171B Final Project (Due within 5 days of the in class Final Exam, 5 p.m. Saturday June 9):

Midterm: 20%, Homework 30%--> 20%, Final: 40%-->30%, Project: 30%

You may work in groups for the project and submit the results in groups.

Project: Use the 2nd order state space models of the inverted pendulum mode of the motor kit for the following design, analysis, simulation, and experiment for regulating the inverted pendulum.

State feedback design:

(a) What is the plant model **G(s)** and it's state space form? For sampling time T = 1/1000 [sec], what is the discrete-time plant model **G(z)** and its state space form? Design a discrete-time state feedback controller so that the dominant closed loop poles are located at 0.9 and 0.93. Give the state feedback gains **K**.

(b) Determine the loop gain of the state feedback system and determine the cross-over frequencies and phase and gain margin. Also show Bode plot of the sensitivity function and give the Vector Gain Margin **VGM**.

State observer feedback design:

(c) Design a state observer feedback control for state feedback poles same as in (a) and observer poles at 374 rad/sec natural frequency and 0.925 damping ratio. Give state observer feedback gain **K** and observer gain **L**.

(d) Determine the loop gain of the state feedback system and determine the cross-over frequencies and phase and gain margin. Also show Bode plot of the sensitivity function and give the Vector Gain Margin **VGM**. Compare results with that of state feedback.

(e) Derive the closed loop transfer function **Gyr(z)** from reference input r to the output y with an appropriate feedforward gain **N**. Perform simulation of the state observer feedback control by simulating step response with sufficiently small step (given the step size value) input that will almost trigger half of the control saturation (50% duty cycle). Determine important performance features such as rising time, overshoot, and steady state error.

(f) Implement the state observer feedback control in (e) on you motor kit (inverted pendulum mode). Compare simulation and experimental results.

You will need to perform a demonstration and turn in a one-page results of your design and experimental results. Show plots of experimental results that may be compared with simulation results with identical ranges and scales. This is not a report so make it concise.

Bonus (5% of course grade): Add an integrator in the state feedback control and perform (a) thru (f) above and demonstrate zero steady error. The location of the additional closed loop pole is of your choice.