Homework #3, BioE 2696/ECE 2695 Control Theory in Neuroscience, Spring 2009

1) The electrical potential of a neuron at rest is governed by the permeabilities of the cell membrane to various ions, and the concentrations of those ions. Given the following table of intracellular and extracellular concentrations, and ion channel permeabilities, compute the resting potential.

species	[intracellular]	[extracellular]	permeability
K^+	100	1	100
Na^+	10	100	1
Cl^-	10	100	10

You can assume room temperature, and work with base-ten logarithms, so that

$$\frac{RT}{F} ln(x) = 58 log(x)$$

Assume that during the initial phase of an action potential, the sodium (Na^+) permeability increases momentarily to 1000. What is the voltage recorded inside the cell at the peak of the action potential?

2) A peri-stimulus time histogram (PSTH) is a commonly-used format for displaying neurophysiological data. In a PSTH, the average firing rate of a neuron is depicted as a function of time. Trials are aligned in time onto the occurrence of a stimulus or behavioral event. Construct a PSTH following these steps:

1) download simulated spike data in matlab format from the course website at http://www.engr.pitt.edu/electrical/faculty-staff/mao/2696/
   The matrix spikedata.m indicates neural activity over five trials, each 1 second long. Each row is a trial, each column is one millisecond. A 1 indicates that an action potential occurred in that time bin.
2) Smooth the data with a Gaussian kernel.
3) Plot the average firing rate across all five trials as a function of time. This is your PSTH.
4) At a certain point in the trial, a stimulus turned on and then turned off. What is your best guess for the timings of the onset and offset of that stimulus?

Please submit the PSTH, your matlab code that generated it, and your estimates of the stimulus onset and offset times.

3) Shown in Fig. 1 is a satellite attitude control system.
(a) Write the system transfer function for this attitude control system.
(b) The system is commanded to assume an attitude of 10^o: $\theta_r(t) = 10u(t)$, where $u(t)$ is the unit step function. After the transients die out (the system reaches steady state), what will be the attitude angle of the satellite, $\theta_{ss}(t)$? (Here “ss” means “steady state.”)

(c) The closed-loop system is to respond to a step input in minimum time with no overshoot, which requires that the damping ratio $\zeta = 1$. Find K_v as a function of K such that this specification is satisfied.
(d) The system of (c) is to reach steady state approximately 6 seconds after a command to change the attitude angle (after the application of an input). Find the value of K that satisfies this specification.
(e) Verify the results of (b), (c), and (d) with a MATLAB simulation of the system.
(f) The rate signal is measured using a rate gyro. Suppose that the rate gyro fails, such that no signal appears in the rate path (effectively $K_v = 0$). What is the nature of the system response in the failure mode? (This failure occurred on a space lab mission of NASA, with the predictable result.)
(g) Simulate the system with $K_v = 0$ to verify the results of (f).

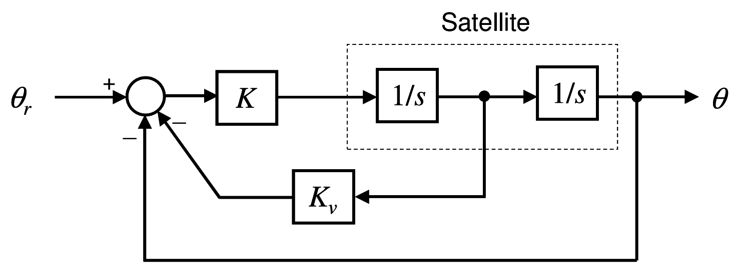

Figure 1