

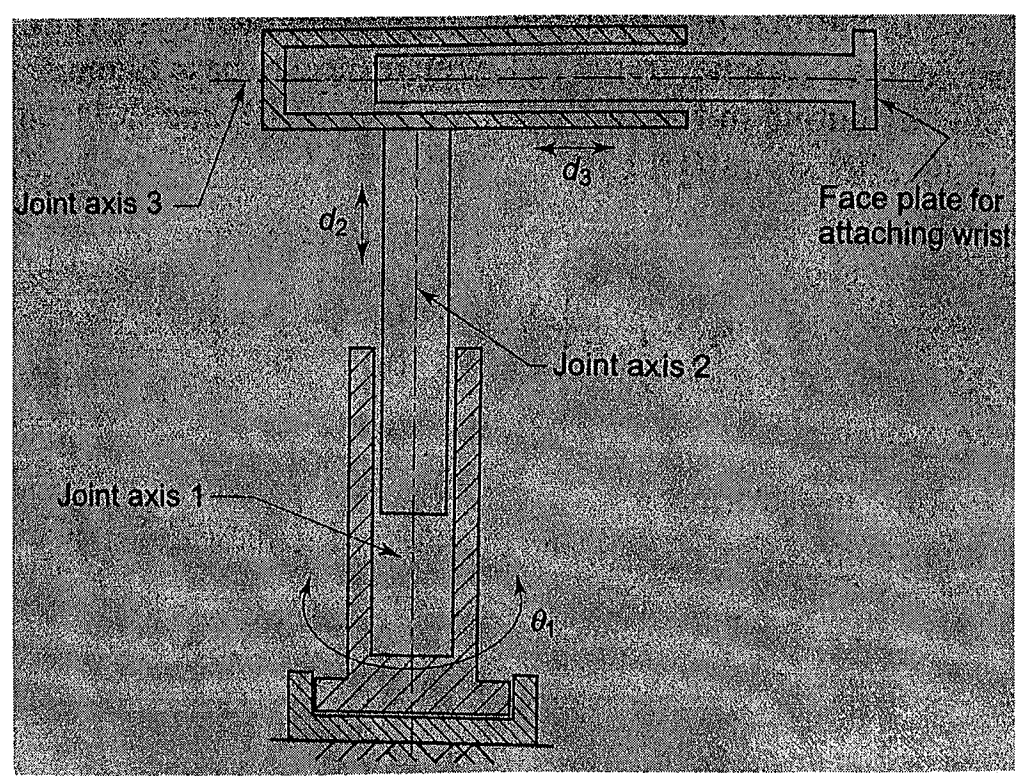
Time: Two (02) Hours

Total 03 Questions  
Answer all questions

1. Define the following terms briefly in terms of robotics where possible with examples.
  - I. Forward Kinematics
  - II. Inverse Kinematics
  - III. Joint
  - IV. Link
  - V. End Effector

(20 marks)

2. FigQ2 shows the mechanical structure of a 3-DOF cylindrical (RPP) manipulator arm. Derive the forward kinematic model for the given manipulator.  $\theta_1$  is the angle of rotation around Joint Axis 1 and  $d_2$  and  $d_3$  are the distances for Prismatic Joints 2 and 3.



FigQ2

(40 marks)

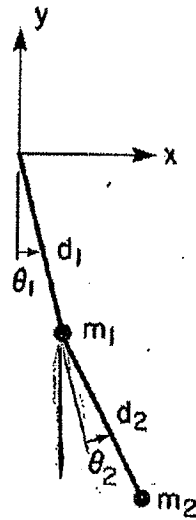
3. In robotics Lagrangian  $L$  is defined as the difference between the kinetic energy  $K$  and the potential energy  $P$  of the system

$$L = K - P$$

The dynamic equations, in terms of the coordinates used to express the kinetic and potential energy, are obtained as

$$F_i = \frac{d}{dt} \frac{\partial L}{\partial \dot{q}_i} - \frac{\partial L}{\partial q_i}$$

Consider the two link manipulator shown in FigQ3 below. The mass of both links  $m_1$  and  $m_2$  is represented by point masses at the end of the links. The links are of lengths  $d_1$  and  $d_2$ , respectively. The manipulator hangs straight down in a gravity field of acceleration  $g$ . The generalized coordinates are chosen as  $\theta_1$  and  $\theta_2$ , as shown in the figure. Obtain the expression for Lagrangian and derive expressions for torques  $T_1$  and  $T_2$  for joints 1 and 2 respectively.



FigQ3

(40 marks)