PSY 568/768 – SDSU Systems Neuroscience *Name:*__________________________________

First midterm exam – 8 equally weighted questions (6-8 min/question)

1. For parts a,b,c, assume: *(i)* a <u>*hypothetical*</u> channel only conducts a <u>*hypothetical*</u> ***negative*** ion, *(ii)* the Nernst potential for this ion is ***-40 mV,*** *(iii)* a cell ***has*** this channel in its membrane, *(iv)* the cell is currently ***at rest*** (defined as ***-70 mV***), and, *(v)* this channel starts out ***closed***.

(a) Is there more of this kind of ion *inside* or *outside of* the cell?

(b) Which *direction* will the ions flow (<u>***in/out*** of cell</u>) if the channel is briefly *opened* (with cell *at rest: -70mv*)?

(c) Would you expect the ***direction of flow*** of the ions though this channel to ***change*** (compared to (b)) if you first voltage clamp the cell to ***-10 mV*** and ***then*** briefly open the channel?

(d) Channels responsible for the <u>***resting potential***</u> (***not*** the channel discussed in part a,b,c!) are ***permanently*** open. What stops net current from continuously flowing through them when the cell is at rest (a few words)?

2. The opening and closing of ***voltage-gated*** sodium and potassium channels supports the ***action potential***.

(a) Draw ***one graph*** with <u>***2 lines***</u> showing amount of <u>***inward***</u> ***current flow*** through axonal ***fast sodium*** channels (use a ***solid*** line) and amount of <u>***outward***</u> ***current flow*** through ***potassium*** channels (use a ***dashed*** line) versus <u>***time***</u>, immediately after a squid axon is suddenly ***voltage-clamped*** to -10 mV (starting from rest) and kept there. ***Label*** <u>***units***</u> on <u>***both***</u> ***x- and y-axes***, and use <u>***arrow***</u> to mark ***onset*** of voltage clamp.

(b) When voltage-gated sodium channels open on the rising edge of a spike, the resulting inward sodium current can (and does) flow in both directions along the axon. Why does the spike keep going in ***one direction***?

(c) The same mammalian neuron can generate a ***burst of spikes*** <u>*or*</u> ***evenly spaced spikes*** in response to a stimulus. A slow calcium current, I_T, is thought to contribute to bursting. Under <u>***what initial condition***</u> will this current be <u>***be disabled***</u>***?*** (so that a stimulus will ***not*** cause a burst of spikes)

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3. Hebbian-like changes in synaptic strength (e.g., long-term potentiation, LTP) are thought to be mediated by NMDA channels that are found in the post-synaptic membrane.

(a) Since NMDA channels are not required for the 'expression' of LTP, ***which channels*** are responsible for 'expressing' the ***larger/strengthened*** excitatory post-synaptic potential?

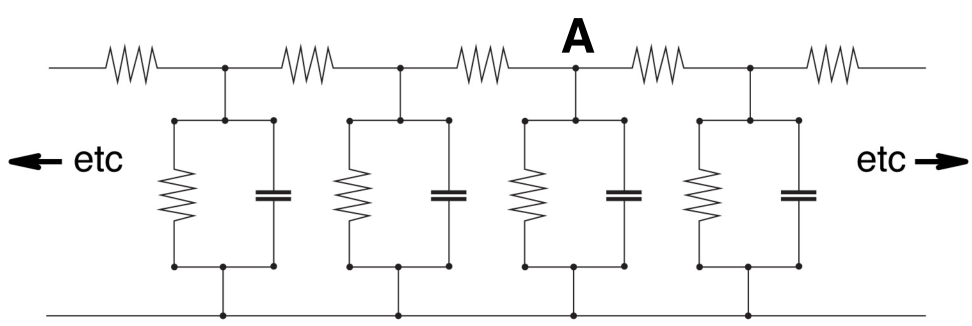
(b) What ***two conditions*** are required in order for NMDA channels to open?

(c) Recent experiments on ***spike-timing-dependent plasticity*** have modified our original understanding of LTP. Would you expect an ***increase*** or ***decrease*** in the strength of an NDMA synapse if the ***pre-synaptic cell*** released glutamate shortly (***50 msec) before*** the ***post-synaptic cell*** was strongly depolarized?

(d) The strength of a simple abstract "Hebbian synapse" increases if ***input*** is correlated with ***output***, so a simple Hebb rule is: ***change in weight*** is proportional to ***input times output***. Give a ***short*** rationale (use simple equations ***or*** a few words) for why we can rewrite that simple Hebb rule using just ***inputs*** and ***weights***.

4. A simple electrical model of a dendrite is shown below.

(a) Label single examples of the four electrical parts below that correspond to: ***membrane resistance (R_M), longitudinal resistance (R_L), membrane capacitance (C_M), extracellular fluid***.



(b) Assume a *constant current* is suddenly injected at point **A**. Out of ***all parts shown***, ***circle*** the part(s) that will have the ***smallest*** amount of current flowing through it/them during ***earliest stages*** of the current injection.

(c) After a ***long period*** of current injection (e.g., a second), draw a ***BOX/BOXES*** around the part/parts shown that will have the ***smallest*** amount of current flowing through it/them

(d) Increasing the ***diameter*** of a dendrite changes the values of all the parts in the circuit above. ***Which part*** experiences the ***largest change*** in value, and ***why*** does that part change the most?

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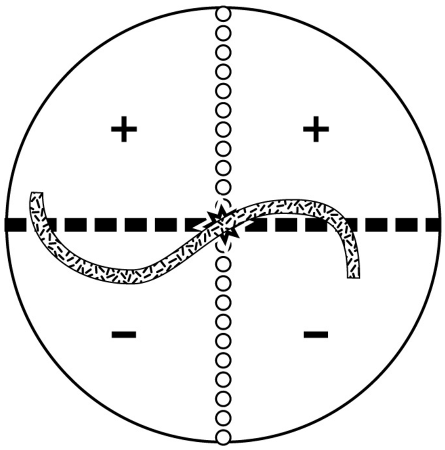
5. Primate area V1 and V2 each have a visual hemifield map. Below ***left***, a visual stimulus (textured shading) in shown in the *left and right* hemifield using ***thick-dashes/small-circles/star/plus-minus to*** indicate ***horizontal/ vertical/center-of-gaze/upper-lower*** in the visual field. At ***right***, draw what activity this stimulus would elicit in the maps in V1 and V2 in ***just*** the ***right hemisphere*** using same ***dashes/small-circles/star/plus-minus*** convention.

***Entire* Visual Field**



***Right* Hemisphere of Brain**

6. Diagram the neural tube in the box below and ***label*** its 6 main caudal-to-rostral segments. Include the ***cerebellum,*** the ***two ventricle openings***, and use ***dotted lines*** to show where the ventricle is ***not*** open.

(a)

(b) Which segment of the neural tube does the ***cerebellum*** belong to and what segment does the ***red nucleus*** belong to?

(c) State a general rule to predict whether the connection between two ***brain structures*** will likely be *crossed* or *uncrossed*.

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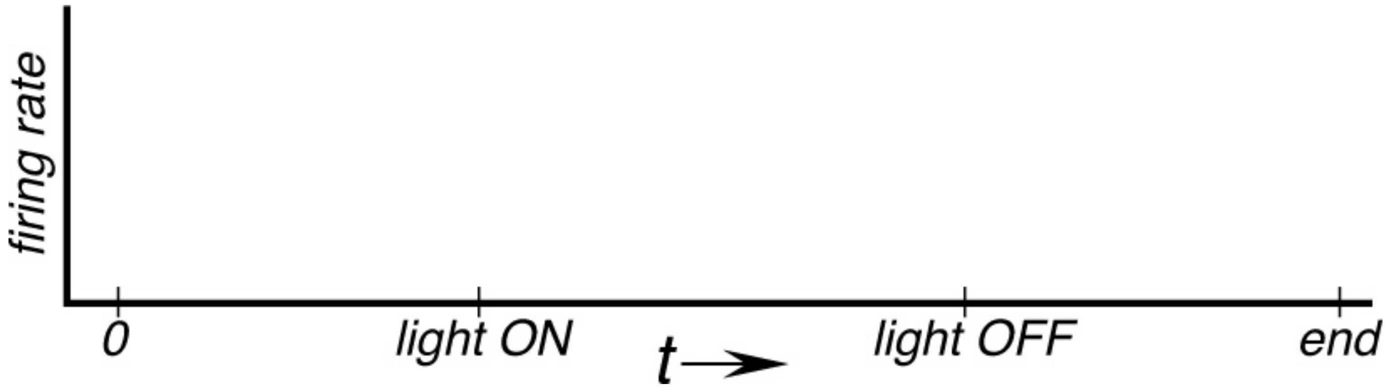
7. The dorsal lateral geniculate nucleus (dLGN) receives a projection from both the left and the right retina and projects to primary visual cortex, area V1.

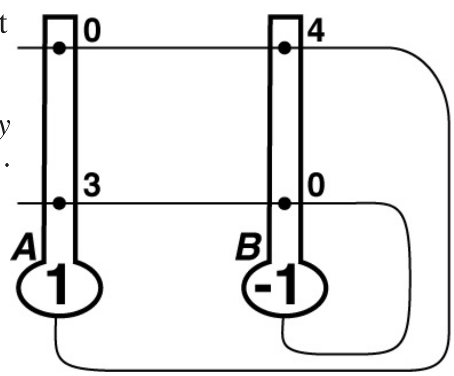
(a) Using <u>***solid***</u> line, indicate how an ***X-like***, ***OFF-center***, ***non-lagged*** cell in the ***cat dLGN*** would respond. Then with a <u>***dashed***</u> line, indicate how an ***Y-like***, ***ON-center***, ***lagged*** cell would respond (same axes!).



(b) Which <u>***stimulus feature strongly modulates***</u> the firing of a V1 cell in a ***cytochrome oxidase*** '***interblob***'? Which <u>***stimulus feature is mostly ignored***</u> by these cells?

(c) We discussed a model for <u>***direction selectivity***</u> called a '***Reichardt detector***' (originally developed for housefly vision!) Describe how it works in a sentence <u>*or*</u> with a simple diagram.

8. Diagram at right shows a simple recurrent network with *2 units* (***A*** and ***B***, current state inside each unit) and *4 weights* (smaller numbers). The *update rule* for this network is the one given in class: if sum of [input × weight] across all inputs is greater than 0, unit activation is 1, else if less than zero, unit activation is -1. *Energy* is defined as the negative of the sum across all weights of [input × weight × output].



(a) What is the ***current*** value for the ***energy*** of the network? (show calculation)

(b) Is the <u>***current state***</u> of the network <u>***stable***</u>? Briefly explain <u>***Why***</u> or <u>***why not***</u>?

(c) Give a brief example <u>***what***</u> the <u>***approach to a stable state***</u> is supposed to be <u>***a model of***</u>