BE 3600 BIOMEDICAL INSTRUMENTATION (LAB) -

Experiment 7

Clinical Sensors: Pulse Oximeters

OBJECTIVE: Learn the basic principles of the clinical sensing systems

BACKGROUND ON CLINICAL SENSORS:

PULSE OXIMETRY

It is clinically important to know the oxygen saturation of the blood under ambulatory conditions. Low amount of oxygen in the arterial system would result in onset of hypoxia, and could lead to tissue damage. Therefore, a system which would detect the presence of blood circulation as well as the amount of oxygen in the blood is needed. Pulse oximeters are the most commonly used tool for this particular purpose.

Hemoglobin is the protein contained in the red blood cells which help carry the oxygen in the blood. 98 % of the oxygen carried by the blood is carried by the hemoglobin while the remaining 2 % is dissolved in the plasma portion of the blood. Pulse oximeters take advantage of the fact that the hemoglobin has different light absorption characteristics at different wavelengths. Optical absorption characteristics of oxygenated and de-oxygenated hemoglobin are shown on Figure 1 below. As it can be seen from the traces, the two spectra intersect at the isobestic wavelength of λ=805 nm, where the absorption is independent of oxygen saturation in the blood. Absorption measured at this frequency is used as a reference value. The two spectra differ greatly at λ=660 nm, which used as the measurement point. Commercial unit that is available in the laboratory uses λ=660 nm measurement and λ=910 nm for reference where the choices are dictated usually be the availability of components and competitive patent coverage.

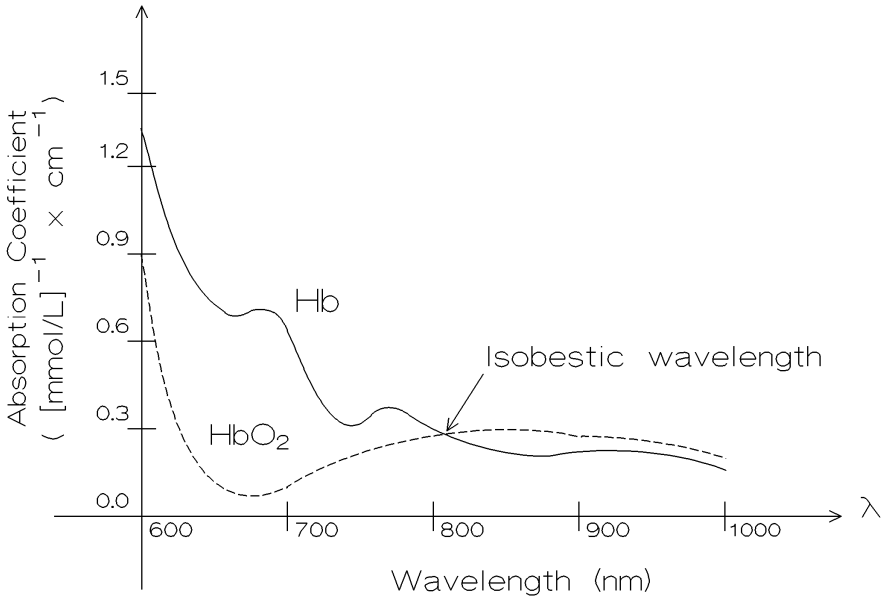

Figure 1. Optical absorption spectra of oxygenated (HbO_2) and de-oxygenated hemoglobin (Hb).

Absorption of light as it passes through the tissue can be measured by shining a light onto the tissue and measuring the received light on the opposite site. If the wavelength of the incident light is known, then the absorption can be determined as

$$\frac{I_R}{I_T} = e^{-acd}, \qquad \text{[Eq. 1]}$$

where I_R is the intensity of the received light,

I_T is the intensity of the transmitted light,

a is the absorption coefficient,

c is the concentration of the absorbing molecule (Hb or HBO_2)

d is the thickness of the tissue.

The term $a.c.d$ is known as the optical density of the tissue, and expressed as

$$O.D. = \ln(\frac{I_T}{I_R}) = a.c.d \qquad \text{[Eq. 2]}$$

In the case of pulse oximetery, the optical density is determined at two wavelengths and the Sa(O_2) is determined using the following relationship:

$$Sa(O_2) = A - B\frac{O.D._{660\,nm}}{O.D._{990\,nm}} \qquad \text{[Eq. 3]}$$

where the coefficients A and B must be determined experimentally.

Above described system is also able to detect the heart beats by sensing the changes in the blood volume following systole. As more blood enters the tissue after each beat, absorption characteristics of the tissue changes, which is reflected in the I_R.

EXPERIMENT:

In this experiment we will use a portable pulse oximeter, Nonin Model 9843.

1) While the device is turned off, connect the finger sensor to the device using the break-out connector. Turn the device on.
2) Notice how the red light is on but no Sa(O_2) is displayed.
3) Place your finger into the sensor and wait until the pulse rate and Sa(O_2) is displayed.
4) Take a shallow breath and hold your breath for at least 20 seconds. Monitor the changes in the heart rate and Sa(O_2).
5) Using an analog oscilloscope (let your TA help you with this one), observe the changes in the received signal strength. Is it synchronized to your heart rhythm?
6) Using your hand held digital oscilloscope, make four recordings of the received optical signals from the light sensor
    a) No objects are in the sensor
    b) Your finger is in the sensor
    c) Pink filter is in the sensor

d) Green filter is in the sensor

7) Turn the pulse oximeter off.

REPORT:

a. Why do we need the reference measurement at λ=805 nm or λ=910 nm ? Why can not we simply measure the absorption at λ=660 nm to determine the $Sa(O_2)$?

b. How does the signal strength change after the heart beat? Does this received signal get stronger or weaker after the systole? Does the pulse oximeter need measurements at both wavelengths for heart rate measurements?

c. Fill in the table below:

	Signal 1 Strength	Signal 1 Strength
Empty		
Finger		
Pink Filter		
Green Filter		

d. Explain the observations for the table above. Why are the effects of different filters on received signal amplitudes different? Based on this, which signal is the representing the λ=660 nm and which signal is representing λ=660 nm.

e. Based on the observations above, rewrite equation 3 in terms of Signal 1 Strength and Signal 2 Strength.