

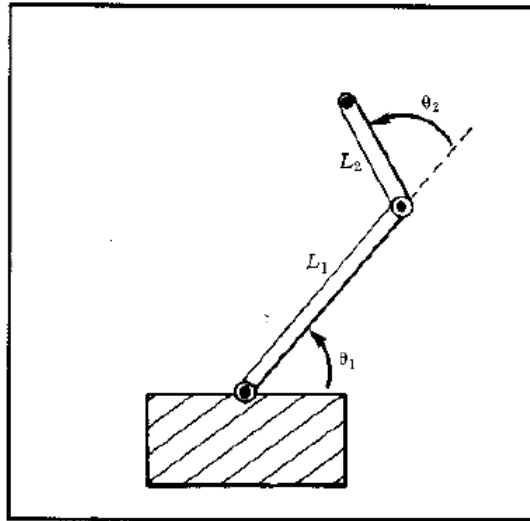


- 1) Figure bellow shows a two link planer arm with rotary joints. for this arm the second link is half as long as the first that is:  $l_1 = 2l_2$ . the joint range limits in degrees are:

$$0 \leq \theta_1 \leq 180$$

$$-90 \leq \theta_2 \leq 180$$

Sketch the approximate reachable workspace of the manipulator of the link2



- 2-a) Show that the distance between points is not changed by rotation i.e.:

$$\|Rp_1 - Rp_2\| = \|p_1 - p_2\|$$

- 2-b) For rotation matrix R prove  $R^T R = I$

- 3) Compute the rotation matrix given by the product:

$$R_{x,\theta} R_{y,\phi} R_{z,\pi} R_{y,-\phi} R_{x,-\theta}$$



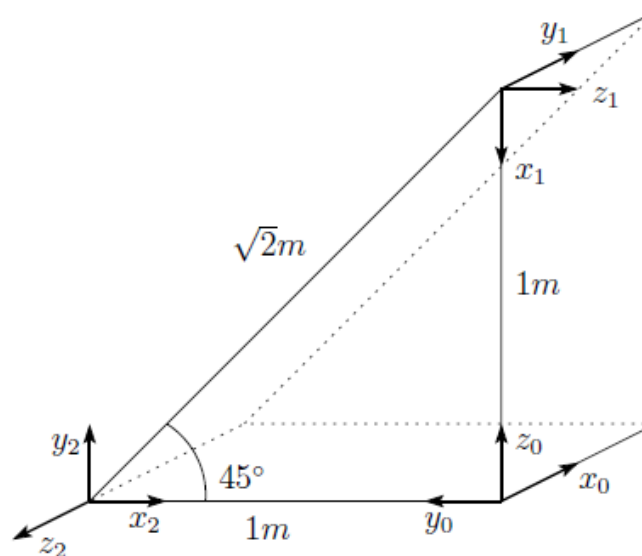
4) Given the following  $3 \times 3$  matrix

$$R = \begin{bmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{1}{\sqrt{2}} & \frac{1}{2} \\ -\frac{1}{2} & -\frac{1}{\sqrt{2}} & \frac{1}{2} \end{bmatrix}$$

- a) Show that it is a rotation matrix.
- b) What is the Euler parameter representing R.

5) Consider the diagram of figure bellow find homogenous transformation representing the transformation  $H_2^0, H_1^0, H_2^1$  among the three frames shown.

Show that:  $H_2^0 = H_1^0 H_2^1$



Good Luck!