ECE 795: Quantitative Electrophysiology

Final Exam 2011

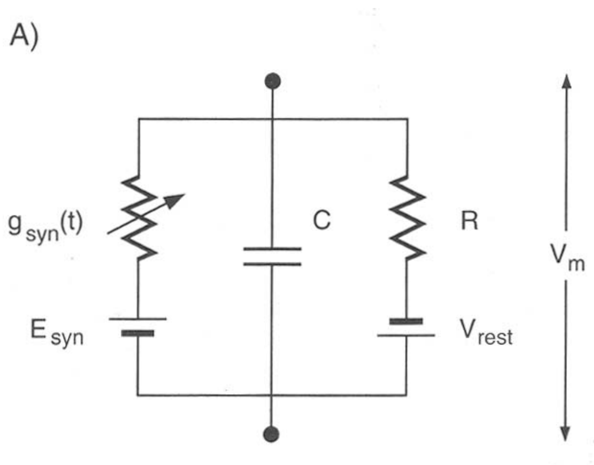
Due date: Exam answers to be submitted by **Friday December 16th, 2011** (my office or mail slot).

The rules:

A. Each student must work on their own answers. If you get stuck, please e-mail Dr. Bruce.

B. It is permissible to refer to books and articles beyond those included on the course reference list, but please provide reference details.

1. Consider the two models illustrated below of synaptic currents providing drive to a patch of neural membrane under subthreshold conditions.



a) Discuss which of the two models for synaptic input, A or B, would be more readily utilized as input into the linear cable equations.

b) For model A, a commonly used functional form for $g_{\text{syn}}(t)$ is the alpha function $g_{\text{syn}}(t) = \text{const}\cdot t\,\text{e}^{-t/t_{\text{peak}}}$. The advantage of the alpha function is that the one parameter t_{peak} directly determines the time of the peak conductance. The disadvantage is that the rise and fall times of the synaptic conductance cannot be controlled independently. Consequently, sometimes an alternative function of the form $g_{\text{syn}}(t) = \text{const}\cdot\left(\text{e}^{-t/\tau_1} - \text{e}^{-t/\tau_2}\right)$ is used. For this double-exponential formulation:

i. determine which of the two parameters, τ_1 and τ_2, determine the rise time and the fall time, respectively, of the synaptic conductance, and

ii. derive an expression for the time of the peak conductance as a function of τ_1 and τ_2.

(20 pts)

2. In the Plonsey & Barr textbook, and the lecture notes, the cable equations were derived for the core conductor model applied to a uniform cylindrical extension from a neuron, such as a dendrite or unmyelinated axon. In muscle cells, the transverse tubules are cylindrical extensions of the cell membrane protruding *into* the cell. Explain how the cable equations would need to be modified in order for them to describe action potential propagation in transverse tubules. **(20 pts)**

3. It is well known that an action potential travels faster along a larger diameter myelinated axon than a smaller diameter myelinated axon (slide 79, lecture 3). The Nodes of Ranvier are also farther apart in larger diameter axons. Give a description of action potential propagation along a myelinated action using equivalent circuit models. Discuss why this increase in propagation velocity occurs with increasing diameter. Why can we still have reliable propagation even when the Nodes are far apart? **(20 pts)**

4. You are asked to design an electrical/electronic stimulator to surface stimulate a major nerve (median) at the wrist. The nerve contains many hundreds of axons, most myelinated but some unmyelinated. What information would you need to determine the amplitude and shape of the stimulating pulse. What electrode materials would you use and why? Would you use an electrolytic paste and why? Where would you put the cathodic and anodic electrodes relative to the nerve and what would be the effect of increasing the inter-electrode spacing? What are the variables determining the stimulation threshold of an axon in that nerve and under which electrode is the axon likely to be stimulated? Use both practical and theoretical (mathematical expressions) to support your answers. **(20 pts)**

5. The source of most electrophysiological signals recorded at a distance from the electrophysiological generators (nerve or muscle fibres) is the trans-membrane action potential which lasts about 1 ms, is almost monophasic, and has about 1 ms durations. Starting with this trans-membrane action potential (sketch it) develop the shape and amplitude of the signal recorded in the plane of the unmyelinated fibre using a recording electrode 0.3 mm in diameter 400 µm away from fibre (perpendicular distance to the fibre direction). The reference electrode is at a large distance away in the external medium. What effect does the resistance of the external medium have on the signal amplitude and/or shape?

(20 pts)

THE END