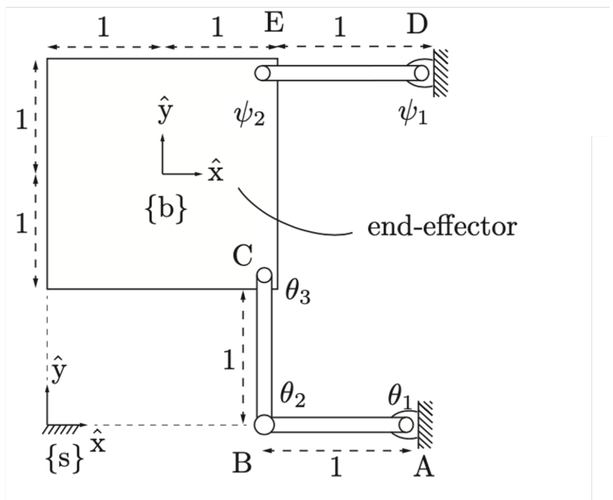
Final Exam

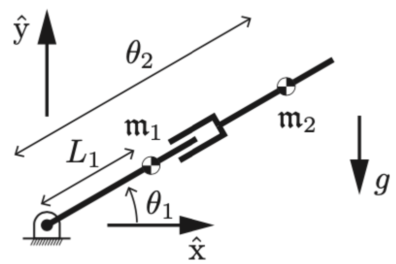
Subject : Modern Robotics, Lecturer : Prof. Youngjin Choi,
Date : June 18, 2020 (Contact e-mail : cyj@hanyang.ac.kr)
Notice that the answers should be written only in English, otherwise you will get a zero point.

Problem 1 (30pt) Assume a five-bar linkage is in its zero position. Let (p_x, p_y) be the position of the {b}-frame origin expressed in {s}-frame coordinates, and let ϕ be the orientation of the {b} frame. Find the forward kinematics Jacobian J_a from $\mathcal{V}_s = J_a \dot{q}_a$ when B, D are actuated, i.e, $\dot{q}_a = (\dot{\theta}_2, \dot{\psi}_1)$ and $\dot{q}_p = (\dot{\theta}_1, \dot{\theta}_3, \dot{\psi}_2)$. You may make use of the matrix inversion of $\begin{bmatrix} 1 & 1 & -1 \\ 0 & 1 & -3 \\ -3 & -2 & 2 \end{bmatrix}^{-1} = \begin{bmatrix} -2 & 0 & -1 \\ 4.5 & -0.5 & 1.5 \\ 1.5 & -0.5 & 0.5 \end{bmatrix}$.



Problem 2 (40pt) The figure illustrates an RP robot moving in a vertical plane. The mass of link 1 is $\mathrm{m}_1 = 1[kg]$ and the center of mass is a distance $L_1 = 1[m]$ from joint 1. The scalar inertia of link 1 about an axis through the center of mass and out of the plane is $\mathcal{I}_1 = 1[kg \cdot m^2]$. The mass of link 2 is $\mathrm{m}_2 = 1[kg]$, the center of mass is a distance θ_2 from joint 1, and the scalar inertia of link 2 about its center of mass is $\mathcal{I}_2 = 1[kg \cdot m^2]$. Gravity g acts downward on the page. Derive the equation of motion ?

$$M(\theta)\ddot{\theta} + c(\theta, \dot{\theta}) + g(\theta) = \tau$$



Problem 3 (30pt) For given a one-dof mass-spring-damper system of the form $\mathrm{m}\ddot{x} + b\dot{x} + kx = f$, where f is the control force and $\mathrm{m} = 4[kg]$ and $b = 2[Ns/m]$ and $k = 0.1[N/m]$, determine the gains k_p and k_d so that the following PD controller

$$f = k_d(\dot{x}_d - \dot{x}) + k_p(x_d - x)$$

can yield the critical damping and the 2% settling time of $0.01[s]$, where $x_d = 1$ and $\dot{x}_d = 0$.