Write up

Please provide your write-up by filling in the write-up template and answering the questions. Space is indicative only – if you need more space, you may enlarge the template. Your answers should be clear and concise; marks will be deducted for long-winded and irrelevant responses.

You should also submit an .stl file of your finished spectrometer housing (with any modifications made) along with your completed CAD model in a ZIP file, and a single .m file containing your Matlab code; the marker will open the code and run it without modification so don't forget to check that it does what you think it does before submitting it! Finally, include the .csv files for all your raw spectra, with appropriate filenames for each file. Make sure your name is on all submitted files so marks can be assigned to the correct student. If your data is not good enough to complete the assignment, there is demo data on Blackboard. If you use this data to complete the programming assignment you **must** include the plots generated with your own data as well.

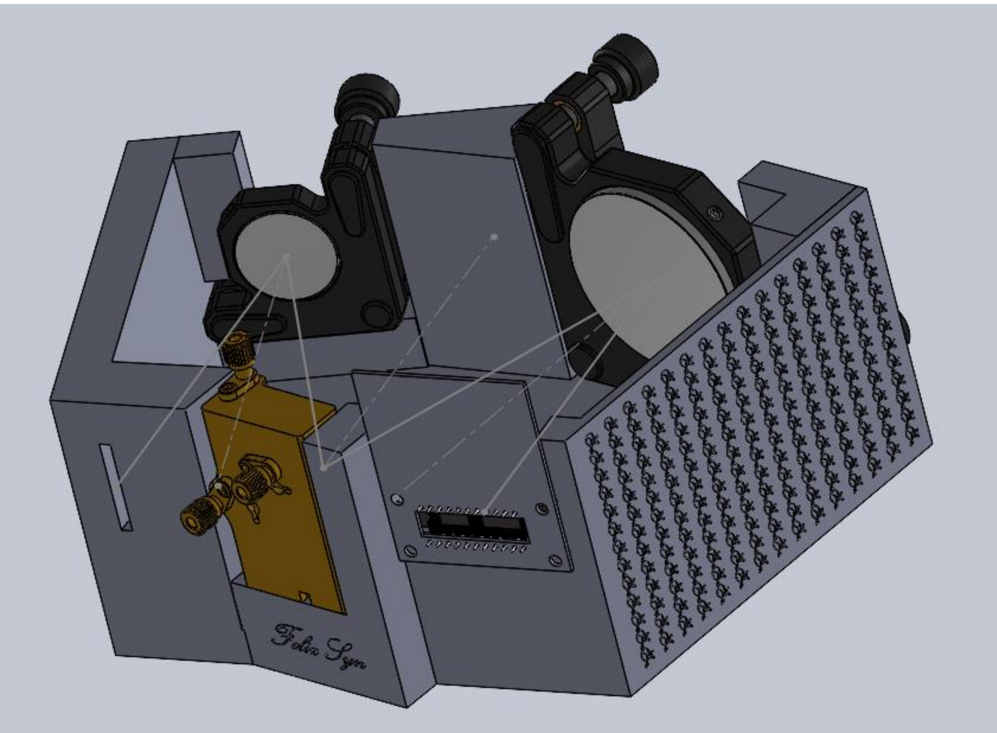
Template

Name: Felix Syn

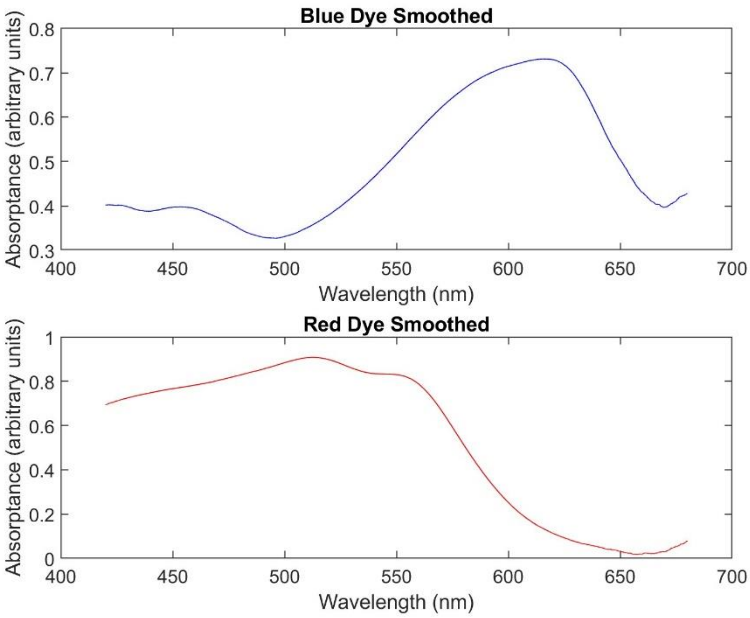
CID: 02193782

Insert an image of your CAD model here, and note any modifications or improvements made:

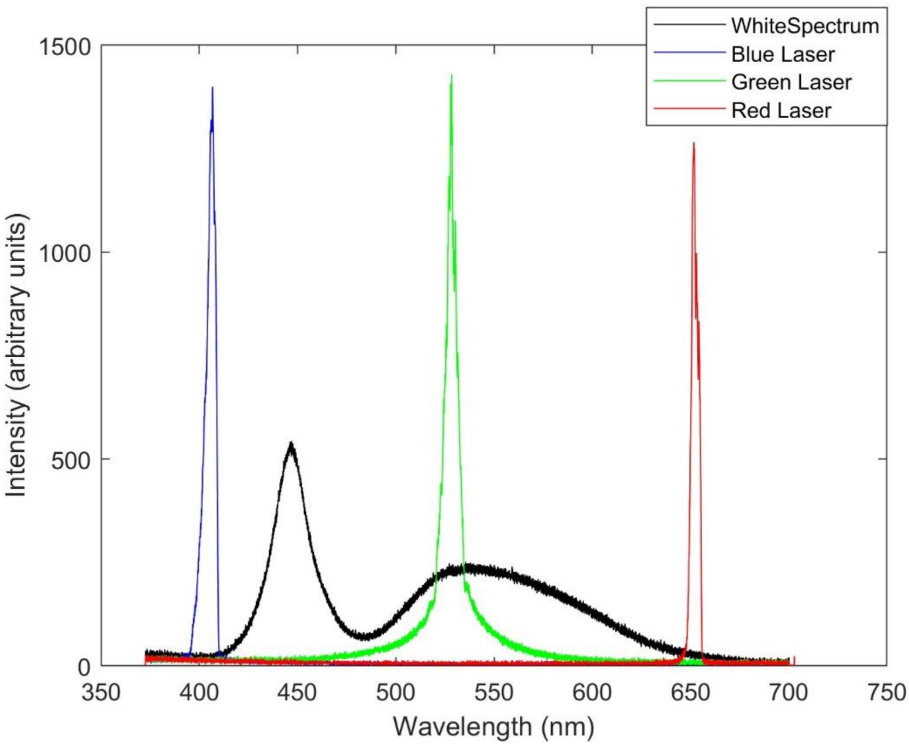
Modifications: I have engraved my name below the DGA-25 grating mount. A pattern on the side of the spectrophotometer housing was also engraved (2mm depth) to allow for more friction for the person carrying the apparatus. The pattern is a series of "Z" characters in Vivaldi script for aesthetic reasons. Walls behind the two mirrors have been measured to allow sufficient space for the mirror frame to fit through while blocking more ambient light. This would make the troubleshooting process easier.



Insert smoothed absorbance spectra of the red and blue dyes, with accurate wavelength axes here:



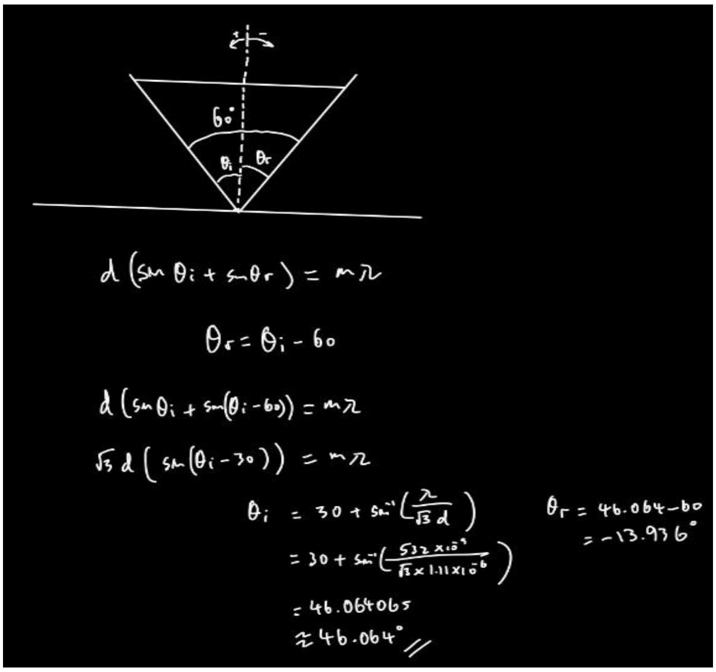
Insert unsmoothed spectra of the white LED and the three calibration lasers here, with accurate wavelength axes:



Questions

1. ***Θ**$_{incident}$* **was set to 46.064deg previously, when you were constructing the CAD model. Derive this value using the grating equation $\mathbf{d}(\sin\theta_{incident} + \sin\theta_{reflected}) = \mathbf{m}\boldsymbol{\lambda}$. You will need to know the following information: the grating frequency is 900 line-pairs per millimeter, which means the period *d* is 1mm / 900 = 1.11 × 10^{-6}m. The angle between *Θ*$_{incident}$ and *Θ*$_{reflected}$ is 60deg, and you may assume that the spectrum's center wavelength is 532nm. The desired diffraction order *m* is 1. Don't forget that angles are measured from the *surface normal*, and *Θ*$_{reflected}$ will be negative. As a hint, you may find the following useful: $\sin(x) + \sin(x - 60°) = \sqrt{3}\sin(x - 30°)$**

Given that the angles are measured from the surface normal, we shall first assume the angle of incidence is measured in the positive direction and thus the reflected angle is measured in the negative direction. $\theta_i =$ angle of incidence, $\theta_r =$ angle of reflection.



2. **Why is 532nm a good wavelength to define the grating angle?**

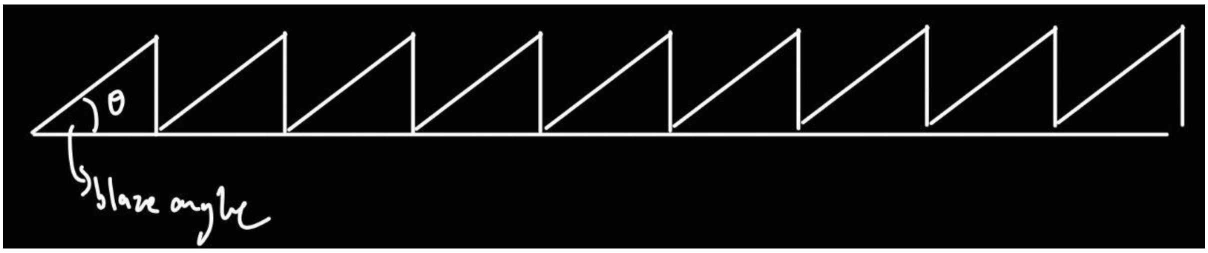
532nm is in the middle of the visible light spectrum, which means if we want to span the entire CCD with the visible spectrum, 532nm arriving in the centre of the CCD after diffraction would be a good reference. This is good to define the grating angle as this wavelength would then follow the "M" path drawn out in the SOLIDWORKS model for the light ray path. The wavelength is several orders of magnitude (10^{-9} vs 10^{-6}) smaller than the grating period (distance of the gap). This makes it suitable to apply Huygens Principle to predict wave behaviour. A smaller wavelength also results in a greater diffraction angle. This allows for a greater resolution between different wavelengths.

3. **What purpose does the entrance slit have? What will happen if it is too narrow? Or too wide?**

It allows incident light to spread out more upon passing through it and reduces the intensity of light which protects light sensitive components like the CCD. If the slit was too narrow, the light would spread out too much and might have an excessively reduced intensity. If the slit was too wide, too much light would enter the spectrophotometer and there would be too little scattering for sufficient diffraction to resolve each wavelength.

4. **What does the term 'blaze angle' signify? Draw a diagram of the grating at very high magnification, and explain what the arrow on the grating signifies**.

The blaze angle on a diffraction grating refers to the angle of elevation of the surface teeth from the grating surface, or the tilt of the grooves.



The arrow on the grating used in the indicates the appropriate direction to place the grating on the housing such that the optimal diffraction occurs and the correct reflective side faces outwards since it is difficult to determine that from a macroscopic level.

5. **What value should be used for R1, the series resistor for the white LED? Resistors are not available in arbitrary values; they have a range of standard values. Which should be used and why?**

R = (Vs-Vf)/Is = (5-3.2)/(0.02) = 90 Ohms. Perhaps a single 100 Ohm resistor could be used since this is a standard resistor value that is widely available and could reduce cost as opposed to two 45 Ohm resistors or a single 90 Ohm resistor which may cost extra to produce specifically.

6. **Why is the absorbance at either edge of the spectrum particularly noisy? How might you overcome this difficulty were you designing a real spectrometer?**

The edge of the spectrum comes from light incident on the edge of the CCD. This would likely be values below 420nm and above 680nm which are beyond the visible light spectrum. Perhaps these wavelengths that the 3D printed housing doesn't block could've interfered heavily with the reading at those wavelengths.

I could perhaps use bluetack or plasticine to seal and secure the frames of the mirrors and diffraction grating housing to reduce interference from ambient light as opposed to tape. Tape could still leave holes for light to enter the spectrophotometer. Furthermore, the housing could be built from a dense material like lead that blocks a wide range of wavelengths, to prevent interference of wavelengths outside the visible spectrum (<400nm & >700nm).

7. **How could you use this spectrometer to measure the fluorescence spectrum of a cuvette full of dye? What extra equipment would be needed?**

To measure the fluorescence spectrum of a cuvette of dye, we would first need an excitation source of a certain wavelength such as from a laser. I would then use the cuvette holder used in the laboratory with an extra slot for a laser or another light source for an excitation wavelength such that it points perpendicular away from the entrance slit but through the cuvette.

If there were any difficulties or problems during the experiment (such as equipment not working), note them here:

The spectrum was initially very noisy but a narrow peak was eventually attained by reducing the Frame Integration Time(FIT) to around 0.05 for the lasers. Another difficulty would be screwing the screw attaching the grating housing to the PLA housing without scratching the diffraction grating itself. Although the alternative would be screwing in the screw before placing the grating in the housing, we run the risk of scratching or dropping the grating while trying to fix it into the housing.