Hand-In Exercise 1: Modeling and Control of Robot Arm

Robot manipulators have multiple degrees of freedom and are described by complicated nonlinear models. Therefore, a one-degree of freedom robot is considered in this exercise. A sketch of the robot is shown in the following figure.

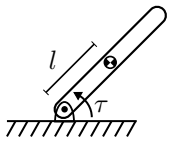

Figure 3: Sketch of the system with mass $m = 1$ kg, length to center of mass $l = 0.5$ m, and a friction given by $\tau_f = b\dot{\theta}$ with $b = 0.1$ Nm/(rad/s).

The input to the system is a torque τ [Nm], which is provided by an actuator and the output (measurement) is the joint angle θ [rad], which is zero when the arm is upright. Study the dynamics of the one-degree of freedom system according to the following steps.

1. **System Modeling**
   - Setup a model (nth-order differential equation) of the system.
   - Derive a linearized model of the system at an angle of $\pi/3$ rad.
2. **Performance Specification**
   - Specify a desired performance of the system.
3. **Controller Design**
   - Design a PID controller for the linearized model of the system such that it attains the desired performance. The tuning procedure should be described.
4. **Simulation**
   - Simulate the linearized system with set point $\pi/3$ rad and initial condition 0 rad.
   - Simulate the nonlinear system model with the designed PID control.

A small report should document the above steps, with derivations, block diagrams, and graphs related to the simulations (plot both the input and output of the system). The report must follow the provided template.