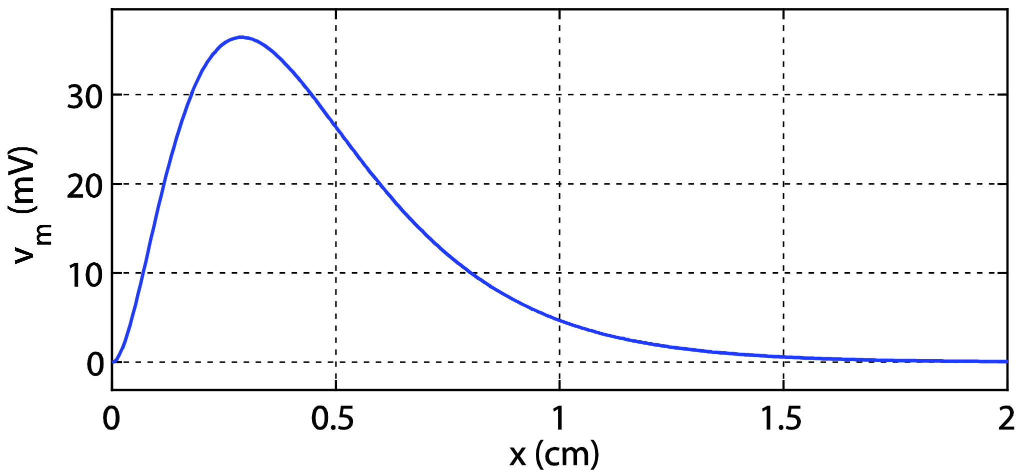
ELEC ENG 3BB3 – Cellular Bioelectricity (2014)

Tutorial 8

1. An action potential with the spatial waveform illustrated below is propagating along a fiber.



The relative transmembrane potential can be described by:

$$v_m = \begin{cases} 0, & \text{for } x < 0, \\ 700\,x\left(e^{-5x} - e^{-10x}\right), & \text{for } x \geq 0, \end{cases}$$

where v_m is in units of mV and x is in units of cm.

The fiber has a diameter of $d = 5\,\mu\text{m}$ and an axoplasmic conductivity of $\sigma_i = 0.04\ \text{S/cm}$.

Find the strengths and locations of *all* the source models, i.e., distributed & lumped monopoles and distributed & lumped dipoles, for the resulting extracellular potential field.

2. A patch of membrane at 25°C has the following intra- and extra-cellular ionic concentrations:

Ion	$[C]_{in}$ (mM)	$[C]_{out}$ (mM)
K^+	202.9	9
Na^+	10	152.75

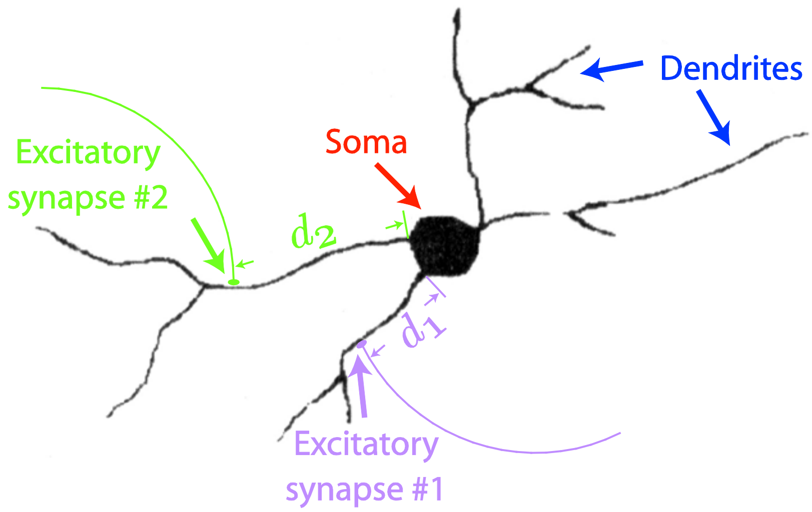
A postsynaptic receptor channel in this patch of membrane is permeable to both potassium and sodium when open. The conductances can be described by $g_{\text{syn,K}}(t) = 4te^{-t/5}\ \text{mS/cm}^2$ and $g_{\text{syn,Na}} = 6te^{-t/5}\ \text{mS/cm}^2$, respectively, for neurotransmitter binding at time $t = 0$.

a. What are the *peak* conductances for sodium and potassium in this ligand-gated ion channel?

b. What is the reversal potential E_{syn} for this synaptic ion channel?

c. If the membrane's resting potential $V_{\text{rest}} = -65\ \text{mV}$, is the synapse excitatory or inhibitory?

3. Consider the neuron shown below.



Assume:

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

ii. the membrane specific resistance is $R_m = 15\ \mathrm{k\Omega \cdot cm^2}$ and the membrane specific capacitance is $C_m = 1\ \mu\mathrm{F/cm^2}$ for the entire cell;

iii. the threshold potential at the soma is 30 mV above the resting membrane potential;

iv. dendrite #1 with the excitatory synapse #1 can be modeled by an infinite uniform cable with a radius of $a_1 = 2\ \mu\mathrm{m}$ and an intracellular resistivity of $R_i = 200\ \Omega \cdot \mathrm{cm}$;

v. dendrite #2 with the excitatory synapse #2 can be modeled by an infinite uniform cable with a radius of $a_2 = 3\ \mu\mathrm{m}$ and an intracellular resistivity of $R_i = 200\ \Omega \cdot \mathrm{cm}$;

vi. synapse #1 is at a distance $d_1 = 20\ \mu\mathrm{m}$ from the soma;

vii. synapse #2 is at a distance $d_2 = 30\ \mu\mathrm{m}$ from the soma;

viii. an input at synapse #1 can be approximated by a step current injection that causes a steady-state depolarization of $v_1 = 50\ \mathrm{mV}$ at the site of the synapse; and

ix. an input at synapse #2 can be approximated by a step current injection that causes a steady-state depolarization of $v_2 = 55\ \mathrm{mV}$ at the site of the synapse.

a. How long would it take for inputs at synapse #1 and synapse #2 each to individually cause the membrane potential at the soma to reach threshold?

b. Which is faster to reach threshold? Explain why.