UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING
FINAL EXAMINATION - TYPE A, DECEMBER 2001
Fourth Year - Programs 5bm, 5ce, 5e, 7, 9
ECE445F - CELLULAR BIOELECTRICITY
Examiner - B.L. Bardakjian

NUMBER OF PAGES = 12
NUMBER OF QUESTIONS = 4

USE BOTH SIDES OF EACH PAGE
BE ORGANIZED AND NEAT IN YOUR PRESENTATION

SURNAME:

FIRST NAME:

STUDENT NUMBER:

MARK/100:

Question #1

Describe the following *(in point form and diagrams)*:

(a) The biological mechanisms of frequency **coding** and **decoding** that govern information transmission in neurons. **[10 Marks]**

(b) The transmembrane voltage in a squid axon when a **large hyperpolarizing** current stimulus is applied for a **finite duration**, in the middle of the axon. Explain using concepts from the Hodgkin-Huxley model and the core-conductor cable theory. **[15 Marks]**

Question #2

Derive **two** separate expressions for the neuronal resting membrane voltage in terms of the membrane's (a) ionic conductances, and (b) ionic permeabilities, respectively. *Consider the sodium-potassium pump and ignore the chloride current.* [25 Marks]

Question #3

(a) Describe *(using mathematical expressions)* the **delta rule** for *error correction learning* in the *jth* general neural unit of a *fully connected feed forward* artificial neural network. How can such learning be accelerated? **[10 Marks]**

(b) Design and **investigate** a *Hopfiled network* having the 2 fundamental memories:

$$\mu_1 = \begin{bmatrix} +1 \\ +1 \\ +1 \\ +1 \end{bmatrix} \quad and \quad \mu_2 = \begin{bmatrix} -1 \\ -1 \\ -1 \\ -1 \end{bmatrix}.$$

[15Marks]

Question #4

Consider the propagation of bioelectricity on a neuron located along the positive x-axis.

• The dendritic tree is represented by a core-conductor cable with a synapse at its terminus. The dendritic cable (*length* = 300 μm, *diameter* = 10 μm, *space constant* = 0.25 cm), has the ionic conductances (g_{Na} = 0.01 mS/cm^2, g_K = 0.367 mS/cm^2), the intracellular ionic concentrations ($[Na^+]_i = 50\ mM$, $[K^+]_i = 397\ mM$) and the extracellular ionic concentrations ($[Na^+]_e = 437\ mM$, $[K^+]_e = 20\ mM$).

• The axon is represented by a core-conductor cable with its terminus at $x = 0$. This cable (*length* = 4 mm, *diameter* = 0.05 mm) has the intracellular and extracellular conductivities of 1 & 10 S/cm, respectively.

• *Ouabain* was perfused and the postsynaptic potential before and after perfusion was $-67\ mV$ and $-65\ mV$, respectively. Before perfusion the presynaptic activity did not cause the soma to fire, whereas after perfusion the same level of presynaptic activity caused the soma to fire an action potential which propagated on the axon with a uniform velocity of 1 m/sec, and is described by

$$v_m(t) = 16 - 4\,[t-2]^2 \quad \text{where } v_m \text{ is in mV and t is in msec.}$$

• **Compute** the following:

(a) The synaptic characteristics in terms of type, conductance g_s, and reversal potential E_s.

(b) The firing threshold of the soma.

(c) The maximum extracellular potential for a field point located 1 mm above the axon, at $t = 4\ msec$. **[25 Marks]**