BME 200
Lesson 7 - Bioinstrumentation
Sep 15, 2020

By the end of the lecture students should be able to:

- Calculate the change in resistance of a resistance temperature detector (RTD).
- Use the thermistor equation to calculate temperature, resistance, or β.
- Calculate transmittance and absorbance.
- Use the Beer-Lambert law to find concentration, intensity, ϵ (molar extinction coefficient), or path length.

I. Overview of bioinstrumentation systems
   A. Three parts
      1. Sensor
      2. Signal conditioning (circuitry)
      3. Output

II. Thermal sensors
   A. Thermal sensors convert temperature to an electrical signal (usually V)

B. Types of thermal sensors
   1. Resistance temperature detector (RTD) - metal wire
   2. Thermistors - semiconductor or polymer
   3. Thermocouples - two dissimilar metals soldered together

C. RTD
   1. All conducting materials have an intrinsic property called *resistivity*
   2. The resistivity of most metals depends on temperature
      a) Higher temperature = higher resistance
      b) Lower temperature = lower resistance (superconductivity if low enough)
   3. We can predict the resistance of a wire using the formula

   4. The important value in this formula is α_0 and that value depends on the type of metal

Table 2-1 Resistivities and Temperature Coefficients*

Material	Resistivity† (micro-ohm cm)	α = Temperature Coefficient† (ohms/ohm/°C)
Copper (annealed)	1.724	0.0039
Copper (hard drawn)	1.77	0.0038
Aluminum (commercial)	2.828	0.0036
Silver	1.629 (18°C)	0.0038
Platinum	10	0.00377
Nichrome	100	0.0004
Iron	10	0.005
Mercury	98.5 (50°C)	0.00089
Carbon	3500 (0°C)	−0.0005

**Handbook of Chemistry and Physics*, Chemical Rubber Publishing Co., Cleveland, Ohio, 1962.
†At 20°C.

5. Example RTD from Omega:

6. Student example. How much voltage change do you expect for a 10 ºC increase in temperature for a silver RTD?

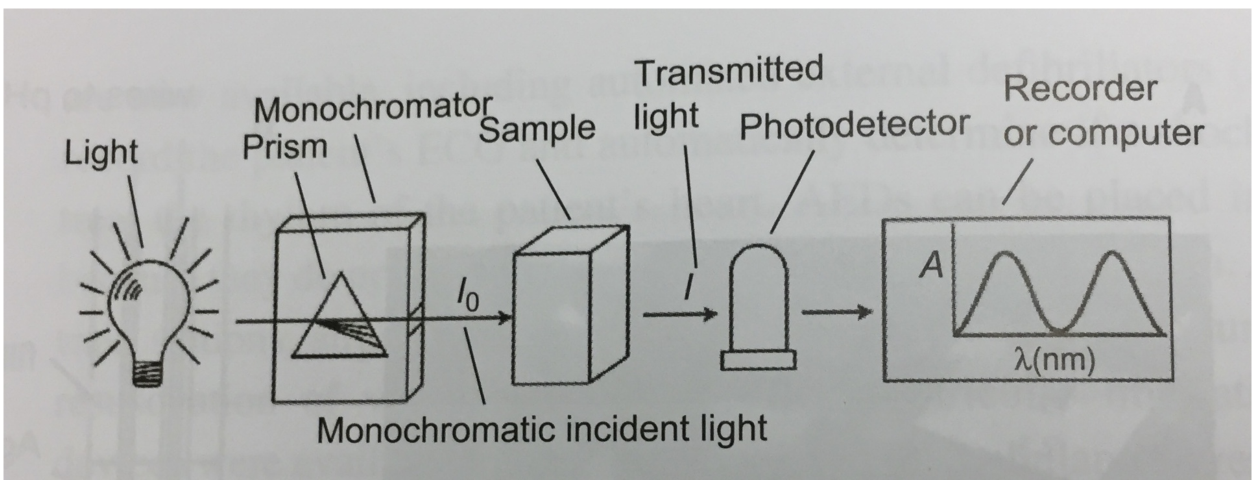
D. Thermistors
   1. Usually made of semiconductor; they are temperature dependent like RTDs
   2. Unlike RTDs, this temperature dependence is exponential

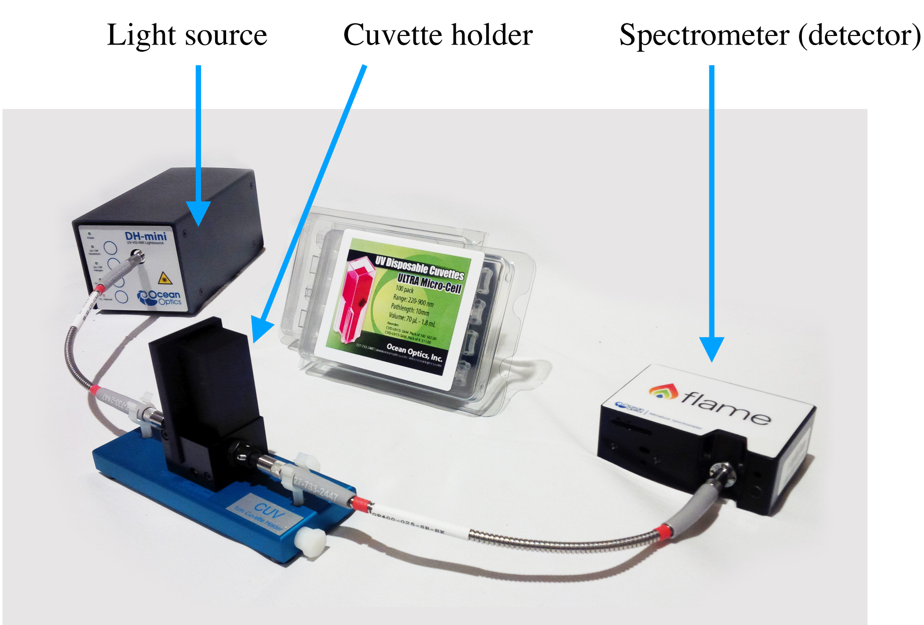
3. Thermistors come in two flavors
   a) Positive Temperature Coefficient (PTC)
      (1) positive beta
      (2) resistance increases when temp increases
   b) Negative Temperature Coefficient (NTC)
      (1) negative beta
      (2) resistance decreases when temp increases
4. Example of an NTC bead thermistor from globalsources.com:

5. Student problem. Find the β of a thermistor if $R_T = 2572\ \Omega$ at $T = 50$ ºC. Assume $R_0 = 2100\ \Omega$. Hint: remember the trick we used for the half-life equation.

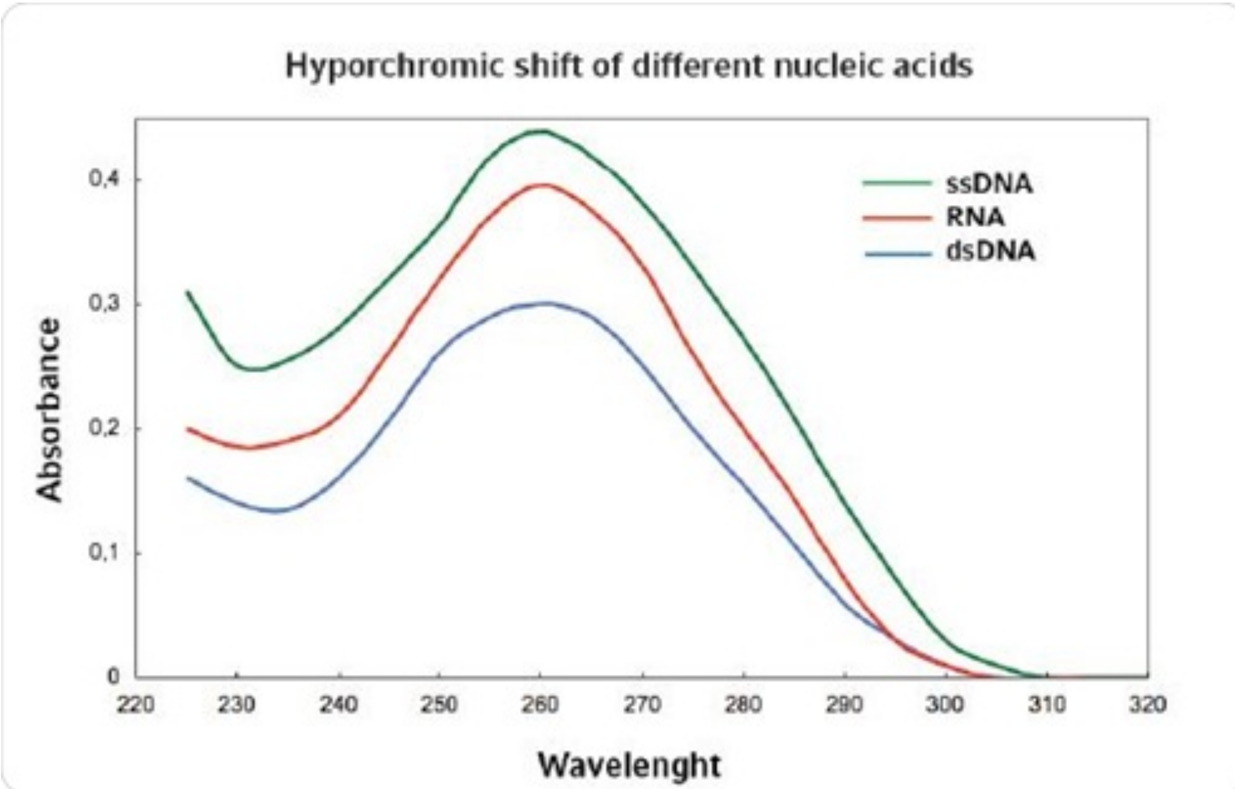
6. Biomedical Engineering application using a thermistor:

E. Optical measurements
1. A spectrophotometer measures the intensity of light transmitted to incident light through a sample over a range of wavelengths.



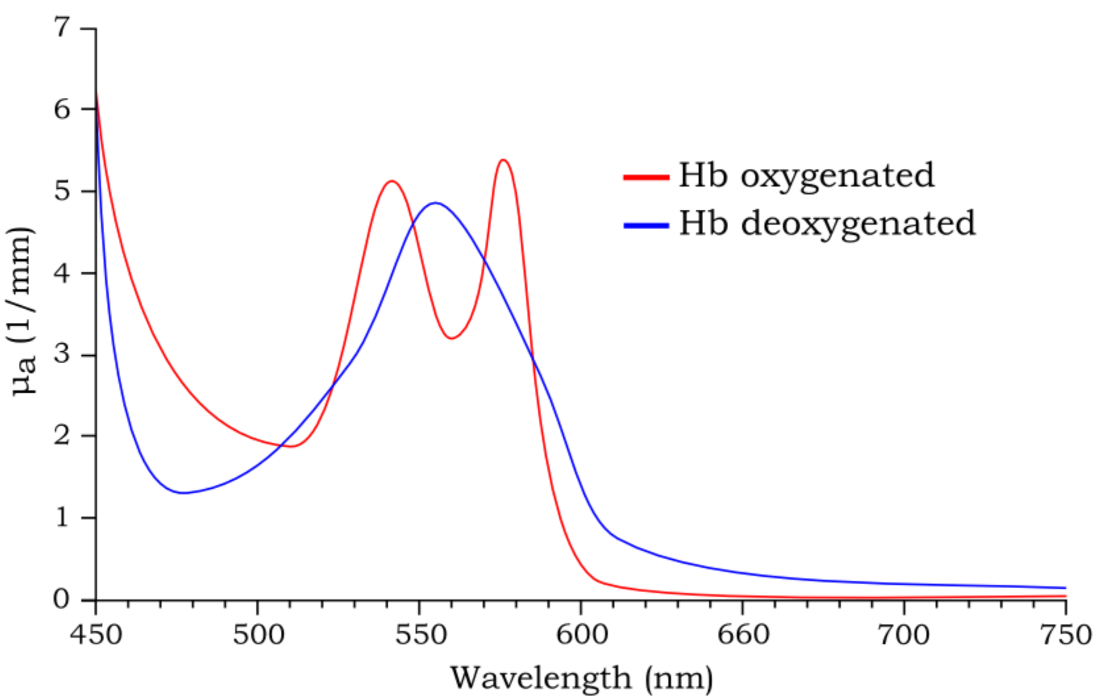


2. A spectrophotometer is used to measure DNA concentration in solution. A ratio is used to determine if there is any contamination.



https://www.news-medical.net/whitepaper/20151119/Using-Eppendorf-BioSpectrometer-Fluorescence-for-Nucleic-Acid-Concentration-Measurements.aspx

3. Ratios can also be used to measure the oxygen levels in blood.



http://www.edaphic.com.au/knowledge-base/articles/light-articles/what-is-absorbance-spectroscopy/

4. If you know the intensity of the light bulb, I_0, and you can calculate the intensity at the output, I, with the Beer-Lambert law:

where

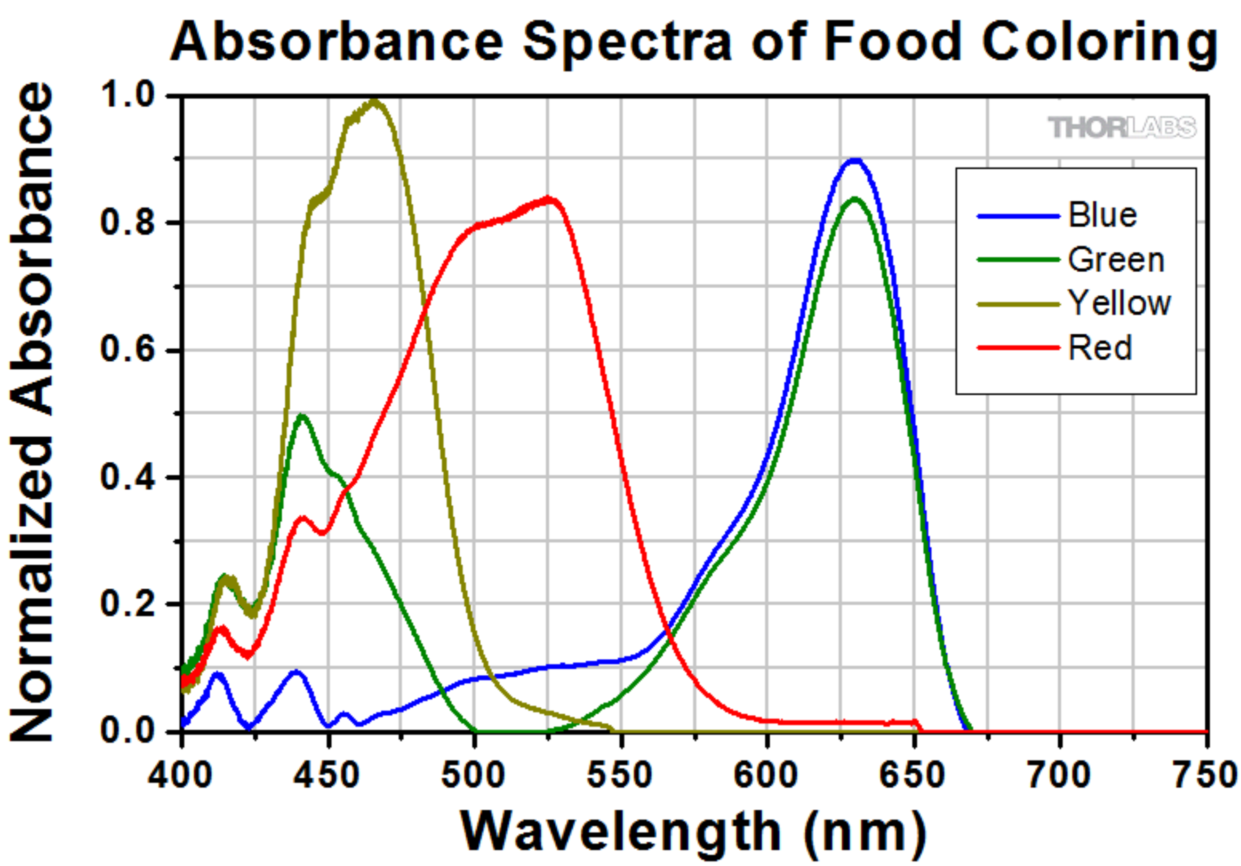
I_0 = radiant power arriving at the cuvette
I = radiant power leaving the cuvette
a = absorptivity of the sample (extinction coefficient)
L = length of the path through the sample
c = concentration of the absorbing substance
A = total absorbance

5. The ratio of the two is called transmittance.

6. More often we use absorbance:

7. Here's what you would likely see if your sample is water (because it's transparent):

8. Here are the absorbances of different food colors:



9. Student example. A dye of concentration 20 mg/dL (1 deciLiter = 0.1 L) has an absorbance of $A = 0.4$. The dye is then diluted by an unknown amount but when measured with a spectrophotometer has an absorbance $A = 0.25$. What is the new concentration?