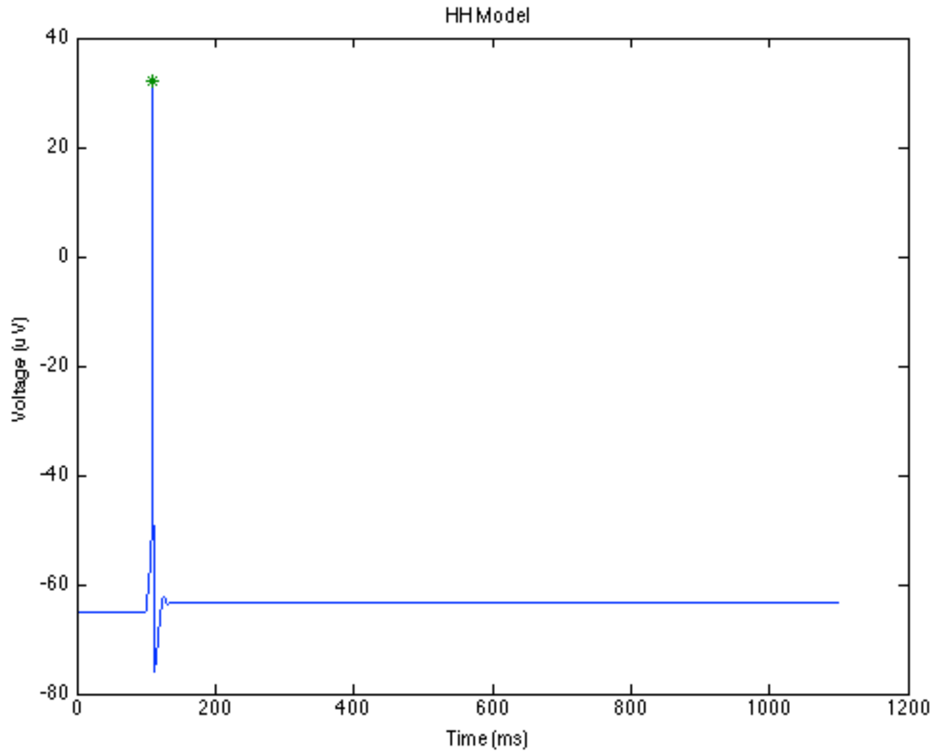
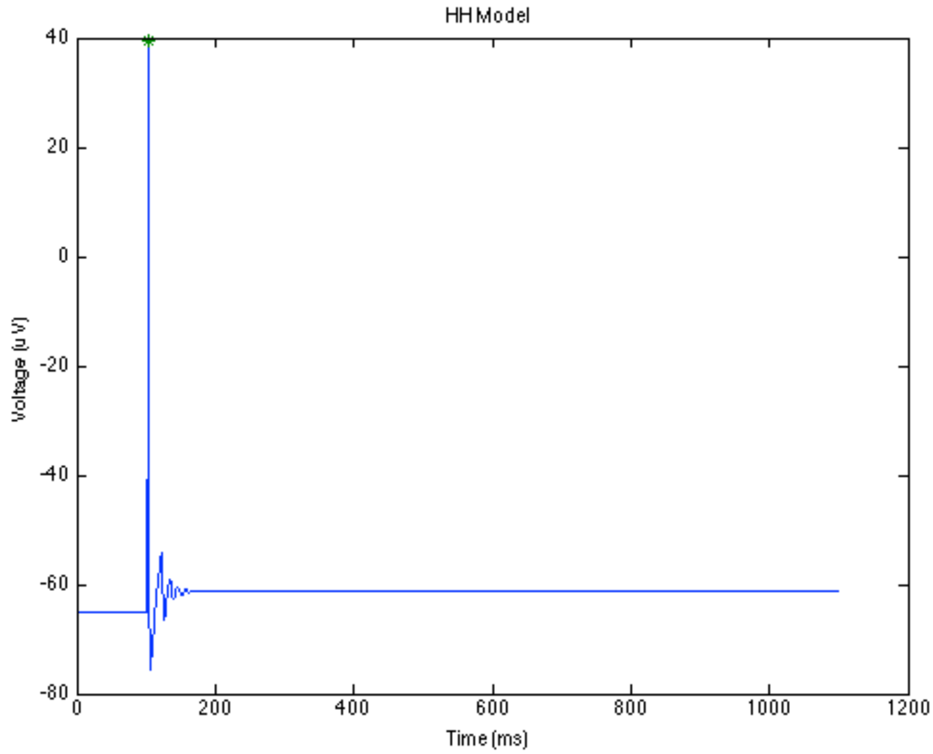
1a. rheobase: 2.25 uA



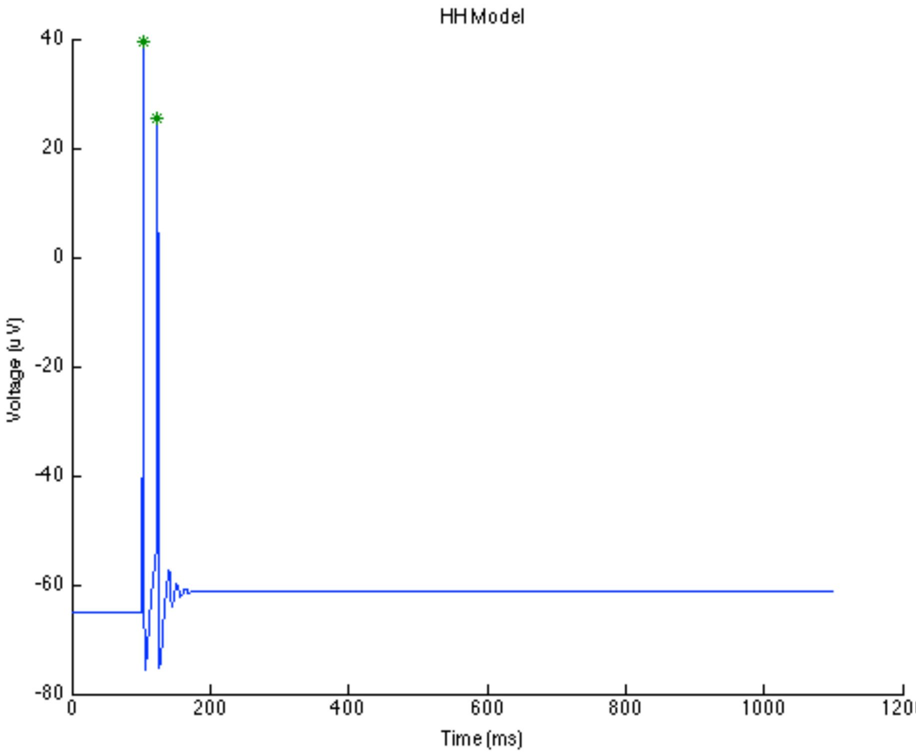

```
for i=2.2:.01:2.3
    [t,v,spiketimes,isis]=HH(i);
    if(~isempty(spiketimes))
        disp(i)
        break;
    end
end
```

1b. current: 5.97 uA, max steady-state voltage: -61.2543 mV



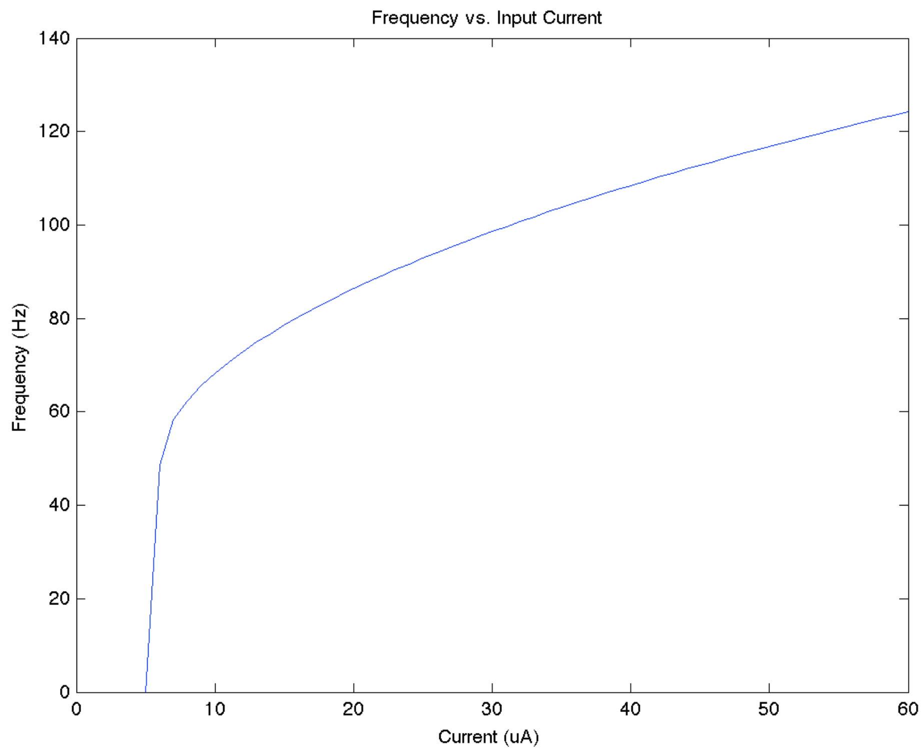

```
vprev = 0;
for i=5:.01:6
    disp(i)
    [t,v,spiketimes,isis]=HH(i);
    if(length(spiketimes)>1)
        disp('1current:')
        disp(i)
        disp('1voltage:')
        disp(v(1,end))
    end
end
```

1c. current: 5.98 uA



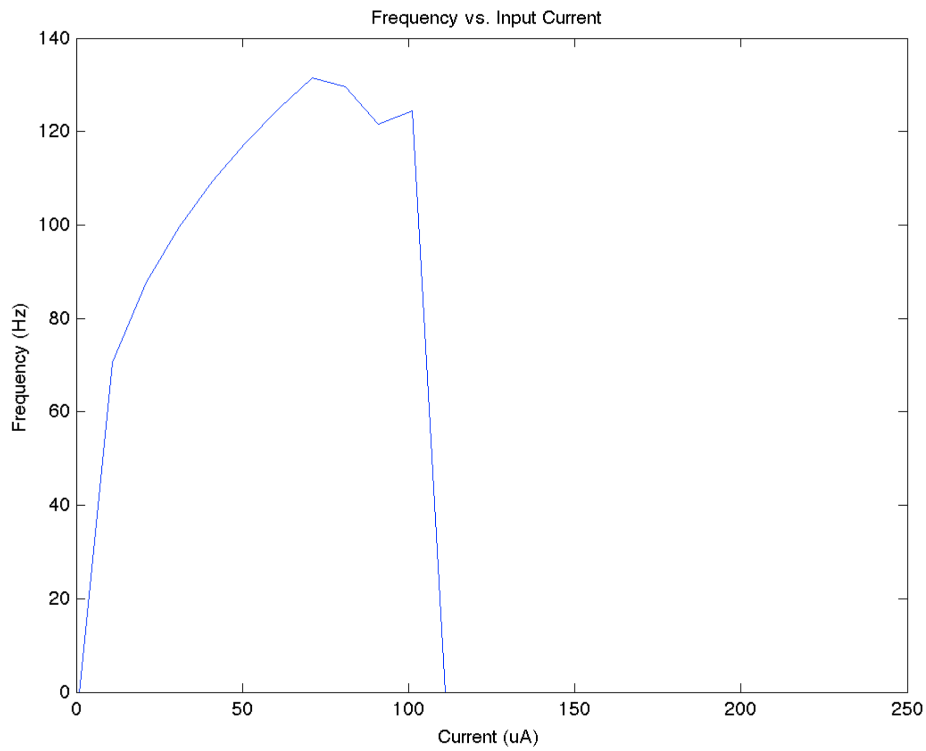
1d. The most profound limitation to the HH model is that it only accounts of ion channel dynamics of the Na2+ and K+ channels. This simplification is computationally advantageous, however it forces the model to exclude certain aspects of neuronal firing that may be present in real biological systems. This model has also been shown to represent ion channel gating kinetics in a means different from neurons.

2a. See plot.




```
trialFreqs=[];
for i=1:60
    disp(i)
    [t,v,spiketimes,isis]=HH(i,false);
    if(~isempty(isis))
        trialFreqs(i)=1000/(mean(isis)); %ms->s,f=1/period
    else
        trialFreqs(i)=0; %only one spike
    end
end
h1=figure;
plot(trialFreqs);
title('Frequency vs. Input Current');
xlabel('Current (uA)');
ylabel('Frequency (Hz)');
saveas(h1,'question2a.png','png');
```

2b. Above 60 uA/cm2, the frequency begins to fall off, and eventually drops to zero due to the depolarization block.



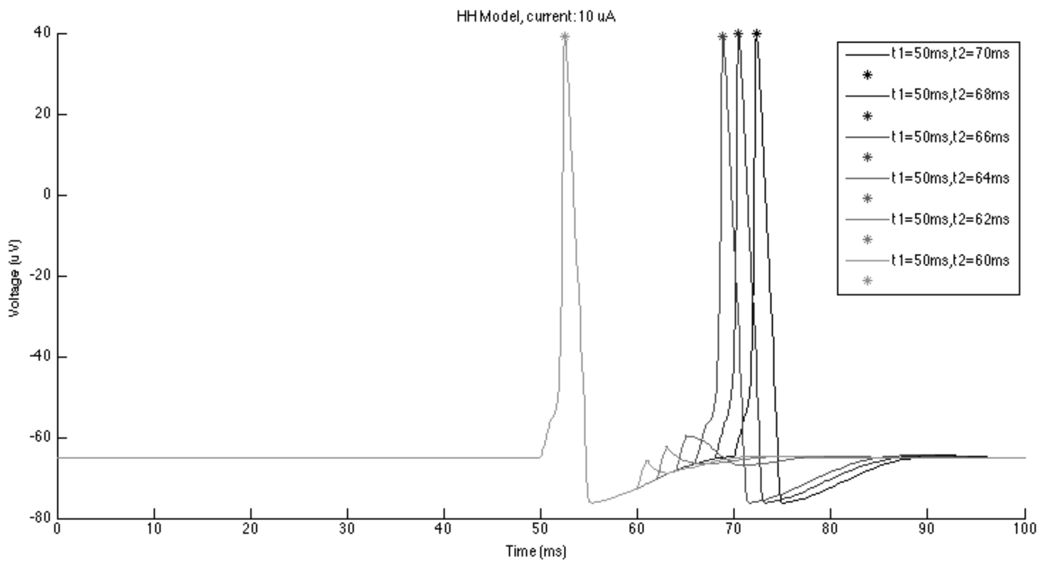

```
trialFreqs=[];
curRange=1:10:250;
j=1;
for i=curRange
    disp(i)
    [t,v,spiketimes,isis]=HH(i,false);
    if(~isempty(isis))
        trialFreqs(j)=1000/(mean(isis)); %ms->s,f=1/period
    else
        trialFreqs(j)=0; %only one spike
    end
    j=j+1;
end
h1=figure;
plot(curRange,trialFreqs);
title('Frequency vs. Input Current');
xlabel('Current (uA)');
ylabel('Frequency (Hz)');
saveas(h1,'question2b.png','png');
```

2c. depolarization block: 108 uA (see plot for 2b)

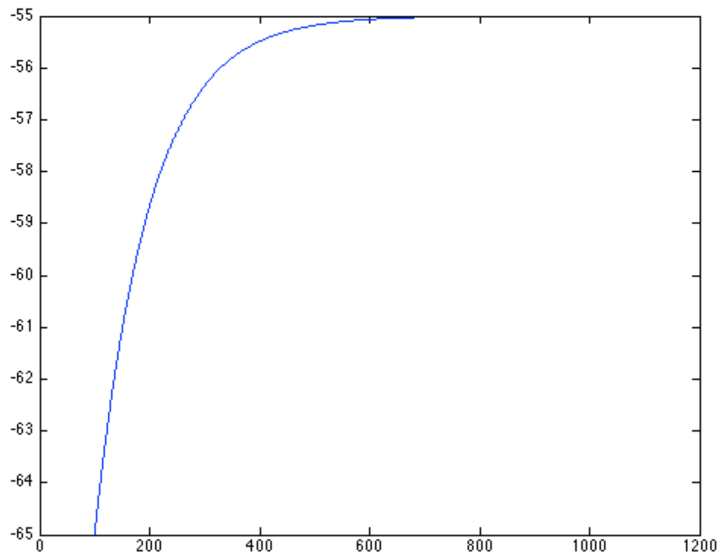
```
spikeData=[];
j=1;
curRange=105:0.1:110; %est. range from 2b
for i=curRange
    [t,v,spiketimes,isis]=HH(i,false);
    spikeData(j,:) = [i,length(spiketimes)];
    j=j+1;
end
h1=figure;
plot(spikeData(:,1),spikeData(:,2));
title('Spike Count vs. Current')
xlabel('Current (uA)')
ylabel('Spike Count')
saveas(h1,'question2c.png','png');

depolarizeIdx = find(spikeData(:,2)==1);
disp('depolarize block:')
disp(spikeData(depolarizeIdx(1),1))
```

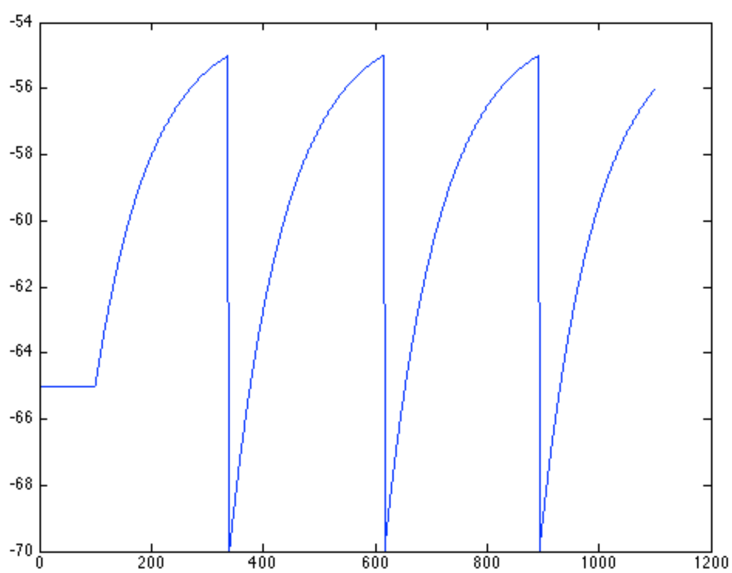
3. The plot shows a 10 uA current impulse being delivered once at 50 ms, and again at a variable time interval from the first impulse (at 60 ms through 70 ms, steps of 2). This data suggests that this current impulse is insufficient to elicit an action potential if it exists within the relative refractory period (RRF) generated by an identical, but previous impulse, with that RRF being about 15 milliseconds.



4a. See plots.



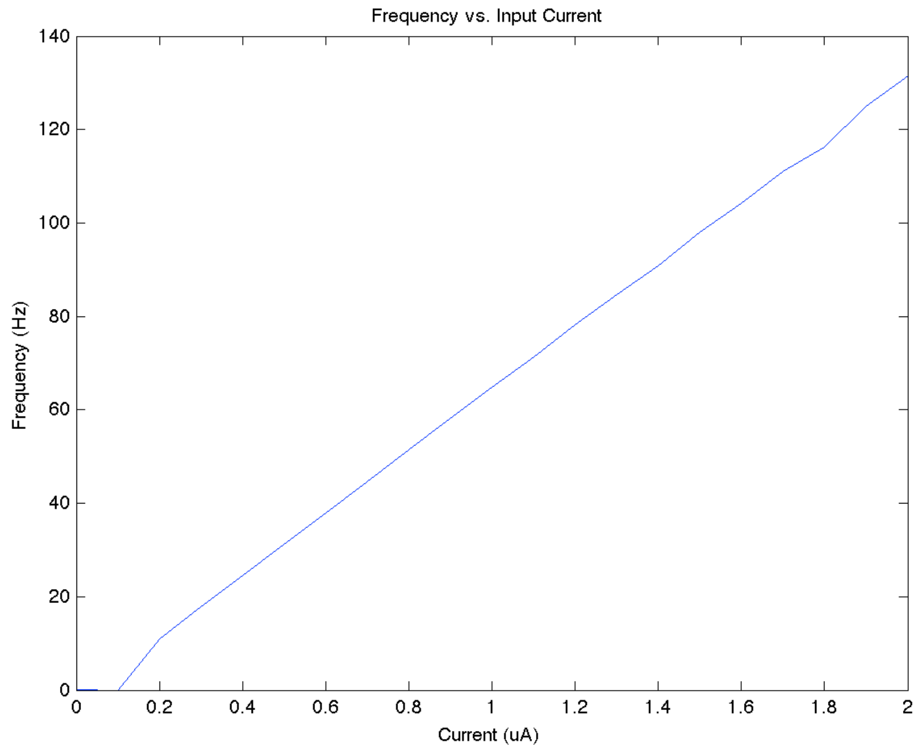
Plot1: 0.10 uA



Plot2: 0.11 uA

```
[t_tot,v_tot spiketimes,isis]=LIF(.11);
[t_tot,v_tot spiketimes,isis]=LIF(.10);
```

4b. See plot.




```
trialFreqs=[];
curRange=0:0.5:10;
j=1;
for i=curRange
    disp(i)
    [t,v,spiketimes,isis]=LIF(i);
    if(~isempty(isis))
        trialFreqs(j)=1000/(mean(isis)); %ms->s,f=1/period
    else
        trialFreqs(j)=0; %only one spike
    end
    j=j+1;
end
h1=figure;
plot(curRange,trialFreqs);
title('Frequency vs. Input Current');
xlabel('Current (uA)');
ylabel('Frequency (Hz)');
%saveas(h1,'question4b.png','png');
```

4c. The f-I curve for the HH model is non-linear, while the f-I curve for the LIF model is linear. The HH model is subject to a depolarization block, which is a hard limit to the firing frequency the model neuron can achieve. In contrast, the LIF model does not have any mechanism for a depolarization block, and is why the f-I curve remains linear into very high frequencies (see plot below). The inter-spike interval (ISI) is much less near the current threshold for firing for the HH model as compared with the LIF model (21 and 277 milliseconds, respectively), which directly speaks to the firing frequency given by each model.