Group – E
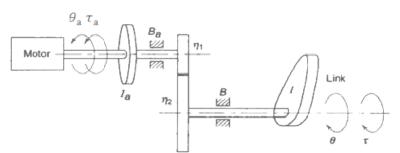
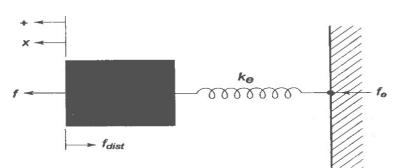8. (a) Write the dynamic equation of any joint i of the manipulator and mention the terms involved in it.

(b)

In the given *actuator –gear–link* assembly of a rotor joint, η, B, θ, τ, I are the gear ratio, viscous friction coefficient, angular displacement, torque and moment of inertia respectively.

i. Derive the effective mathematical model of the *actuator –gear–link* assembly.

ii. Modify the above model for injection of an external disturbance 'D' to the system.

3 + (6 + 3) = 12

9. (a) Explain hybrid position / force control in a robotic arm with example.

(b)

i. Design a force control scheme for the above 1DOF mass spring system by applying PD controller; where f, f_e, f_{dist}, k_e and x are used to represent the control force, reaction force, disturbance force, spring constant and displacement respectively.

ii. Modify the above force control scheme for practical application by considering f_e and f_{dist} are constants.

3 + (5 + 4) = 12

ROBOTICS ENGINEERING
(AEIE 6133)

Time Allotted : 3 hrs　　　　　　　　　　**Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and
any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following:　　　**10 × 1 = 10**

　(i) The main objective(s) of Industrial robot is to
　　(a) to minimise the labour requirement
　　(b) to increase productivity
　　(c) to enhance the life of production machines
　　(d) all of the above.

　(ii) Number degrees of freedom exhibited by robot wrist is,
　　(a) 1　　　　(b) 2　　　　(c) 3　　　　(d) 4 .

　(iii) Piston movement inside the engine cylinder is.................................type of joint.
　　(a) prismatic　　　　　　　　(b) rotational
　　(c) twisting　　　　　　　　(d) revolving.

　(iv) According to D-H algorithm, for a link l_n, if z_{n-1} and z_n axes intersect, which of the following parameter is definitely zero?
　　(a) a_i　　　(b) d_i　　　(c) α_i　　　(d) θ_i .

　(v) Computational complexity for an n-DOF manipulator in Lagrange-Euler formulation is
　　(a) $O(n)$　　(b) $O(n^2)$　　(c) $O(n^3)$　　(d) $O(n^4)$.

　(vi) The device which is used to hold or grasp the objects
　　(a) end effectors　　　　　　(b) gripper
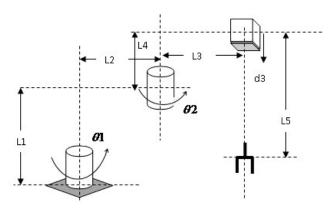　　(c) manipulator　　　　　　(d) joint.

(vii) A blacksmith's tong has _____ DOF.
   (a) 2   (b) 4   (c) 6   (d) 3.

(viii) Which controller / controllers can be used for linear robotic control?
   (a) PID   (b) PI
   (c) PD   (d) any of the above.

(ix) For revolute type joint the only variable among the D-H parameters is
   (a) θ_i (b) d_i
   (c) α_i (d) a_i .

(x) For a manipulator, the reachable workspace (RWS) is _____ compared to dexterous workspace (DWS)
   (a) smaller   (b) same
   (c) larger   (d) both (b) and (c).

Group - B

2. (a) What does open kinematic chain means? Describe the spherical arm configuration with a neat sketch.

   (b) Find the D-H parameters for the manipulator shown below.

(2 + 4) + 6 = 12

3. (a) Explain the role of environment sensors used in robotic systems.

   (b) Describe the operation of a proximity sensor with suitable diagram. State the guidelines for selecting correct sensors for robotic applications.
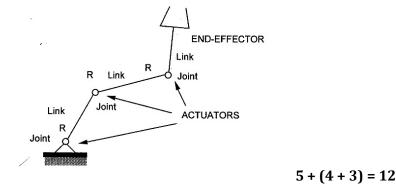
4 +(5 + 3) = 12

Group – C

4. (a) Define Serial chain and kinematic chain. Draw the diagram of a revolute- prismatic planar manipulator.

   (b) What is the mobility of a chain? Write its mathematical expression.

   (c) Distinguish between direct kinematics and inverse kinematics.

(3 + 2) + (1 + 2) + 4 = 12

5. (a) Derive the inverse kinematics of a 2D robotic arm.

   (b) A schematic of a planar manipulator with three revolute joints is shown in the figure below. Derive (i) forward and (ii) reverse kinematics of the system by considering different link length and corresponding angles between the links.

5 + (4 + 3) = 12

Group – D

6. (a) What does Jacobian singularities mean? Discuss the categories of singular configurations.

   (b) Determine the rotation matrix for a rotation of 45° about y-axis, followed by a rotation of 120° about z-axis, and a final rotation of 90° about x-axis.

(2 + 4) + 6 = 12

7. (a) State the objective of trajectory planning. Discuss the steps involved in joint space trajectory planning technique.

   (b) Compute the transformation matrix relating two frames attached to the adjacent links.

(2 + 6) + 4 = 12