2.7 Measured data in millimeters for the position coordinates of three points of a moving body are known such that:

$$\boldsymbol{r}_1 = \begin{bmatrix} 50 \\ 0 \\ 0 \\ 1 \end{bmatrix}, \qquad \boldsymbol{r}_2 = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}, \qquad \boldsymbol{r}_3 = \begin{bmatrix} 0 \\ 125 \\ 0 \\ 1 \end{bmatrix},$$

$$\boldsymbol{R}_1(t_1) = \begin{bmatrix} 37.325 \\ -98.175 \\ 132.045 \\ 1 \end{bmatrix}, \quad \boldsymbol{R}_2(t_1) = \begin{bmatrix} 71.800 \\ -118.925 \\ 161.725 \\ 1 \end{bmatrix}, \quad \boldsymbol{R}_3(t_1) = \begin{bmatrix} 152.450 \\ -28.425 \\ 131.225 \\ 1 \end{bmatrix}.$$

Find the (4×4) homogeneous transformation matrix for this displacement.

2.11 Consider a robot end-effector with two coordinate systems attached to it as illustrated in Figure P2.17*a*. One coordinate system is attached to the end-effector with its origin at the wrist center point and the other is attached to the tip of the end-effector. The kinematic structure of the wrist is a spherical linkage and is illustrated in Figure P2.17*b*.

Show that if we use the coordinate system attached to the end-effector at the wrist center point, the order in which we perform the roll, pitch, and yaw rotations is irrelevant; however, if we use the coordinate system attached to the end effector at its tip then the order does make a difference unless we are only concerned with differential or instantaneous rotations.

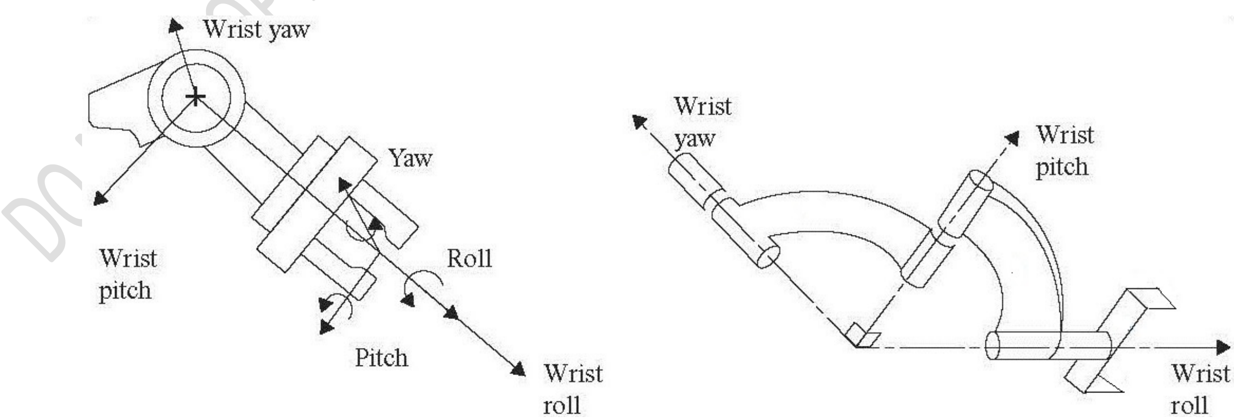

Figure P2.15 (*a*) (*b*)