CSEN 1099: Introduction to Biomedical Engineering
Spring 2020
Quiz #1 Model Answer

Name: .....

App #: .....

Group #: .....

Instructions: Read carefully before proceeding.

1) The duration of this quiz is **20 minutes**.
2) Write your name, application number, and group number in the provided space above.
3) No books, notes or other aids are permitted for this quiz.
4) When you are told that time is up, please stop working on the test.
5) Calculators are allowed to the quiz.

Good Luck!

Question 1: **(6 Marks)**

Consider a cell with the following intracellular and extracellular concentrations:

Na^+:	Intracellular = 25 mM	Extracellular = 125 mM
Cl^-:	Intracellular = 8 mM	Extracellular = 140 mM
K^+:	Intracellular = ?? mM	Extracellular = 30 mM
Ca^{2+}:	Intracellular = 2 mM	Extracellular = 4 mM

Anions: Intracellular = 100 mM (Anions have an average negative charge/molecule of -1.5).

i – **What** is the intracellular concentration of the K^+ needed to achieve electrical equilibrium inside the cell? **Explain** your answer.
Answer:

Positive Charges = 25 + K^+ + 2 x 2 = 29 + K^+
Negative Charges = 8 + 100 x 1.5 = 158
Therefore, K^+ + 29 = 158 → K^+ = 129 mM

ii – **What** is the intracellular concentration of K^+ needed to achieve its diffusion equilibrium? **Is** the cell in electrical equilibrium in this case? **Explain** your answer.
Answer:
For K^+ diffusion equilibrium, intracellular concentration should be equal to extracellular equilibrium
Since extracellular K^+ = 30 mM and intracellular K^+ = 129 mM
Therefore, for diffusion equilibrium, intracellular K^+ = extracellular K^+ = (129 + 30)/2 = 79.5 mM
In this case, positive charges intracellular = 79.5 + 25 + 2x2 = 108.5 mM
Negative charges intracellular = 8 + 100 x 1.5 = 158 mM
So, the cell is not at electrical equilibrium.

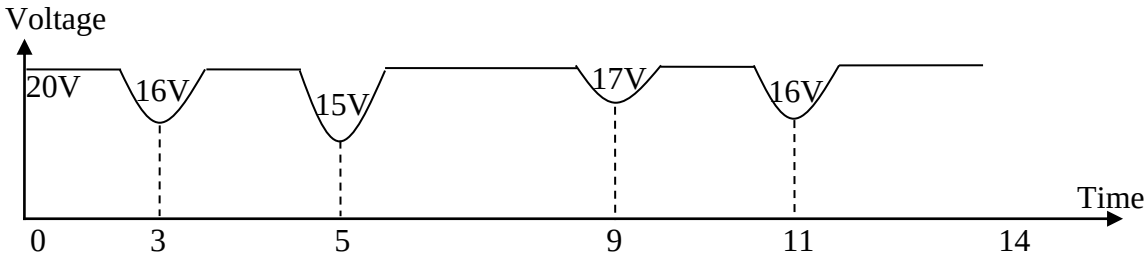
iii – If the cell is at electrical equilibrium based on (i) and if K^+ channels are open, **what** is the direction of movement of K^+? **Explain** your answer.
Answer:

From inside the cell to outside the cell as the diffusion is from high concentration to lower concentration.

iv – If K^+ channels also allow Na^+ to move, **what** is the direction of movement of Na^+ in this case? **Explain** your answer.
Answer:
From outside the cell to inside the cell (from high concentration to lower concentration).

Question 2: **(4 Marks)**

One way to measure respiration (breathing) rate of a patient is to place a thermistor close to his nose where the temperature of the thermistor will increase every time the patient exhales (breathes out). Consider the voltage measured using a thermistor placed at the nose of a patient given below:



Assume that a constant current of 2mA is passing through the thermistor and that the reference temperature is T_0 = 25 °C with R_0 = 10 kΩ and β = 3000K where $R_T = R_0 \times \exp\left[\beta \times \left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$.

i – **Find** the temperature of air measured by the thermistor at second 3.

Answer:

Since $R_T = R_0 \times \exp\left[\beta \times \left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$ we can reach an expression for T that takes the form:

$$T = \frac{\beta}{\ln\left(\frac{R_T}{R_0}\right) + \frac{B}{T_0}}$$

At 3 sec, V = 16V = 2mA x R_T → R_T = 8 $k\Omega$. Therefore, T = 304.75 K = 31.75 °C

ii – **Suggest** the steps of an algorithm that could be used to find the average respiratory rate per minute from the measured voltage. **What** is the average respiration rate of the voltage given in the figure above?

Answer:

1- Detect the peaks in the voltage

2- Measure the time between the peaks

3- Average the intervals obtained in step 2

4- Convert to rate per minutes

For the given voltage: Average = 2.66 sec → 11.4 times/minute