Design and analyze an electrophysiology experiment

This problem set requires you to combine the skills you have learned so far in the course to set up and analyze an experiment about a sensory neuron. Students have previously reported that this is the most challenging set of the course, so please leave yourself a little extra time to complete it.

For this problem set, please submit .m files with the code you used to solve these problems. If the problem asks for a number answer at the end of the problem, write that number in a comment after the code. Example:

```
x = [1 2 3 4 5];
y = 2;
z = mean(x./y);  % z = 1.5
```

The challenge: We're recording from a mechanosensory neuron that might fire spikes when we stimulate it at certain frequencies. We want to test it by stimulating it with sine waves at several different frequencies and recording spikes in the neuron. To do this, we need to send instructions (voltages) to a motor that will stimulate the neuron by oscillating it up and down. The motor can accept voltages between 0 (all the way down) and 5V (all the way up). Create this stimulus by answering the following questions.

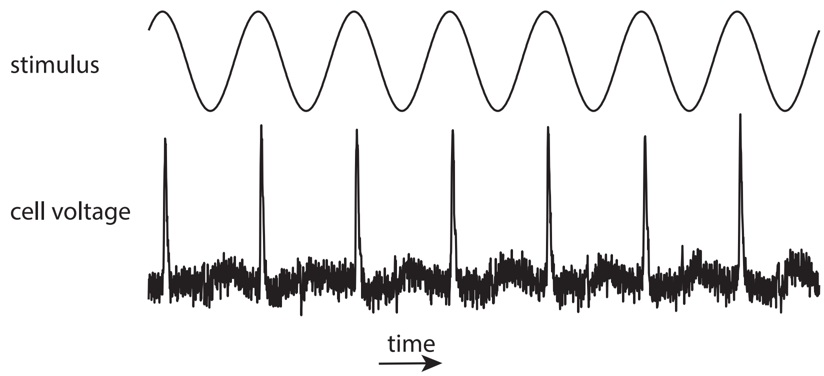
1a. (1pt). The motor needs instructions at a rate of 10,000 samples per second. We would like to oscillate the mechanosensor 40 times (40 sine wave cycles) at a frequency of every 5 Hz between 1 and 150 Hz (1, 5, 10, 15… 145, 150). How many samples will we need to send it to complete 40 cycles at 1Hz? How many samples will we need for 40 cycles at 100Hz?

1b (3pts) The formula for a sine wave is $A \sin \omega t$ (where A is the amplitude of the sine wave and ω is the frequency). Make a vector that will oscillate the mechanosensor 40 times (40 sine wave cycles) at a frequency of every 5 Hz between 1 and 150 Hz (1, 5, 10, 15… 145, 150). Tip: Start with a 5Hz sine wave and figure out how many samples 40 cycles of a 5Hz stimulus should take (like you did above). Make a time vector of this length and create a 5Hz sine wave. Then write a for loop that will do the same for the other frequencies.

1c (1pts) Use `zeros` to add 100 ms of rest in between each frequency.

1d (2pts) Plot the stimulus. If we play this stimulus through the motor to oscillate our mechanosensor, how long will the experiment take?

2. Now that we've designed the stimulus, let's look at some data from a real cell. The data in the files on the website are spike times and stimulus peak times for an experiment like the one you wrote in Question 1. The raw recording looks something like this:



Each .out file contains the spike times and the sine wave stimulus peak times for a given frequency. The spike times are in column 1, and the stimulus peak times are in column 3.

2a (4pts) Write a script that calls the phase function you wrote in class and loops through each of the files. Use your function to find the phase of each spike for a given frequency, then find the mean phase of all of the spikes for each frequency.

2b (2pts). Sometimes this cell had the audacity to spike twice in the same sine wave cycle. If that happens, find the phase of the first spike in the cycle only. You may have to adapt your function to do this.

2c (2pts). Plot the mean phase and the standard deviation versus frequency. Turn in your phase function and the script you used to loop through the files and call the function. We'll add to the script for the next question.

3. When we observe a phenomenon that seems to be related to a particular phase, we would like to apply some statistics to determine the precision of the phase locking. One means of measuring this is vector strength, which is a circular statistic that compares the phases and finds the length of the mean vector of the phases. The formula for vector strength is:

$$v = \sqrt{\left(\sum_{i=1}^{n} \sin \phi_i\right)^2 + \left(\sum_{i=1}^{n} \cos \phi_i\right)^2} / n$$

where $\boldsymbol{\phi}$ is the phase and n is the total number of phases being compared. Notice that this formula is based on the trigonometric identity, $\sin^2 + \cos^2 = 1$. Thus, if all of the phases are exactly the same, the vector strength will be 1; if they are all different, the vector strength will be closer to 0.

3a. (2pts) Write a function that takes a collection of phases (in radians) as the input and outputs the vector strength. Then, use that function in a script to calculate the vector strength at each frequency. These cells happen to be extremely good at phase locking; therefore, you should expect to get vector strengths that are very close to 1.
3b. (3pts) Once you have the vector strengths calculated, use the `compass` function to make a plot of the data. Each arrow on the compass should point in the direction of the mean phase for each frequency, and should have a length equal to the vector strength of that frequency. Turn in your vector strength function, and also turn in the script that addresses this question and the last one. This script should loop through all of the frequencies, calculate the phases, find the mean and standard deviation for the phases, plot them (with error bars) versus the frequency (as in the question above), and then calculate vector strength and make the compass plot.