**CISC 3250: Systems Neuroscience**
**Homework 1**
**due February 3, 2019**

1. In class, we learned to model the change in neuron voltage as an integrate and fire neuron

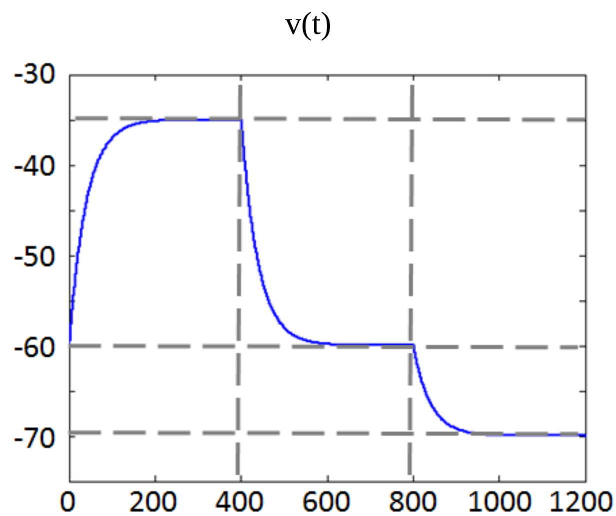
$$\tau \frac{dv}{dt} = -(v(t) - E_L) + RI(t)$$

The voltage is reset to $v(t^f+\delta)=v_{res}$ after the voltage rises above the threshold $v_{thresh}$.

For all questions a-e, let us say $E_L$=-65mV, $v_{thresh}$=-30mV, $v_{reset}$=-75mV, $\tau$=**0.1**, and v(0)=-60mV.

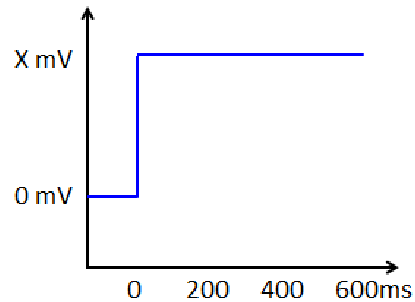
a) Assume RI(t)=$\begin{cases} 0 & t < 0 \\ 40 & t \geq 0 \end{cases}$. Compute update at 10ms intervals. Calculate the new voltage at 30ms. (You will get partial credit if you show your work.)

b) Now, assume we have a different input function. RI(t)=0 when t<0. Draw input RI(t) given the v(t) shown below. (Estimate RI(t) voltages to the nearest 5mV – if you think the input should be 13mV, you would label the input as 15mV.)



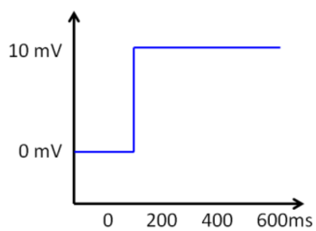
c) Now let us say that RI(t) is characterized as shown below. What is the smallest possible value for X to allow v(t) output to spike.

RI(t)

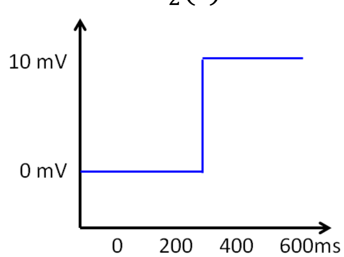



d) Now let us say **RI(t)=**$\sum_j \boldsymbol{w_j \alpha_j(t)}$, with the $\alpha_j(t)$'s shown below to the left. Estimate the weights $w_1$, $w_2$, and $w_3$ for the two outputs v(t) shown below to the right. (Estimate to the nearest **0.5**, so **-0.7** would be written as **-0.5**.) Partial credit will be given!

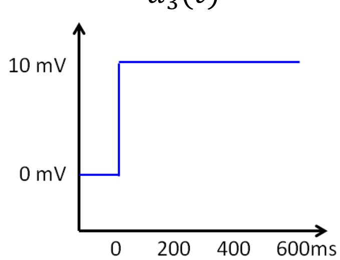
$\alpha_1(t)$



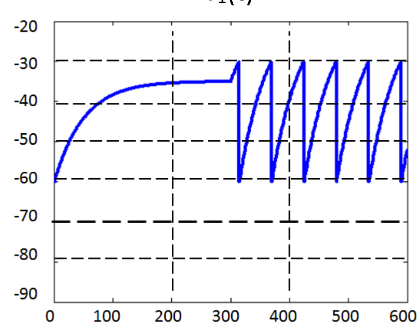

$\alpha_2(t)$



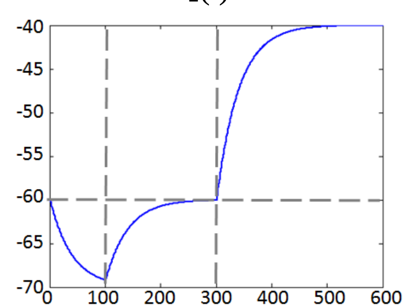

$\alpha_3(t)$




$v_1(t)$




$v_2(t)$

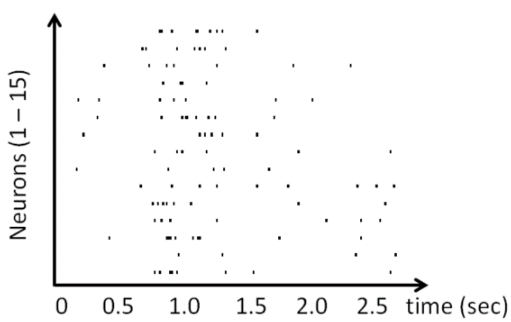


e) Recall $E_L$=-65mV, $v_{thresh}$=-30mV, $v_{reset}$=-75mV, $\tau$**=0.1**, and v(0)=-60mV. Assume RI(t)=70mV for t>0ms.
List three changes you can make to the above variables to increase the spiking rate of the model neuron.

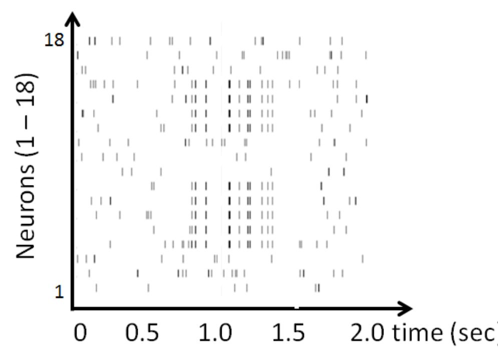
2. Below are example responses of neural populations to the onset and offset of a strong sweet odor. Specifically, initially there is no odor (no smell), then a strong sweet odor enters the nose for a few seconds, then there is no odor again (perhaps the nose is blocked); we record the neural responses. For each plot,

- identify whether the population of neurons is responding using rate coding or temporal coding
- identify whether the presence of odor is inhibitory or excitatory to the population, or both!
- identify when the odor begins and ends (estimating to the nearest 100 ms)

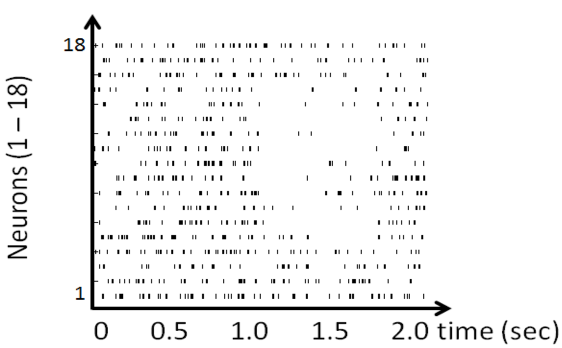
a)



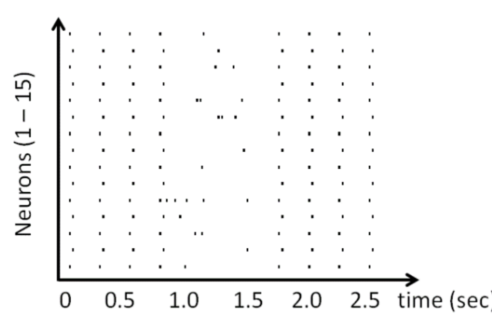

b)




c)




d)



3. In class, we learned about activation functions that model linear and non-linear changes from dendrite input to axon output. Let us say we have a set of neurons each with $E_L$=-60mV and $v_{thresh}$=-25mV. In the following, questions we observe the sum of dendrite input voltages to each neuron RI(t) and we also determine g(RI(t)), the resulting observed input after transformation by the function g(…).

For each of the three neurons below, name the type of activation function that is a model for each neuron, and, **if applicable**, provide either:

- the input/interval-of-inputs where the function transitions between minimum and maximum outputs, or
- the interval-of-inputs where the function rises to a maximum value and returns back to a minimum value.

**Example neuron:**

| RI(t) | g(RI(t)) |
|---|---|
| -20 mV | 0 mV |
| -5 mV | 0 mV |
| 10 mV | 20 mV |
| 40 mV | 20 mV |

Activation function: Step    Threshold: some voltage between -5mV and 10mV

Neuron 1:

| RI(t) | g(RI(t)) |
|---|---|
| -10 mV | 0 mV |
| 0 mV | 0 mV |
| 10 mV | 4 mV |
| 20 mV | 13 mV |
| 30 mV | 19 mV |
| 40 mV | 20 mV |
| 50 mV | 20 mV |

Neuron 2

| RI(t) | g(RI(t)) |
|---|---|
| -10 mV | 10 mV |
| 0 mV | 10 mV |
| 10 mV | 10 mV |
| 20 mV | 10 mV |
| 30 mV | 50 mV |
| 40 mV | 50 mV |
| 50 mV | 50 mV |

Neuron 3:

| RI(t) | g(RI(t)) |
|---|---|
| -10 mV | 0 mV |
| 0 mV | 2 mV |
| 10 mV | 20 mV |
| 20 mV | 30 mV |
| 30 mV | 5 mV |
| 40 mV | 0 mV |
| 50 mV | 0 mV |

Which of the neurons will spike using $\tau \frac{dv(t)}{dt} = -(v(t) - E_L) + g\big(RI(t)\big)$ if RI(t)=50mV  for t>0ms ?

4. Assign each of the following statements to one of Marr's three levels. **Important note:** these statements are (probably) not accurate neuroscience statements! This is to get practice with recognizing the three levels from Marr.

Statement 1: Gustatory (taste) neurons in the tongue send axons directly to neurons in the amygdala (associated with emotion).

Statement 2: Memory formation rate is represented by R. Apricot fragrance concentration in the air is represented by the function A.
k is a constant value (which we can learn by careful study)

$$\frac{dR}{dt} = A(t) - k$$

Statement 3: The presence of light modulates happiness.

5. Presume we have a Matlab vector:

```
milliVolts = [-50, -48, -52, -50, -40, -38, 2, 10, -62];
```

a) Provide an expression to give the first element of the vector. (The expression will look something like `vector[3]`)

b) Provide a single command containing 25 characters or less to define the vector `Volts` that contains the contents of `milliVolts`, but measured in volts. In other words, the first two elements of `Volts` will be -0.05 and -0.048, respectively; the final element of `Volts` will be -0.062. (The command `x=32+4;` contains 7 characters in total, counting each digit, operator, and semicolon.)

Consider the following code:

```
V0=-55;
El=-68;
tau=0.04;
RI=10;
step=0.01;
deltaV=(-(V0-El)+RI)/tau;
V=V0+deltaV*step;
RI=50;
V=V0+deltaV*step;
RI=100;
V=V0+deltaV*step;
```

c) What is the value of V after each evaluation of the "`V=…`" command? (You may run Matlab to test this)

d) Why does `V` not change even though `RI` changes?

e) What code can we use to store the evaluation of each "`V=...`" command in a separate entry in a vector `V_vector`. (After `V_vector` is fully defined, `length(V_vector)` would be 3.)