German University in Cairo
Faculty of Media Engineering and Technology
Spring 2020

CSEN 1099 – Introduction to Biomedical Engineering

Problem Set #2 – Solution

Question 1

Cadmium and zinc electrodes are placed in an electrolyte solution. Calculate the current that will flow through the electrodes if the equivalent resistance of the solution is equal to 14 kΩ.

Answer:

$I = \Delta V / R$ = (-0.401) – (-0.763)/14*1000 = 0.0258 mA

Question 2

By how much would the inductance of an inductive displacement transducer coil change if the number of coil turns is decreased by a factor of 6?

Answer:

$L = \mu n^2 LA$

$L_{new} \,/\, L_{old} = (n_{new}/n_{old})^2 = 1/36$

Question 3

A 15-cm long elastic resistive transducer with a resting resistance of 1kΩ is wrapped around the chest. Assume constant current of 3mA is flowing through the transducer. If at some point in time, the measured voltage is equal to 30V, find the corresponding increase in inhaled air relative to exhale.

Answer:

For length = 15cm → R = 1kΩ

$R = \rho l / A$ → 1kΩ = ρ/0.15*A = 6.667 kΩ/m

For V=30V

30V = IR = 0.003 x R → R = 30/0.003 = 10kΩ

10 kΩ = 6.667 kΩ/m x l → l = 1.5m

$l = 2\pi r = \pi$ * Diameter

Diameter = 1.5/ π = 0.47 m

Question 4

A 20-cm long elastic resistive transducer with a resting resistance of 5kΩ is wrapped around the chest. Consider the case of a normal person whose normal breathing produces a measured voltage during inhalation equal to 30V. If the same system is used for the same person but when he is playing sports, the

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measured voltage is 40V during inhalation, **find** the chest diameter in both cases. Assume a constant current of 1mA is flowing through the transducer.

Answer:

$$R = \rho \frac{l}{A}$$

$$5k\Omega = \frac{\rho}{A}\frac{20}{100}$$

$$\therefore \frac{\rho}{A} = 25k\Omega.m$$

$$V = IR_1$$

$$30 = 1mA \times R_1$$

$$\therefore R_1 = 30k\Omega$$

$$\because R_1 = \rho \frac{l}{A} \rightarrow 30k\Omega = 25k\Omega \times l$$

$$l = 120cm$$

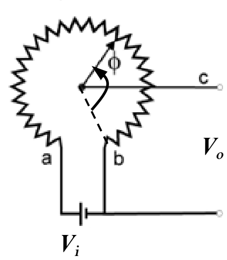
$$\because l = 2\pi r = \pi d \rightarrow d_1 = 38.19cm$$

In the case of 40V

$$d_2 = \frac{4}{3} \times 38.19 = 50.92cm$$

Question 5

Consider the angular potentiometer given in the figure below



i – Given that the resistance can be computed as $R = \rho l/A$ where ρ is the resistivity, l is the length and A is the cross-sectional area, **show** that

$$V_o = \frac{\phi}{Max_\phi} V_i$$, where Max_φ is the maximum angular displacement.

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ii – **Explain** how you can use this potentiometer to measure the angular displacement of the knee. Specifically, **how** will you attach such potentiometer to the knee and **what** is Max_φ in this case?

iii – For a total resistance of 5 kΩ between points (a) and (b) in the figure and given Max_φ that you found in (ii), **calculate** the output voltage for a 70° angle of the knee. Assume that a constant current of 10 mA is supplied to the transducer.

Answer:

a) i –

$$R_1 = \frac{\rho l_1}{A}$$

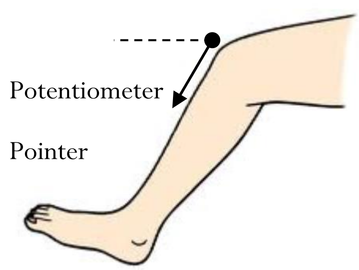
$$l = \frac{2\pi r \phi}{360}$$

$$R_2 = \frac{\rho l_2}{A} = \frac{2\pi r\left(Max_\phi - \phi\right)}{360}$$

$$V_o = \frac{R_1}{R_1 + R_2} V_i = \frac{\frac{2\pi r \phi}{360}}{\frac{2\pi r \phi}{360} + \frac{2\pi r\left(Max_\phi - \phi\right)}{360}} V_i$$

$$V_o = \frac{\phi}{Max_\phi} V_i$$

ii –



$$Max_\phi = 135°$$

Note: If the pointer is attached to another part of the knee or the leg, Max_φ will change accordingly.

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iii – V_i = (10A/1000) x 5kΩ = 50V
V_o = (70/135) x 50 = 24.9V

Question 6

Calculate β of a thermistor assuming that it has a resistance of 4.4 kΩ at 21°C (room temperature) and a resistance of 2.85 kΩ when the room temperature increases by 20 percent.

Answer:

$$R = R_0 \exp\left(\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right)$$

$$R_0 = 4.4k\Omega$$

$$T_0 = 21 + 273 = 294K$$

$$T = 21*1.1 + 273 = 298.2K$$

$$R = 2.85k\Omega$$

$$\beta = \frac{\ln\left(\frac{R}{R_0}\right)}{\frac{1}{T} - \frac{1}{T_0}} = 9065.3K$$