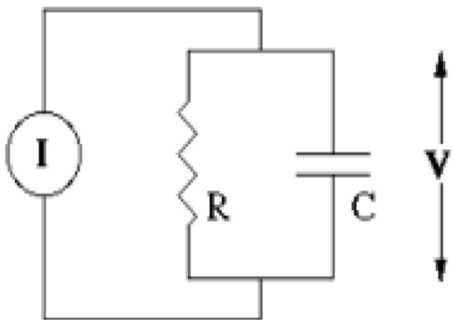
HW2 MATLAB Simulation:

1.

Write down a differential equation that describes the behavior of the RC circuit shown below. The equation should describe the voltage change (dV/dt) as a function of the applied current (I). Arrange the equation such that the term (dV/dt) is alone on the left-hand side of the equation and all of the other terms are on the right.



2. To simulate the behavior of this circuits, you'll need to numerically integrate the differential equations that describe the rate-of-change of the voltage. The simplest approach to implement is *Euler's method*. To solve the differential equation:

$$\frac{dy}{dt} = f(y,t)$$

use the iterative procedure

$$y(t + \Delta t) = y(t) + f(y(t),t) \cdot \Delta t$$

where delta_t is the integration step size and y is the quantity that is being integrated.

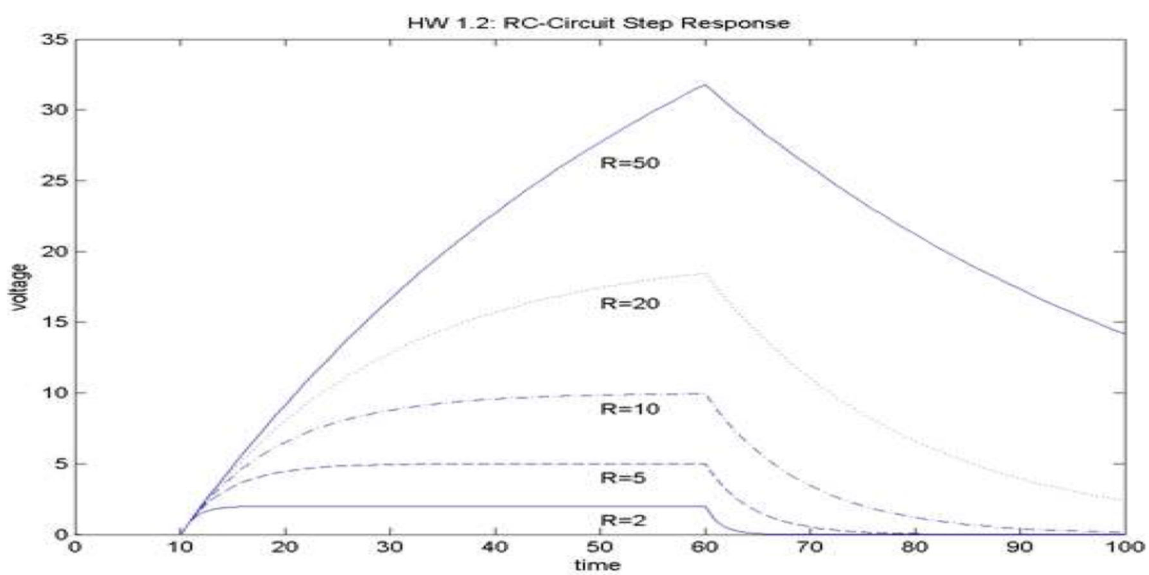
Using the Euler integration technique, simulate the response of the circuit in (1) to a step change applied current . Use the following parameters in you simulations:

R = {2, 5, 10, 20, 50} (i.e. simulate responses for 5 different values of R)

$C = 1$, $V_0 = 0$, delta_t = 1

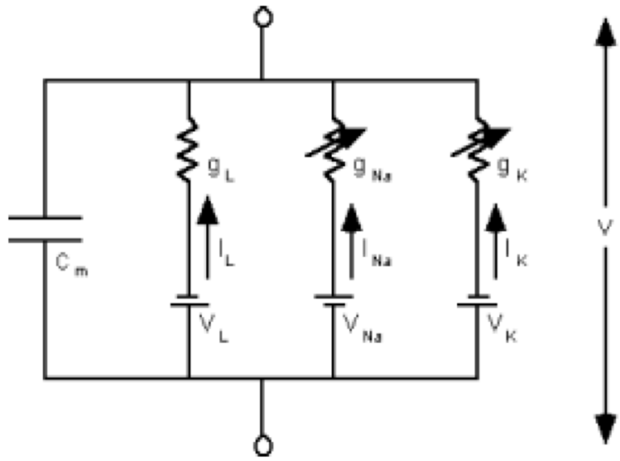
$$I = \begin{Bmatrix} 1 & \text{for} 10 < t \leq 60 \\ 0 & \text{otherwise} \end{Bmatrix}$$

Turn in a listing of your code and a plot of the voltage as a function of time for 0 < t <= 100 for the 5 values of R given above. Your plot should look similar to the following figure.



3.

This assignment is devoted to modeling voltage-dependent membrane currents in the squid giant axon using the Hodgkin-Huxley formalism. The equivalent circuit is shown below. To carry out this assignment, you'll need a copy of Hodgkin and Huxley's 1952 paper, "A quantitative description of membrane current and its application to conduction and excitation in nerve", J. Physiol. 117, 500-544.



1. One of the most error-prone steps in implementing HH models is in evaluating the voltage-dependent rate constants *alpha(v) and beta(v).* For that reason, it's always a good idea to check you implementation by plotting the time constants and steady-state values as a function of voltage. It's much easier to spot errors in these plots than in the raw rate plots. Recall*:*

$$\tau_m(v) = \frac{1}{\alpha_m(v) + \beta_m(v)}$$

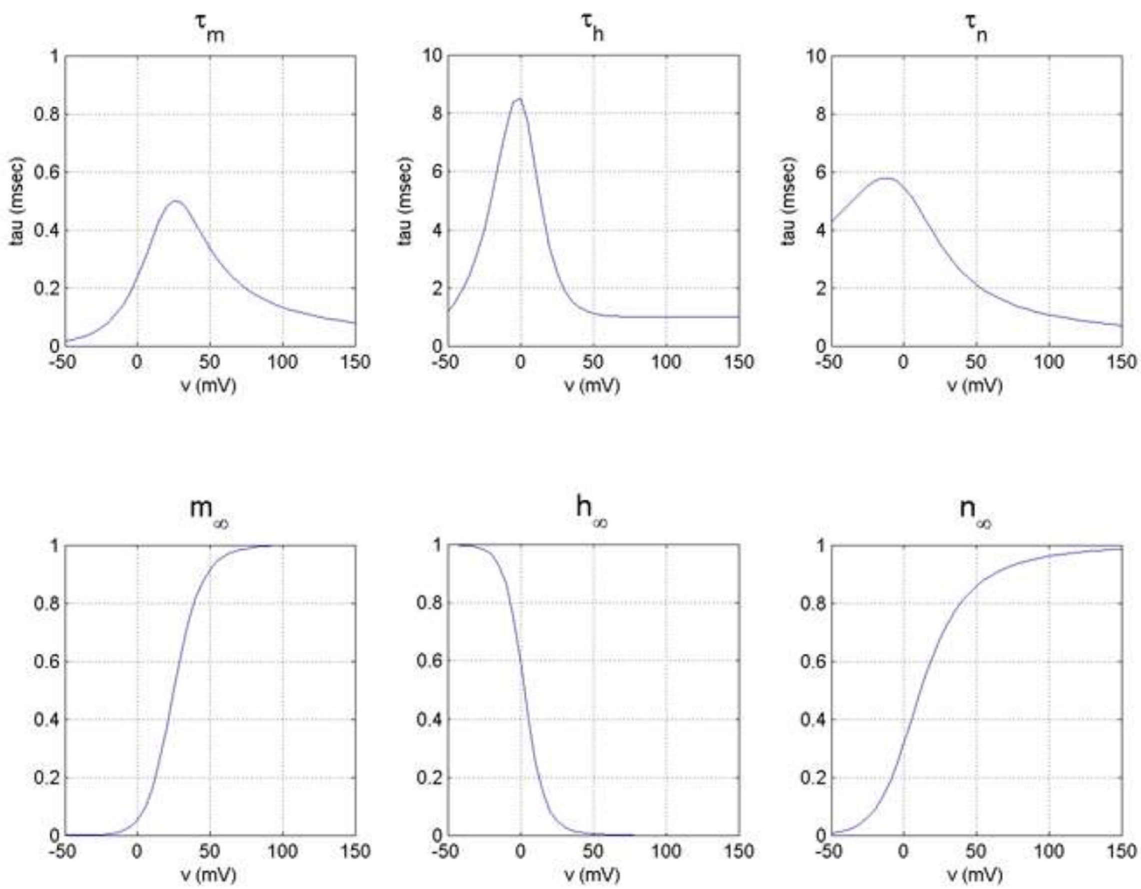
$$m_\infty(v) = \frac{\alpha_m(v)}{\alpha_m(v) + \beta_m(v)}$$

(a) Write a set of six subroutines (alpha_m, beta_m, alpha_h, beta_h, alpha_n and beta_n) that return rate constants as a function of voltage for the HH state variables m, n and h. Use the expressions given in HH52 (eqs. 12, 13, 20, 21, 23, 24) BUT REVERSE THE SIGN OF THE VOLTAGE to conform to the modern voltage convention. Note that some of the expressions evaluate to the indeterminant form "0/0" at certain voltages. Handle this case properly in your subroutines by applying L'Hopitals Rule: i.e. for *$f(a) = g(a) = 0$:*

$$\lim_{x \to a} \frac{f(x)}{g(x)} = \lim_{x \to a} \frac{f'(x)}{g'(x)}$$

(b) Generate and turn in plots of $TAU_m(v)$, $TAU_h(v)$, $TAU_n(v)$, $m_{infty}(v)$, $h_{infty}(v)$ and $n_{infty}(v)$ for voltages in the range -50 <= v <= 150.

Check your results against the following figure.



τ_m
τ_h
τ_n
tau (msec)
v (mV)
m_∞
h_∞
n_∞