AM5510 : BIOMEDICAL SIGNALS & SYSTEMS
Programming Assignment #2 : ACTION POTENTIAL SIMULATION

AM23M022
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MATLAB CODE

```
% Initializing Constants
Erest = -68; % mV
EK = -74.7; % mV
ENa = 54.2; % mV

C = 1; % 10^-6F/cm2

GK = 12; % m/cm2
GNa = 30; % m/cm2

Vm0 = Erest;
dt = 0.01; % ms
tmax = 10; % ms

t = 0:dt:tmax;
n = zeros(size(t));
m = zeros(size(t));
h = zeros(size(t));
Vm = zeros(size(t));
gK = zeros(size(t));
gNa = zeros(size(t));

% Initializing Io_values and tPW_values
Io_values = [5, 25, 75]; % uA
tPW_values = [0.2, 0.8]; % ms

% Simulation loop
for Io = Io_values
for tPW = tPW_values

% Initializing values at t=0
Vm(1) = Vm0;
n(1) = 0.3;
m(1) = 0.065;
h(1) = 0.6;

% Stimulus current
Is = zeros(size(t));
Is(t > 0 & t < tPW) = Io;

  % Simulation
  for i = 2:length(t)
  % Step 1: Calculating rate constants
  v = Vm(i - 1) - Erest;
  alpha_n = (0.01 * (10 - v)) / (exp((10 - v) / 10) - 1);
  beta_n = 0.125 * exp(-v / 80);
  alpha_m = (0.1 * (25 - v)) / (exp((25 - v) / 10) - 1);
  beta_m = 4 * exp(-v / 18);
  alpha_h = 0.07 * exp(-v / 20);
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  beta_h = 1 / (exp((30 - v) / 10) + 1);

  % Step 2: Calculate changes in n, m, and h
  delta_n = dt * (alpha_n * (1 - n(i - 1)) - beta_n * n(i - 1));
  delta_m = dt * (alpha_m * (1 - m(i - 1)) - beta_m * m(i - 1));
  delta_h = dt * (alpha_h * (1 - h(i - 1)) - beta_h * h(i - 1));

  % Update n, m, and h
  n(i) = n(i - 1) + delta_n;
  m(i) = m(i - 1) + delta_m;
  h(i) = h(i - 1) + delta_h;

  % Step 3: Calculating ionic conductance and currents
  gK(i) = GK * n(i)^4;
  gNa(i) = GNa * m(i)^3 * h(i);

  % Step 4: Calculating total current
  IK = gK(i) * (Vm(i - 1) - EK);
  INa = gNa(i) * (Vm(i - 1) - ENa);
  IC = Is(i) - (IK + INa);

  % Step 5: Calculating membrane voltage
  delta_VM = (IC / C) * dt;
  Vm(i) = Vm(i - 1) + delta_VM;

end

% Plotting results
figure;
subplot(3, 1, 1);
plot(t, Vm);
title(['Membrane Voltage (Io = ', num2str(Io), ', tPW = ', num2str(tPW), '
ms)']);
xlabel('Time (ms)');
ylabel('Vm (mV)');

subplot(3, 1, 2);
plot(t, gK);
title('Potassium Conductance (gK)');
xlabel('Time (ms)');
ylabel('gK (mS/cm^2)');

subplot(3, 1, 3);
plot(t, gNa);
title('Sodium Conductance (gNa)');
xlabel('Time (ms)');
ylabel('gNa (mS/cm^2)');
end
end
```
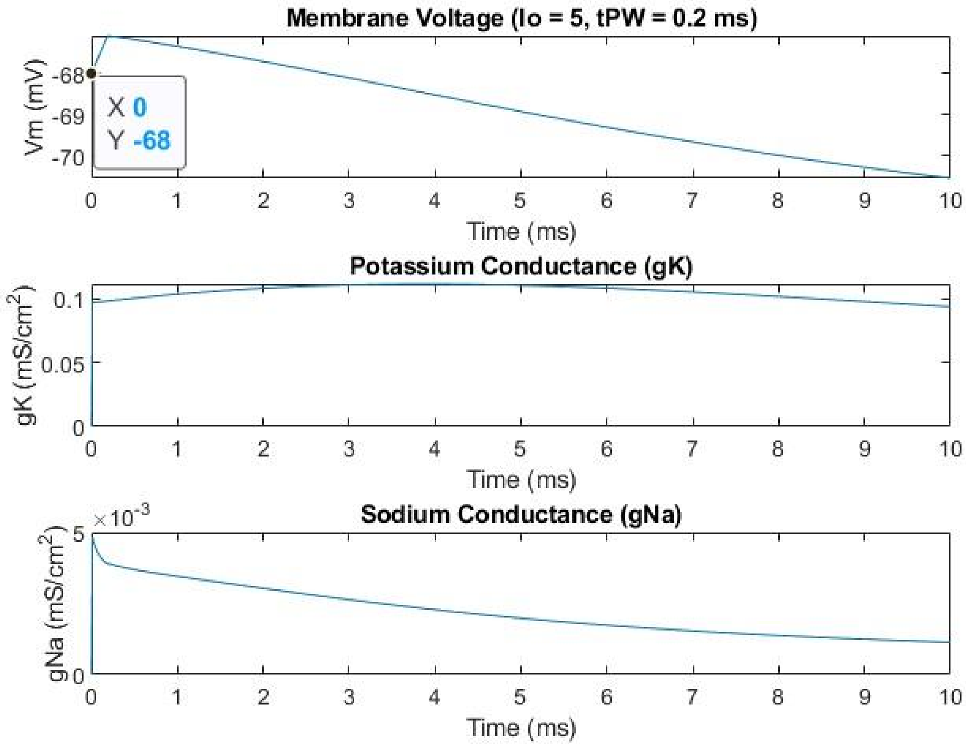
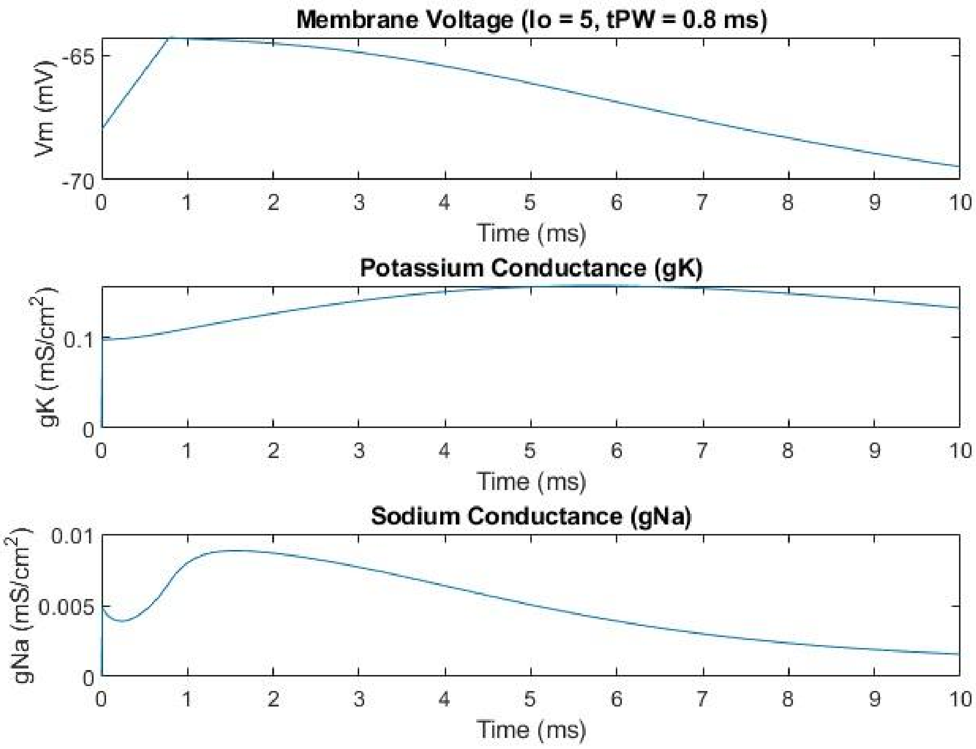
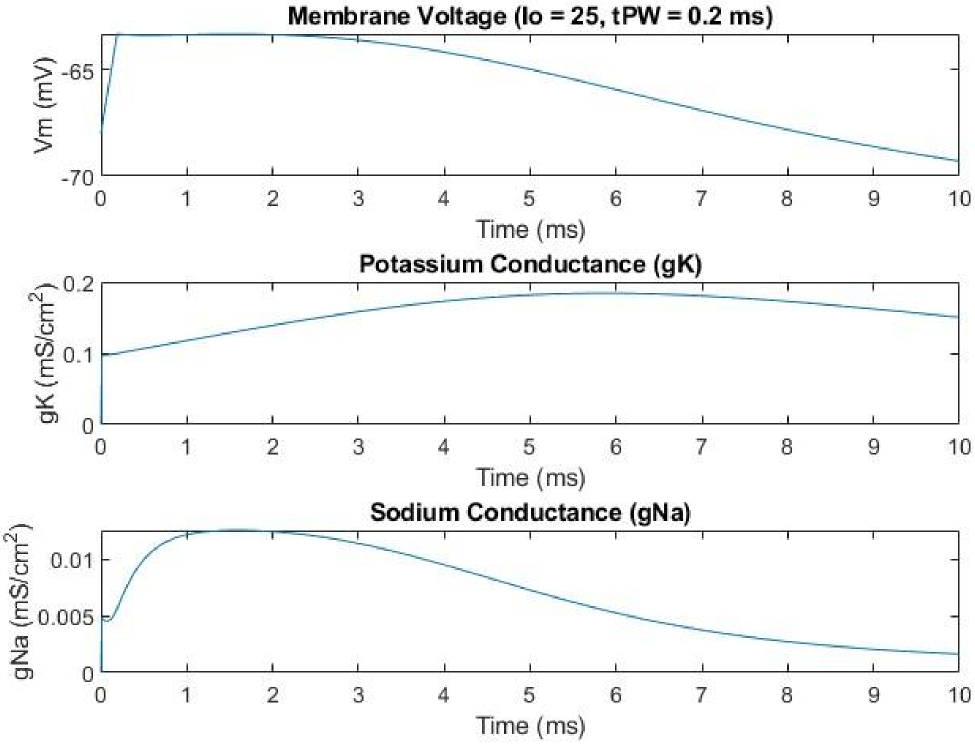

OUTPUT WHEN dt = 0.01ms

Step 1 - Rate Constants (t = 0.01 ms):
Alpha_n = 0.038838
Beta_n = 0.13584
Alpha_m = 0.13945
Beta_m = 5.7893
Alpha_h = 0.097636
beta_h = 0.024953
Step 2 - Changes in n, m, and h at t = 10 ms
Delta_n = -0.0002912
Delta_m = 3.2441e-07
Delta_h = 0.00039634
Step 3 - Ionic Conductance at t = 10 ms
gK = 0.27408
gNa = 0.00018472
Step 4 - total current at t = 10 ms
IK = 0.012334
INa = -0.023802
IC = 0.011469
Step 5 - membrane voltage at t = 10 ms
delta_VM= 0.00011469
Vm(i) = -74.6549

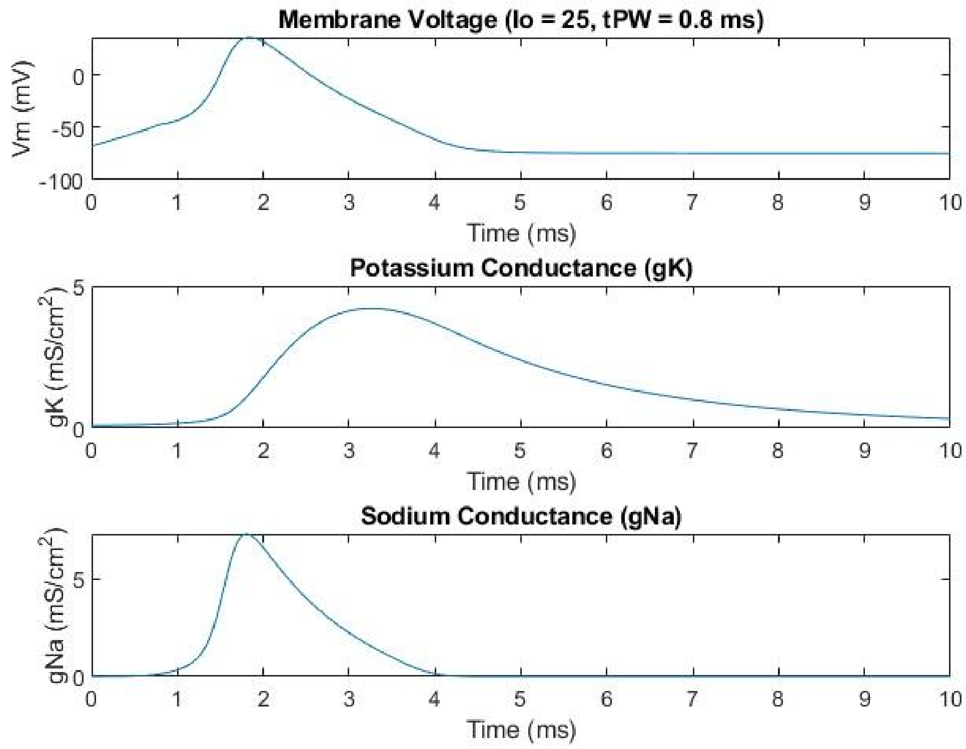
Io is in uA and t_PW is in ms.


Membrane Voltage (Io = 5, tPW = 0.2 ms)
Vm (mV)
-68
-69
-70
X 0
Y -68
Time (ms)
Potassium Conductance (gK)
gK (mS/cm2)
0.1
0.05
0
Time (ms)
Sodium Conductance (gNa)
×10-3
gNa (mS/cm2)
5
0
0 1 2 3 4 5 6 7 8 9 10
Time (ms)

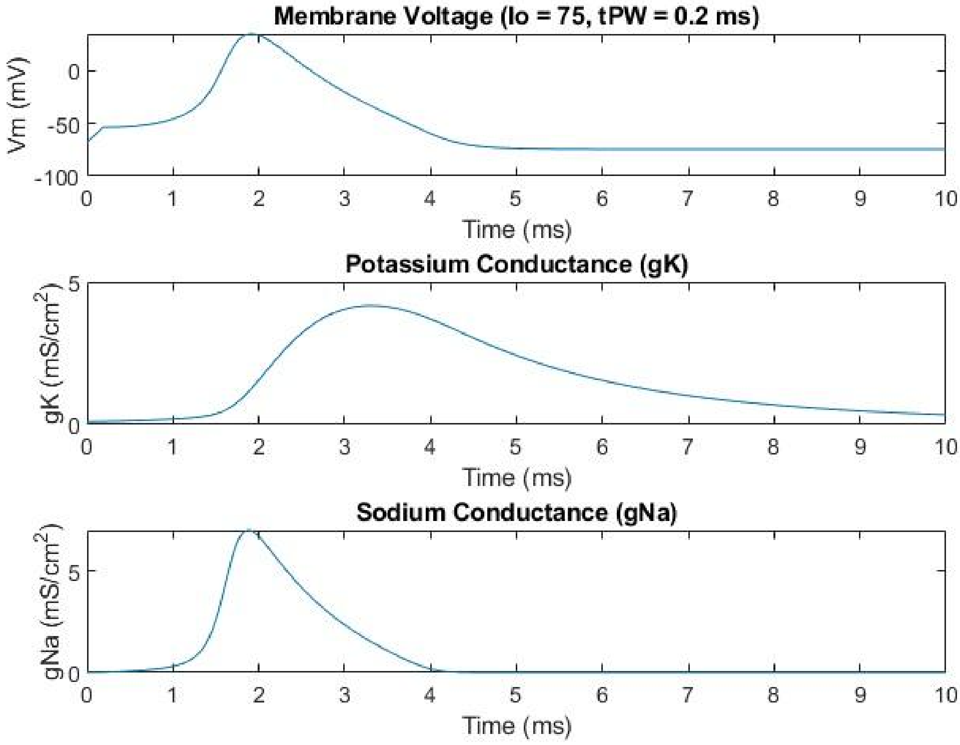

Membrane Voltage (Io = 5, tPW = 0.8 ms)
Vm (mV)
-65
-70
Time (ms)
Potassium Conductance (gK)
gK (mS/cm2)
0.1
0
Time (ms)
Sodium Conductance (gNa)
gNa (mS/cm2)
0.01
0.005
0
0 1 2 3 4 5 6 7 8 9 10
Time (ms)

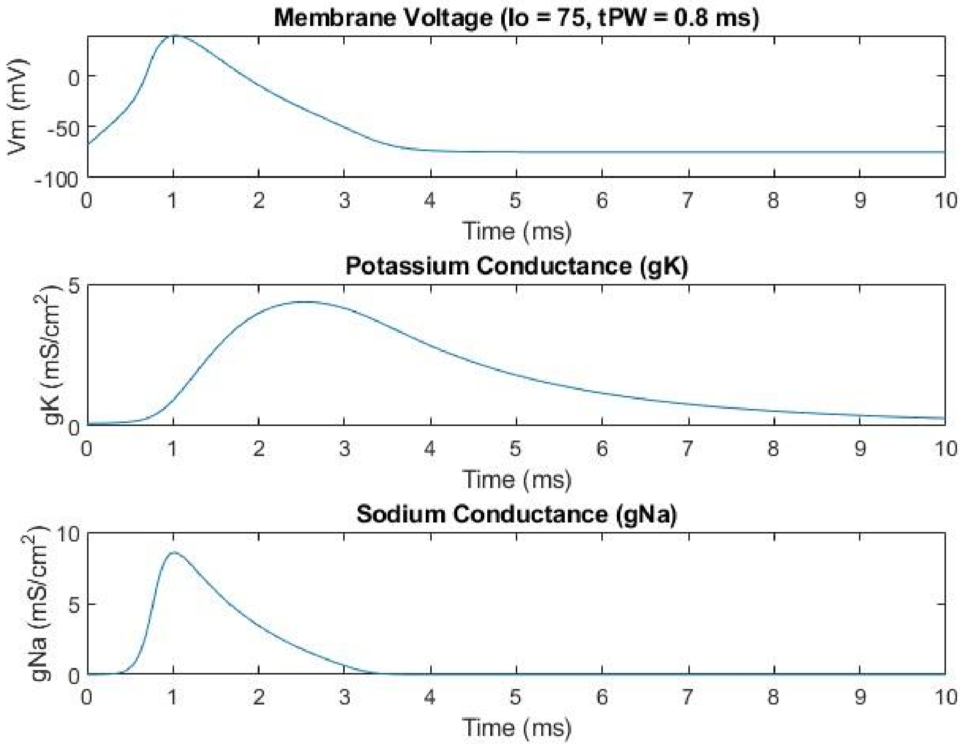


Membrane Voltage (Io = 25, tPW = 0.2 ms)
Vm (mV)
-65
-70
0
1
2
3
4
5
6
7
8
9
10
Time (ms)
Potassium Conductance (gK)
gK (mS/cm^2)
0.2
0.1
0
Time (ms)
Sodium Conductance (gNa)
gNa (mS/cm^2)
0.01
0.005
0
Time (ms)



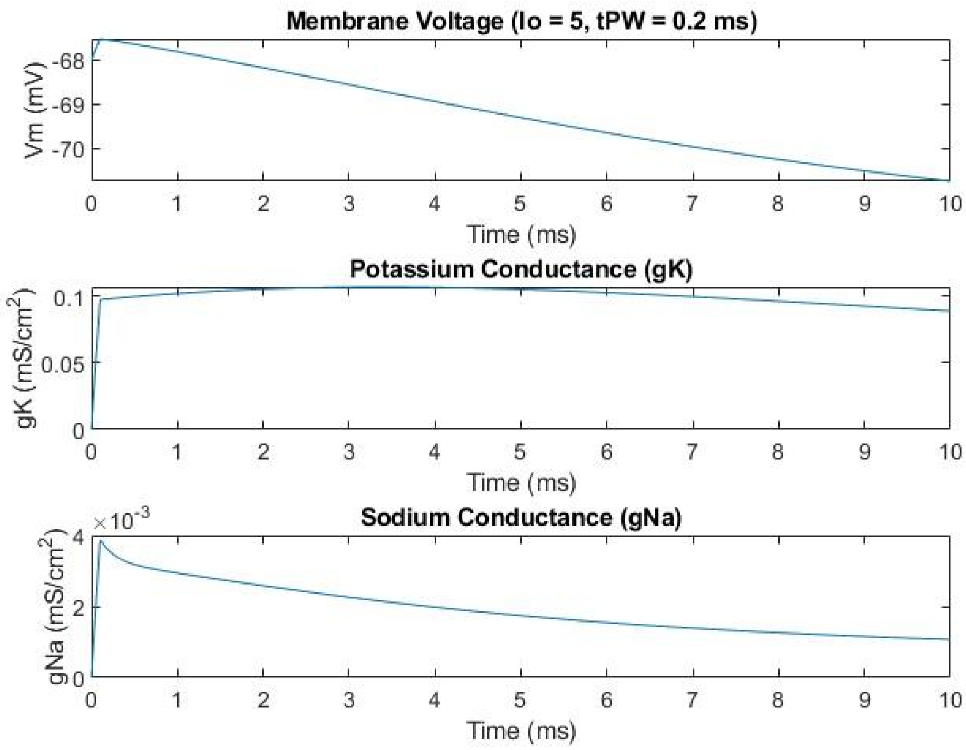
Membrane Voltage (Io = 25, tPW = 0.8 ms)
Vm (mV)
0
-50
-100
0
1
2
3
4
5
6
7
8
9
10
Time (ms)
Potassium Conductance (gK)
gK (mS/cm^2)
5
0
Time (ms)
Sodium Conductance (gNa)
gNa (mS/cm^2)
5
0
Time (ms)


Membrane Voltage (Io = 75, tPW = 0.2 ms)
Vm (mV)
Time (ms)
Potassium Conductance (gK)
gK (mS/cm^2)
Time (ms)
Sodium Conductance (gNa)
gNa (mS/cm^2)
Time (ms)

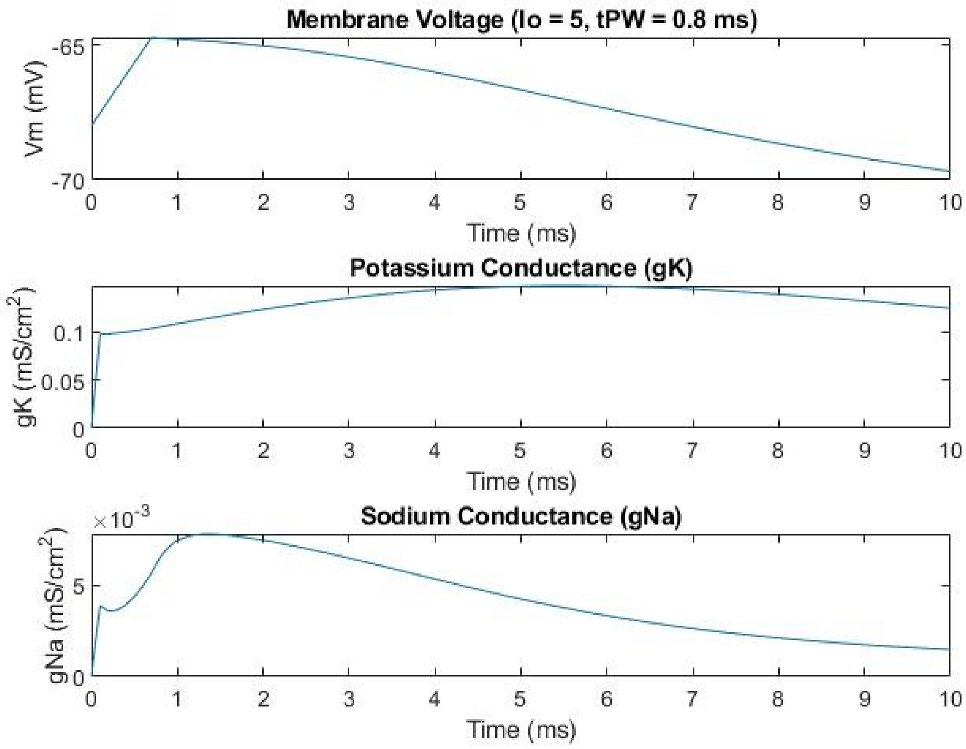

Membrane Voltage (Io = 75, tPW = 0.8 ms)
Vm (mV)
Time (ms)
Potassium Conductance (gK)
gK (mS/cm^2)
Time (ms)
Sodium Conductance (gNa)
gNa (mS/cm^2)
Time (ms)

OUTPUT WHEN dt = 0.1ms

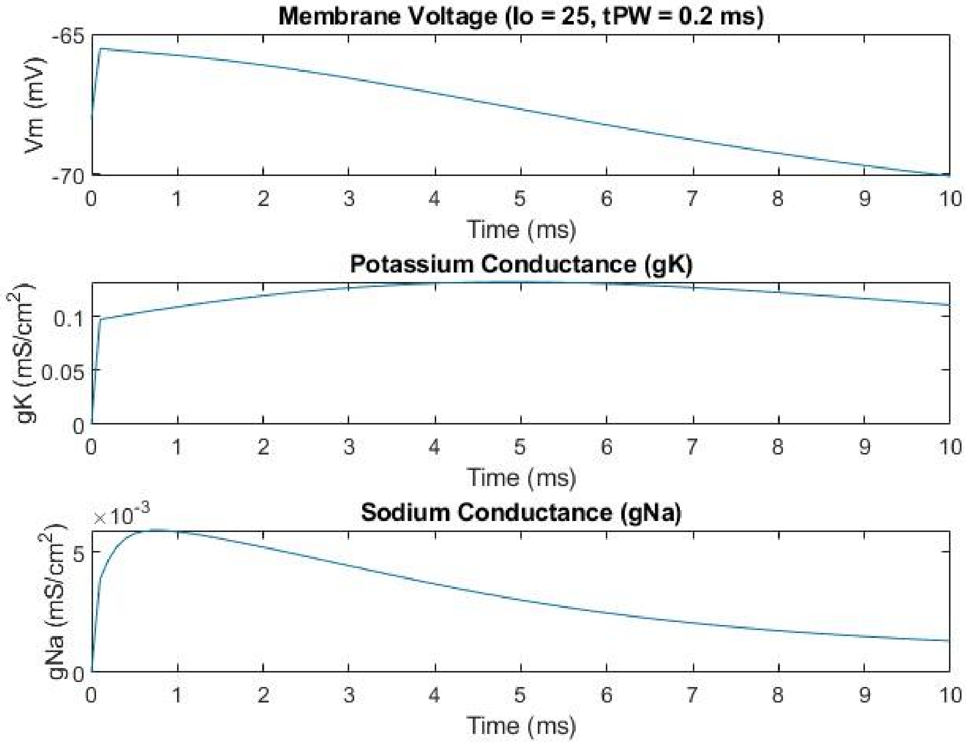
```
Step 1 - Rate Constants (t = 0.1 ms):
Alpha_n = 0.03884
Beta_n = 0.13584
Alpha_m = 0.13946
Beta_m = 5.789
Alpha_h = 0.097631
beta_h = 0.024955
Step 2 - Changes in n, m, and h at t = 10 ms
Delta_n = -0.0028264
Delta_m = 3.6314e-06
Delta_h = 0.0038707
Step 3 - Ionic Conductance at t = 10 ms
gK = 0.25372
gNa = 0.00018915
Step 4 - total current at t = 10 ms
IK = 0.011663
INa = -0.024372
IC = 0.012709
Step 5 - membrane voltage at t = 10 ms
delta_VM= 0.0012709
Vm(i) = -74.6528
```



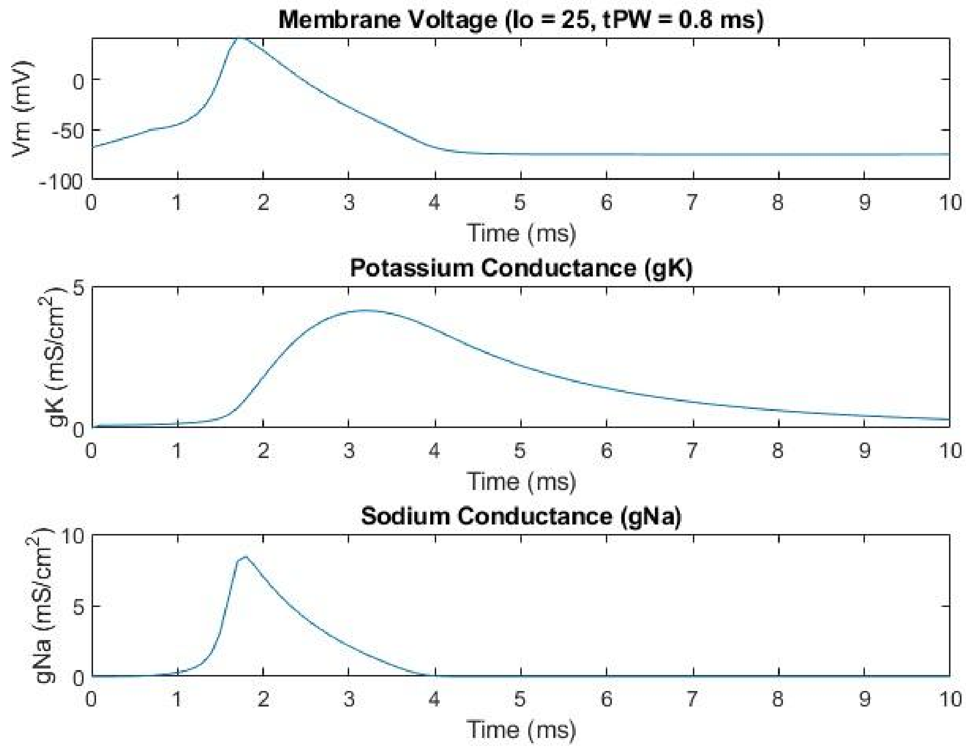
Membrane Voltage (Io = 5, tPW = 0.2 ms)
Vm (mV)
Time (ms)
Potassium Conductance (gK)
gK (mS/cm^2)
Time (ms)
Sodium Conductance (gNa)
$\times 10^{-3}$
gNa (mS/cm^2)
Time (ms)



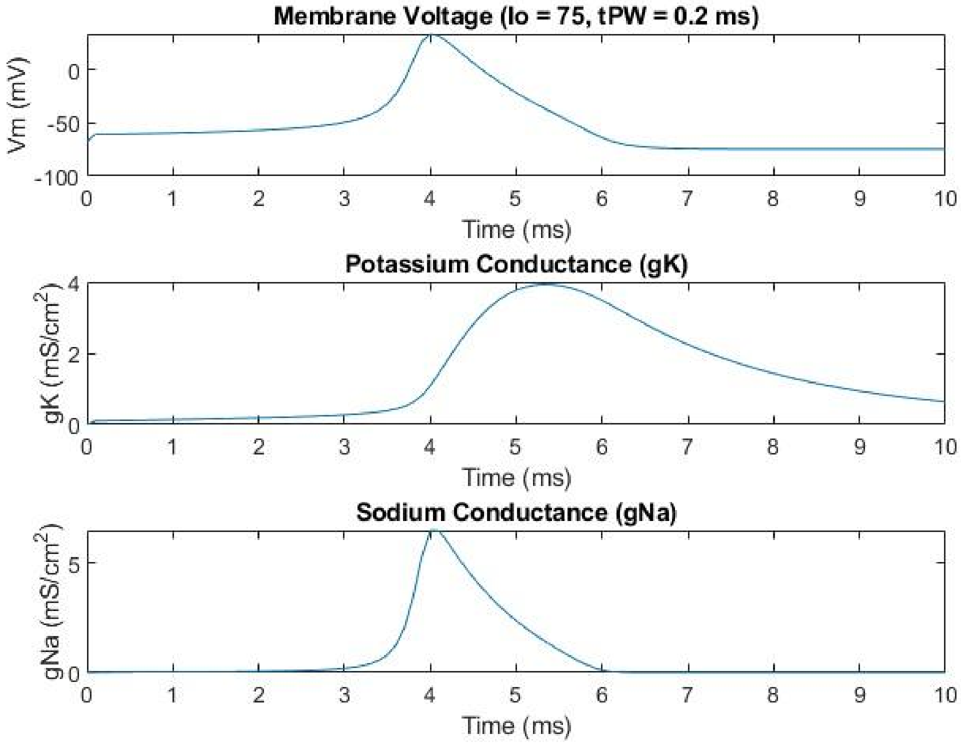
Membrane Voltage (Io = 5, tPW = 0.8 ms)
Vm (mV)
Time (ms)
Potassium Conductance (gK)
gK (mS/cm^2)
Time (ms)
Sodium Conductance (gNa)
$\times 10^{-3}$
gNa (mS/cm^2)
Time (ms)

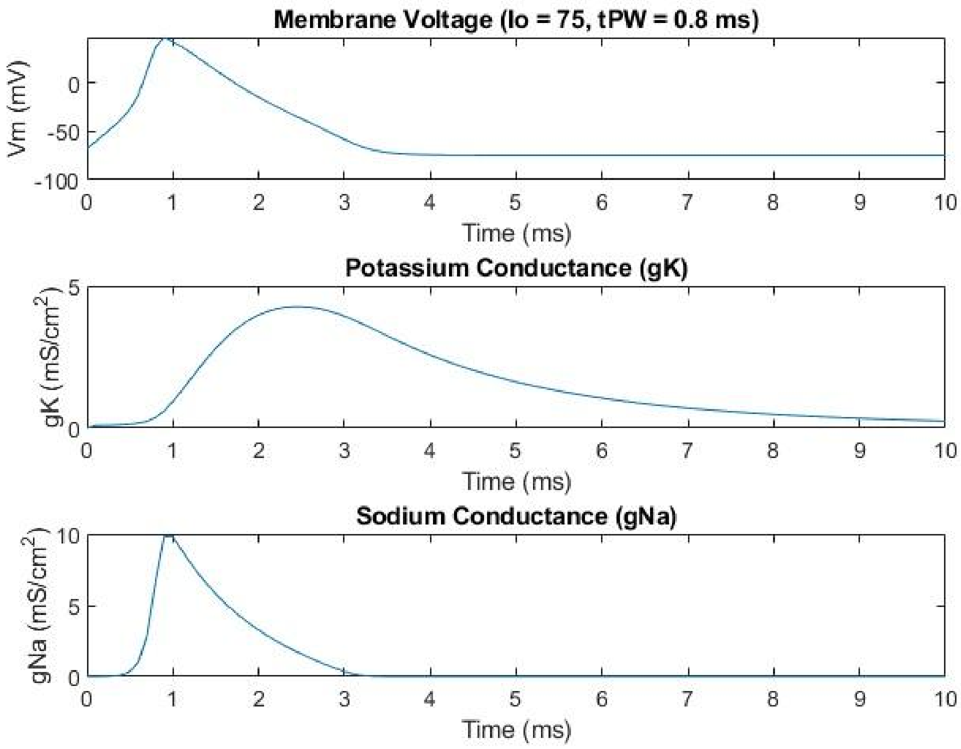


Membrane Voltage (Io = 25, tPW = 0.2 ms)
Vm (mV)
-65
-70
Time (ms)
Potassium Conductance (gK)
gK (mS/cm^2)
0.1
0.05
Time (ms)
×10^-3
Sodium Conductance (gNa)
gNa (mS/cm^2)
5
Time (ms)



Membrane Voltage (Io = 25, tPW = 0.8 ms)
Vm (mV)
0
-50
-100
Time (ms)
Potassium Conductance (gK)
gK (mS/cm^2)
5
Time (ms)
Sodium Conductance (gNa)
gNa (mS/cm^2)
10
5
Time (ms)


Membrane Voltage (Io = 75, tPW = 0.2 ms)
Vm (mV)
Time (ms)
Potassium Conductance (gK)
gK (mS/cm2)
Time (ms)
Sodium Conductance (gNa)
gNa (mS/cm2)
Time (ms)


Membrane Voltage (Io = 75, tPW = 0.8 ms)
Vm (mV)
Time (ms)
Potassium Conductance (gK)
gK (mS/cm2)
Time (ms)
Sodium Conductance (gNa)
gNa (mS/cm2)
Time (ms)

OBSERVATION

- The selection of the time step (dt) in the simulation plays a crucial role in balancing simulation accuracy and computational efficiency.
- A smaller time step enhances accuracy but demands greater computational resources, whereas a larger time step sacrifices some accuracy to expedite simulations.
- The decision regarding dt should align with the simulation's particular objectives and the computational capabilities at hand