Exam.Code:0941
Sub. Code: 33864

2124

B. E. (Mechanical Engineering)
Fifth Semester
MEC-503: Robotics

Time allowed: 3 Hours **Max. Marks: 50**

***NOTE:** Attempt <u>five</u> questions in all, including Question No. I which is compulsory and selecting two questions from each Part.*

x-x-x

Question 1:

a) Why is the concept of solvability critical in inverse manipulator kinematics?
b) Why is Pieper's solution considered an important approach in inverse kinematics?
c) Why is feedback essential in the closed-loop control of manipulators?
d) Discuss the importance of selecting an appropriate kinematic configuration in manipulator design.
e) Describe the roles of force and position sensing in manipulator control.

[10 marks]

Part A

Question 2:

a. Explain the significance of homogeneous transformation matrices in spatial descriptions of robotic systems. How do these matrices combine position and orientation in a single representation?
b. Discuss how frames are conventionally affixed to robotic links. Why is it important to follow a systematic approach, such as the Denavit-Hartenberg (D-H) convention, for frame assignment in robotic manipulators?

[10 marks]

Question 3:

a. Explain the concept of solvability in inverse manipulator kinematics. What factors determine whether an inverse kinematics problem has a unique solution, multiple solutions, or no solution?
b. Compare algebraic and geometric methods for solving inverse kinematics. Discuss the advantages and limitations of each approach with examples.

[10 marks]

Question 4: A planar two-link robotic manipulator has the following parameters: Link 1: Length $L1=2$ m, joint angle $\theta1=45$ degree, Link 2: Length $L2=1$ m, joint angle $\theta2=30$ degree
a. Derive the Jacobian matrix for the manipulator using its forward kinematics.
b. If a force $F=[10,15]^T$ N acts on the end-effector in the Cartesian space, calculate the joint torques required to maintain static equilibrium.
c. Analyze how changes in the angles $\theta1$ and $\theta2$ affect the Jacobian matrix and the resulting torques.

[10 marks]

Part B

Question 5:

a. Explain the Newton-Euler formulation for deriving the dynamic equations of a robotic manipulator. How does it account for both linear and angular accelerations of the links?
b. Discuss the iterative nature of the Newton-Euler method and its advantages for multi-link robotic systems. Highlight the difference between forward and backward iterations in this approach.

[10 marks]

Question 6:

A robotic manipulator moves its end-effector from an initial position with joint angles:
$\theta 1=30$ degree, $\theta 2=45$ degree to a final position with joint angles:
$\theta 1=60$ degree, $\theta 2=90$ degree in 5 seconds using a cubic polynomial trajectory.
a. Write the general cubic polynomial equation for joint motion and determine the coefficients assuming zero initial and final velocities.
b. Calculate the joint angles $\theta 1$ and $\theta 2$ at t=2.5 seconds.

[10 marks]

Question 7:

a. Compare and contrast proximity sensors and range sensors in terms of working principles, advantages, and limitations. Provide examples of applications in robotic systems for each.
b. Explain the role of force and tactile sensors in robotics. How do these sensors enable robots to perform tasks like object manipulation or assembly in dynamic environments?

(10 marks)

x-x-x