**Mechanical Engineering Department, IIT Kharagpur**

**Test 1 (27th March 2020 @ 10 AM)**

Subject Code: ME60412 Subject: Mechanism and Robot Kinematics Time: 1 Hr

Name: Roll No:

*Instructions:* Answer all questions in a copy of this doc file – use additional space to attach any scanned document if you use physical paper for your work. If any additional information is required the data may be assumed with adequate reasoning. Marks for each question are stated in brackets.

Q 1. Answer the following (5+3+2)

* 1. Write down the rotation matrix for rotation about Y axis by angle phi followed by rotation about X axis by angle theta. Write the steps to obtain the inverse solution. (Determination of angles from the matrix).
  2. Show the difference in obtaining the rotation matrices for Fixed Angle and Euler Angle rotations. How many possible combinations exist of each?
  3. Given *k = [ax ay az]T*, what is ? Explain any two properties of .

Q 2. A frame {B} is located initially coincident with a frame {A}. Rotate {B} about YB by 30 degrees, and then rotate the resulting frame about ZB by 45 degrees. Give the rotation matrix that will change the description of a point on a rigid body described vector *A* ***p*** to*B* ***p***. How will you represent above using exponential matrices? (6+4)

Q 3. What is the unit quaternion? Why is it useful? Write the unit quaternion of the case given in question 1(i) and describe its inverse. (10)

Q 4. For the 3 link planar manipulator shown in Figure 1 below derive the velocity Jacobian for the reference point velocities [ , ωx, ωy] vector in terms of input angles [1,2,3]. In brief mention how singularities are identified with this method and how to determine the Force Jacobian. (10)

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| Figure 1 |  |