Lab 6."Segway" Inverted Pendulum Robot.

Deliverables: **Each lab group must submit a *short* (~3-4 page) Lab Report, processing data collected during Lab 5, by 5pm Wed., May 11 (in the dropbox).** Include the following:

1. Include your derivation of the equations of motion, via paper calculation or MATLAB code (using the symbolic toolbox and fulldiff). Be sure to list model parameters you used, as well as the resulting A and B matrices (numeric values) for the modeled plant.

2. Also clearly specify your controller gains, i.e., the values in vector K, and how you obtained them. For example, if you used the `lqr` function in MATLAB, also document your Q and R matrices in your report. Or, if you used the "`place`" command (or "`acker`") in MATLAB, be sure to document your closed-loop pole locations.

3. What were the modeled open-loop poles? And what are the expected closed-loop poles?

4. Test how sensitive your LQR solution is to various of the model parameters. For example, what if your estimate for (Jb + mb*L^2) is greater or smaller by a factor of 2? Identify any other "parameter groups" such as this which would affect the A and B matrices. Comment on the resulting sensitivity of various elements in the gain vector, K, to variations in the model. In particular, how does wheel radius affect K?

5. Also include plots of body angle and wheel angle(s) over time, including response to an external perturbation. (i.e., an impulse response) Does the impulse response agree with your predicted closed-loop poles?

<u>Overview</u>

In this lab, you will modify a template simulink file to enable your Lego inverted pendulum robot to balance in place. This will require deriving equations of motion, modifying estimates of model parameters, finding offsets for the gyro and accelerometers, and (finally) determining a gain vector, K, for state space control. We expect most people will find gains via MATLAB's `lqr` function, which solves for the optimal gains to minimize a quadratic cost function of states (weighted by values in Q) and of actuator output (weighted by values in R).

As always, you are encouraged to explore other solutions, too, depending on your personal knowledge, interests, curiosity, and persistence.

Credit for the lab includes check-off by TA (40%), and a lab report (60%). We hope to obtain short video documenting several different robot controllers. The assignment requires that you have completed the tasks listed below. **We are creative/flexible about how you approach particular problems.** *Please be concise and efficient in your presentation; well-labeled plots are always appreciated – and often can be much more effective in communicating details than excessive text.*