# EE 368 机器人运动与控制方法（Robotic Motion and Control）
# Assignment #5

**Due time:** 5:00pm on Monday, June 5, 2023 via Blackboard

Q-1. Given the nonlinear control equation for an $\alpha, \beta$ partitioned controller for the system:

$$\tau = 5\theta\dot{\theta} + 2\ddot{\theta} - 13\dot{\theta}^3 + 5.$$

Choose gains so that this system is always critically damped with the closed-loop stiffness $K_P = 10$.

Q-2. Draw a block diagram showing a Cartesian-space controller for the two-link robot arm with the Cartesian-space dynamic equation as follows:

$$\tau = J^T(\Theta)M_X(\Theta)\ddot{X} + B_X(\Theta)[\dot{\Theta}\dot{\Theta}] + C_X(\Theta)[\dot{\Theta}^2] + G(\Theta)$$

such that the robot arm is critically damped over its entire workspace. Assume that the forward kinematics of this robot arm is represented by $KIN(\Theta)$.

Q-3. Consider a position-regulation system with the open-loop dynamics as

$$\tau = M(\Theta)\ddot{\Theta} + V_M(\Theta, \dot{\Theta})\dot{\Theta} + G(\Theta)$$

that attempts to maintain $\Theta_d = 0$. Prove using Lyapunov stability that the control law

$$\tau = -K_P\Theta - \widehat{M}(\Theta)K_V\dot{\Theta} + G(\Theta)$$

with the Lyapunov function candidate

$$\mathcal{V} = \frac{1}{2}\dot{\Theta}^T M(\Theta)\dot{\Theta} + \frac{1}{2}\Theta^T K_P \Theta$$

yields an asymptotically stable nonlinear system. You may take $K_V$ to be of the form $K_V = k_v I_n$, where $k_v$ is a scalar and $I_n$ is the $n \times n$ identity matrix. The matrix $\widehat{M}(\Theta)$ is a positive definite estimate of the manipulator mass matrix.