Exercises 1-3: Feedback Control and Trajectory Control (ex.py)

1. *PID tuning*. Consider a 1-joint robot that should be kept at the zero setpoint (held horizontal). The PID constants are currently set to $K_p=K_i=K_d=1$, which gives slow recovery behavior.
    a. Uncomment problem="1a". In the indicated line in control_loop(), tune your controller on the given problem, which initializes the position of the joint at the vertical position, and asks the controller to recover to zero. Make sure the controller recovers quickly, does not overshoot or oscillate too much, and converges to zero. What constants did you end up with?
    b. Uncomment problem="1b". Tune your controller on the given problem, which starts at the setpoint but adds a disturbance force: a ball bounces on the arm from above. Does your controller from 1a also work well for this problem?

2. *Model-based control*. Since this system is well modeled, we use inverse dynamics to compute the torques that would be required to achieve a desired joint acceleration.
    a. Uncomment problem="2a". In the indicated lines in control_loop(), solve the fundamental dynamics equation to compute the torques T that would control the robot at the given accelerations ddq. You may make use of the methods in RobotModel, or you may calculate the dynamics equation yourself.
    b. Uncomment problem="2b". This problem introduces a calibration error in the model, where the mass of the robot is underestimated by a factor of two. What happens when running your controller from 2a? Why? Implement a method for correcting for these errors so that your controller converges to zero.

3. *Trajectory control*. In this problem you will control a 2-joint robot so that its tip touches the indicated target point via a smooth, controlled motion. The current method simply snaps to a desired configuration too quickly, and moreover, is incorrect.

    Use inverse kinematics to find a target configuration that precisely matches the target point, and construct a smooth interpolating path so that the robot reaches the target over the course of 2 seconds.