ROBOTICS FUNDAMENTALS -EXAMPLE SHEET 1

Goals: Coordinate Frames, Analyze forward kinematics (placement of frames, assignment of DH parameters).

Question 1: For the following homogeneous transformation matrix, find the values of the missing elements:

$$T = \begin{bmatrix} ? & 0 & -1 & -1 \\ ? & 0 & 0 & 5 \\ ? & -1 & 0 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Question 2: Calculate the homogeneous transformation matrix for the following transform sequence that describes frame $\{1\}$ with respect to the reference frame:

Trans(4,-3,7)Rot(x,-60)Rot(y,45)Rot(z,90)

What is the origin of this frame (with respect to the reference frame)? What are the coordinates of a point at $(1, 1, 1)$ in frame $\{1\}$ with respect to the reference frame?

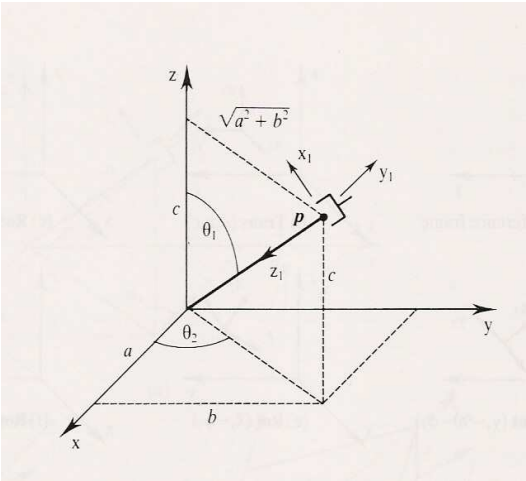
Question 3: A robot base (R) and an object (O) are located in the world (W) coordinate system. The robot end-effector is grasping the object so that the end-effector frame is aligned with the object frame (same orientation) but the object position is offset 2 units along the z axis of the end-effector frame so we have:

$${}^{E}T_{O} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

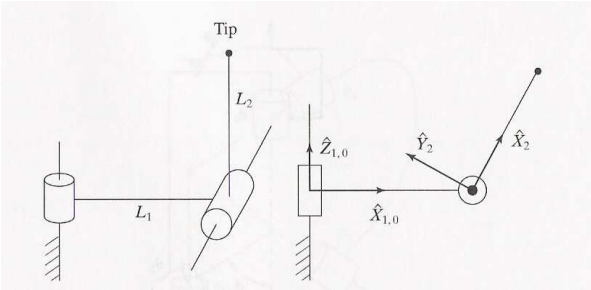
Given the following transformation matrices, find the transformation from the base of the robot to the end-effector of the robot.

$${}^{W}T_{O} = \begin{bmatrix} 1 & 0 & 0 & 11 \\ 0 & 0 & -1 & 14 \\ 0 & 1 & 0 & 20 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad {}^{W}T_{R} = \begin{bmatrix} 0 & -1 & 0 & 2 \\ 1 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Question 4: The hand of a robot is to be located at the location (a, b, c) and pointing towards the origin (as shown) - the z axis of the hand frame points towards the origin. What is the transformation matrix from the origin of the reference frame to the hand?



Question 5: Consider the two-link manipulator shown:



The link-transformation matrices ${}^0T_1$ and ${}^1T_2$ were constructed. Their product is

$$ {}^0T_2 = \begin{bmatrix} c\theta_1 c\theta_2 & -c\theta_1 s\theta_2 & s\theta_1 & l_1 c\theta_1 \\ s\theta_1 c\theta_2 & -s\theta_1 s\theta_2 & -c\theta_1 & l_1 s\theta_1 \\ s\theta_2 & c\theta_2 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

The link-frame assignments are shown on the right hand side - note that frame $\{0\}$ is coincident with frame $\{1\}$ when $\theta_1 = 0$. The length of the second link is l_2. Find an expression for the vector ${}^0P_{tip}$, which locates the tip of the arm relative to the $\{0\}$ frame.