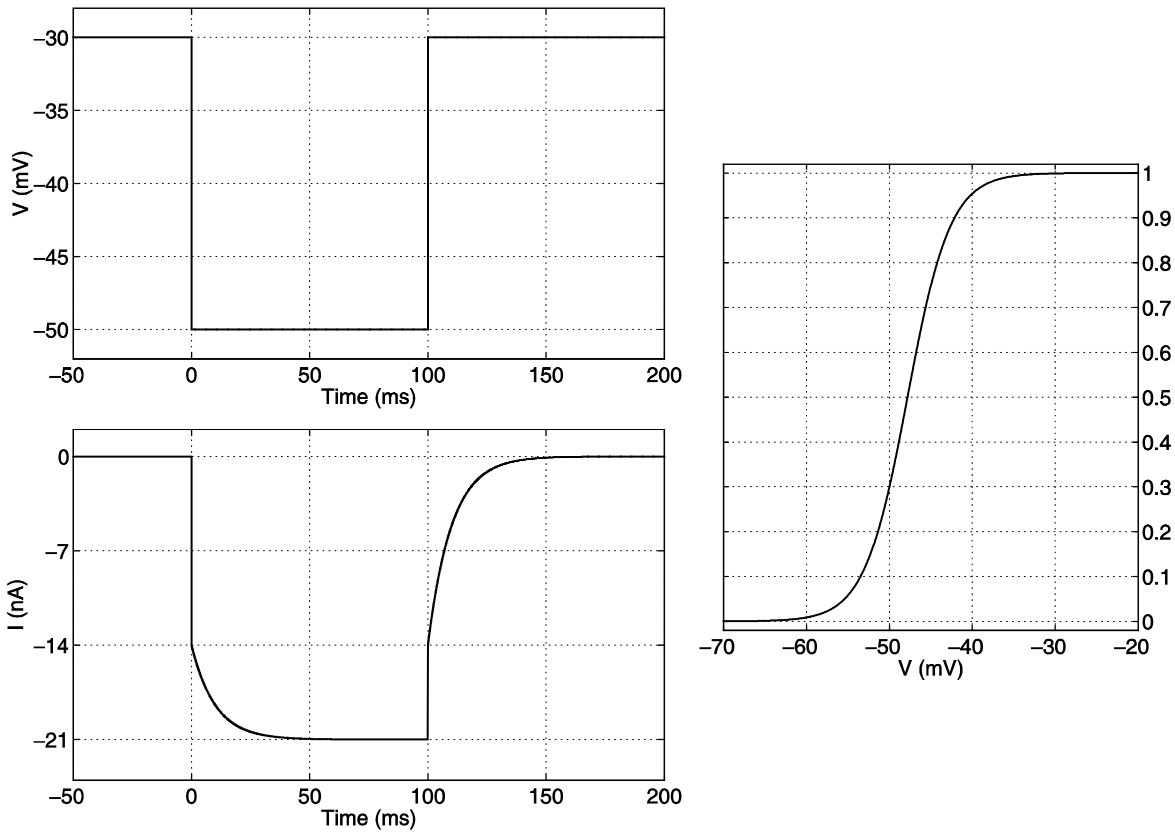
ELEC ENG 3BB3 – Cellular Bioelectricity (2013)

Tutorial #3

1. The results of a voltage-clamp experiment are shown below.

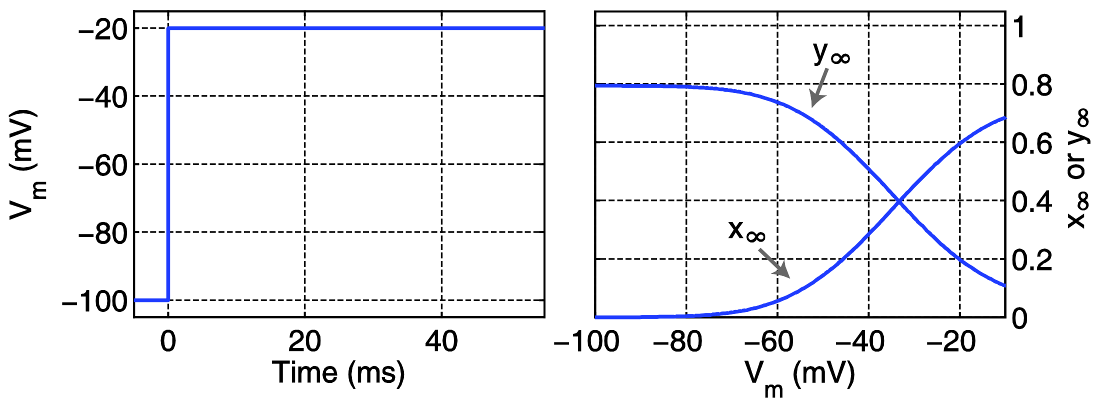


Assume that the measured transmembrane current $I(V,t)$ is comprised of a passive leakage current $I_L(V) = g_L\left(V - E_L\right)$ and a time- and voltage-dependent current $I_y(V,t) = \bar{g}_y y\left(V - E_y\right)$, where the dynamics of the gating particle y are first-order, i.e., $\mathrm{d}y(V,t)/\mathrm{d}t = (y_\infty - y)/\tau_y$. The time-constant τ_y is independent of voltage, whereas the voltage dependence of the steady-state value $y_\infty(V)$ is shown in the figure above. It is known that the Nernst equilibrium potential $E_y = -70$ mV.

a. Is the current $I_y(V,t)$ activated by depolarization or hyperpolarization? Is $I_y(V,t)$ an inward or an outward current in the voltage-clamp experiment performed above?

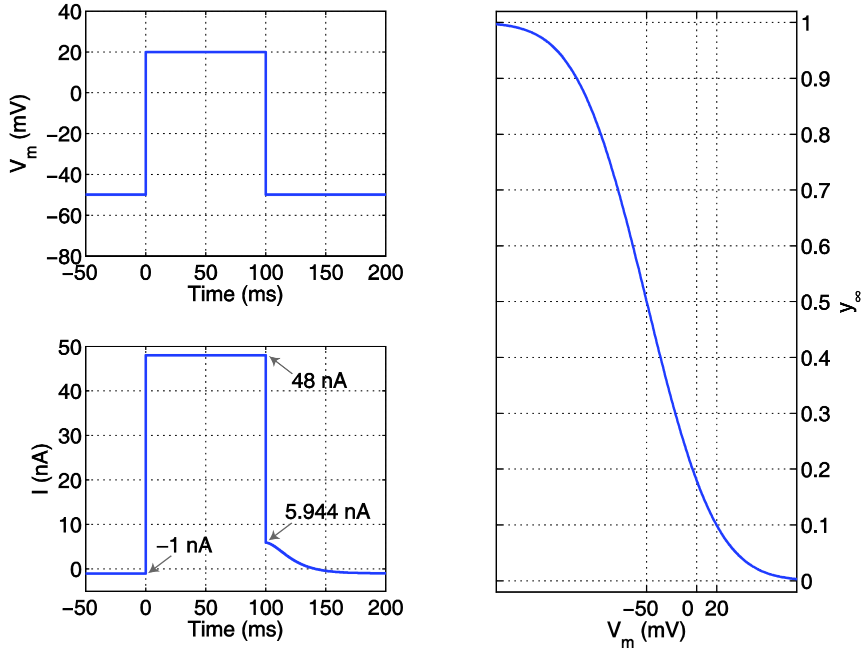
b. From the results of the voltage-clamp experiment, find the values of g_L, E_L and $\bar{g}_y$.

2. Consider the voltage clamp experiment in the left panel below applied to an ion channel with the steady-state activation/inactivation characteristics given in the right panel below.



If the conductance per unit area for this ion channel is $g_{xy}(t) = 200 \cdot x^3(t) \cdot y^2(t)\ \mu\text{S/cm}^2$ and the gating particle kinetics are first-order, i.e., $\text{d}x/\text{d}t = (x_\infty - x)/\tau_x$ and $\text{d}y/\text{d}t = (y_\infty - y)/\tau_y$, with $\tau_x = 1\,\text{ms}$ and $\tau_y = 8\,\text{ms}$, then derive an expression for $g_{xy}(t)$ for $t \geq 0$ in response to the voltage step shown above and sketch the approximate form of $g_{xy}(t)$ for $t \geq 0$.

3. The results of a voltage-clamp experiment are shown below.



Assume that the measured transmembrane current $I(V_m,t)$ is comprised of a passive leakage current $I_L(V_m) = g_L\left(V_m - E_L\right)$ and a time- and voltage-dependent current $I_y(V_m,t) = \bar{g}_y y^3\left(V_m - E_y\right)$, where there are three y gating particles per channel and the dynamics of each gating particle y are first-order, i.e., $\mathrm{d}y(V_m,t)/\mathrm{d}t = (y_\infty - y)/\tau_y$. The time-constant τ_y is independent of voltage, whereas the voltage dependence of the steady-state value $y_\infty\left(V_m\right)$ is shown in the figure above.

a. From the results of the voltage-clamp experiment, find the values of g_L, E_L, $\bar{g}_y$ and E_y.

b. Is the current $I_y(V_m,t)$ activated by depolarization or hyperpolarization? Is $I_y(V_m,t)$ an inward or an outward current in the voltage-clamp experiment performed above?