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

CSEN 1099 – Introduction to Biomedical Engineering

Problem Set #1 - Solution

Question 1

Using as many appropriate anatomical terms as apply, write sentences that describe the positional relationship between your mouth and (a) your left ear, (b) your nose, and (c) the big toe on your right foot.

Answer:

(a) Mouth is medial and ventral relative to left ear

(b) Mouth is caudal relative to nose

(c) Mouth is medial, cranial and dorsal relative to big toe on right foot

Question 2

Find the volume of a cell if it contains 2×10^{16} molecules of Na^+ if the intracellular concentration of Na^+ is 15mM.

Answer:

Volume = $2 \times 10^{16} / (15 \times 10^{-3} \times 6.02 \times 10^{23}) = 2.214 \times 10^{-6}$ L

Question 3

Consider a cell with the following intracellular and extracellular concentrations:

- Na^+: Intracellular = 12 mM Extracellular = 145 mM
- K^+: Intracellular = 139 mM Extracellular = 4 mM
- Cl^-: Intracellular = 4 mM Extracellular = 116 mM
- Ca^{2+}: Intracellular = 0.8 mM Extracellular = 1.8 mM

a) Determine the diffusion gradient for each of those ions.

b) If the cell contains Anions of 138 mM, determine whether the cell is in electrical equilibrium or not (Assume that the average negative charge per anion is 1).

Answer:

a) Na^+: Extracellular to intracellular
K^+: Intracellular to extracellular
Cl^-: Extracellular to intracellular
Ca^{2+}: Extracellular to intracellular

b) Total positive charges = 12 + 139 + 2x0.8 = 152.6mM
Total negative charges = 4 + 138 = 142 mM
The cell is not at electrical equilibrium.

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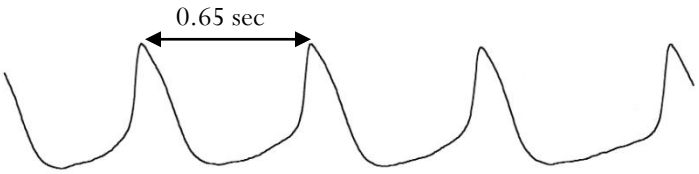
Question 4

Consider the membrane potential measurement of a pacemaker cell given below:



a) Find the heart rate in bpm (beats per minute).

b) Find the cardiac output of the heart if the stroke volume is 80 ml.

Answer:

a) Number of beats per second = 1/0.65

Number of beats per minute = 60/0.56 = 92.3 bpm

b) Cardiac output = 92.3 x 80 x 10^{-3} =7.384 L

Question 5

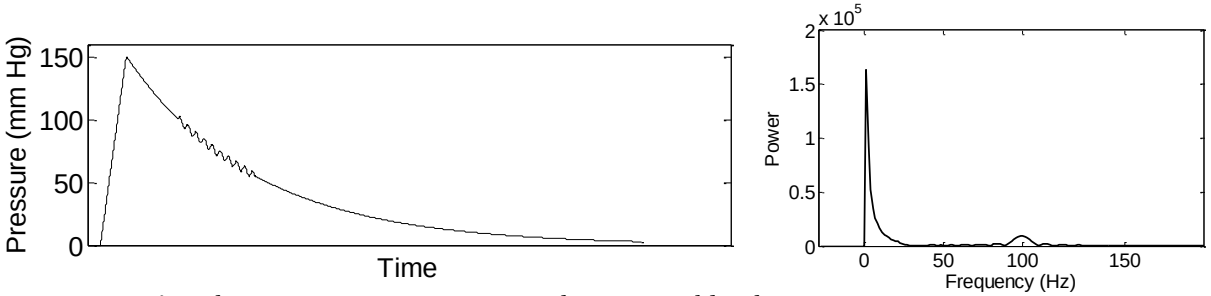
Why are R waves in ECG used to determine heart rate rather than T waves?

Answer:

Because the R wave has the highest amplitude among ECG heart beat signal components, so it will be easier to detect compared to other components.

Question 6

Consider the pressure measured from a cuff of an oscillometer (left figure) and the corresponding frequency-domain of the pressure (right figure) given below:



i – **Determine** the approximate maximum and minimum blood pressures.

ii – **State** the purpose of each of the low-pass and band-pass filters that are used in the oscillometer block diagram.

iii – From the figures above, **determine** how to set the cutoff frequencies of each filter.

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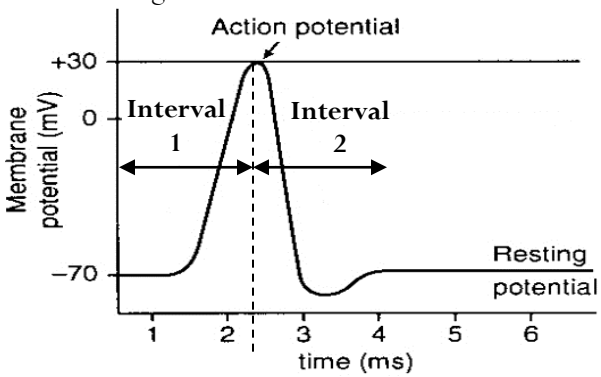
Answer:
i – From the left figure, the beginning of the fluctuations is at ~100mmHg (maximum pressure), while the end of fluctuations is at ~50mmHg (minimum pressure).
ii – The low-pass filter extracts the pressure of the cuff excluding the fluctuations while the band-pass filter extracts the fluctuations excluding the cuff pressure
iii – The cutoff of the low-pass filter from the right figure would be any number around the 50Hz while for the band-pass filter would be with a band-pass range of ~75Hz to ~125Hz.

Question 7

Consider the Action Potential waveform given below:



i – For Interval 1, **choose** one or more of the following that could correspond to this interval.
Justify your answer:
1 – Na^+ moves out of the cell
2 – Na^+ moves into the cell
3 – Cl^- moves into the cell

ii – For Interval 2, **choose** one or more of the following that could correspond to this interval.
Justify your answer:
1 – K^+ moves out of the cell
2 – K^+ moves into the cell
3 – Cl^- moves into the cell

Answer:
i – (2) As this will increase the potential of the cell relative to the extracellular space
ii – (1) and (3) as both will decrease the potential of the cell relative to the extracellular space

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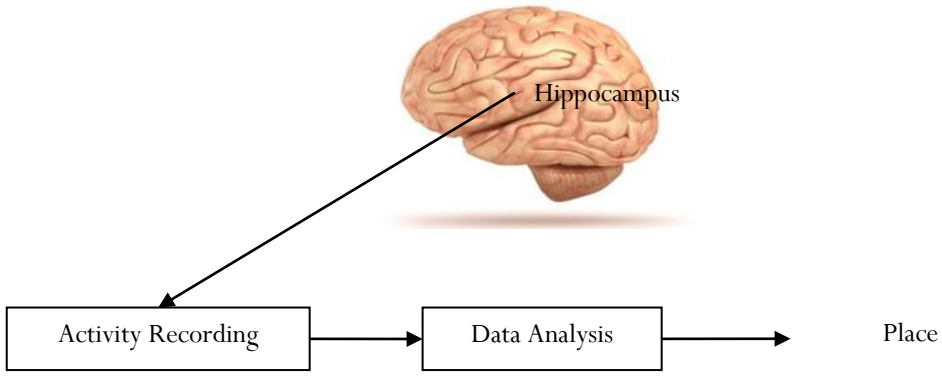
Question 8

Consider designing a system that can determine the location of a subject based on his brain activity. Draw a general block diagram that describes such system indicating which part of the brain to interface with. Explain the steps that should be undertaken to train the system.

Answer:

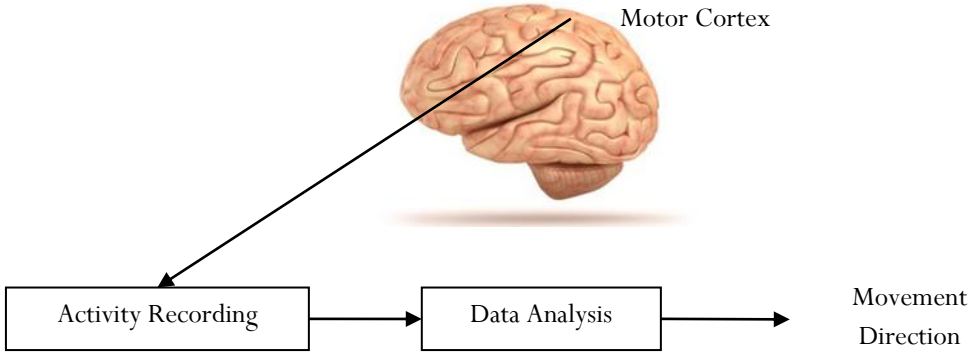


We can train this system by moving the person around different places and record the place cells activity from the hippocampus using the trained model. We can specify the location then by identifying which cell has the highest activity at each time instant.

Question 9

Consider designing a system that can be used to move a cursor on a screen using brain activity. Draw a general block diagram that describes such system indicating which part of the brain to interface with. Explain the steps that should be undertaken to train the system.

Answer:



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1 – Determine the preferred direction of each neuron in a training session in which the subject is instructed to imagine moving his arm in different directions.
2 – When testing the system, find which neuron is active.
3 – Determine movement direction as a function in the preferred direction of active neurons.