Systems Bioengineering II

Exam 1

March 4th, 2014

Dr. Wang: 30 points
Dr. Young: 36 points
Dr. Kirkwood: 16 points
Dr. Hsiao: 18 points

(This table is for grading use only)

Dr. Wang			Dr. Young				Dr. Kirkwood		Dr. Hsiao		Total
1	2	3	1	2	3	4	1	2	1	2	

You are reminded that you are under an Honor Code at Johns Hopkins. You are not permitted to use any of your own electronic equipment during the exam. All work on this exam must be entirely your own.

You are not permitted to discuss this exam with anyone until the next day.

Print Name: ______________________________

Signature: ______________________________

Please write your name on every page of the exam.

[Blank page]

Exam 1 Questions by Prof. Wang

Question 1 (12 points)

Design a psychophysics experiment to test a subject's hearing threshold in detecting the presence of a 1000 Hz tone in quiet. Assume you can vary the intensity of the tone from 0 dB to 100 dB. Please answer the following questions:

1) How will you present stimuli and record and analyze the subject's responses?
2) Sketch the psychometric function of this experiment, label x-axis and y-axis clearly.
3) Explain how you will determine the subject's hearing threshold.
4) If the above experiment is conducted in the presence of a background noise with a mean intensity of 50 dB, sketch the psychometric function on the same plot of Question 1-(2) and mark the subject's hearing threshold in the presence of the noise.

.

[Blank page]

Question 2 (12 points)

Consider a psychophysics experiment in which a subject is presented with a stimulus that is either a noise of 500 msec in duration (S1) or a 1000 Hz tone added to a noise (both 500 msec in duration) (S2). The subject is asked to determine if a tone is heard each time a stimulus is presented (the subject does not know whether S1 or S2 is presented). Use the detection theory to analyze the subject's behavior in this psychophysics experiment. Assume that the noise is Gaussian with a mean m and standard deviation θ. Please answer the following questions:

(1) Assume S1 is a Gaussian noise with a mean (m) of 50 dB and standard deviation (θ) of 20 dB, and S2 is made up by adding a 20 dB tone to the same Gaussian noise in S1. Now S2 has a Gaussian distribution with a mean (m) of 70 dB and standard deviation (θ) of 20 dB. Sketch the two distributions and label the hit rate (detection probability), false alarm probability and the detection threshold if the subject decides a tone is heard when the total energy of a stimulus is 60 dB or greater.

(2) What is the detection probability if the subject's decision threshold is 70 dB?

(3) What is the false alarm probability if the subject's decision threshold is 50 dB?

(4) Sketch an ROC curve describing the subject's performance in this psychophysics experiment. Mark the three points on the ROC curve (and corresponding hit rate and false alarm probability on y-axis and x-axis) corresponding to the three decision thresholds, 50, 60, 70 dB, respectively.

[Note: You do not need a calculator to complete the above questions. Estimate a value if you can't compute it by hand.]

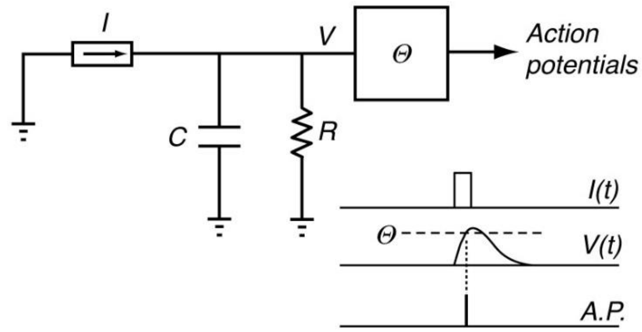
Question 3   (6 points)
Below is the time of occurrences (in msec) of spikes recorded from one auditory neuron in response to 5 repetitions of a tone with a duration of 100 msec. The onset time of the tone is at 10 msec. Please sketch and label the post-stimulus histogram (PSTH) (use binwidth of 10 ms).

Trial-1: [8   23   37   51   65   72   84 86 95]
Trial-2: [12   17   21   33   47   62   76   81 98 100 113]
Trial-3: [19   29   35   38   58   91   108 110]
Trial-4: [16   22   32   44   51   65   72   84   99]
Trial-5: [11   31   41   49   57   86   97   105 122]

Exam 1 Questions by Prof. Young

Question 1 (10 points)

In Homework 2, the integrate-and-fire model shown at right was introduced. To simplify the model, the resistor R is not voltage-dependent, as it would be if it contained ion channels, and the resting potential is set at 0 mV. Suppose that you want to investigate the effect of a non-inactivating voltage-gated sodium channel on the membrane potential V. Show how you would add such a channel to the circuit (i.e. show the new circuit with the Na channel added) and write a differential equation for V in the modified circuit. Would you need any other differential equations for this modified model? If so, write them. A non-inactivating Na channel has an m gate but no h gate. Remember that Θ is just an ideal threshold device and it draws no current at its input. (Hint: you do not have to change anything in Θ.)



Question 2 (16 points)
Part a) [10 points]
To model bursting in neurons, we used a modified HH model in which a calcium-dependent potassium channel *KCa* was added to the system, giving the set of differential equations below.

$$C\frac{dV}{dt} = I_{ext} - G_K(V - E_K) - G_{KCa}(V - E_{KCa}) - \bar{G}_{Ca}m_\infty(V)(V - E_{Ca}) - G_L(V - E_L)$$

$$\frac{dw}{dt} = \frac{w_\infty(V) - w}{\tau_w(V)} \qquad\qquad G_K = \bar{G}_K w$$

$$\frac{dCa}{dt} = A\left(-\frac{I_{Ca}}{2F} - B \cdot Ca\right) \qquad\qquad G_{KCa} = \bar{G}_{KCa}\frac{Ca}{Ca+1}$$

In this model, bursting is terminated by the increase in the conductance of the *KCa* channel as *Ca* accumulates. There is some evidence that voltage or Ca-dependent inactivation of the calcium channel participates in burst termination. Suppose that there is no *KCa* channel in the system and bursting is terminated instead by voltage and Ca-dependent inactivation of the *Ca* channel. Rewrite the equations above to model this system. (Hint: this is easier than it sounds; delete a couple of things and add inactivation to the calcium current and an inactivation model.)

Part b) (6 points)

There should be a function $h_\infty(V,Ca)$ in your model above. Given that this is an inactivation function that should terminate bursting in response to depolarization and the rise in Ca during the burst, which of the following are possible $h_\infty(V,Ca)$ functions, in the sense that the qualitative change (increase or decrease) in $h_\infty(V,Ca)$ is correct as V and Ca increase from zero?

(1) $h_\infty(V,Ca) = \frac{Ca\left(1-e^{-(V-E_{rest})}\right)}{Ca+K_I}$

(2) $h_\infty(V,Ca) = \frac{2K_I}{(Ca+K_I)\left(1+e^{(V-E_{rest})}\right)}$

(3) $h_\infty(V,Ca) = \frac{K_I\left(1-e^{-(V-E_{rest})}\right)}{Ca+K_I}$

K_I is a constant near the resting value of Ca and E_{rest} is the resting potential.

Question 3 (5 points)
The wimple synapse, when activated, produces an outward potassium current. Is this enough evidence to conclude that it is an ionotropic channel? If yes, give your reasoning. If no, give a counterexample.

Question 4 (5 points)
Dendrites have active conductances, meaning voltage-gated ion channels in their membrane. What effect should a Na^+ channel have on the amplitude of an EPSP produced by an excitatory receptor channel? Should it increase the amplitude of the EPSP or decrease it? Justify your answer. A qualitative answer is sufficient.

Exam 1 Questions by Prof. Kirkwood

Question 1 (8 points)
Part a) (6 points) What is LTP? How is it induced and expressed?

Part b) (2 points) Name one type of experiments implicating LTP/LTD in learning and memory.

Question 2 (8 points)
What is spike timing dependent plasticity (STDP)? What is so exciting about that, and what is the role of the backpropagating action potential in STDP?

Exam 1 Questions by Prof. Hsiao

Question 1 (9 points)
Both the SA1 and Pacinian afferents are A-Beta mechanoreceptors that innervate the skin. What is the evidence that these afferent types different? Include in your answer a) location and type of receptor endings, branching of the receptor endings b) adaptive properties and receptive field structures, c) approximate innervation density d) role in behavior

Question 2 (9 points)
It is thought that area 3b neurons code for orientation.

Part (a) (3 points) Describe the receptive field structure of a typical area 3b neuron. How does the receptive field of a cortical neuron in area 3b compare with the peripheral receptive fields of an SA1 afferent?

Part (b) (2 points) Draw an orientation tuning curve for a typical area 3b neuron.

Part (c) (4 points) When a bar is indented into the skin, multiple neurons with different tuning curves are activated. How does the brain decide what is the actual orientation of the bar?

[Blank page]

[Blank page]