481 sample paper[1]

27 March 2009

2 hour exam, do three questions.

1. (a) (5) Draw a labelled diagram of a neuron indicating the soma, axon and dentrites along with the regions with high concentrations of sodium and potassium concentration.

   (b) (4) The Hodgkin-Huxley equation is

   $$c_m \frac{dV}{dt} = -i_m \qquad (1)$$

   where i_m is the membrane current

   $$i_m = g_L(V - E_L) + g_K(V - E_K) + g_{Na}(V - E_{Na}) + \ldots \qquad (2)$$

   The E_L, E_K and E_{Na} are *reversal potentials*, in the case of E_K and E_{Na} explain what is meant by reversal potential.

   (c) (5) The potassium channel is a persistent channel with

   $$g_K \propto n^4 \qquad (3)$$

   Draw a Potassium channel and explain where the exponent comes from. Likewise, the sodium channel is a transient channel with

   $$g_{Na} = m^3 h \qquad (4)$$

   Draw a transient channel and explain the meaning of m and h.

   (d) (6) What equation is satisfied by n, m and h? What do the terms in this equation mean? Give a rough account of the dynamics that produces spikes.

2. (a) (6) Write down the equation governing a leaky integrate and fire neuron and describe the model. Is it linear?

   (b) (8) Calculate the firing rate for a leaky integrate and fire neuron with a constant injected current.

   (c) (6) What is spike rate adaptation? How is it modelled?

3. (a) (5) With reference to the famous Hubel and Wesel study of vision describe what is meant by a tuning curve.

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(b) (5) What is the spike triggered average?

(c) (10) Show how the spike triggered average can be related to the kernel in a linear filter model of the firing rate.

4. (a) (5) Draw a labelled diagram of a synapse and give a brief account of what happens when a spike arrives. What is meant by a *post-synaptic potential*?

(b) (10) In a useful model of synpatic conductance, the conductance is $g_s = g_0 P_s$ where

$$\tau_s \frac{d}{dt} P_s = -P_s \tag{5}$$

where $\beta_s = 1/tau_s$ is the closing rate for the synaptic ionic gates and

$$P_s \rightarrow P_s + P_0(1 - P_s) \tag{6}$$

whenever there is a presynaptic spike. Show how this model can be justified.

(c) (5) What is *Hebb's rule* and how does it differ from 'Neurons that fire together wire together'. What is *spike timing dependent plasticity*?