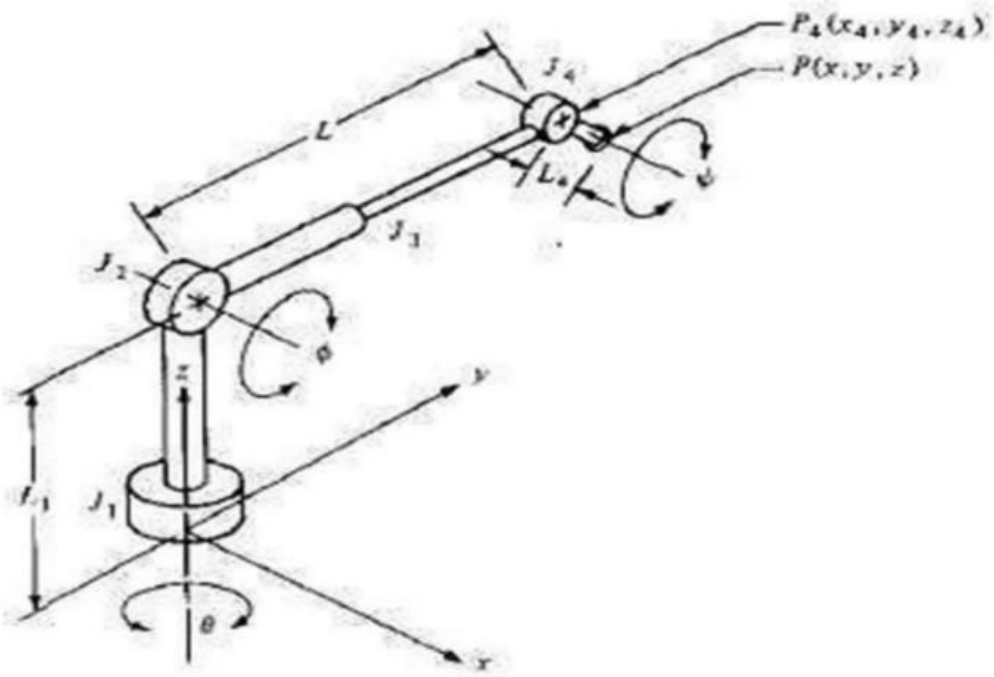
Forward and inverse kinematics of manipulato with 4 Degrees of Freedom in 3 Dimension

- **A 4-Degree of Freedom Manipulator in (3D) Three Dimensions:**
  - The configuration of a manipulator in three dimensions. The manipulator has 4 degrees of freedom: joint I (type T joint) allows rotation about the z axis; joint 2 (type R) allows rotation about an axis that is perpendicular to the z axis; joint 3 is a linear joint which is capable of sliding over a certain range; and joint 4 is a type R joint which allows rotation about an axis that is parallel to the joint 2 axis. Thus, we have a TRL: R manipulator.



- Let us define the angle of rotation of joint I to be the base rotation 0; the angle of rotation of joint 2 will be called the elevation angle 4.;
- The length of linear joint 3 will be called the extension L (L-represents a combination of links 2 and 3);
- and the angle that joint 4 makes with the x — y plane will be called the pitch angle 4.
- The position of the end of the wrist, P, defined in the world coordinate system for the robot.

of the joint positions relative to the world coordinate system. Using P_4 (x_4, y_4, z_4), which is the position of joint 4, as an example,

$$x_4 = x - \cos\theta(L_4 \cos\psi) \quad (4\text{-}12)$$

$$y_4 = y - \sin\theta(L_4 \cos\psi) \quad (4\text{-}13)$$

$$z_4 = z - L_4 \sin\psi \quad (4\text{-}14)$$

The values of L, ϕ, and θ can next be computed:

$$L = [x_4^2 + y_4^2 + (z_4 - L_1)^2]^{-1} \quad (4\text{-}15)$$

$$\sin\phi = \frac{z_4 - L_1}{L} \quad (4\text{-}16)$$

$$\cos\theta = \frac{y_4}{L} \quad (4\text{-}17)$$