

CISC 3250 example exam questions

This gives a sense of the type of questions that can be included. Further math topics covered in the homeworks (but not in this practice set) may appear on the exam as well.

We use the voltage model: $\tau \frac{dv}{dt} = -(v(t) - E_L) + RI(t)$

With voltage resetting to E_L once it reaches the threshold v_{thresh} , as specified by $v(t^f + \delta) = E_L$

Let us say $E_L = -60\text{mV}$, $\tau = 1$, and $v_{\text{thresh}} = -35\text{mV}$.

Furthermore, we define the axon voltage at time $t = 0\text{ms}$ to be: $v(0) = -40\text{mV}$

Presuming a constant input $RI(t) = 10\text{mV}$, how does the axon voltage change from time $t = 0\text{ms}$ to $t = 1,000\text{ms}$? For example, does the voltage spike, stay the same, plateau at another voltage value? Explain why, using the above equation(s) for the voltage model.

Presuming the input rises to $RI(t) = 300\text{mV}$ starting at $1,001\text{ms}$, what is the axon voltage from time $t = 1,001\text{ms}$ to $t = 2,000\text{ms}$? Does the voltage spike, stay the same, plateau at another voltage value? Explain why, using the above equation(s) for the voltage model.

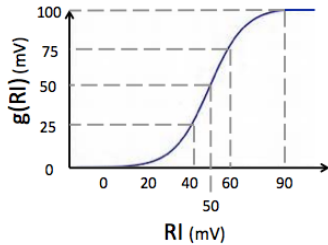
Presuming a constant positive input $RI(t)$ over a long period of time, what is the minimum input value to produce spiking?

Let us assume $\tau = 1000$ (and all other parameters are the same as initially described). How does the change in τ change the minimum input value required to produce spiking, if at all?

Explain a biological mechanism by which spiking information is communicated from the axon of neuron A to the dendrite of neuron B.

We can replace the $RI(t)$ term from the equation above with $g(RI(t))$, where $g()$ is the sigmoid function we learned in class, now scaled to have a maximum output of 100mV, rather than just 1:

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



Let us consider three scenarios:

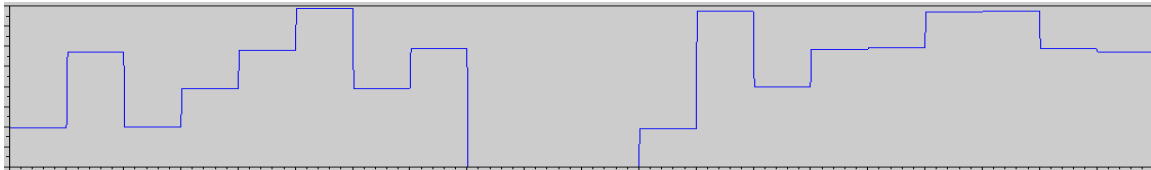
- 1: RI is a constant 60 mV
- 2: RI is a constant 120 mV
- 3: RI is a constant 240 mV

What is the change in spiking frequency from scenario 1 to scenario 2 (increase, decrease, stay roughly the same)?

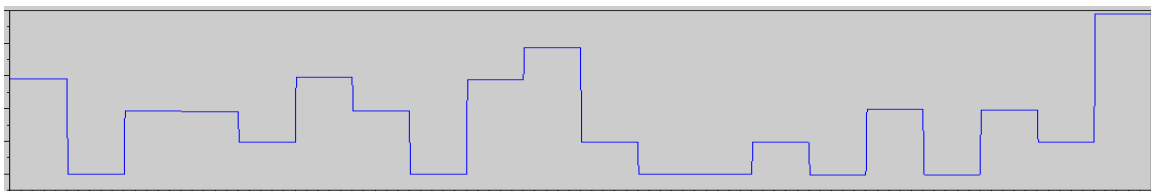
What is the change in spiking frequency from scenario 2 to scenario 3?

Which rate plot describes the spiking pattern shown here?

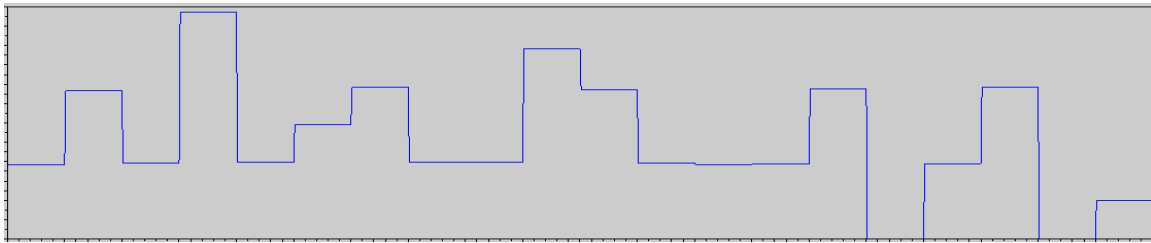
Rate plots have time on the x axis and rate over fixed time window on the y axis.



A



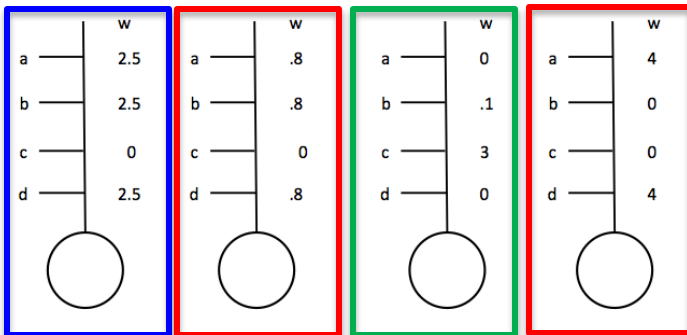
B



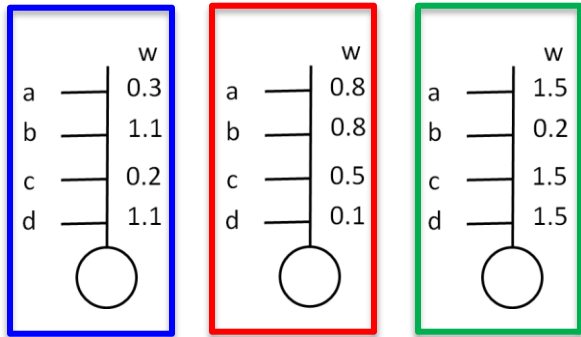
C

The following neuron computes the weighted sum of its inputs as $h = \sum_j w_j r_j$. It then outputs a 1 if $h > 2$ and otherwise outputs a 0. Each input provides a rate r_j of either 0 or 1 (no values in between).

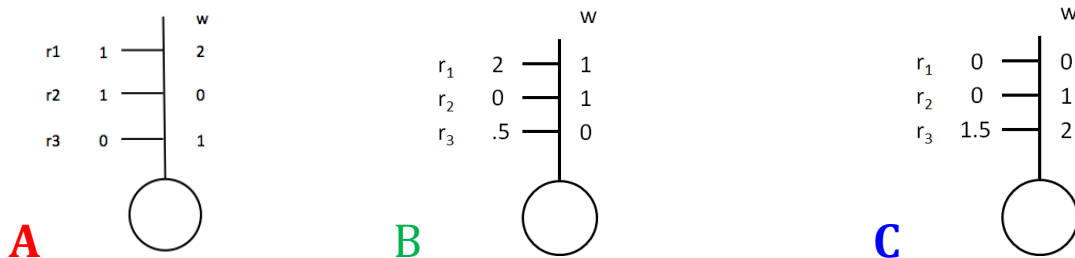
For each set of weights, say if the neuron performs generalization/pattern completion, and if so, name the inputs that are tied together in the pattern.



For each set of weights, say if the neuron performs template recognition, and if so, name the inputs that are tied together in the pattern.



Presume each of the following neuron's output is computed by taking the weighted sum of inputs $h = \sum_j w_{ij}r_j$, and outputting 2 if $h > 1.5$ and outputting 0 otherwise.

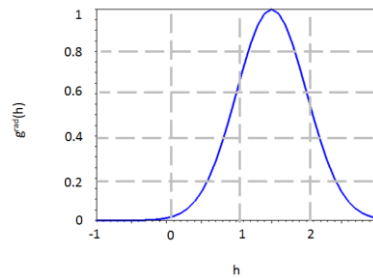
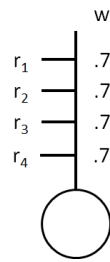


Provide new weights using learning rule $\Delta w_{ij} = \epsilon r_i r_j$ and $\epsilon(w) = \begin{cases} 1 & \text{if } w \geq 0 \\ -1 & \text{if } w < 0 \end{cases}$ for all weight values

Provide new weights using learning rule above, followed by normalization of weights

Provide new weights using the Willshaw learning rule.

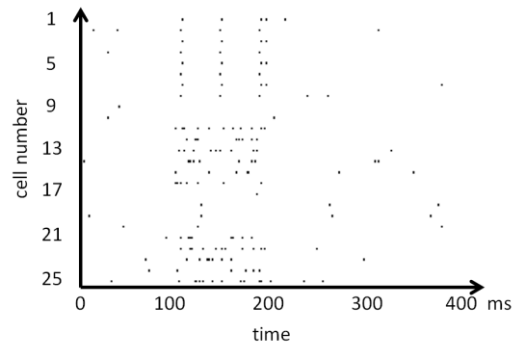
The neuron 5 takes four inputs r_1 , r_2 , r_3 , and r_4 . Presume each of the four inputs is either 0 or 1. Further presume neuron 5 takes the weighted sum of its inputs and then has an output determined by $g^{\text{rad}}(h)$ below.



Propose two combinations of inputs that will produce an output great than 0.8 .

Propose two combinations of inputs that will produce an output less than 0.1 .

To the right is a spikegram recording of a group of neurons in an animal's olfactory bulb. (This is actually fake data for the sake of testing concepts from class.) At some point, in time an odor is presented to the animal and at some later point the odor is removed.



Some of the recorded neurons respond through change in spiking rate. Which are these neurons?

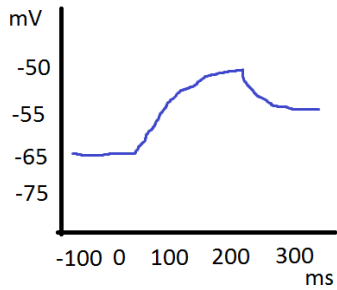
For these neurons, estimate the spike rate (per second) while the smell is presented.

Some of the recorded neurons respond through change in temporal coding. Which are these neurons?

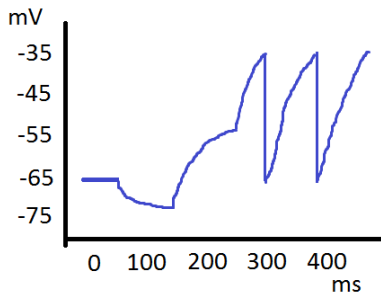
At what time is the smell presented? At what time is it taken away?

Assume $E_L = -65\text{mV}$, $v_{\text{thresh}} = -35\text{mV}$, $v_{\text{reset}} = -65\text{mV}$, and $\tau = .05$

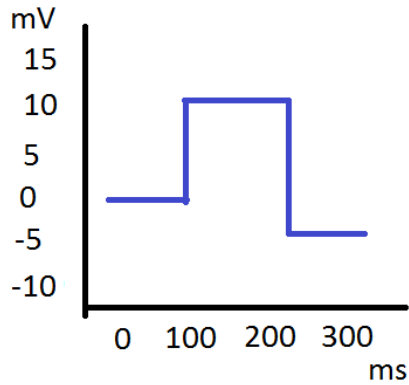
Draw $RI(t)$ that will produce the resulting $v(t)$



Draw $RI(t)$ that will produce the resulting $v(t)$



Draw $v(t)$ that results from the following $RI(t)$



Matlab commands:

Matrix1 is defined with the following content:

$$\begin{bmatrix} 10 & 20 & 20 & 30 & 0 \\ 1 & 1 & 0 & 0 & 1 \\ 12 & -5 & -8 & 9 & 5 \\ 6 & 0 & 0 & 2 & 4 \end{bmatrix}$$

What is the value of variable x at the end of each chunk (or line) of code:

Chunk 1:

```
x=Matrix1(2:4,5);
```

Chunk 2:

```
val=find(Matrix1(2,:) == 0);  
x=Matrix1(1,val);
```

Chunk 3:

```
x=min(Matrix1(:,2));
```

What is the value of variable v at the end of each chunk of code:

Chunk 1:

```
v(1)=3;  
for i=1:5  
    v(i+1) = v(i)*2;  
end
```

Chunk 2:

```
v=[4,5,8,10,12];  
for k=3:5  
    v(k)=v(k)-2;  
end;
```

Chunk 3:

```
v=4:2:10;  
v(4)=15;
```

Convert the following to an equivalent for loop:

```
v(1)=-70;  
v(2)=v(1) + (-1*(v(1)-70)+50)*0.1;  
v(3)=v(2) + (-1*(v(2)-70)+50)*0.1;  
v(4)=v(3) + (-1*(v(3)-70)+50)*0.1;  
v(5)=v(4) + (-1*(v(4)-70)+50)*0.1;  
v(6)=v(5) + (-1*(v(5)-70)+50)*0.1;  
v(7)=v(6) + (-1*(v(6)-70)+50)*0.1;
```

For all computations, you may estimate your answer to the first decimal place – for example, if the correct answer is 0.341, I will accept 0.3 or 0.4 as answers.

What is the approximate ratio of the number of neurons in the primary auditory cortex to the number of neurons or in the cochlea?

- (a) 1:1
- (b) 300:1
- (c) 1:200
- (d) -5:4,020,000

This observed ratio supports which information representation principle in the brain?

Beyond studying vision, we can also use fMRI recordings of neural activity to study human emotions. It has been observed when one brain region (let's say the amygdala) shows high activity and another region (let's say the dorsomedial prefrontal cortex) shows low activity, we can predict the subject in the fMRI scanner is a calm person. If, on the other hand, the amygdala and the dorsomedial prefrontal cortex both show high activity, we can predict the subject in the scanner is an aggressive person.

	Amygdala	dmPFC
Calm	High	Low
Aggressive	High	High

1: Presuming there are only two types of activity that can be measured (high or low) for each region, what is the maximum number of personality states (e.g., calm, aggressive, cheery) we can identify with just two brain regions?

2: Let's say we perform another study where we identify 16 personality states using combinations of high and low brain region activity. What is the minimum possible number of brain regions he needs to use to identify these states?

You are trying to listen to a band in a crowded bar. While listening, you record the responses of 5 neurons. The 5 neurons have distributed firing rates to respond to the instrumental music, the singers, and people talking in the background. The maximum response for each individual sound source (i.e., at loudest volume) is as follows.

Neuron 1	30 Hz	0 Hz	0 Hz
Neuron 2	10 Hz	30 Hz	0 Hz
Neuron 3	0 Hz	20 Hz	0 Hz
Neuron 4	0 Hz	10 Hz	30 Hz
Neuron 5	30 Hz	0 Hz	30 Hz
	Instruments	Singers	Talkers

What is the neural response for:

hearing instruments at maximum volume (1), not hearing the singers (0), and hearing the talkers at half volume (0.5)

hearing instruments at low volume (0.2), hearing the singers fairly loudly (0.8), and not hearing the talkers (0)