# Building an absorption spectrophotometer: science emersion through construction and calibration of an instrument and using it to design an experiment.

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## Introduction

Students will be introduced to a spectrophotometer during the unit of Astronomy. Students will study the history of spectrophotometers and understand there uses. A spectrophotometer is a device that is used to measure properties of light over a specific portion of the electromagnetic spectrum and is typically used to identify materials such as, how the color and temperature of stars are interconnected.

Students will be actively involved in the design and research phase of their spectrophotometer. Groups would be assigned to teach collaboration skills but students could work independently if justified.

Students will then build their spectrophotometers and keep a journal recording the building process. This will serve as good notes when they are asked to improve upon their models.

Students will then design experiments to utilize their spectrophotometers. We will encourage the use of their spectrophotometer in other fields of science as well such as, MST's aquatics lab. The goal is for students to discover practical real world applications for their spectrophotometer through experimentation, inquiry, and design.

## Project Overview

Main Objective: Students will use the complete scientific method themselves by developing an instrument and using it to analyze their own experiment.

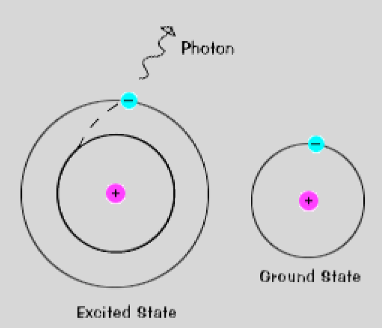
1. Build successively more complicated devices for using the EM spectrum as an analysis tool.
2. Learn how scientists use a known relationship such as a the EM spectrum to quantify the environment.
3. Understand how to calibrate an instrument and why it is necessary.
4. Design an experiment that can be analyzed with the spectrophotometer.
5. Interpret the results with collected data.

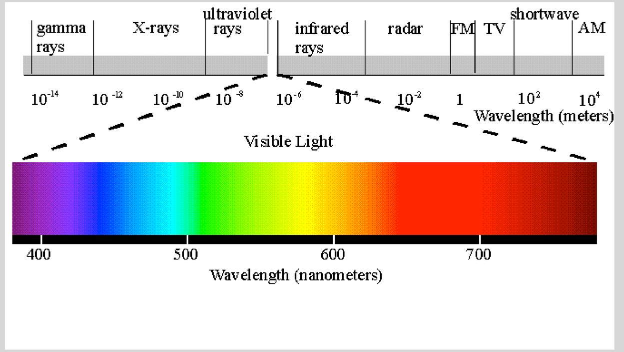
## Tools and Parts

1. Voltmeter
2. Diffraction Grating
3. Old CD's
4. Wire stripper
5. ~400 hole electronics breadboard
6. 20-24 gauge electrical wire
7. Shoe box
8. Cereal box
9. 5x magnifying lens
10. Cuvettes
11. Box cutter
12. Wire clips "gator clips'
13. Flashlight
14. 9v, AA and D batteries
15. Paper towel tube
16. 741 op-amp
17. Battery clips
18. 1, 2.2, 4.7 k-ohm resistors
19. Bright Incandescent Bulb
20. Black card board
21. Aluminum Foil
22. Battery holders
23. Tape
24. Razor or fine scissors
25. Ruler
26. Protractor

## EM spectrum

The Electromagnetic (EM) spectrum or light interacts with matter. Atoms of different kinds are able to absorb light and emit light when they are exposed to certain parts of the EM spectrum, which can be detected with the proper equipment

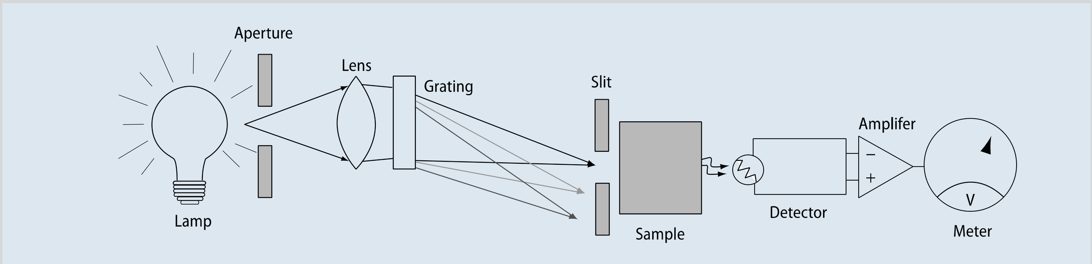



## Spectrophotometer Background

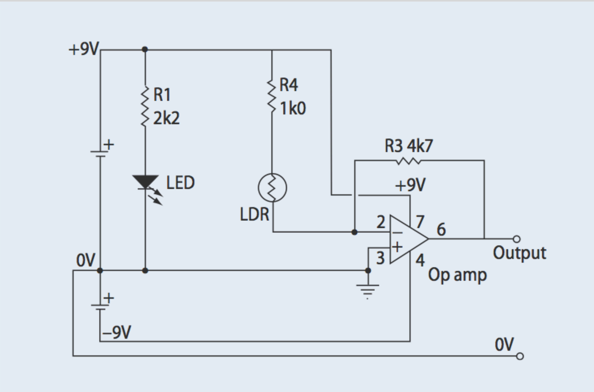
A spectrophotometer uses the relationship of atomic absorption of certain EM frequencies to quantify the concentration of a colored solution. In order for the device to work the sample in the cuvette must have a color intensity linearly proportional to the concentration of of solute in water (ex: food coloring). When light is split through the diffraction grating, a certain wavelength is chosen by the slit to contact the sample. The light which reaches the detector is that which is emitted by the sample after the initial illumination. The voltage picked up by the voltmeter allows back calculation of the sample's absorbance.

$$A = -\log\left(\frac{V_{sample} - V_{darkness\ no\ sample}}{V_{clear\ water} - V_{darkness\ no\ sample}}\right)$$




## Step 1: Building Instrumentation

In order to achieve a good understanding of all the working components we suggest a sequential approach:
1.The spectrometer: Use this instrument to teach the students how a diffraction grating splits light. The simple instrument displayed with this poster is just the diffraction grating and a cereal box. Cut a slit 30-45 degrees to the left of the desired view and point the device at different light sources. Students will be able to analyze the EM spectrum.
2.The photometer: Use this instrument to build the simple circuitry and teach students how the detector works.

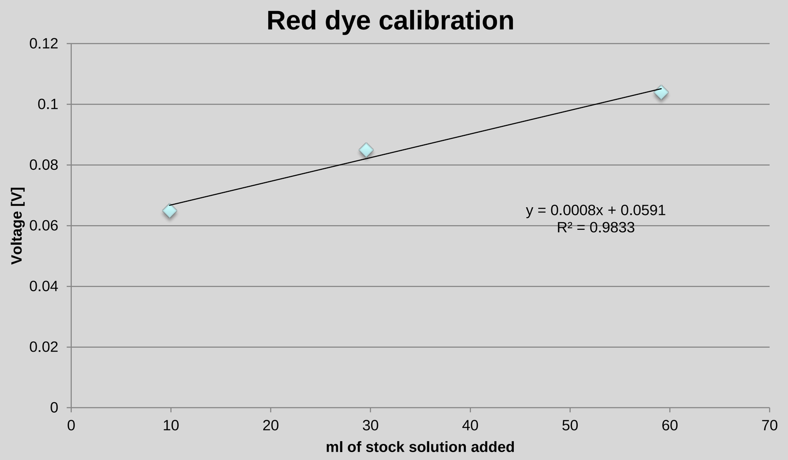



Shining unfiltered light on the sample will allow some light to pass and hit the detector.
3. The spectrophotometer: This is the final instrument. Have the students add the lens, cardboard tube, and diffraction grating. The students will now need to experiment with different wavelengths of light.

## Step 2: Methods and Calibration

Calibration is an important step in developing a scientific instrument. In order to calibrate an instrument one must develop a set of known values and determine how the instrument will read them. A relationship is then discovered from a plot of absorbance versus concentration. This relationship allows interpolation to be used to determine unknown samples in the future.

Using clothing dye from a craft store you can add drops of dye to a known volume of clear water and measure the voltage the spectrophotometer gives. Doing this for several concentrations will give a straight line. In this case the curve works between 10 and 60 ml of dye added to 250 ml of water. We selected red light for this calibration.




## Step 3: Experiment

The next step is to allow students to create and analyze their own ideas. They can use many different solutions and reactions to explore their world. We suggest some ideas for use:

1. Food coloring or clothing dye with different wavelengths of light and different colors.
2. Miracle Gro (blue) plant fertilizer in a mixture of algae to measure nutrient uptake.
3. Using universal pH indicator or bromocresol green and use absorbance as a pH indicator for acid base reactions.

## Conclusion

Students will put into practice the scientific method to design experiments for there home-made spectrophotometer while understanding the use of spectrophotometers in Astronomy as well as other areas of science. Extension activities are abundant such as, testing water quality in environmental science or discovering different gas producing biofilms in biology.

Students will be able to keep the spectrophotometers that they built and use it in throughout there time at MST for example: to test the pond water in the learning garden or the tanks in the aquatics lab.