All Code (hw2.m) are given in the last section of this report. Continuing are the answers to the problems excluding code.

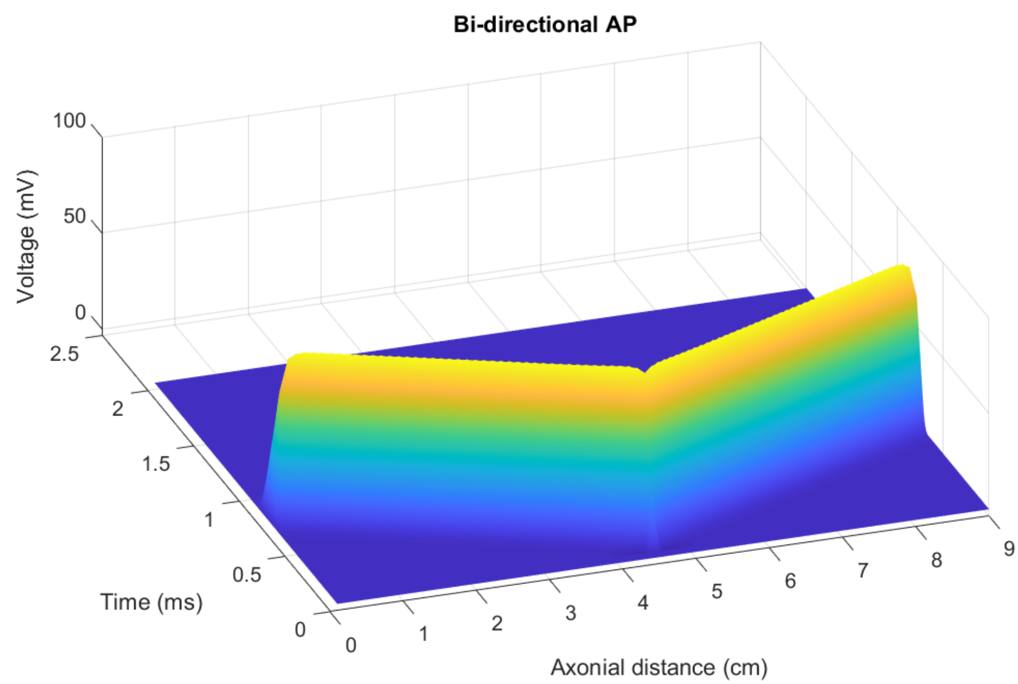
1) Using the CRRSS equations and the parameters below, develop a Matlab program (e.g. m-file) that will solve for a propagating action potential along a 9 cm axon segment.

>> See the last section for code.

2) Using an extracellular, cathodic, monopole source with a 0.2 ms square pulsewidth, determine the minimum current needed to induce a bi-directional propagating action potential in the axon from the following distances: 1, 2, 4 and 8 mm away. (center the monopole over the middle of the axon and displace the monopole normal to the axis of the axon. Make a surface plot of Vm(x,t) for one of the four simulations. Make a movie of the propagating action potential.

>> Simulation Movie for "8mm away" attached. Below Figures are the result obtained.

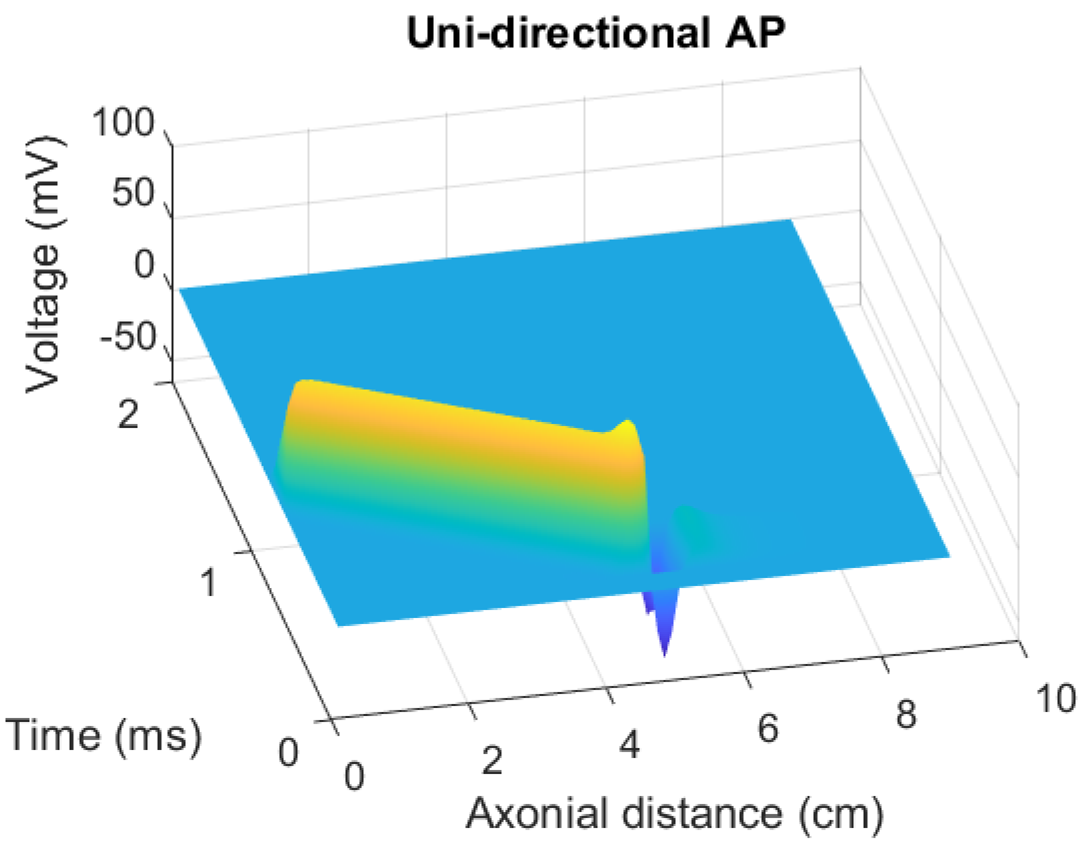
Distance Away (mm)	Current Density Minimum (uA)
1	125
2	300
4	950
8	3600



3) Using any combination of multiple anodes and cathodes as well as waveshapes and pulsewidths, generate a unidirectional propagating action potential in the axon. Run the simulation long enough such that all anodes and cathodes have been turned off for a significant amount of time. Make both a surface plot and movie of the unidirectional action potential.

- A Cathode and an anode were used to recreate unidirectional propagating action potential (Video attached). The two electrodes were 0.5cm apart with a cathode located at the middle of the axon. Applied at 0.8cm above the axon with -4K and 12K stimulation current. .

Figure below shows simulation result. Video attached.



Code

```
close all;
clear all;
clc;

%Fixed Variables
re = 0.35; % Ω·kcm
ri = 0.11; % Ω·kcm
cm = 2.5; % uF/cm^2
ar = 0.0007;% Axon Radius (cm)
w = 0.0001; % Node of Ranvier width
dx = 0.1; % internodal gap (cm)
msc = 1445; % Max Sodium Conductance
mlc = 128; % M Leak C
snp = 115; % Sodium Nernst Potential
lnp = -0.01 % Leak N P

%Adjustable Variables
x = 90; %Length of Axon scaled
f = 0.001;
t = 0:f:2; %0.2 ms
is_cat = -4000; %current density trigger
is_an = -3 * is_cat; % Comment out for #3
ist = zeros(length(t), x);
ist(100:350, 50) = is_an; % Comment out for #3
ist(100:350, 45) = is_cat;
%dw = 0.1; %Adjust for distances away
%dw = 0.2;
%dw = 0.4;
dw = 0.8;

%Pre-simulation prep
v = zeros(length(t), x);
dvdt = zeros(length(t),x);
m = zeros(length(t), x);
dmdt = zeros(length(t),x);
h = zeros(length(t), x);
dhdt = zeros(length(t),x);
act = zeros(length(t),x);
cable = zeros(length(t),x);
im = zeros(length(t),x);
ve = zeros(length(t),x);
Vm = v(1,1);

alpha_m = (97+0.363*Vm)/(1+exp((31-Vm)/5.3));
beta_m = alpha_m/exp((Vm-23.8)/4.17);
beta_h = 15.6/(1+exp((24-Vm)/10));
alpha_h = beta_h/exp((Vm-5.5)/5);
m(:,:) = alpha_m / (alpha_m + beta_m);
h(:,:) = alpha_h / (alpha_h +beta_h);

% Update Extracellular voltage respect to axon diameter
for i = 1:x
    for j = 1:x
```

```
        ve(:,i) = ve(:, i) + (ist(:,j) * re / (4 * pi * sqrt(0.1 * (i-j)^2 + dw^2)));
    end
end

for i = 1:length(t)
    for j = 2 : (x-1)
        Vm = v(i,j);

        alpha_m = (97+0.363*Vm)/(1+exp((31-Vm)/5.3));
        beta_m = alpha_m/exp((Vm-23.8)/4.17);
        beta_h = 15.6/(1+exp((24-Vm)/10));
        alpha_h = beta_h/exp((Vm-5.5)/5);

        act(i,j) = (2*ar) * (ve(i,j-1) - (2 * ve(i,j)) + ve(i,j+1)) / (4 * ri * w *
dx);
        cable(i,j) = (2*ar) * (v(i,j-1) - (2 * v(i,j)) + v(i,j+1)) / (4 * ri * w *
dx);

        im(i,j) = msc * m(i,j)^2 * h(i,j) * (Vm - snp) + mlc * (Vm - lnp);
        dmdt(i,j) = (-1 * (alpha_m + beta_m) * m(i,j) + alpha_m);
        dhdt(i,j) = (-1 * (alpha_h + beta_h) * h(i,j) + alpha_h);

        dvdt(i,j) = (-im(i,j) + cable(i,j) + act(i,j)) / cm;
        end

    m(i+1,:) = m(i,:) + dmdt(i,:)*f;
    h(i+1,:) = h(i,:) + dhdt(i,:)*f;
    v(i+1,:) = v(i,:) + dvdt(i,:)*f;
end

%plot

figure
xaxis = (1:x) / 10;
y = 0:f:2+f;
surf(xaxis,y,v,'edgecolor','none','facecolor','interp')
xlabel('Axonial distance (cm)')
ylabel('Time (ms)')
zlabel('Voltage (mV)')
%title('Bi-directional AP')
title('Uni-directional AP')
set(gca,'fontweight','light','fontsize',15);


plt = figure('units','normalized','outerposition',[0 0 1 1]);
video = VideoWriter('Directional Propagating AP', 'MPEG-4');
open(video);

xaxis=1:x;

for i = 1:10:length(t)
    plot(xaxis/10 , v(i,xaxis) )
    ylim([-100 100])
    %title('Bi-Directional AP')
    title('Uni-directional AP')
```

```
    xlabel('Axonial Distance (cm)')
    ylabel('Voltage (mV)')
    set(gca,'fontweight','light','fontsize',15)
    mov = getframe(plt);
    writeVideo(video,mov)
end
close(video)
```