

## ECE 470/ ME 445: Introduction to Robotics- Homework 04

### Question 1.

You are tasked to design the joint control for the manipulator arm analyzed in Homework 3. Using the control partitioning law, and the formulated dynamics in Homework 3, design a control scheme for the system with gain of  $(k_p, k_v)$ . (3 Points)

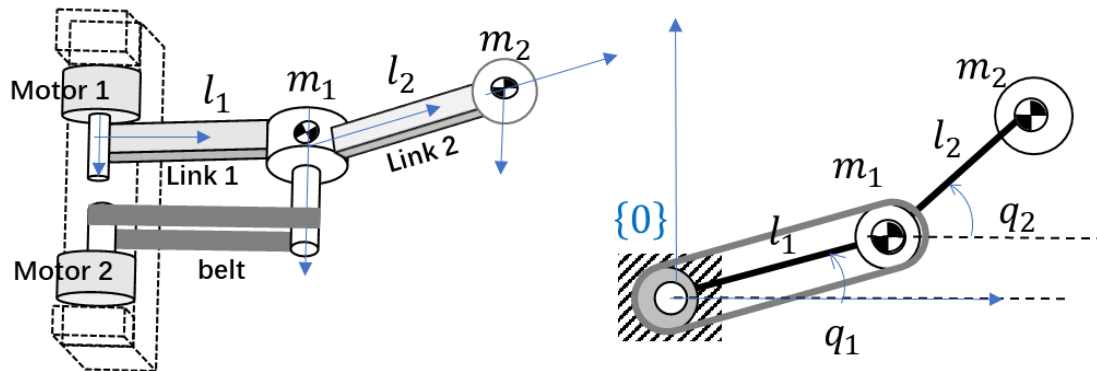


Figure 1

## Question 2.

a) Consider a single-link manipulator arm shown Figure 2.

i) Formulate the dynamic equation factoring coulomb and viscous force acting on the joint and loading due to gravity. You may assume that viscous and coulomb frictions result in resisting moment  $M_v = b_v \dot{\theta}$  and  $M_c = b_c \text{sgn}(\dot{\theta})$ , respectively. (2 Points)

ii) Draw the control block diagram illustrating the use of control law partitioning for the non-linearities in the system. (8 Points)

You may assume negligible mass distribution for the link and assumed lumped mass at the distal time as shown.

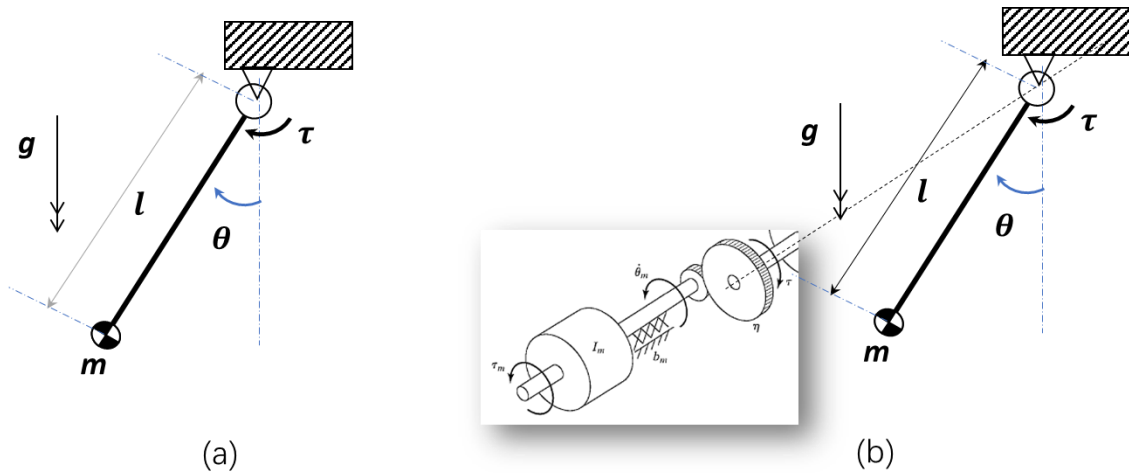


Figure 2 (a)-(b).

b) A DC motor is installed to drive the arm with motor torque  $\tau_m$  input to a gear transmission ratio  $\eta$ .

Show that the dynamics equation can be written as

$$\tau = (\eta^2 I_m + ml^2) \ddot{\theta} + (\eta^2 b_m + b_v) \dot{\theta} + b_c \text{sgn}(\dot{\theta}) + mlg \sin \theta$$

Redesign the control diagram with the dynamics of the actuator in the form of Figure 2(c). State the expression from (i) to (v) (5 Points)

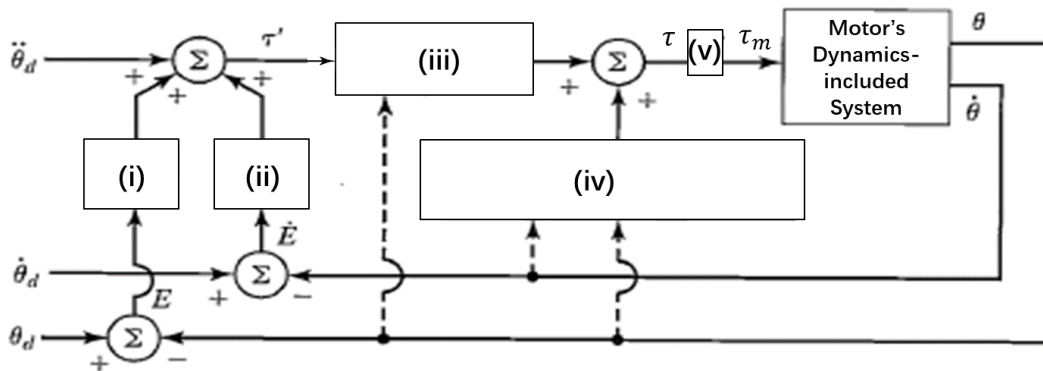


Figure 2 (c)