EC591 Lab 6 Report Notes

Examples of measured spectra are shown at the bottom of this document

6.1A) The spectrum of light from a fluorescent source consists of multiple lines at different wavelengths (different colors) across the visible range, which add up to produce white light.

The boxcar parameter is the number of adjacent pixels in the CCD array whose signals are averaged to produce the recorded spectrum

The larger the fiber-core diameter, the larger the number of modes guided by the fiber, and therefore the larger the range of angles of the light incident on the diffraction grating. As a result, the larger the diameter, the larger the number of pixels illuminated by each wavelength.

$\Rightarrow$ increasing the boxcar setting or the fiber-core diameter has the effect of broadening narrow features in the recorded spectrum

6.1B} The flashlight spectrum extends over a broad range across the visible and therefore again appears as white

6.1D} Regardless of fiber-core diameter, the spectral resolution of this spectrometer is not sufficient to accurately measure the linewidth of typical laser light

6.2) The reference spectrum is $I_{out}^{ref}(\lambda) = \eta \, I_{in}(\lambda) \, e^{-\alpha_w(\lambda) L}$

η: coupling efficiency from the source to the fiber through the cuvette

$I_{in}(\lambda)$: spectrum of the light from the source

$\alpha_w(\lambda)$: water absorption spectrum

$L = 1\,cm$: lateral size of the cuvette

The spectrum of the light transmitted through each salt solution is

$$I_{out}(\lambda) = \eta \, I_{in}(\lambda) \, e^{-[\alpha_w(\lambda) + \alpha_s(\lambda)] L}$$

where $\alpha_s(\lambda) = C \, \varepsilon(\lambda)$

$\varepsilon(\lambda)$ → salt extinction coefficient [cm^{-1}/(mole/liter)]

C → salt concentration [moles/liter]

$\alpha_s(\lambda)$ → salt absorption coefficient [cm^{-1}]

The transmission spectrum recorded in each measurement is

$$T(\lambda) = \frac{I_{out}(\lambda)}{I_{out}^{ref}(\lambda)} = e^{-\alpha_s(\lambda) L}$$

$$\Rightarrow \alpha_s(\lambda) = \frac{1}{L} \ln \frac{1}{T(\lambda)} = C \varepsilon(\lambda)$$

NOTE: C is equal to the mass concentration [in g/liter] divided by the formula weigth [in g/mole]

With these formulas, you can fill in all the missing data in the table on page 5 of the handout. A completed table (based on old measurement results) is included at the bottom of this document.

<u>Mystery solution:</u>

The absorption spectrum of the mystery solution (included below) looks like a superposition of the absorption spectra of solutions A ($CuSO_4$) and C ($CoSO_4$)

At $\lambda = 800\,nm$, the absorption coefficient of solution C is negligibly small. Therefore:

$$\alpha_{mix}(\lambda = 800\,nm) \cong x_A\, C_A\, \varepsilon_A(\lambda = 800\,nm),$$

where C_A is the concentration of $CuSO_4$ in solution A,

x_A is the concentration of solution A in the mystery mix,

and $\varepsilon_A(\lambda)$ is the extinction spectrum of $CuSO_4$

By the same argument, $a_{mix}(\lambda = 500\,nm) \cong x_c C_c \varepsilon_c(\lambda = 500\,nm)$

From the measured values of a_{mix} at 800 & 500 nm and the relevant data in the table, you can compute x_A & x_c

$\Rightarrow$ the mystery solution is a mixture of solutions A & C with relative concentrations x_A & x_c (nominally 40% & 60%, respectively)

6.3 A| The absorption spectrum of the green dye (included below) has a minimum at about 500 nm (in the green portion of the visible range), consistent with the dye color.

6.3 B| Here $I_{out}^{ref}(\lambda) = \eta_1 I_{in}(\lambda)$

$\hookrightarrow$ coupling efficiency from the source to the fiber after reflection from the white paper

$I_{out}^{milk}(\lambda) = \eta_2 I_{in}(\lambda) e^{-\mu_{milk}(\lambda) L}$ > neglecting the water absorption which is small

$\hookrightarrow$ spectrum of the light transmitted through the milk cuvette

η_2: coupling efficiency from the source to the fiber through the cuvette on the plastic box

$\mu_{milk}(\lambda)$: scattering coefficient spectrum of milk

The transmission spectrum recorded in this measurement is

$$T_{milk}(\lambda) = \frac{I_{out}^{milk}(\lambda)}{I_{out}^{ref}(\lambda)} = \frac{\eta_2}{\eta_1} e^{-\mu_{milk}(\lambda) L}$$

$$\Rightarrow \mu_{milk}(\lambda) = \frac{1}{L} \ln \frac{1}{T(\lambda)} + \underbrace{\frac{1}{L} \ln \frac{\eta_2}{\eta_1}}_{\text{unknown additive constant}}$$

The resulting scattering spectrum (included below) decreases with increasing wavelength, similar to the behavior of Rayleigh scattering

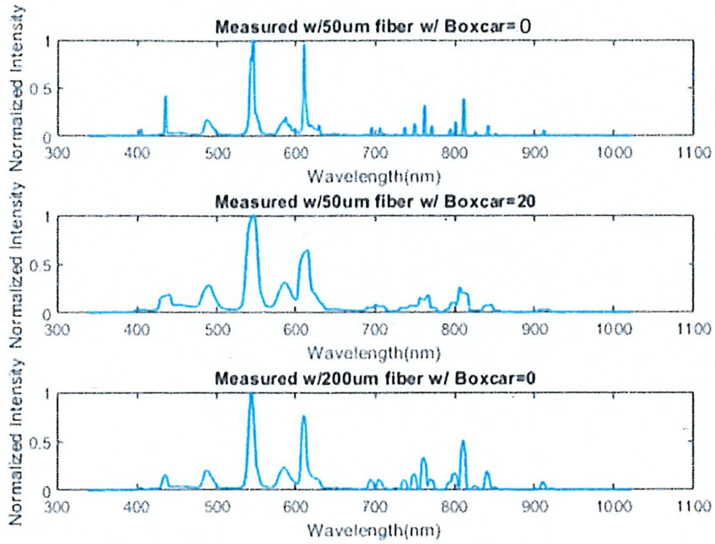
6.3 C) Here the recorded transmission spectrum is

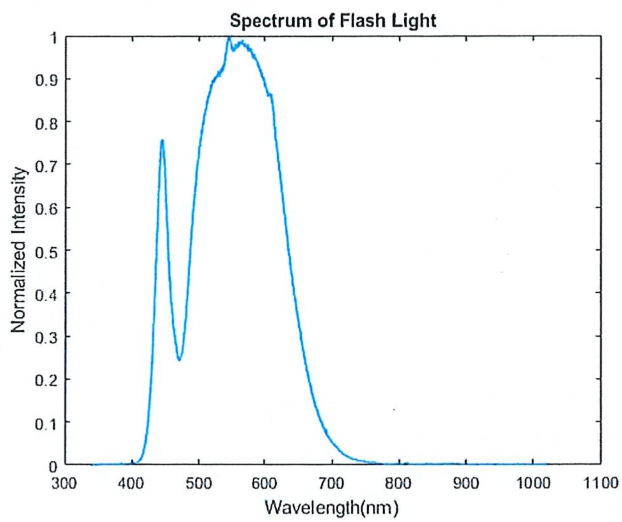
$$T_{milk+dye}(\lambda) = \frac{\eta_2}{\eta_1} e^{-\mu_{milk}(\lambda) L} e^{-\alpha_{dye}(\lambda) L} = T_{milk}(\lambda) e^{-\alpha_{dye}(\lambda) L}$$

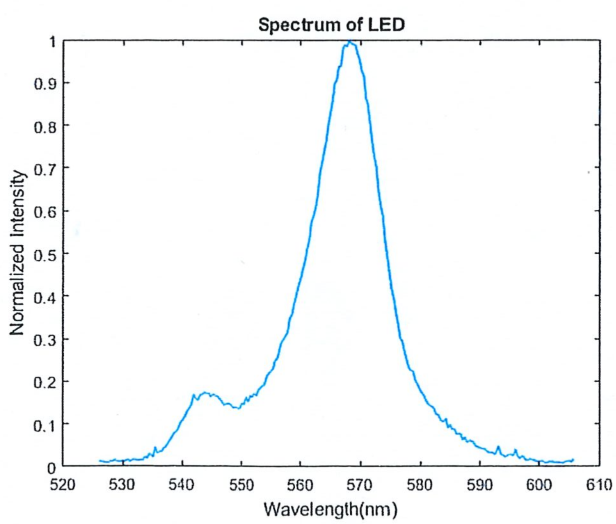
$$\Rightarrow \alpha_{dye}(\lambda) = \frac{1}{L} \ln \frac{T_{milk}(\lambda)}{T_{milk+dye}(\lambda)}$$

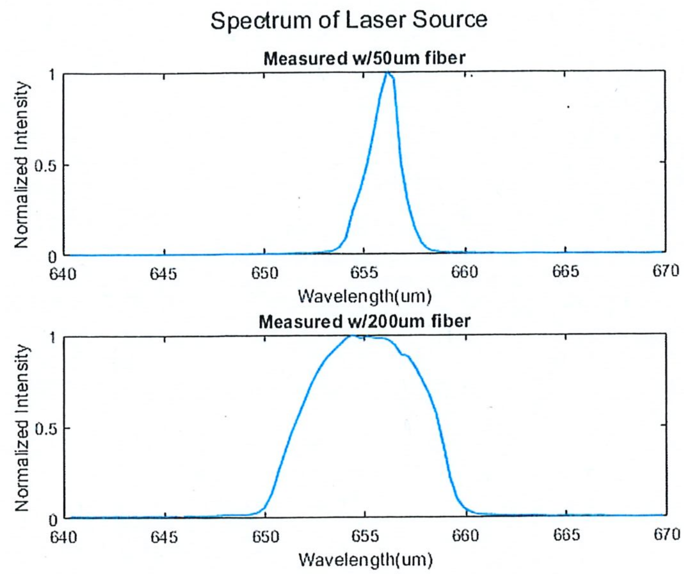
The dye absorption coefficient obtained from this measurement (assuming L=1c will be larger than in 6.3A, because here light travels a longer average distance from the source to the fiber due to multiple scattering events

Spectrum of Fluorescent Light Source

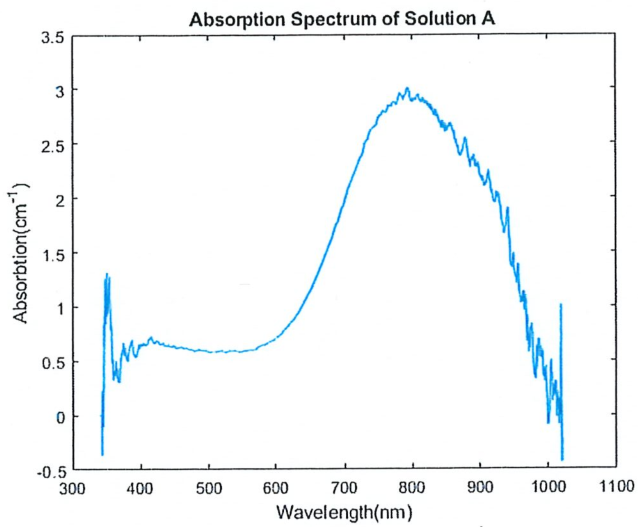




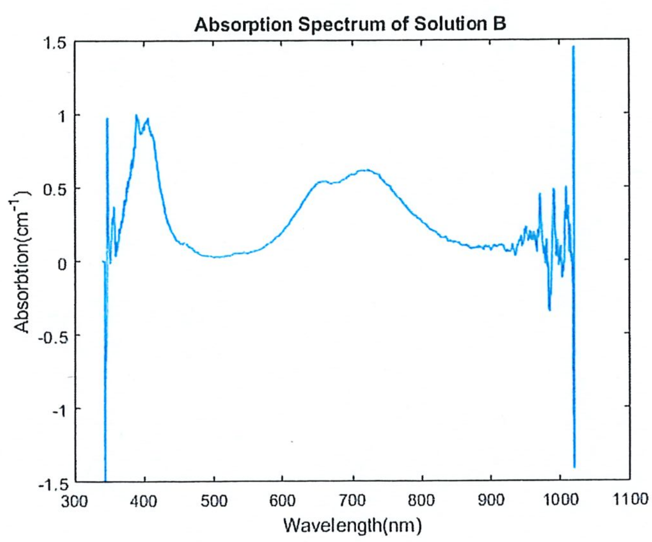




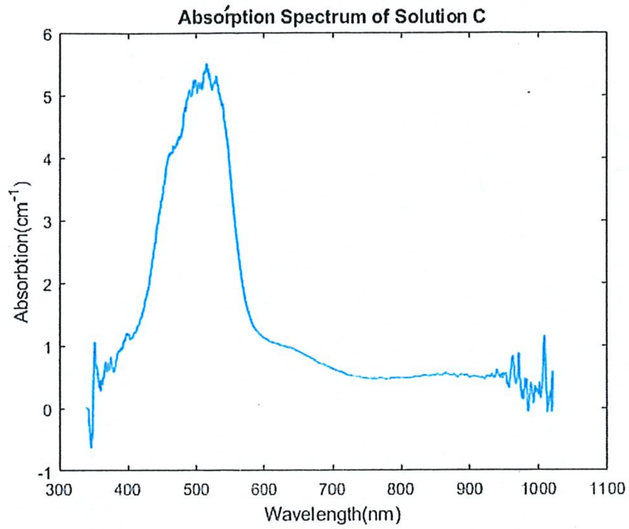
Spectrum of Laser Source
Measured w/50um fiber
Normalized Intensity
1
0.5
0
640
645
650
655
660
665
670
Wavelength(um)
Measured w/200um fiber
Normalized Intensity
1
0.5
0
640
645
650
655
660
665
670
Wavelength(um)

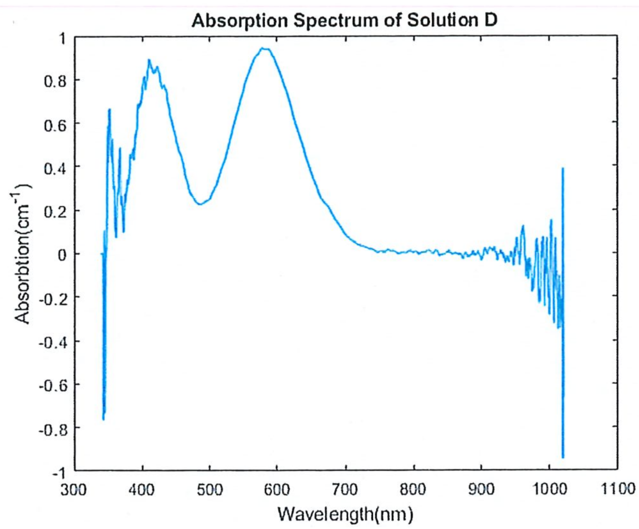


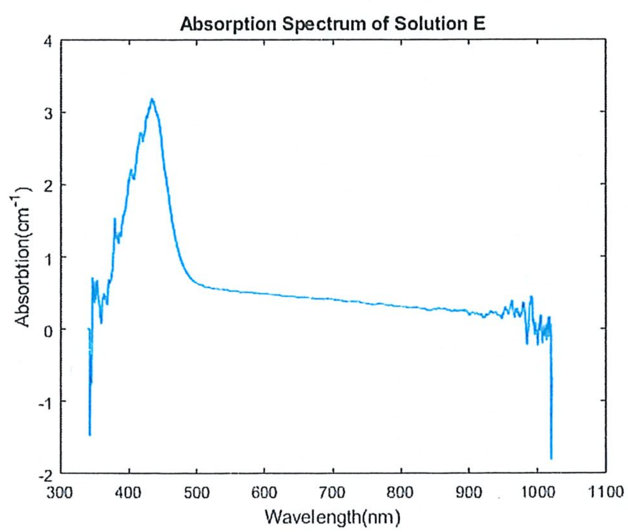
Absorption Spectrum of Solution A
Absorbtion(cm⁻¹)
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
300
400
500
600
700
800
900
1000
1100
Wavelength(nm)



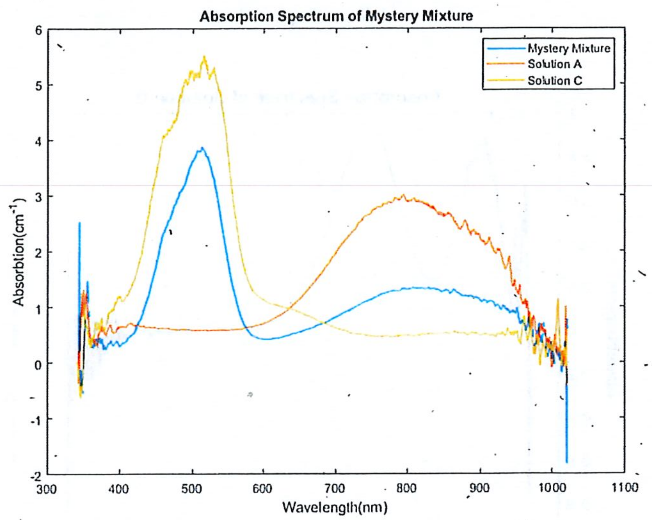
Absorption Spectrum of Solution B
Absorbtion(cm⁻¹)
1.5
1
0.5
0
-0.5
-1
-1.5
300
400
500
600
700
800
900
1000
1100
Wavelength(nm)

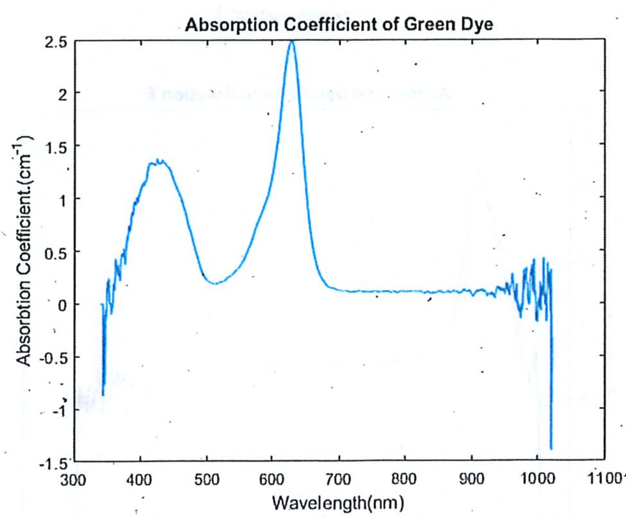

Absorption Spectrum of Solution C
Absorbtion(cm^{-1})
Wavelength(nm)
6
5
4
3
2
1
0
-1
300
400
500
600
700
800
900
1000
1100

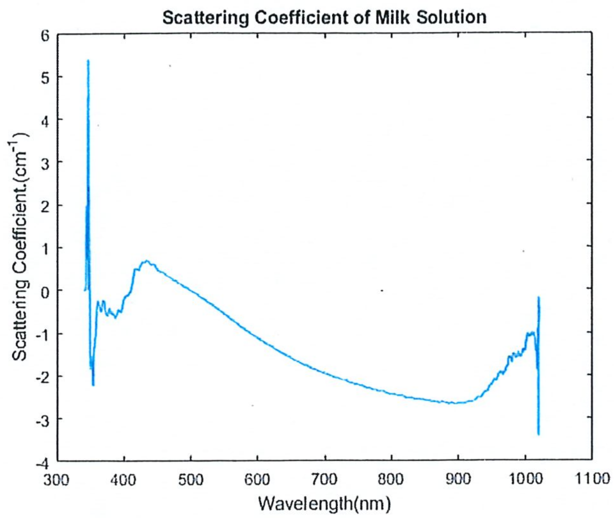

Absorption Spectrum of Solution D
Absorbtion(cm^{-1})
Wavelength(nm)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
300
400
500
600
700
800
900
1000
1100

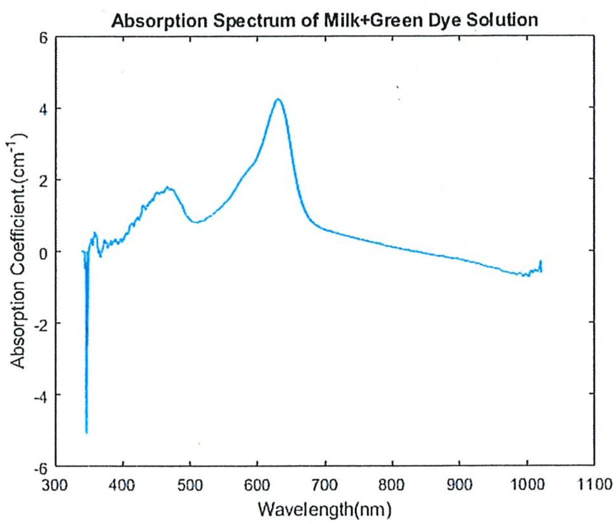

Absorption Spectrum of Solution E
Absorbtion(cm^{-1})
Wavelength(nm)
4
3
2
1
0
-1
-2
300
400
500
600
700
800
900
1000
1100

	Name	Formula	Formula weight	Mass conc. [g/liter]	Molar conc. [moles/liter]	ε [cm^{-1}/(m/l)] @ λ(nm)
A	Copper sulfate	$CuSO_4 \cdot 5H_2O$	249.7	18	0.072	29.6 @ 800
B	Nickel sulfate	$NiSO_4 \cdot 6H_2O$	262.8	20	0.076	5.1 @ 700
C	Cobalt sulfate	$CoSO_4 \cdot 7H_2O$	281.1	47	0.167	11.3 @ 500
D	Chromium potassium sulfate	$CrK(SO_4)_2 \cdot 12H_2O$	499.4	10	0.020	35.8 @ 600
E	Potassium chromate	K_2CrO_4	194.2	0.99	0.0051	138 @ 465






Scattering Coefficient of Milk Solution
Scattering Coefficient.(cm-1)
Wavelength(nm)
6
5
4
3
2
1
0
-1
-2
-3
-4
300
400
500
600
700
800
900
1000
1100


Absorption Spectrum of Milk+Green Dye Solution
Absorption Coefficient.(cm-1)
Wavelength(nm)
6
4
2
0
-2
-4
-6
300
400
500
600
700
800
900
1000
1100