***Spectroscopy, Grating, Slits, &c***

**Instructions:** There are four stations in the back area of room 478, corresponding to the 4 sections below. Some of the stations are intended to be more exploratory, some ask specific questions aimed at the teacher level, and some require quantitative measurements. As you go through these stations, think about whether this could be useful to your students or your colleagues who teach NGSS earth science, and also think about what sort of student questions might be valuable in each case.

**A. Diffraction Gratings** (holographic, blazed, sine, high/low dispersion, etc)

Task: you’ve heard some brief information from Dr. Wonnell about different types of grating and prism. In front of you are several of those mentioned. Determine which is which, and justify each identification with experimental evidence. Explain your results using the “CER” method (claim-evidence-reasoning).

If time permits, take a look at some of the holographic gratings under the provided microscope.

**B. Guess the unknowns**

1. This station provides you with the [Vernier version](https://www.vernier.com/product/diffraction-apparatus/) of a multiple-slit diffraction / interference experiment. Two lasers are provided, but the wavelength of the red laser has been hidden. Using the apparatus provided, calculate the wavelength of the red laser and justify with experimental evidence, in the CER style.
	1. Small hints for LoggerPro/equipment:
		1. The laser has two screws on the back that allow you to adjust its aim at the slits.
		2. The green laser’s wavelength is printed on the front but the red has been covered.
		3. By default, the program will provide two separate graphs, one for intensity and one for position. By clicking on the axes, you can instead display a single graph of intensity vs. position.
		4. The “statistics” function (button at top:  ) is useful for finding mean/median, min/max and stddev values.
2. Using the materials provided at this station and the 532nm green laser, determine the slit spacing in the diffraction grating. Justify your answer using calculations based on experimental data, in the CER style.

**C. Various bulbs**

*For each bulb type, save at least one screenshot of the spectrum you produce. The questions below are intended to be answered using the spectra you produced, with perhaps a small amount of additional web research.*

1. Incandescent bulb
	1. With some thought, this spectrum will probably remind you of the thermal emission spectrum for a hot object, aka blackbody spectrum – or at least the peak section, at any rate. Can you produce any evidence to justify this similarity? For example, what about the idea that an object’s peak emission wavelength varies with temperature?
2. CFL
	1. For decades, fluorescent bulbs have been used to approximate the light produced by incandescent lights, which themselves approximate sunlight. How does the spectrum show both this approximation and the often complained-of fact that fluorescent bulbs seem too “harsh” compared to incandescent bulbs?
	2. Fluorescent bulbs use rarefied mercury vapor to produce light; however, as you probably remember, mercury lamps tend to be a light blue color. Provide experimental evidence that the light being produced contains both emission lines for mercury and emission lines for the phosphors that coat the inside of the bulb.
3. White LED
	1. From the Nobel Prize official [website](https://www.nobelprize.org/prizes/physics/2014/summary/): ***The Nobel Prize in Physics 2014 was awarded jointly to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura "for the invention of efficient blue light-emitting diodes…."*** Based on the spectrum for the white LED, why did the Nobel committee bestow such a high honor on this trio?
	2. As you can see from the disassembled LED bulbs in front of you, there are no phosphors coating the inside of the plastic bulb, as there would be for a fluorescent tube or a “soft white” incandescent bulb. However, LEDs are marketed and sold at various “color temperatures” and the ones disassembled are 5000K and 3000K (“soft white”) varieties. How do the LED bulbs accomplish the task of varying the color profile? Justify with experimental evidence. (hint: the 405nm laser has been provided to help answer the question.)
4. Absorption investigations
	1. The bulbs labeled “Reveal” on top are [marketed by GE](https://www.gelighting.com/led-hd-bulbs/reveal?gclid=Cj0KCQjw6NmHBhD2ARIsAI3hrM0zBK0Oh6_XSyBtJ_oWWiX_iBULDjW6nbSajlIaz99NutrhAtirwT8aAqx4EALw_wcB&gclsrc=aw.ds) as providing *“incredible color contrast and whiter whites for exceptional clarity. It’s perfect for your kitchen, bathroom, or any other space where clarity matters.”* What type of bulb is this fundamentally (incandescent, CFL, LED etc.) and what is different about the spectrum of the GE Reveal as compared to the garden-variety version of the bulb? How does GE accomplish this?
	2. The small lavender glass disks contain a material called “didymium” – glassblowers often use goggles with didymium-containing lenses to [aid in their work](https://www.youtube.com/watch?v=gtZT5kCc0CQ).
		1. How does didymium affect the spectrum of a garden-variety incandescent bulb?
		2. How does this particular effect explain why glassblowers use didymium goggles when working with particular types of glass called “soda lime?”
	3. How could you use either or both of the previous two materials to help students understand the effect of the Sun’s own atmosphere on the solar spectrum measured here on Earth?
	4. Helium was not discovered based on inspection of the typical absorption lines in the spectrum produced by sunlight (aka the “Fraunhofer Lines”); rather, it was discovered using spectra produced during solar eclipses. Why do you think helium remained hidden for so long in the Fraunhofer Lines?
5. Just for fun: the LED+ bulb 😊
6. Just for fun #2: Shine shortwave and longwave UV at various things, including uranium-containing rocks!

**D. Gas Tubes**

**NOTE: be sure to turn off the gas tubes when not being used to make an observation or measurement: they burn out very easily and quickly when left on!**

1. You have been provided with several different types of equipment (at various different cost scales) to quantitatively measure the emission spectrum for gases:
	1. Handheld “Project STAR” spectrometer (~ $35 from e.g. [Arbor Scientific](https://www.arborsci.com/products/project-star-spectrometer) or [Amazon](https://www.amazon.com/Project-Star-Precision-Spectrometer/dp/B00KWCYUQ6))
	2. Student spectroscope ($275 from [surplusshed](https://www.surplusshed.com/pages/item/I1430D.html))
	3. RSpec explorer ($400 from [Arbor](https://www.arborsci.com/products/rspec-explorer) or [Amazon](https://www.amazon.com/Explorer-Classroom-Spectrometer-Spectrum-Spectra/dp/B00CP719CO)) – camera plus software
	4. RSpec software – standalone program intended to analyze uploaded images
	5. Vernier emission spectrometer ($800 for [device](https://www.vernier.com/product/vernier-emissions-spectrometer/) + $90 for optical [fiber](https://www.vernier.com/product/vernier-emissions-fiber/); $400 for [spectrophotometer version](https://www.vernier.com/product/go-direct-spectrovis-plus-spectrophotometer/) but you must also buy the $75 [cuvette-plus-optical-fiber](https://www.vernier.com/product/vernier-spectrophotometer-optical-fiber/) to use it for emissions)
2. **Top priority** is to obtain numerical values for the visible (and possibly near-IR) emission lines of hydrogen – the most precise value will likely be obtained using the Vernier “red tide” spectrometer which can make both optical and near-IR measurements.
3. Second priority is to explore the possibilities for students with the various options and cost scales, and think about what system or combo of systems could work at your school, if you don’t already have this equipment and/or would like to augment what you’ve already got.
4. Third priority is to obtain numerical values and spectrum plots for tubes other than hydrogen.
5. Fourth priority is to experiment with the Vernier spectrometer and see if you can obtain and measure any UV and IR lines for the various tubes.
6. Fifth priority: if time permits, experiment with the provided mercury lamp.