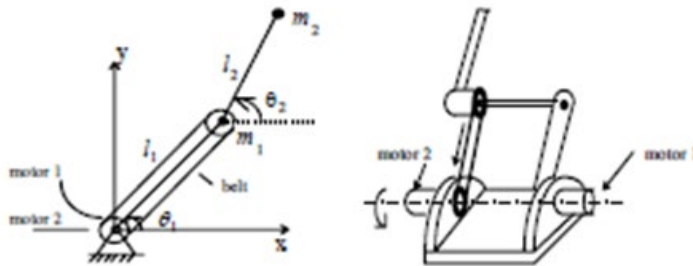


## ECE 470: Introduction to Robotics Homework 3

### Question 1.

A manipulator arm is designed as illustrated by the following figure. It can be assumed that the mass distributions of the links are insignificant and can be treated as lumped equivalent masses  $m_1$  and  $m_2$ .



- a) Write down the position of masses  $m_1$  and  $m_2$  in terms of  $\theta_1$  and  $\theta_2$  referenced from the given frame. (2 marks)
- b) Obtain the velocities  $v_1$  and  $v_2$  of the mass  $m_1$  and  $m_2$ , respectively. (4 marks)
- c) Show that the total kinetic energy of the system,  $K$  can be written as  
$$K = \frac{1}{2}(m_1 l_1^2 + m_2 l_1^2) \dot{\theta}_1^2 + m_2 l_1 l_2 \cos(\theta_2 - \theta_1) \dot{\theta}_1 \dot{\theta}_2 + \frac{1}{2} m_2 l_2^2 \dot{\theta}_2^2$$
 (4 marks)
- d) Obtain the total potential energy of the system. (3 marks)
- e) Write down the Lagrangian  $L$ . (2 marks)
- f) Obtain the equation of motion. (5 marks)