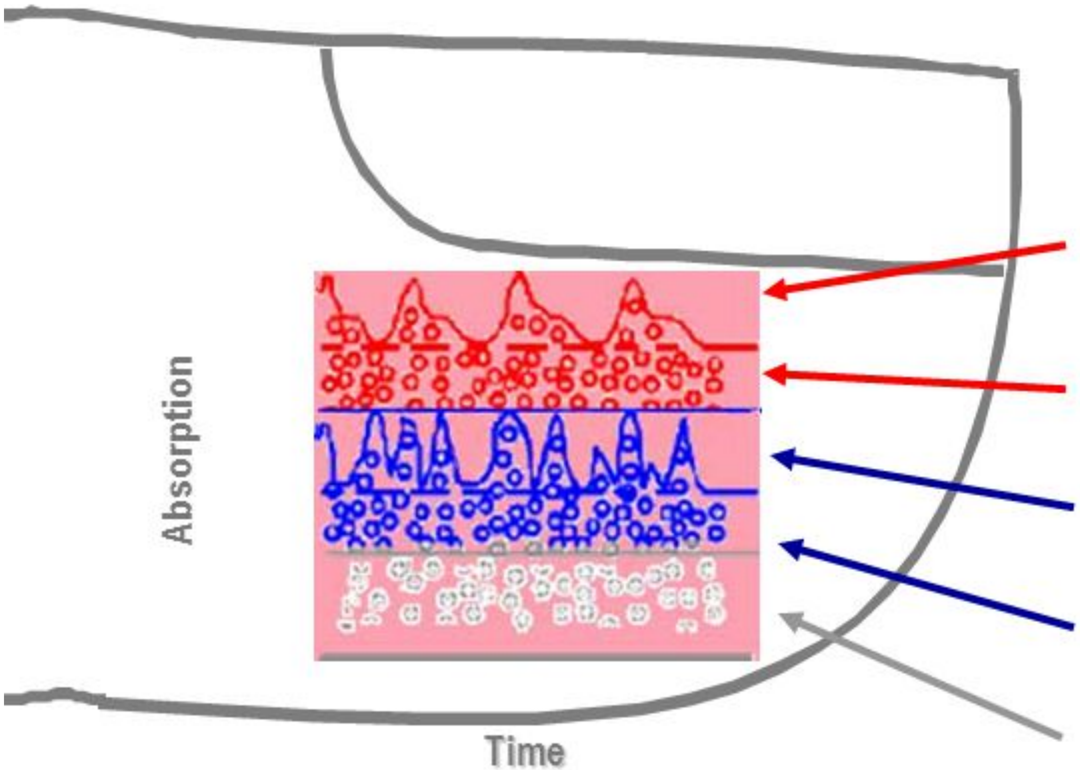
Tutorial 2

Question 1

- In pulse oximetry, In addition to oxyhemoglobin and deoxyhemoglobin in the artery, oxyhemoglobin and deoxyhemoglobin in the vein, water, finger nail, other soft tissue and bone also attenuates light. Design a method to reduce or reject these interfering/modifying inputs.

Model of Light Absorption At Measurement Site With Motion



AC Variable light absorption due pulsatile volume of arterial blood

DC Constant light absorption due to non-pulsatile arterial blood.

AC Variable light absorption due to moving venous blood

DC Constant light absorption due to venous blood.

DC Constant light absorption due to tissue, bone ...

Pulse Oximetry Assumption: The only absorbance that fluctuates is arterial blood

MASIMO

Solution

Assuming the total light attenuation coefficient of other tissue is α_{other}^{red} and it does not change significantly within a pulse cycle, when arterial blood volume reaches a minimum

$$I_{red}^{\max} = I_0 e^{-\alpha_{Hb}^{red} c_{Hb}^{\min} l - \alpha_{HbO_2}^{red} c_{HbO_2}^{\min} l - \alpha_{other}^{red} c_{other} l}$$

$$\Rightarrow \alpha_{Hb}^{red} c_{Hb}^{\min} + \alpha_{HbO_2}^{red} c_{HbO_2}^{\min} + \alpha_{other}^{red} c_{other} = \frac{\ln I_0 - \ln I_{red}^{\max}}{l} \qquad \text{Eq. 1}$$

when arterial blood volume reaches the next maximum

$$I_{red}^{\min} = I_0 e^{-\alpha_{Hb}^{red} c_{Hb}^{\max} l - \alpha_{HbO_2}^{red} c_{HbO_2}^{\max} l - \alpha_{other}^{red} c_{other} l}$$

$$\Rightarrow \alpha_{Hb}^{red} c_{Hb}^{\max} + \alpha_{HbO_2}^{red} c_{HbO_2}^{\max} + \alpha_{other}^{red} c_{other} = \frac{\ln I_0 - \ln I_{red}^{\min}}{l} \qquad \text{Eq. 2}$$

Subtract Eq. 1 from Eq. 2, we have

$$\alpha_{Hb}^{red}(c_{Hb}^{\max} - c_{Hb}^{\min}) + \alpha_{HbO_2}^{red}(c_{HbO_2}^{\max} - c_{HbO_2}^{\min}) = \frac{\ln I_{red}^{\min} - \ln I_{red}^{\max}}{l} \qquad \text{Eq. 3}$$

Similarly, we can have

$$\alpha_{Hb}^{ir}(c_{Hb}^{\max} - c_{Hb}^{\min}) + \alpha_{HbO_2}^{ir}(c_{HbO_2}^{\max} - c_{HbO_2}^{\min}) = \frac{\ln I_{ir}^{\min} - \ln I_{ir}^{\max}}{l} \qquad \text{Eq. 4}$$

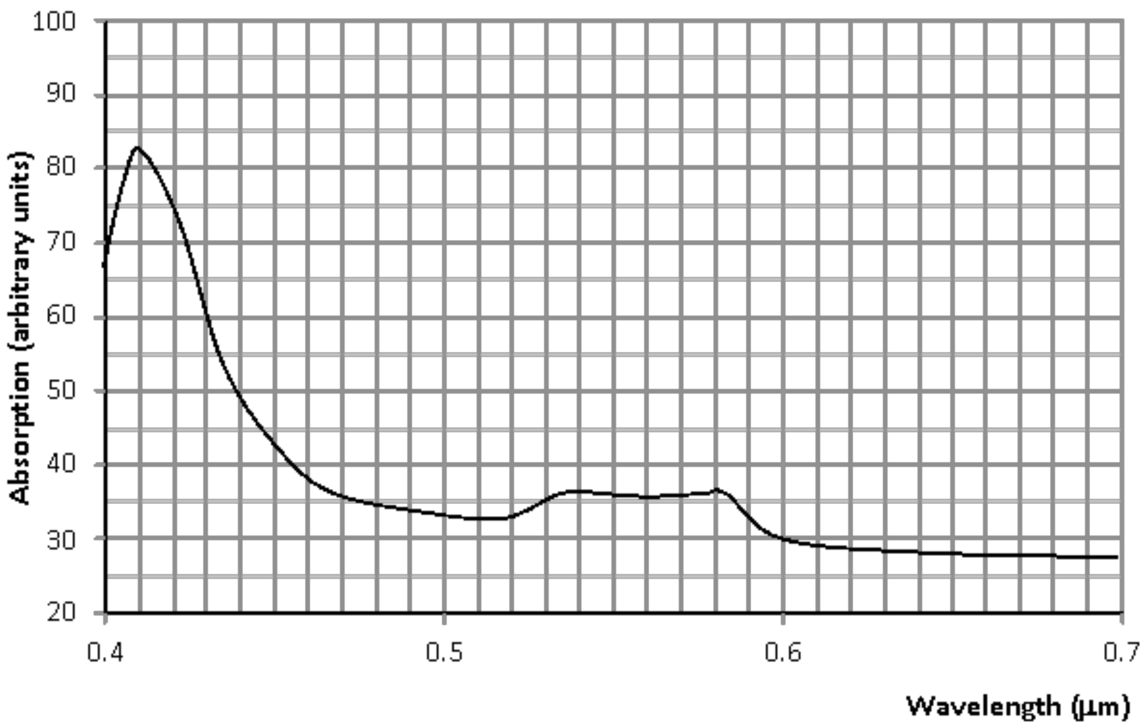
Since,

$$\frac{c_{Hb}^{\max}}{c_{Hb}^{\min}} = \frac{c_{HbO_2}^{\max}}{c_{HbO_2}^{\min}}$$

$$SpO_2 = \frac{c_{HbO_2}}{c_{HbO_2} + c_{Hb}} \times 100 = \frac{c_{HbO_2}^{\max} - c_{HbO_2}^{\min}}{c_{HbO_2}^{\max} - c_{HbO_2}^{\min} + (c_{Hb}^{\max} - c_{Hb}^{\min})} \times 100$$

Question 2

The absorption of visible light for a sample of blood is shown below.



(a) Which wavelength of light does the sample absorb most?

(b) Use the graph to explain why the blood appears red.

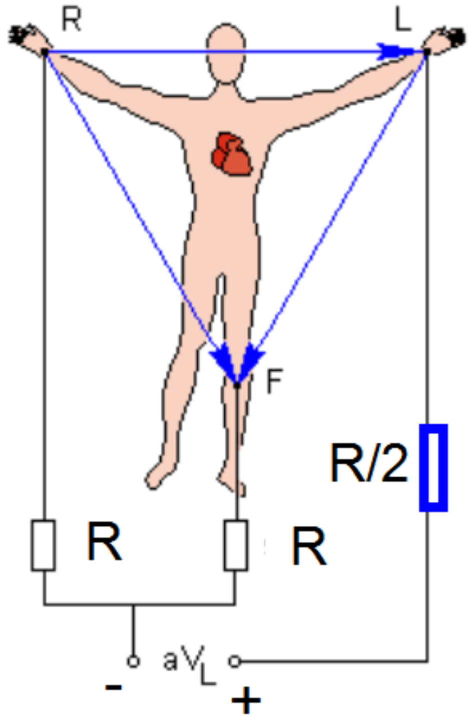
Solution:

a) ~410 nm;

b) hemoglobin in red blood cells absorbs purple, blue, and part of green light so that blood scatters more red light.

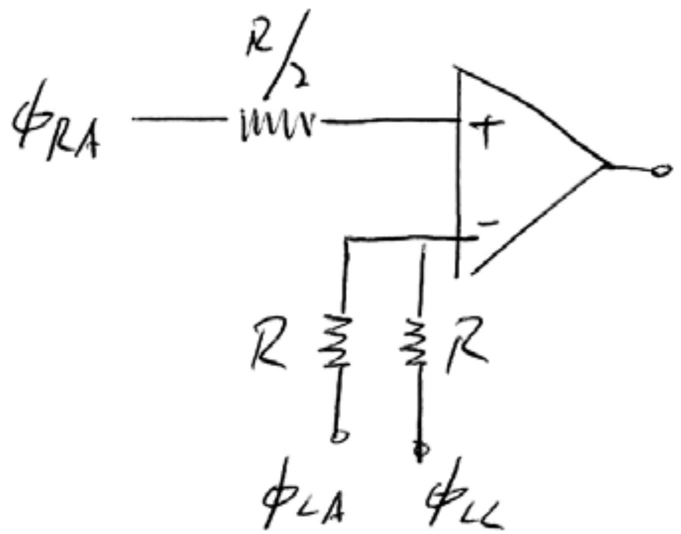
Question 3

- In an ECG recording circuit, an engineer sees no purpose for R/2 in the following figure and replaces it with a wire in order to simplify the circuit. What is the result? Please show the equivalent circuit and explain.



Solution

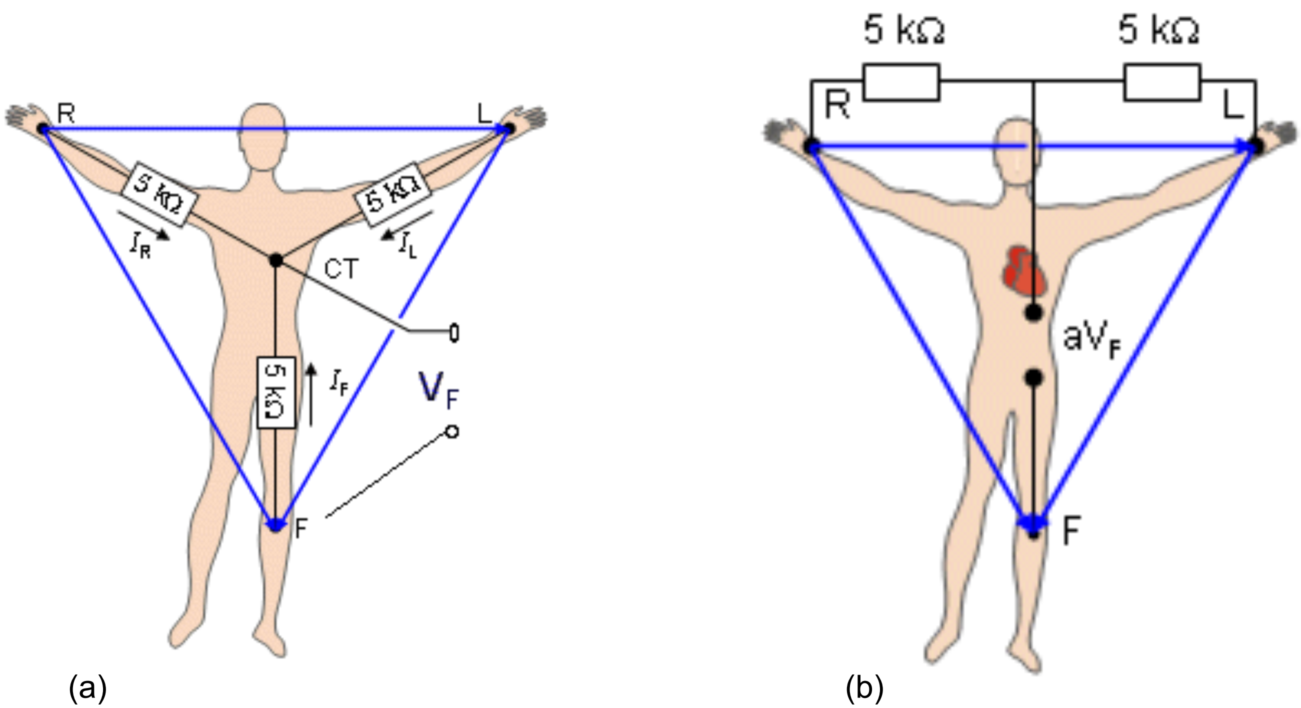
Equivalent circuit



If R/2 is removed, the signal strength will be the same since Φ_{RA} is connected directly to the amplifier with high input impedance. However, there will be a dc offset due to the op-amp bias current.

Question 4

Show that the voltage in lead aV_F (Figure b) is greater than that in lead V_F.



Solution

Considering the connections for aV_F and V_F, bio-potentials at RL, LL, foot and the Wilson Central terminal are Φ_R, Φ_L, Φ_F, and Φ_{CT}. When no current is drawn by the voltage measurement circuit,

In figure (a), assuming R= 5kΩ, according to Kirchhoff's current law

$$\frac{\Phi_R - \Phi_{CT}}{R} + \frac{\Phi_L - \Phi_{CT}}{R} + \frac{\Phi_F - \Phi_{CT}}{R} = 0$$

Therefore,

$$\Phi_{CT} = \frac{\Phi_R + \Phi_L + \Phi_F}{3}$$

$$V_F = \Phi_F - \Phi_{CT} = \Phi_F - \frac{\Phi_R + \Phi_L + \Phi_F}{3} = \frac{2\Phi_F - \Phi_L - \Phi_R}{3}$$

In figure (b), since the food lead (F) is not connected with the central terminal, the potential at the central terminal

$$\Phi_{CF/aV_F} = \frac{\Phi_R - \Phi_L}{2R} \bullet R + \Phi_L = \frac{\Phi_R + \Phi_L}{2}$$

The potential of the augmented lead

$$aV_F = \Phi_F - \frac{\Phi_R + \Phi_L}{2} = \frac{2\Phi_F - \Phi_R - \Phi_L}{2}$$