Question 1:

See code in Appendix 1

Question 2: I_stim = 275 μA

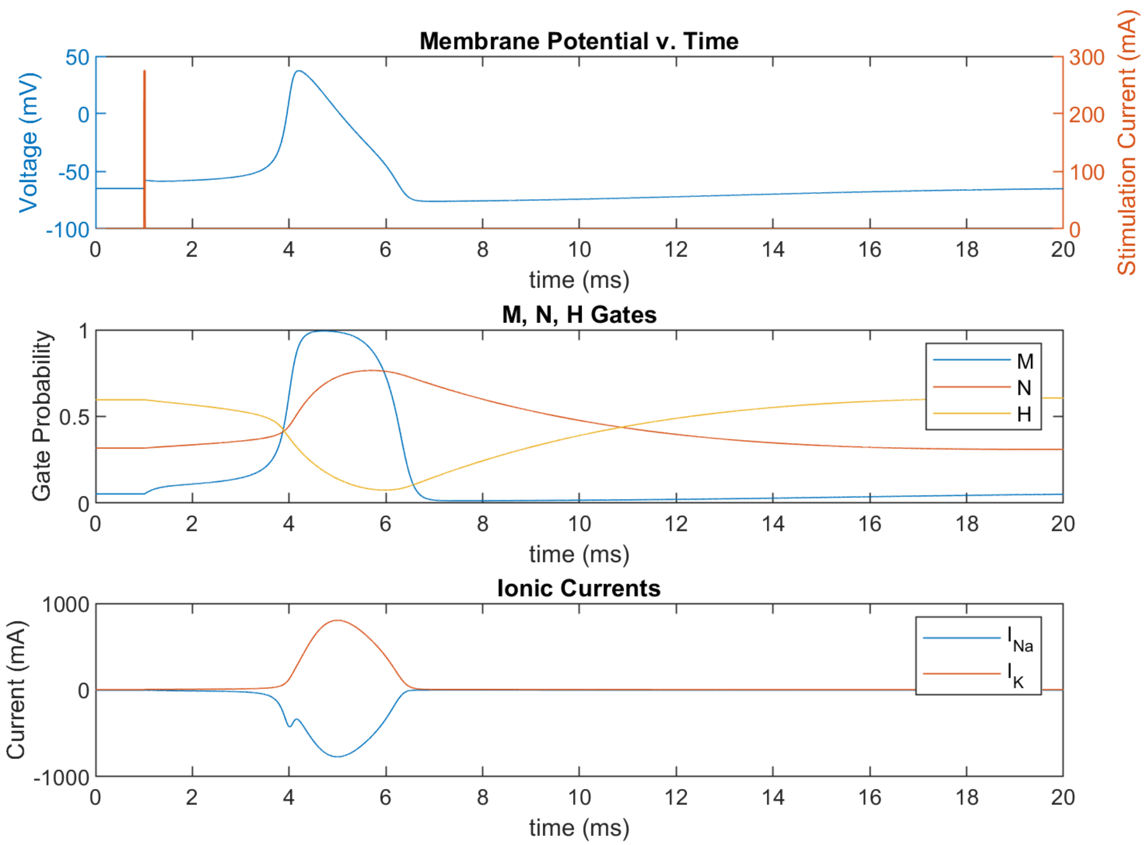

Figure 1: Membrane voltage, stimulation currents, ionic currents and M, N, H gate values for a .25ms stimulation of 275 μA.

Question 3A: I_stim = 275 µA, Refractory Period = 17.2ms

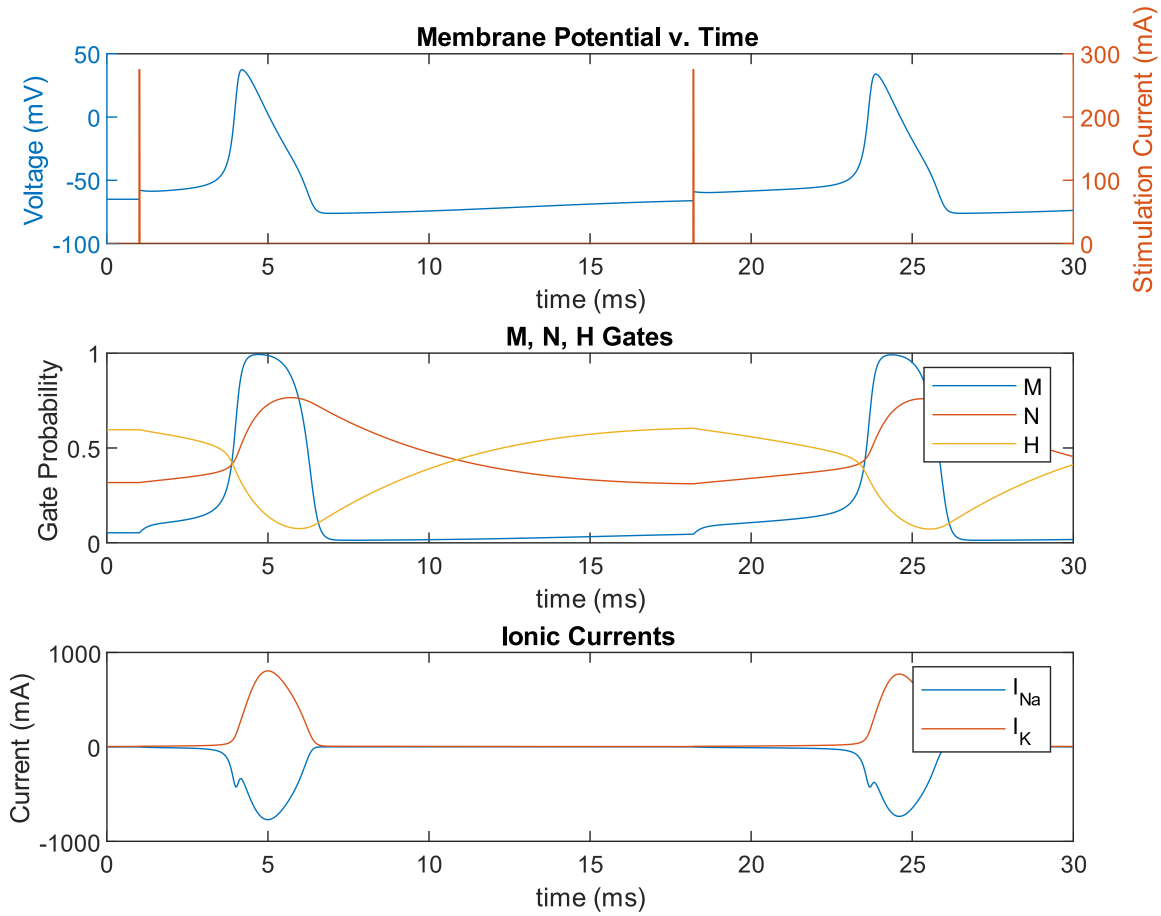

Figure 2: Membrane voltage, stimulation currents, ionic currents and M, N, H gate values for two .25ms stimulation of 275 µA. The minimum refractory period (relative) is 17.2 milliseconds.

Question 3B: I_stim = 275 μA and 825 μA, Refractory Period = 11.8 ms

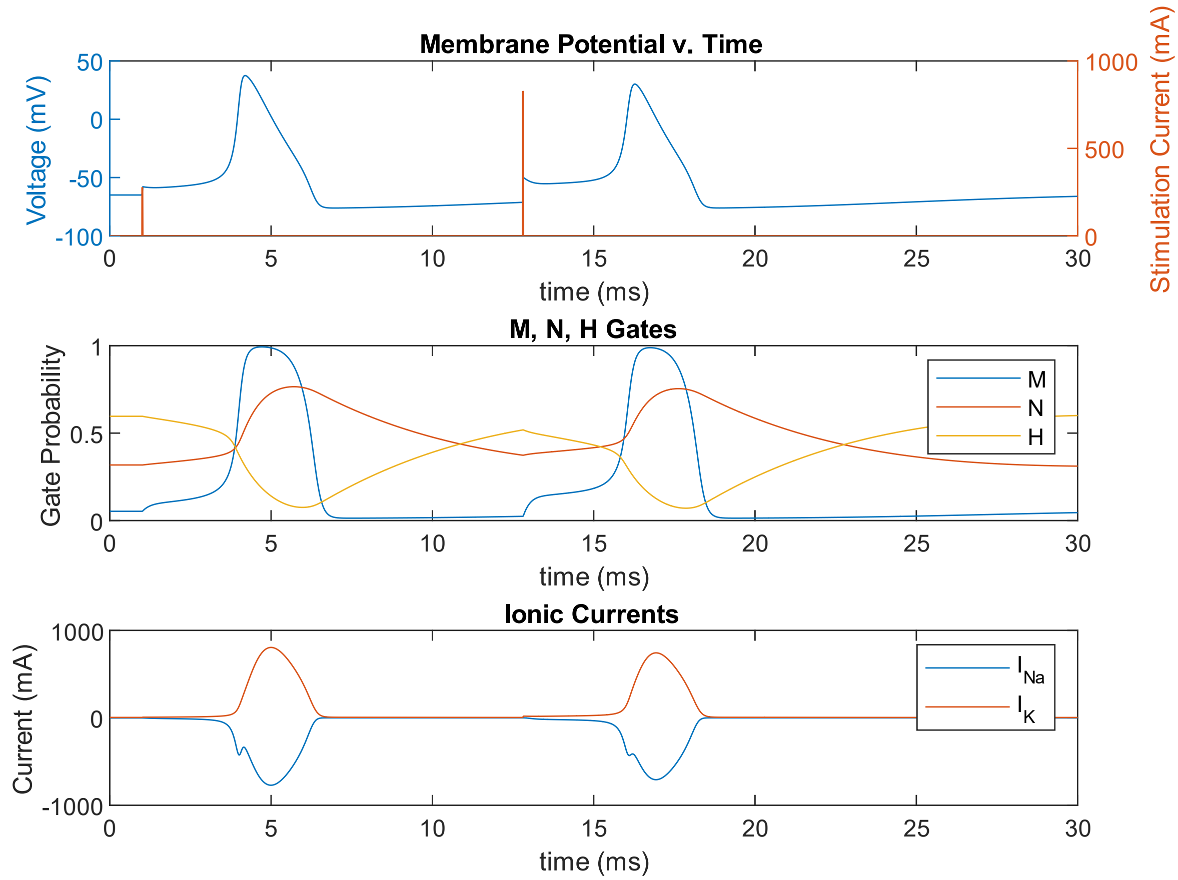

Figure 3: Membrane voltage, stimulation currents, ionic currents and M, N, H gate values for two .25ms stimulation, first of 275 μA, and second of 825 μA. The minimum refractory period (relative) is 11.8 milliseconds.

Question 4: : I_stim = -100 µA for .5ms

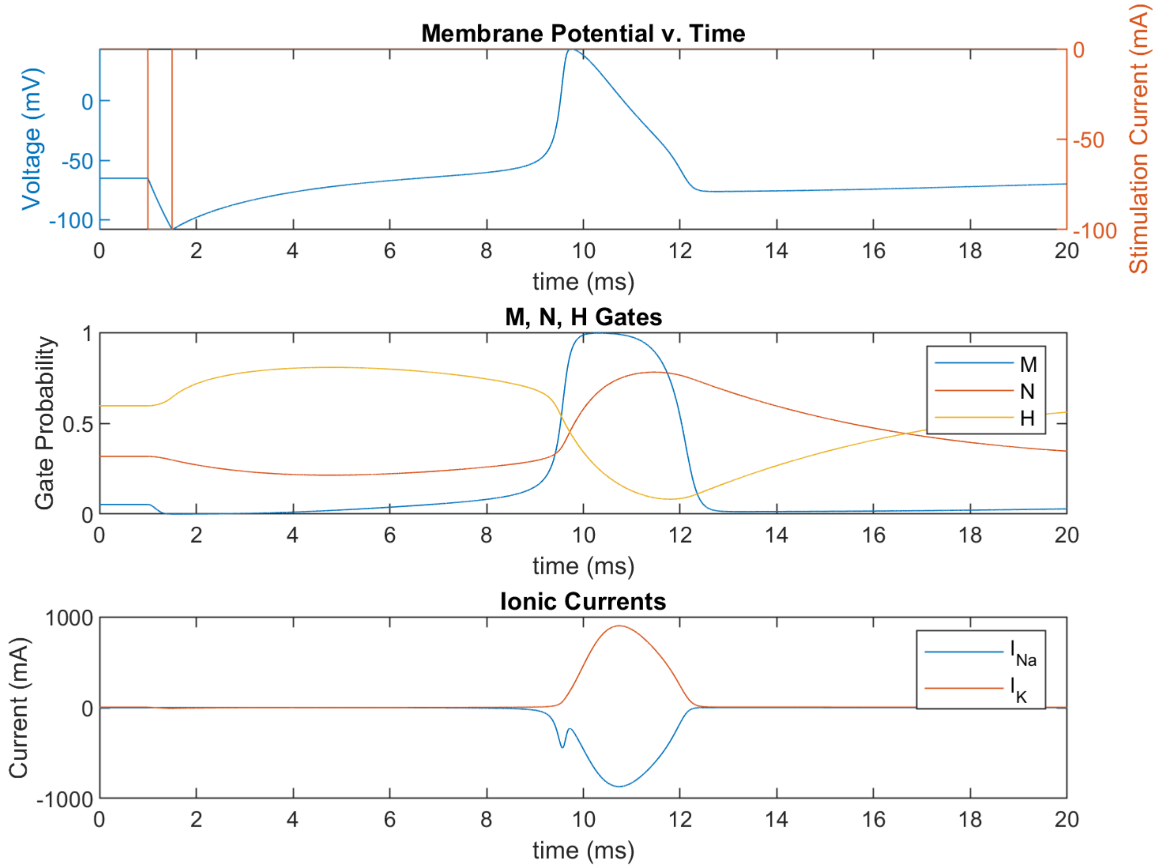

Figure 4: Membrane voltage, stimulation currents, ionic currents, and M, N, H gate values a .5 millisecond long hyperpolarizing pulse of -100 µA to trigger an anode break excitation.

Appendix 1:

HH_Run

```
close all; clear all; clc;

T = 6.3;
gNa = 120;
gK = 36;
Na_Out = 490;
Na_in = 50;
K_out = 20;
K_in = 400;
R = 8.314;
F = 9.6485*10^4;
E_Na = 1000*(R*T/F)*log(Na_Out/Na_in);
E_K = 1000*(R*T/F)*log(K_out/K_in);

V_rest = -60.34;
m_0 = 0.05;
n_0 = 0.32;
h_0 = 0.6;
y_0 = [V_rest; m_0; n_0; h_0];

dt = [0,20];
options = odeset('RelTol',1e-4,'AbsTol',[1e-8,1e-8,1e-8,1e-8],'MaxStep',0.01);

[t,y] = ode45(@(t,y) HH(I),dt,y_0,options);
V = y(:,1);
M = y(:,2);
N = y(:,3);
H = y(:,4);

figure;
plot(t,V); title('Voltage'); xlabel('Time (ms)'); ylabel('Voltage (mV)');
figure
plot(t,M);
hold on; plot(t,H);
hold on; plot(t,N);
title('M, N, H Gates');
xlabel('Time (ms)');
ylabel('Probability Open');
legend('M','N','H');

I_K = gK.*N.^4.*(V-E_K);
I_Na = gK.*M.^3.*H.*(V-E_Na);

figure;
plot(t,I_K);
hold on; plot(t,I_Na);
title('Ionic Currents'); xlabel('Time (ms)'); ylabel('Current (mA)');
legend('I_{Na}','I_{K}');
```

ODE

```
function Dydt = HH(t,y)
I_s = 0
V_rest = -65 ;
T = 6.3;
T_k = 273.15+T;
V = y(1,1);
m = y(2,1);
n = y(3,1);
h = y(4,1);
v_m = V-V_rest;
gNa = 120;
gK = 36;
gL = 0.3;
Na_out = 490;
Na_in = 50;
K_out = 20;
K_in = 400;
R = 8.314;
F = 9.6485*10^4;
E_Na = 1000*(R*T_k/F)*log(Na_out/Na_in);
E_K = 1000*(R*T_k/F)*log(K_out/K_in);
E_L = -50;
C = 1.0;
k = 3^(0.1*T-0.63);

alpha_m = .1*(25-v_m)./(exp((25-v_m)/10)-1);
alpha_h = .07*exp(-v_m/20);
alpha_n = .01*(10-v_m)./(exp((10-v_m)/10)-1);
beta_m = 4*exp(-v_m/18);
beta_h = 1/(exp((30-v_m)/10)+1);
beta_n = .125*exp(-v_m/80);

dVdt = (1/C).*(I_s-gNa*m^3*h*(V-E_Na)-gK*n^4*(V-E_K)-gL*(V-E_L));
dmdt = (-(alpha_m+beta_m)*m+alpha_m)*k;
dndt = (-(alpha_n+beta_n)*n+alpha_n)*k;
dhdt = (-(alpha_h+beta_h)*h+alpha_h)*k;

Dydt = zeros(4,1);
Dydt(:,1) = [dVdt; dmdt; dndt; dhdt];
end
```