**Zagazig University, Faculty of Engineering** | **Mid-term Exam** | **Date: 9/1/2016**
**Academic year:** 2015-2016 | **Exam Time: 45 Min.**
**Specialization:** Computer and Systems | **No. of pages: 6**
**Course Name:** Selective Course (5) | **No. of Questions: 5**
**Course Code :** CSE4316 | **Full Mark**: 80
**Examiners:** Dr.\ Mohammed Nour

**a)** Write your solutions in the space provided. If you need more space, write on the back of the sheet containing the questions.
**b)** The exam is in **6 pages**. Page 6 contains supplementary material that may be needed.
**c)** Please show all work. **Intermediate steps must be legible to receive credit**.

| **No.** | **الاسم :** |
|---|---|

## Problem 1 [12 Marks]

For each of the following statements:

(a) Check (✓) for true or (✕) for the false.
(b) Give short comment for the correct one and correct the false one.

| | |
|---|---|
| 1. A rover is a kind of industrial robots. | |
| ........................................ | |
| 2. The inverse of the rotation matrix is its transpose. | |
| ........................................ | |
| 3. The dimension of SO(3) is 3. | |
| ........................................ | |
| 4. If $r_1$ and $r_2$ are two rows in a rotation matrix, then $r_1 r_2^T = 0$. | |
| ........................................ | |

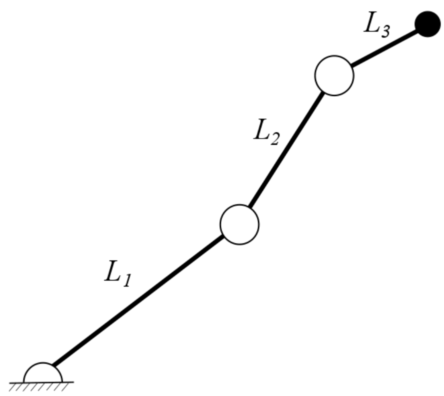
**Problem 2** [2+10= 12 Marks]

For the three link manipulator shown in figure:

a) What is the term for the set of all points that the end effector can reach?

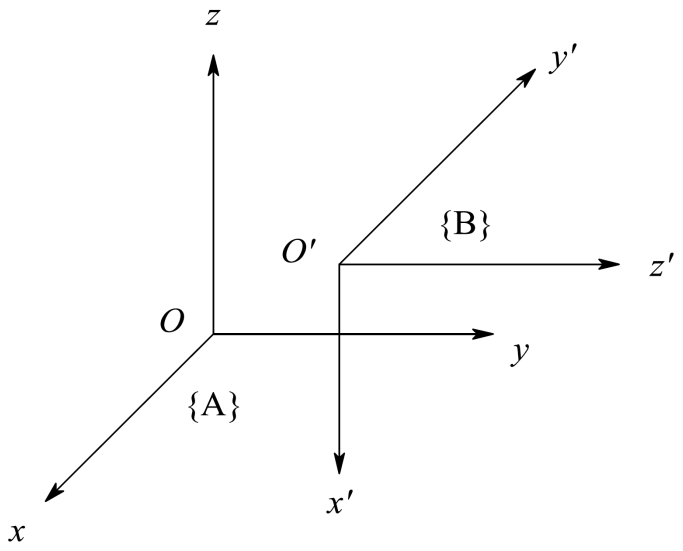
………………………………………………………………………………………

b) Draw the set of all points that the end effector can reach where the base joint angle is limited to 0° to 180°, $L_1 > L_2 > L_3$ and $L2 + L3 < L1$.



## Problem 3 [4+4+4+4= 16 Marks]

Two coordinate frames *A(x, y, z)* and *B(x', y', z')* are shown below. The origin of *{B}* with respect to *{A}* is given by $[1\ 2\ 3]^T$




Find $H_B^A$ (i.e. $^A B$, the homogeneous transformation matrix to represent B w.r.t. A).

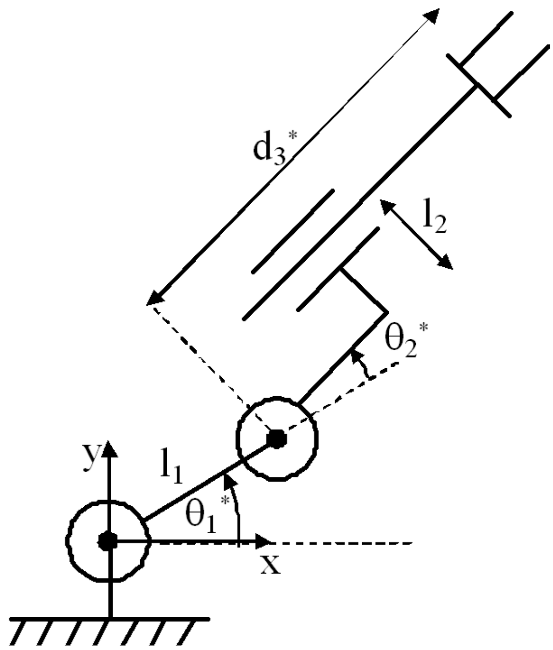
**Problem 4** [2+18 = 20 Marks]

A planar 2–link RRP robot is given in the figure below.

a) What are its configuration space variables?

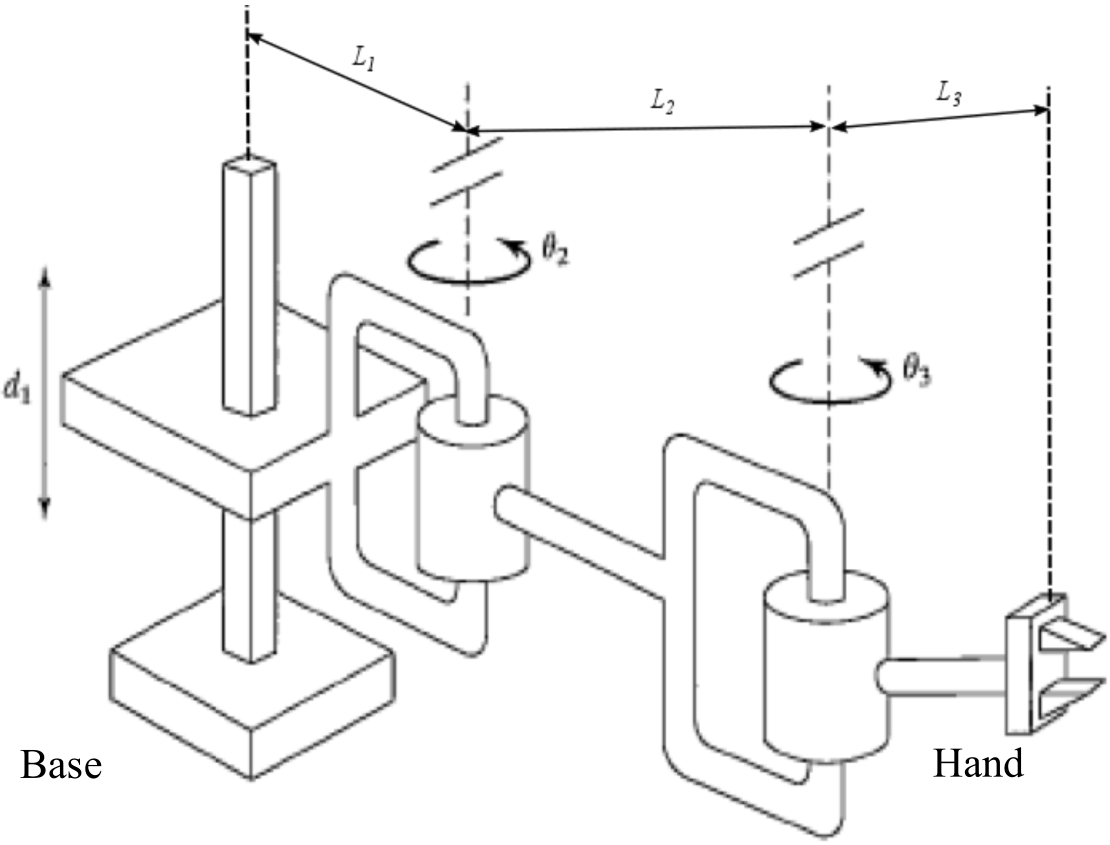
…………………………………………………………………………………………

b) Find its forward kinematics



**Problem 5** [4+6+3+7= 20 Marks]

For the three-link PRR manipulator shown in the following figure
(a) Assign appropriate frames for D-H representation (draw them on the figure).
(b) Fill out the D-H parameters table.
(c) Write all the *A* matrices.
(d) Write the $H_H^0$ (hand frame relative to base frame) in terms of the *A* matrices.



## Supplementary Material

Note: you may need some or none of these identities:

$$R_X(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix},$$

$$R_Y(\theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix},$$

$$R_Z(\theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}.$$

$$A_i = \begin{bmatrix} \cos\theta_i & -\cos\alpha_i \sin\theta_i & \sin\alpha_i \sin\theta_i & a_i \cos\theta_i \\ \sin\theta_i & \cos\alpha_i \cos\theta_i & -\sin\alpha_i \cos\theta_i & a_i \sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\sin\theta = -\sin(-\theta) = -\cos(\theta + 90°) = \cos(\theta - 90°),$$

$$\cos\theta = \cos(-\theta) = \sin(\theta + 90°) = -\sin(\theta - 90°).$$

$$\cos(\theta_1 \pm \theta_2) = c_{12} = c_1 c_2 \mp s_1 s_2,$$

$$\sin(\theta_1 \pm \theta_2) = s_{12} = c_1 s_2 \pm s_1 c_2,$$

$$c^2\theta + s^2\theta = 1.$$

$$A^2 = B^2 + C^2 - 2BC\cos a.$$

$$\sin(\alpha \mp \beta) = \sin\alpha\cos\beta \mp \sin\beta\cos\alpha$$

$$\cos(\alpha \mp \beta) = \cos\alpha\cos\beta \pm \sin\beta\sin\alpha$$

$$if \quad \cos\theta = b \quad then \quad \theta = A\tan 2(\pm\sqrt{1-b^2}, b)$$

$$if \quad \sin\theta = b \quad then \quad \theta = A\tan 2(b, \pm\sqrt{1-b^2})$$

$$if \quad a\cos\theta + b\sin\theta = c \quad then \quad \theta = A\tan 2(b,a) + A\tan 2(\pm\sqrt{a^2+b^2-c^2}, c)$$

$$if \quad a\cos\theta - b\sin\theta = 0 \quad then \quad \theta = A\tan 2(a,b) \quad and \quad \theta = A\tan 2(-a,-b)$$