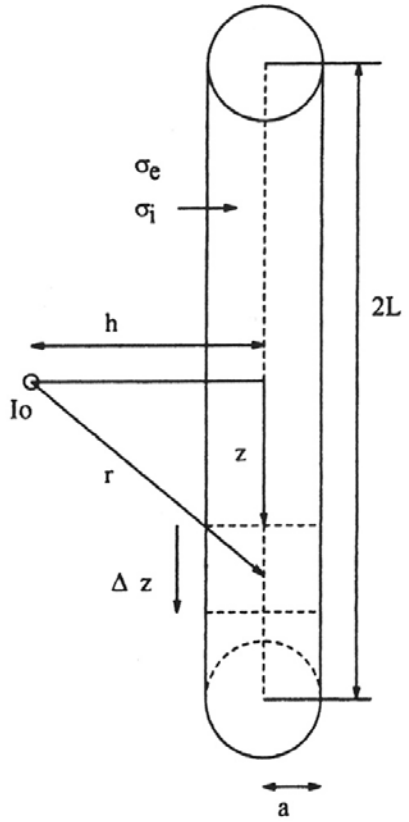
ELEC ENG 3BB3 – Cellular Bioelectricity (2014)

Tutorial #5

1. Consider the source-fiber geometry shown below, such that the extracellular potential is given by Eqn. (7.55):

$$\phi_e = \frac{I_0}{4\pi\sigma_e r},$$

where r is the distance from the source to the fiber at the axial distance z from the middle of the fiber. h is the distance between the source and the fiber where the source is perpendicular to the fiber, i.e., at $z = 0$.



Find:

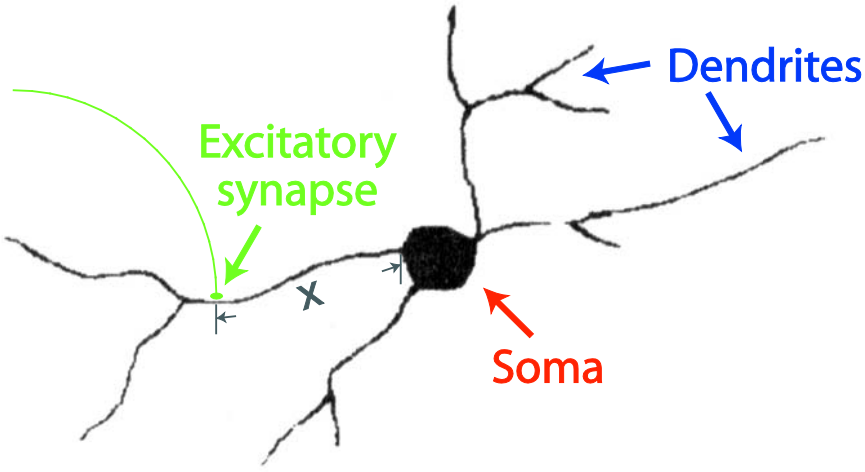
a. the extracellular potential as a function of z, i.e., $\phi_e(z)$,

b. the activating function $\frac{\partial^2 \phi_e}{\partial z^2}$,

c. the positions of the peaks of the resulting regions of initial depolarization and hyperpolarization predicted by the activating function, *stating which are a peak of depolarization and which are peaks of hyperpolarization*, and

d. the positions of the boundaries between the initial depolarized and hyperpolarized regions.

2. Consider the neuron shown below.



Assume:

i. the dendrite with the excitatory synapse can be modeled by an infinite uniform cable with a radius of $a = 1\,\mu\text{m}$ and an intracellular resistivity of $R_i = 187\,\Omega\cdot\text{cm}$;

ii. the extracellular axial resistance is negligible, i.e., $r_e \approx 0$;

iii. the membrane specific resistance is $R_m = 10\,\text{k}\Omega\cdot\text{cm}^2$ and the membrane specific capacitance is $C_m = 1\,\mu\text{F}/\text{cm}^2$;

iv. the threshold potential at the soma is 25 mV above the resting membrane potential; and

v. synaptic input can be approximated by a step current injection that causes a steady-state depolarization of $v_m = 30\text{ mV}$ at the site of the synapse.

a. If the synaptic input stays on long enough for the membrane potential at the soma to reach its steady state, how close does the synapse need to be to the soma (i.e., what is the minimum distance x) in order for an action potential to be generated?

b. If the synapse is $40\,\mu\text{m}$ from the soma, how long does it take for an action potential to be generated after the onset of the synaptic input? Is this time greater than or less than the membrane time constant?