COMPUTATIONAL NEUROSCIENCE (NBIO136B) MIDTERM MARCH 9th 2022

Answer all 8 questions. (There are 80pts total so allow for 1 minute per pt).

1) If the extracellular concentration of potassium gets reduced, what do you expect to happen to the resting membrane potential of a neuron, and why? (5pts)

2) Sketch the inter-spike interval (ISI) distribution of each of the following processes and then:
(i) rank them from the one with smallest to largest coefficient of variation (CV = standard deviation divided by the mean) of ISIs;
(ii) rank them again from the one with the smallest to largest CV_2 of ISIs (CV_2 is the mean of the CVs of each pair of consecutive ISIs averaged across all consecutive pairs in the series).

a) A neuron with regular spikes every 100ms.
b) A Poisson process with mean rate of 10Hz.
c) A regularly bursting neuron with 4 spikes separated by 4ms within a burst then a pause of 500ms before the next burst.
d) A regularly spiking neuron whose rate gradually increases from 1Hz to 50Hz over an hour.

(16pts)

3) Explain what the following code does—you can write on the lines beside the code and say what each line does or simply say what the code as a whole does if you are sure. State what the final value of "`tally`" represents, and what is stored in a column of "`solutions`":

```
tally = 0
solutions = []
for j in range(1440):
     for k in range(1440):
          if (j+1)*(k+1) == 1440:
               tally += 1
               solutions.append([j+1, k+1])
```

(8pts)

4) The following snippet of code is designed to produce a vector of applied current that has a baseline of 1nA and increases to 2nA in the time window from 250ms to 750ms before switching off. Find the two errors in the code.

```
import numpy as np

dt = 0.0001
t = np.arange(0,1,dt)
Ion = 250
Ioff = 3*Ion
Ilow = 1e-9
Ihigh = 2e-9
Iapp[Ion:Ioff] = Ihigh
Iapp = Ilow*np.ones(np.shape(t))
```

(5pts)

5) Sketch, being as quantitative as you can, the spatio-temporal receptive field of a neuron that responds most to a drifting grating with a spatial period of 2 degrees, moving from right (negative-x) to left (positive-x) at a speed of 20 degrees per second. Assume there is no response beyond 100ms from the stimulus offset and the receptive field has a total/maximum width on the order of 5 degrees. (10pts)

6) A receiver-operating characteristic (ROC) curve for a neuron is a plot of its probability of correctly identifying stimulus-A on the y-axis against the probability of a false positive on the x-axis, as the threshold for identification of A is varied. (Here a false positive means it responded to stimulus-B above the threshold for identification of A). For the following two examples, ketch the ROC curve and state the area under it, explaining anything that can be understood by the area under the curve in terms of probability, for the following two examples of neural response
a. The neuron always fires more spikes to stimulus A than it ever does to stimulus B?
b. The neuron responds identically to the two stimuli? (8pts)

7) The activation variable of a channel follows the standard equations,

$$\frac{dm}{dt} = \alpha(1-m) - \beta m$$

a) If the rate constants, α and β, are fixed, what is the steady state of m (where $\frac{dm}{dt} = 0$), in terms of α and β?
b) If m is not initially at its steady state, with what time constant does it approach its steady state?

The voltage-dependent rate constants α and β, given in units of 1/sec, are fitted using the functions:
$\alpha = 1000\frac{(V_m+0.080)}{(V_m+0.100)}$, for $V_m \geq -0.080$ and $\alpha = 0$ for $V_m < -0.080$

$\beta = 1000\frac{(-0.040-V_m)}{(0.020-V_m)}$, for $V_m \leq -0.040$ and $\beta = 0$ for $V_m > -0.040$

where the membrane potential, V_m, is measured in V.

Using voltage clamp, the membrane potential is held at -80mV for a long period of time before being increased to -60mV where it remains.

c) What are the values of α and β at -80mV and -60mV?
d) What is the steady state of m at -80mV and -60mV?
e) Sketch how m changes with time showing as much detail as possible (including time constants for any change) when the membrane potential is changed as described above.

(20pts)

8) In the Hodgkin-Huxley model, during an action potential there are three forms of negative feedback (two are due to voltage-dependent properties of ion channels, one is not). Describe each of these three processes. In particular, explain how they result in negative feedback, being clear to demonstrate the meaning of negative feedback. (8pts)