Lesson Title	Calibration - Grating Spectrometer
Length of Lesson	2 class periods (100 min)
Created By	Charles Vaughan
Subject	Physics
Grade Level	11 - 12
State Standards	1d, 1e
DOK Level	DOK 3 - Formulate, Assess, Use Concepts to Solve Non-Routine Problems
DOK Application	Develop a scientific model for a complex situation. Apply a concept in other contexts.
National Standards	9-12: A: Science as Inquiry
Graduate Research Element	Any device used to collect or output information must be calibrated properly. My research involves spectral analysis of comets. Any time the detectors are to be used, the must be calibrated first.

Student Learning Goal:

MS Physics:

1d (Inquiry): Organize data to construct graphs

1e (Inquiry): Evaluate procedures, data, and conclusions to critique the scientific validity of research

National Science Standards for Grades 9-12:

A: Science as Inquiry: Use technology and mathematics to improve investigation and communication:

- A variety of technologies, such as hand tools, measuring instruments, and calculators, should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data is also a part of this standard. Mathematics plays an essential role in all aspects of an inquiry. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results.

Materials Needed (supplies, hand-outs, resources):

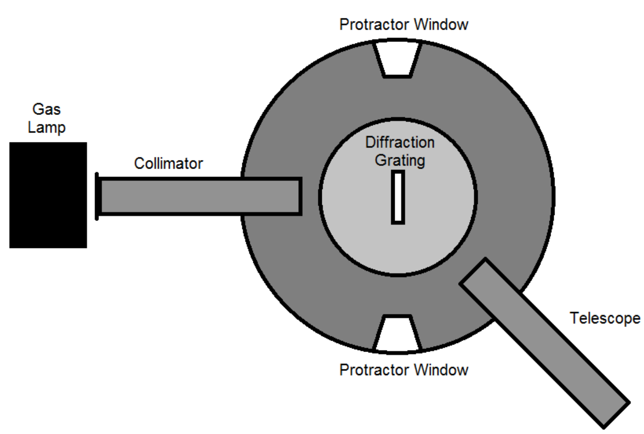
For this lesson, a computer with some form of plotting/spreadsheet application is needed to fulfill the technology standard. The exact device to be calibrated can be chosen by the instructor. Because my class will be learning about atomic emission during this time of the semester, I will use a grating spectrometer and several gas bulbs (hydrogen and helium) to perform the calibration. Flashlights and a table of emission spectra for helium will be needed (File name: INSPIRE_Vaughan_10_01_12_Helium.doc).

Lesson Performance Task/Assessment:
Students will be given a device (grating spectrometer) and will be asked to calibrate it. They will need to record the angle at which each light band of known wavelength is observed. Students will then make a plot of their wavelength versus angle measurements. Using a graphing tool, a curve should be drawn through the data points. This curve represents their calibration curve. It serves as the standard by which all other spectral data is analyzed.

Lesson Relevance to Performance Task and Students:
Learning to calibrate a device is a highly transferrable skill. Any device used to collect or output information - from simple automotive speedometers to more complex radiation detectors - must be calibrated properly.

Anticipatory Set/Capture Interest:
"Your car has a speedometer, which shows you how fast your car is travelling down the road. But in reality, the speedometer dial only moves based on how fast the wheels are spinning. How does the angular speed of the rotating wheels get translated into the linear speed indicated on your dashboard? The speedometer had to be calibrated based on the size of the tire. Changing the size of the tire without recalibrating the speedometer will cause an inaccurate reading. This happens to many people who unknowingly get larger tires without readjusting the speedometer!"

Guided Practice:
Show students how to set up the diffraction grating and gas lamp. Do NOT move the grating once setup is complete, else the calibration will likely be ruined. If the spectrometer's protractor has a Vernier scale, make sure all students know how to read this. As an example, show that the telescope tube will rotate while the collimator, gas lamp, and grating remain stationary.



Using computer software (common spreadsheet applications work well), show how to record and plot some sample data points for wavelength versus angle (using real data observations is not necessary, but works better). Create a curve through the data, which serves as the calibration curve. Then, propose to the students that you have a new, unknown gas, in which a few emitted lines were observed and their corresponding spectrometer angles were recorded. Plots those new angles against the calibration curve to estimate the wavelengths of the emitted lines.

Independent Practice:

- Line up the collimator and telescope. Position the grating so that its window is perpendicular to the collimator and telescope.
- Make a table with three columns: color, angle, and wavelength.
- Begin with helium gas, which has numerous easy-to-find emission lines. With the lights turned off, rotate the telescope until a distinct colored line comes into view. Record the color of the line and angle on the spectrometer (using a flashlight will make this much easier).
- Using a table of known wavelengths and colors for helium, pair each recorded angle with its corresponding wavelength. Depending on bulb intensity and ambient light in the room, students may not be able to see all the lines.
- Once all helium data has been collected, turn off the gas lamp. Plot the wavelength (y-axis) versus angle (x-axis) and generate a curve through this data. Save this graph or print it out.
- Now replace the helium bulb with hydrogen (CAUTION: the helium bulb may still be very hot). Turn on the lamp, and try to find four emission lines for this gas. This is known as the Balmer series for hydrogen. One line is red, one line is cyan, and two are violet (one of which may be very dim).
- Record the angle on the spectrometer for each of these lines. Using the calibration curve generated for helium, estimate the value of the wavelength for each hydrogen line.

Remediation and/or Enrichment:

Remediation – IEP

For more advanced classes with sophisticated software, have the students generate a function (n-order polynomial or exponential) through the original helium calibration data. This will be the calibration function. Using a function rather than graphical estimation will give much more accurate values when finding the wavelengths of the unknown gasses.

Check(s) for Understanding:
Compare the estimates for the hydrogen wavelengths with known values. These can be very easily found online, but I will also list them here: 656.28nm (red), 486.13nm (cyan), 434.05nm (violet), and 410.17nm (dim violet). Do NOT tell your students these values until after they have attempted to find the values by themselves.

Source: http://www.phys.utk.edu/labs/modphys/BalmerSeries.pdf

Closure:
- The slit on the collimator narrows the beam of light from the bulb. What is the advantage of having a very narrow beam, and what is the disadvantage?
- What would happen if I moved the diffraction grating while I was calibrating? Would I need to start my calibration over?
- How much uncertainty is there when I read the protractor on the spectrometer? Is that uncertainty greater or less than the estimate used with the calibration curve?

As with any scientific observation, my research on comets requires that the telescopic instruments be calibrated properly so that observations can be accurate.

Possible Alternate Subject Integrations:
Math, chemistry, and any technology or pre-engineering courses

Teacher Notes:
The spectroscope used for this lesson was contributed by a partner university. However, any device requiring calibration can be used to teach this topic.