NBIO 303
Problem set 2

DUE at time and place posted on website

Please turn in a writeup of your solutions including all relevant plots, together with copies of your MATLAB code.

I **Filtering of inputs: what matters in driving the membrane response?** Let's say we know the voltage right now: at a time t_{now}. (For example, we could have just seen a spike, so we know $V(t_{now})$ has just risen above threshold.) And – we'd like to know what current $I(t)$, defined over a time interval $[0, t_{now}]$, could have driven the neuron to this voltage. For the current-driven (RC) circuit, find

- Choose $t_{now} = 30ms$, and $R * C = 10ms$. Find two input currents $I_1(t)$ and $I_2(t)$, that look very different but produce the same value of $V_{t_{now}}$. What do these currents have in common? Hint: use the explicit solution for $V(t)$ from class to achieve this.

In both cases demonstrate your results by plotting the relevant voltage and current traces using MATLAB.

II **Summation of simultaneous impulses: does conductance "help or hurt"?**

- Consider the current-driven (RC) circuit, with $R*C = 10ms$. Consider an incoming current impulse, with magnitude $\bar{I}$ μA and width Δ_1 ms (choose whatever values you wish for these constants). Starting from $V(0) = 0$ mV, what is the peak voltage achieved over time in response to this impulse? If the threshold for spike generation is 10 mV, what fraction of the way to threshold does this impulse drive the voltage response (if your impulse take the cell over threshold, reduce $\bar{I}$ and repeat)? Call this fraction f. Next consider the case in which N such impulses arrive simultaneously (equivalent to taking the amplitude $\bar{I} \to N\bar{I}$). What is the lowest value N that will drive the voltage over threshold? How are f and N related? Solve this question using either the matlab code, or the explicit solution from class (or both to check your work)!
- Now answer the same question, for a conductance-based model. Now, the impulses should be in $g(t)$ conductance instead of the current $I(t)$. Choose $E = 11$ mV. Explain your findings.

III **HH model**

- Modify the code provided to plot the *firing rate - current* tuning curve. That is: as a function of the constant value of applied current (i.e., $I_A(t) = \bar{I}$), plot the firing frequency in Hz. Hint: start at $\bar{I} = 0$ μA and gradually test more negative currents.
- Now repeat, but with a sinusoidal background current of frequency ω kHz. That is, plot firing frequency as a function of $\bar{I}$ for the applied current $I_A(t) = \bar{I} + \epsilon \sin(2\pi t\omega)$, where you choose values for ϵ and ω (try several different values). How does your *firing rate - current* tuning curve change? Can you provide a qualitative explanation? Hint: look for changes around the $\bar{I}$ value near the threshold for repetitive firing. Hint: check out the related figures in the book Chapter by C. Koch. Here, the "background" is white noise, which is given by a mixture of many simultaneously applied periodic inputs with different frequencies.

- Above, we've been considering how a single aspect of the stimulus, $\bar{I}$, is represented by a single aspect of the neural response: the firing rate. In actuality, there are three aspects that define a stimulus: ϵ, ω, *and* $\bar{I}$. And there are many different aspects of the neural response, beyond the firing rate. Think of several other such possibilities for quantifiable aspects of the neural response. How well is each aspect of the stimulus encoded by these different aspects of the neural response? How does this depend on the three stimulus parameters?

NOTE! You will have the opportunity to do exactly this experiment with the snail neuron next week in lab. The only difference is that the sin wave will be replaced by periodic pulses of frequency ω and strength ϵ (and some width Δ in time).