(3 Hours) [Total Marks: 80]

NB.
(1) **Question No.1 is compulsory.**
(2) **Attempt any three questions from remaining.**
(3) **All questions carry equal marks.**
(4) **Assume suitable data wherever necessary.**

Q.1] Answer **any four** of the following :- **(20 Marks)**

(a) Define the terms 'path' & 'trajectory'. What is the difference between them?
(b) Explain what is direct kinematics & inverse kinematics?
(c) Describe Generalized Voronoi Diagrams (GVD) with a neat sketch.
(d) Explain edge detection in robotic vision.
(e) Write a short note on fine motion planning with a neat sketch.

Q.2] (a) Explain significance & use of the Denavit-Hartenberg (D-H) algorithm. **(05 Marks)**
(b) Develop DH representation of a four axis SCARA robot and obtain its arm matrix. **(10 Marks)**

(c) Define & explain kinematic joint and link parameters with a neat sketch. **(05 Marks)**

Q.3] (a) With a neat sketch, explain the typical four point, pick & place trajectory for carrying out pick & place operation. Define pick-up point, lift-off point, set-down point & place point. **(10 Marks)**

(b) In detail, explain continuous path motion & interpolated motion with appropriate sketches wherever necessary. **(10 Marks)**

Q.4] (a) Obtain inverse kinematic analysis of a 2 axis planar robot as shown in Fig. 4.1 as below:-
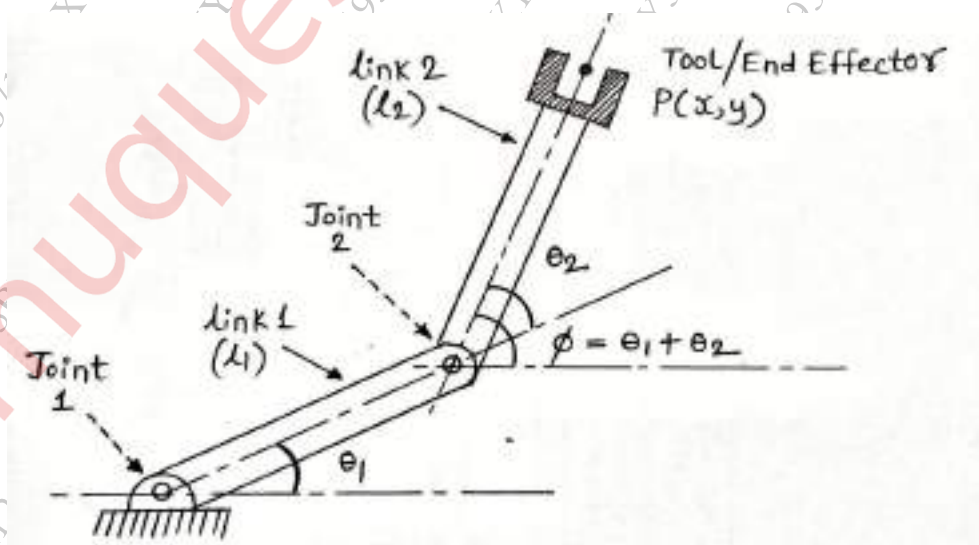
(10 Marks)

Fig. 4.1 – Planar two link manipulator robotic arm for Q.4 (a)

(b) Classify robots based on the drive technology used, the work envelope geometry & motion control methods with neat sketches wherever necessary. **(10 Marks)**

Q.5] (a) Evaluate the trajectory profile of position, velocity & acceleration for a 1 DOF planar robotic manipulator such that initial angular position $\theta_o = 0°$ & final angular position $\theta_f = 120°$ with a 15 second movement from point A to point B ($t_o = 10$ sec. & $t_f = 25$ sec.). Assume velocities at each points are zero ($v_o = v_f = 0$ °/sec.) **(10 Marks)**

(b) What is a robot programming language ? Describe the different types of robotic programming languages in detail. **(10 Marks)**

Q.6] Attempt **any four** of the following **(20 Marks)**

(a) Write a short note on image segmentation in robot vision.

(b) What is workspace analysis ? Define joint space work envelope, total work envelope & dexterous work envelope.

(c) Describe linear interpolated motion with parabolic blends, giving neat sketches as appropriate.

(d) Explain grasp planning with a neat sketch.

(e) Describe the following robot specifications / characteristics (any five) with appropriate units & draw a neat sketch as required :-

   (i) No. of axes & degrees of freedom (DOF)

   (ii) Maximum speed & load carrying capacity

   (iii) Reach & stroke

   (iv) Tool orientation

   (v) Repeatability, accuracy & precision

   (vi) Operating environment

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