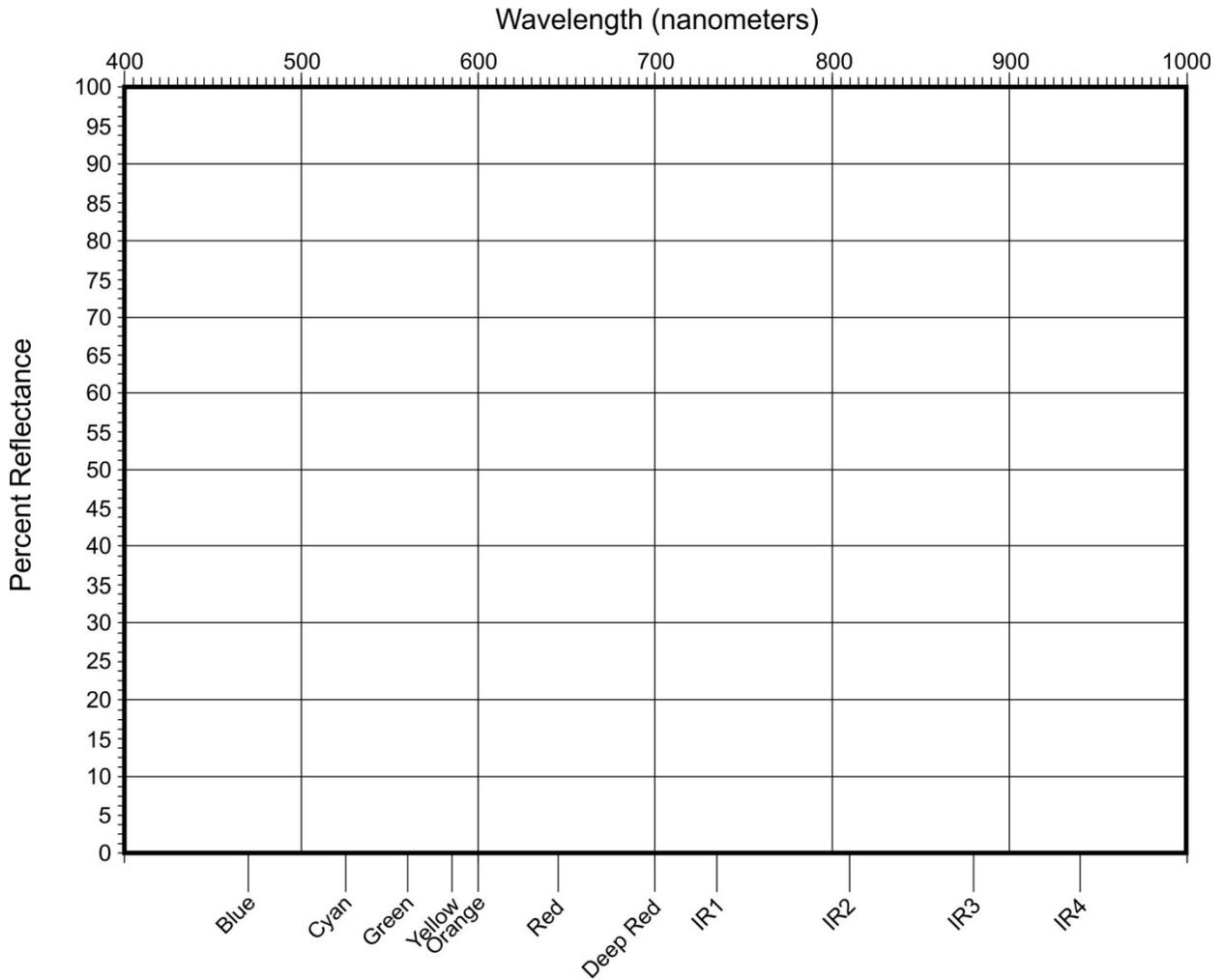
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Data Table with Reflectance Calculation

		Dark Voltage (mV):		
		Voltage (mV)		% Reflectance
Color	Light Wavelength	Standard White Poster	Sample:	$\left[\frac{\text{Sample Voltage} - \text{Dark Voltage}}{\text{Standard Voltage} - \text{Dark Voltage}} \right] \times 100$
Blue	470 nm			
Cyan	525 nm			
Green	560 nm			
Yellow	585 nm			
Orange	600 nm			
Red	645 nm			
Deep Red	700 nm			
Infrared 1	735 nm			
Infrared 2	810 nm			
Infrared 3	880 nm			
Infrared 4	940 nm			

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Graph Paper: Percent Reflectance vs. Color



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