Homework 2 – Electrical Signals (posted 3/9/06; due 3/17/06)

1. After a particular step depolarization in Hodgkin and Huxley's squid axon the parameter n follows the curve

   $$n = 0.891 - 0.376e^{-t/1.7(m\sec)}$$

   t is in msec, and $\bar{g}_K$ is known to be 24.3mS/cm^2.

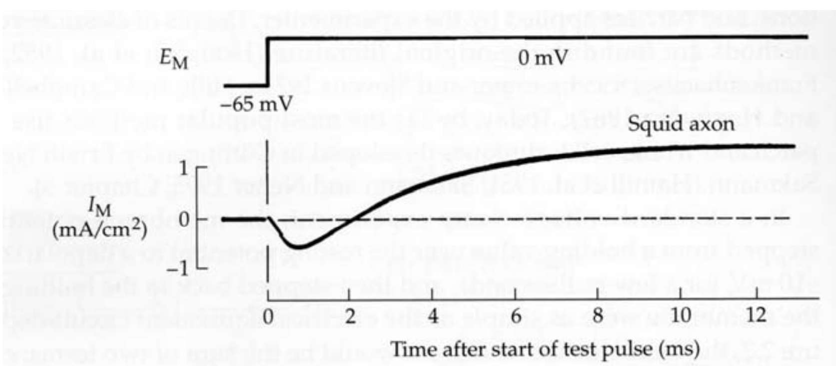
   Plot g_K as a function of time, using 1 msec steps for 10 msec. What is $g_{K\infty}$?

2. After the same depolarization as above, the parameters m and h follow the curves

   $m = 0.963\left(1 - e^{-t/0.252(m\sec)}\right)$ and $h = 0.605e^{-t/0.84(m\sec)}$. t is in msec and $\bar{g}_{Na}$ = 70.7 mS/cm^2.

   What is the largest value of g_{Na} reached?

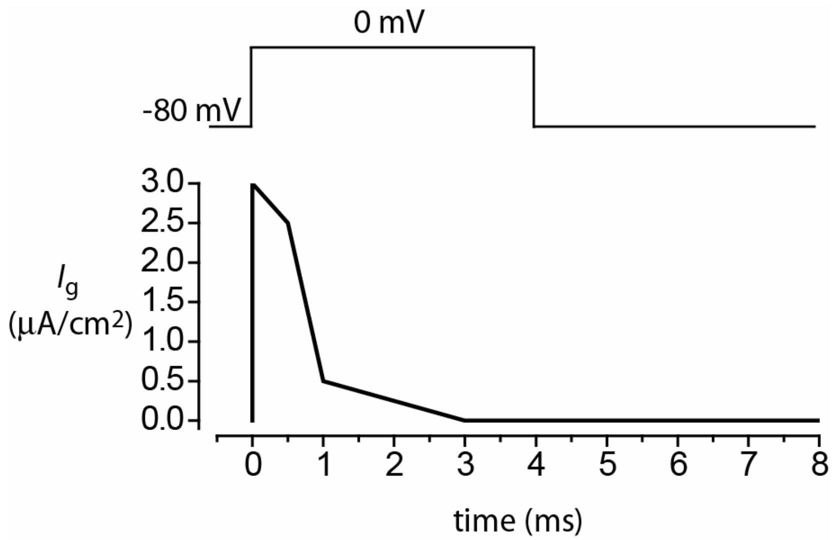
3. When a healthy squid axon is voltage-clamped in artificial se water, one obtains the following membrane current in response to a step change in membrane potential from V_m = -70 mV to V_m = 0 mV.



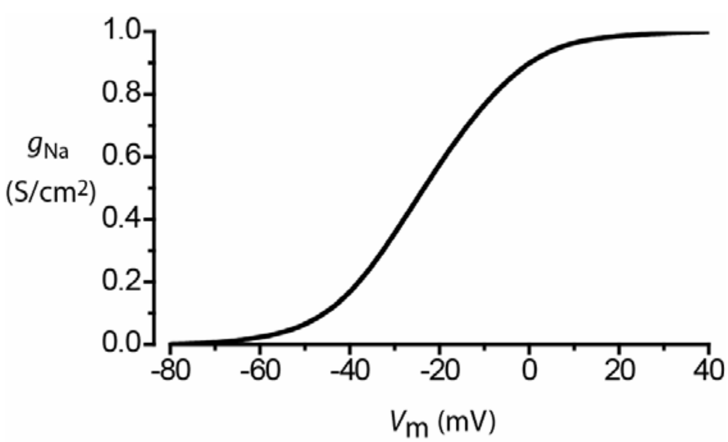
Draw similar plots of I_m vs. t (when Vm is stepped from -65 mV to 0 mV) when the recordings are made under each of the following experimental conditions. For each of your plots, explain in one or two sentences how and why your graph differs from that in the figure above.

(a) TTX is added to the bath surrounding the axon.
(b) TEA is added to the interior of the axon.
(c) $[Na^+]_{out}$ is adjusted so that $[Na^+]_{out} = [Na^+]_{in}$.
(d) $[K^+]_{out}$ is adjusted so that $[K^+]_{out} = [K^+]_{in}$.
(e) Ouabain, a specific inhibitor of the Na^+-K^+ pump is added to the bath five minutes before the experiment.

4. The figure below shows the gating current (I_g) obtained (in the presence of agents that block all ion currents, and with linear capacitive transients subtracted) using a voltage depolarization (from -80 to 0 mV).



This gating current is known to be associated with opening Na^+ channels in a snail neuron, and 2 gating particles (each carrying a charge of e = 1 electronic charge) are required to open one Na^+ channel. In the absence of Na^+ channel blocker, the activation curve of the Na^+ channel is shown below:

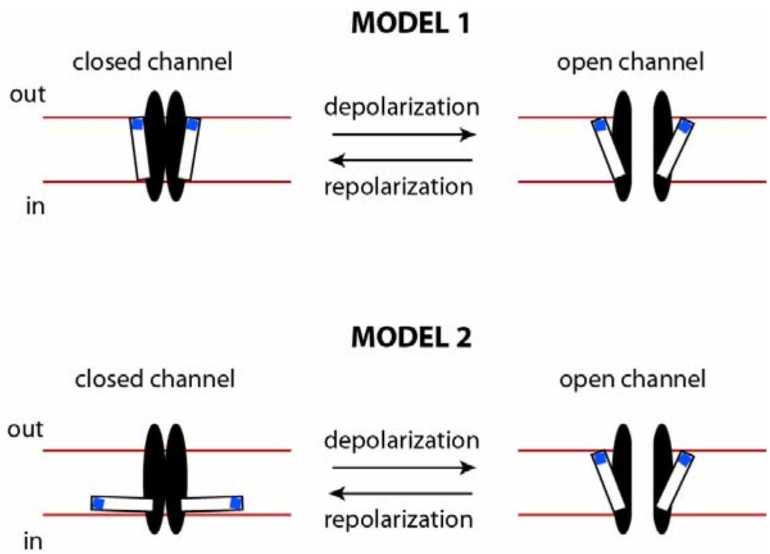


(a) What is the density (channel/cm^2) of Na^+ channels in the membrane of the snail neuron?

(b) What is the single channel conductance of the Na^+ channels in the snail neuron?

(c) Assuming that Na^+ channels do not inactivate, redraw figure A on graph paper, and add the gating current trace you would expect upon repolarization.

5. You are a researcher interested in discriminating between two models (shown in the figure) for the relative movement of the voltage-sensor (rectangles in the figure) of a voltage-gated ion channel in response to changes in membrane potential. You design a novel small molecule non-fluorescent hydrophobic cation (XYZ) that can quickly redistribute in the inner and outer leaflets of the membrane in response to changes in membrane potential. You engineer in a fluorophore to the voltage sensor at the position shown (blue square). The emission spectra of the fluorophore overlaps extensively with the absorbance spectra of XYZ, enabling you to use FRET to probe voltage sensor movements. The channel is normally closed at the resting membrane potential (-80 mV), and maximum conductance is achieved following a step depolarization to +10 mV.



(a) For each model, draw the profiles of donor emission fluorescence you would expect to see following a step depolarization to +10 mV from a holding potential of -80 mV. Briefly explain your answers.

(b) For each model, draw the profiles of donor emission fluorescence you would expect to see following a hyperpolarization to -130 mV from a holding potential of -80 mV. Briefly explain your answer.