THE ALTA II SPECTROMETER: A TOOL FOR TEACHING ABOUT LIGHT AND REMOTE SENSING.

Allan H. Treiman and Pamela B. Thompson. Lunar and Planetary Institute, 3600 Bay Area Boulevard. Houston, TX 77058-1113 <treiman@lpi.usra.edu>, <thompson@lpi.usra.edu>.

Introduction. The ALTA II is a classroom instrument designed to teach about light and its interactions with matter in participatory, hands-on classroom exercises. It is small, lightweight, colorful, has buttons to push, lights that go on, and a display number that responds to student actions. The ALTA II allows students to do 'remote sensing;' it allows measurement of reflectances, in light of 430 - 980 nm wave-lengths in seven visible colors and four near-infrared 'colors.' For objects > 1" in diameter with matte or rough surfaces, reflectances can be measured to within a few percent of those determined in the laboratory. ALTA spectrometers have been tested and used in the classroom for several years. The ALTA II comes with a booklet with operating instructions and ten lessons, all tested, covering topics on color, vision, environmental and planetary remote sensing, and physics [1]. The ALTA has been quite successful in helping middle-school students learn about color, infrared light, interactions of light with matter, and remote sensing.

The ALTA® hand-held Reflectance Spectrometer measures 3.75" × 6.75" and weighs only 9 ounces

Description. The ALTA II is an 11-band photometer, actually not a spectrometer. It is used to measure reflectance by: illuminating a target with light from commercial light-emitting diodes (LEDs); measuring a voltage proportional to the intensity of light reflected off a target and into a sensor; comparing this result to a similar result for a standard material; and mathematically reducing the results. The LEDs span the visible and near-IR, 470 to 940 nm (Table 1). The LEDs are turned on via push buttons on the spectrometer face; each button is coded with the color and peak wavelength of its LED. Reflected light is detected with a silicon photodiode. The current output of photodiode is converted to voltage across a resistor, which is digitized and displayed. The brightness of each LED is adjusted in the factory so that white paper produces about 100 mv output, seen on display as ~1000. Voltage offsets in the electronics leave a "dark voltage," typically 0.2 to 10 mv, when no light hits the photodiode. There is no temperature compensation.

The ALTA II is suitable for many types of samples available in the classroom. The light entry/exit port is 1" diameter, which is a minimum sample size. The lamp/sensor system is relatively insensitive to sample roughness on the order of 0.5 cm, provided that ambient light does not leak to the sensor. Shiny or specular surfaces will produce spurious results.

Table 1. ALTA II LED Colors and Wavelengths

Color	Wavelength (nm)	Color	Wavelength (nm)
Blue	470	Deep Red	700
Cyan	525	IR1	735
Green	560	IR2	810
Yellow	585	IR3	880
Orange	600	IR4	940
Red	645		

Data Acquisition and Manipulation. To use the ALTA II, a student would place it on the target object so that room light doesn't leak to the photodiode. The student would record the dark voltage and then, one by one, turn on each LED lamp and record the voltage reading in the display. Then, the student would place the ALTA II on the standard and again turn on each LED lamp and record the voltage.

Output voltage is converted to reflectance using an external standard of known reflectance. We typically use stack of white paper, which reflects 90-95% of the incident light (itself calibrated against an 18% gray card). For most applications, the white paper can be considered to reflect all the incident light.

Using a calculator, the percent reflectance '%R' for each wavelength (each lamp) is calculated as:

$$\%\mathrm{R} = 100 \times \frac{\text{voltage for target} - \text{dark voltage}}{\text{voltage for standard} - \text{dark voltage}}$$

For our target audience (5th grade gifted/talented), percentages as whole numbers are less challenging than decimals. Dark voltages are ignored for bright objects, younger grades, and the numerically challenged.

Reflectance values are then graphed versus wavelength of light on templates provided in the lesson booklet.

Typical Spectra. Figures 1 and 2 show some typical reflectance spectra taken with the ALTA II. The green leaf of Fig. 1 clearly shows why leaves look green (reflectance peak at 560 nm), the two reflectance minima caused by chlorophyll (<470 nm and ~650 nm), and the high reflectance in the near infrared.

Figure 2 shows the reflectance spectra of three rocks of planetary significance: basalt scoria with a reddish hematitic coating (Hawaii); a peridotite mantle xenolith (Arizona); and a gray dunite (Oregon).

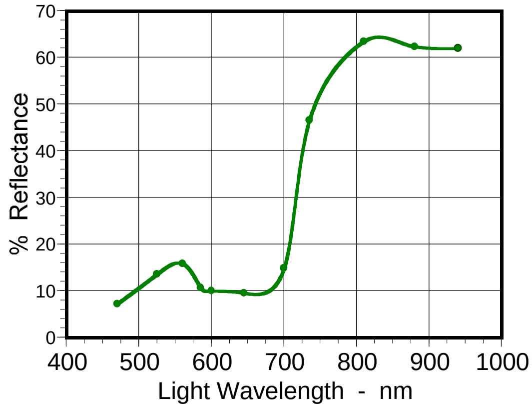

Figure 1. Reflectance Spectrum - Philodendron Leaf

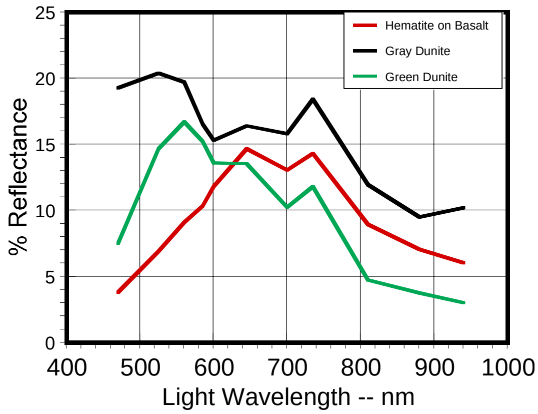

Figure 2. Reflectance Spectra - Three Rocks.

The spectrum of hematitic basalt shows very little reflectance in the blue and green, and a typical drop in the near infrared [2]. The gray dunite appears greenish-gray, and has only slightly higher reflectances in blue through green. Overall, its brightness is similar to an 18% gray card, and its average reflectance in the visible is (in fact) 18%. It has a reflectance minimum at 880 nm, which is characteristic of Mg-rich olivine [2]. The green dunite has a significantly higher reflectance in green compared to the other wavelengths.

Other Uses. Beyond its use as a spectrometer, the ALTA has enhanced our teaching of light and color. The LED lamps in the ALTA can be used as sources of monochromatic light (albeit dim), which can be viewed with an emission spectrometer/spectrographs for comparison with other lamps. The light sensor in the ALTA can be used to demonstrate the existence of infrared light – an invisible emission that nevertheless behaves like visible light.

Classroom Response. Students have responded enthusiastically to the ALTA spectrometer. After being shown that the buttons turn on colored lights, students explore the different colors, and question the buttons that appear to do nothing (infrared) and the meaning of the display numbers. After coming to satisfactory answers (or questions), the students are walked through a single measurement of reflectance (with calculators to do the math), and are then grouped in twos or threes to take reflectance spectra, typically first of leaves. Other targets for spectra include Mars Soil Simulant JSC-1 (in conjunction with other exercises). Of their own volitions, students commonly measure reflectances on classroom objects, including their skin and their eyes.

Evaluation. We did not set out to measure the efficacy of the ALTA II in teaching about light and remote sensing. Its predecessors were created as an immediate fix to an inability to teach remote sensing and spectroscopy effectively, so it was not accompanied by a formal evaluation program. The local schools, Clear Creek Independent School District, required administration of identical tests before and after a gifted/talented course – the pre-test and post-test. These tests provide some insight into the value of the ALTA spectrometer.

Our pre- and post-tests end with a short essay question, “How do we figure out what a distant planet is made of even when we haven’t been able to visit it in person?” Spectroscopy and remote sensing are among its target answers: The question was graded on a scale of zero–three. In 1993, before we used the ALTA spectrometer, the average scores on this pre-test and post-test question were 1.1 and 1.6 respectively. In 1998, after a few years of using the ALTA spectrometer, the average pre- and post-test scores were 0.8 and 2.3 respectively. The pre-test scores in the two years are similar, but the post-test scores improved dramatically after the ALTA was introduced.

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References: [1] Treiman A. (1998) *ALTA Reflectance Spectrometer: Introduction and Classroom Lessons*. Lunar and Planetary Institute, Houston. [2] Farmer F. (1974) ch.13 in *Infrared Spectra of Minerals* (ed. F. Farmer). Min. Soc.