

Setup

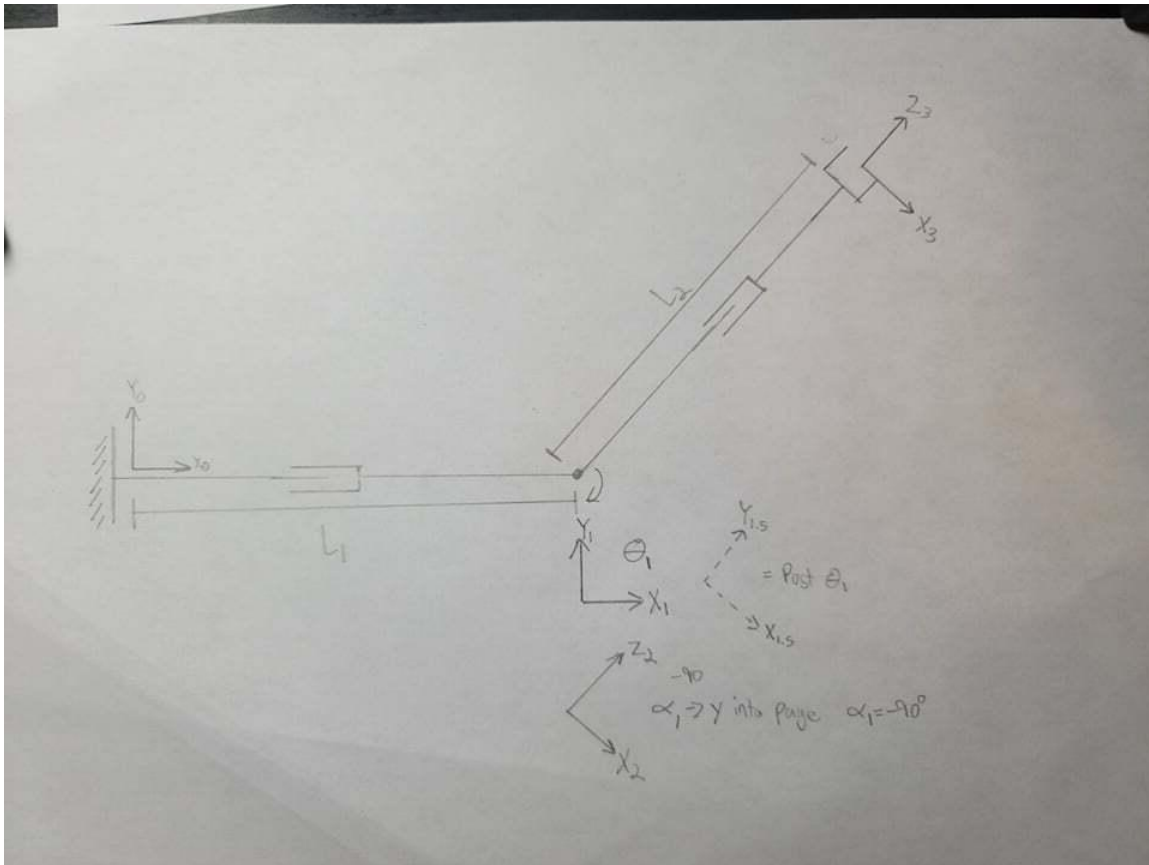
```
sympref('AbbreviateOutput', false);
```

Question 1

1. Done

2.
$$\begin{bmatrix} n+1 & \theta & d & a & \alpha \\ 1 & 0 & 0 & L_1 & 0 \\ 2 & \theta_1 & 0 & 0 & -90 \\ 3 & 0 & L_2 & 0 & 0 \end{bmatrix}$$
 The joint variables are L_1, θ_1 .

3.



4.

```
syms L1 L2 theta1
A1 = create_identity(4) * translate_frame([L1 0 0])
```

A1 =

$$\begin{pmatrix} 1 & 0 & 0 & L_1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

```
A2 = rotate('Z', theta1) * rotate('X', -90)
```

A2 =

$$\begin{pmatrix} \cos(\theta_1) & 0 & -\sin(\theta_1) & 0 \\ \sin(\theta_1) & 0 & \cos(\theta_1) & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

```
A3 = translate_frame([0 0 L2])
```

A3 =

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & L_2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

```
T = simplify(A1* A2 * A3)
```

T =

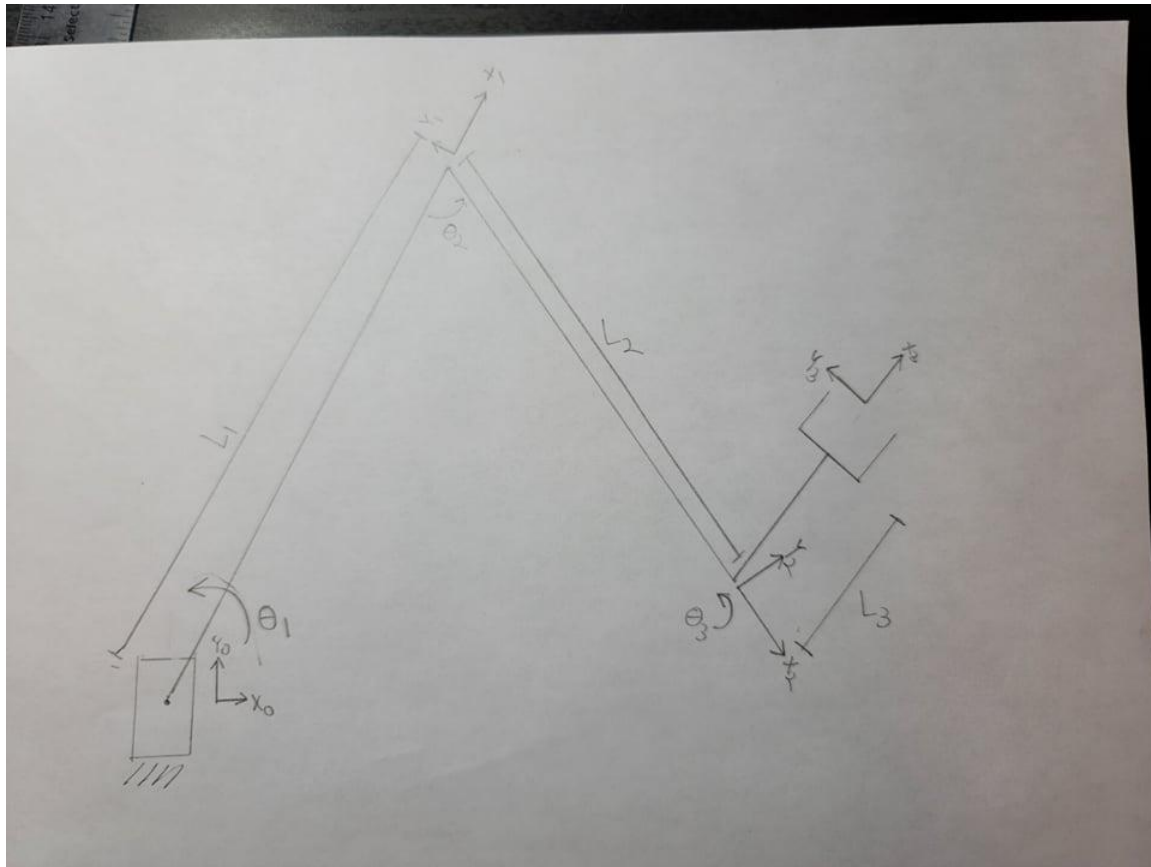
$$\begin{pmatrix} \cos(\theta_1) & 0 & -\sin(\theta_1) & L_1 - L_2 \sin(\theta_1) \\ \sin(\theta_1) & 0 & \cos(\theta_1) & L_2 \cos(\theta_1) \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Question 2

1. Done

2.
$$\begin{bmatrix} n+1 & \theta & d & a & \alpha \\ 1 & \theta_1 & 0 & L_1 & 0 \\ 2 & \theta_2 & 0 & L_2 & 0 \\ 3 & \theta_3 & 0 & L_3 & 0 \end{bmatrix}$$
 The joint variables are $\theta_1, \theta_2, \theta_3$.

3.



4.

```
syms theta1 theta2 theta3 L1 L2 L3
```

```
A1 = create_identity(4) * rotate('Z', theta1) * translate_frame([L1 0 0])
```

A1 =

$$\begin{pmatrix} \cos(\theta_1) & -\sin(\theta_1) & 0 & L_1 \cos(\theta_1) \\ \sin(\theta_1) & \cos(\theta_1) & 0 & L_1 \sin(\theta_1) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

```
A2 = create_identity(4) * rotate('Z', theta2) * translate_frame([L2 0 0])
```

A2 =

$$\begin{pmatrix} \cos(\theta_2) & -\sin(\theta_2) & 0 & L_2 \cos(\theta_2) \\ \sin(\theta_2) & \cos(\theta_2) & 0 & L_2 \sin(\theta_2) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

```
A3 = create_identity(4) * rotate('Z', theta3) * translate_frame([L3 0 0])
```

A3 =

$$\begin{pmatrix} \cos(\theta_3) & -\sin(\theta_3) & 0 & L_3 \cos(\theta_3) \\ \sin(\theta_3) & \cos(\theta_3) & 0 & L_3 \sin(\theta_3) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

```
T = simplify(A1* A2 * A3);
```

T =

$$\begin{pmatrix} \cos(\theta_1 + \theta_2 + \theta_3) & -\sin(\theta_1 + \theta_2 + \theta_3) & 0 & L_2 \cos(\theta_1 + \theta_2) + L_1 \cos(\theta_1) + L_3 \cos(\theta_1 + \theta_2 + \theta_3) \\ \sin(\theta_1 + \theta_2 + \theta_3) & \cos(\theta_1 + \theta_2 + \theta_3) & 0 & L_2 \sin(\theta_1 + \theta_2) + L_1 \sin(\theta_1) + L_3 \sin(\theta_1 + \theta_2 + \theta_3) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$