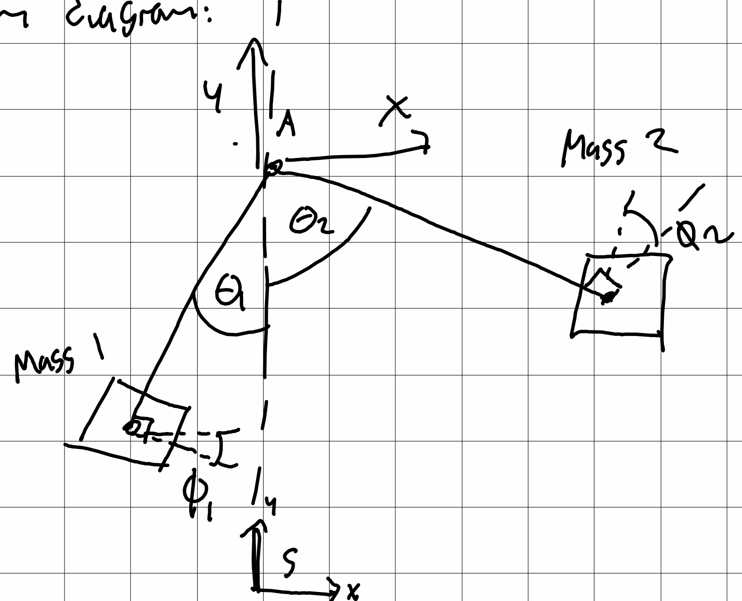
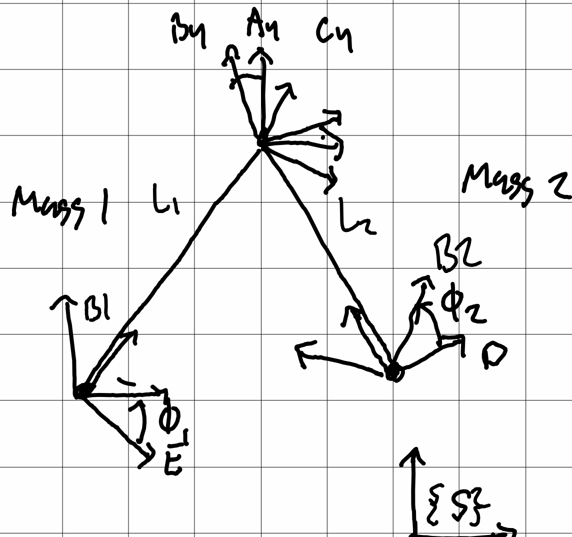
System diagram:

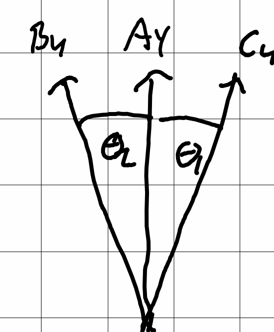


Variables to specify state: $x, y, \theta_1, \theta_2, \phi_1, \phi_2$

System frames:



Enlarged:



Transformation matrices: Right Side

$$R_{AB} = \begin{bmatrix} \cos\theta_2 & -\sin\theta_2 & 0 \\ \sin\theta_2 & \cos\theta_2 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad P_{BD} = \begin{bmatrix} 0 \\ -L_2 \\ 0 \end{bmatrix}$$

$$R_{DB2} = \begin{bmatrix} \cos\phi_2 & -\sin\phi_2 & 0 \\ \sin\phi_2 & \cos\phi_2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

"$SE3(R, P)$" yields

$$\begin{bmatrix} R & P \\ 0 & 1 \end{bmatrix}$$

$G_{AB} = SE3(R_{AB}, [0, 0, 0])$
$G_{BD} = SE3(I, P_{BD})$
$G_{DB2} = SE3(R_{DB2}, [0, 0, 0])$

$G_{SA} = SE3(I, [x, y, 0])$
$G_{SB} = G_{SA} @ G_{AB}$
$G_{SD} = G_{SB} @ G_{BD}$

$G_{SB2} = G_{SD} @ G_{DB2}$

"@" means matrix multiplication in both Sympy and Numpy

"I" = identity mat., 3x3

Transformation matrices: left side

$$R_{AC} = \begin{bmatrix} \cos(\theta_1) & -\sin(\theta_1) & 0 \\ \sin(\theta_1) & \cos(\theta_1) & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad P_{CE} = \begin{bmatrix} 0 \\ -l_1 \\ 0 \end{bmatrix}$$

$$R_{EB1} = \begin{bmatrix} \cos\phi_1 & -\sin\phi_1 & 0 \\ \sin\phi_1 & \cos\phi_1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$G_{AC} = SE3(R_{AC}, [0,0,0])$
$G_{CE} = SE3(I, P_{BO})$
$G_{EB1} = SE3(R_{EB1}, [0,0,0])$

$G_{SA} = SE3(I, [x, y, 0])$
$G_{SC} = G_{SA}$ @ G_{AC}
$G_{SE} = G_{SC}$ @ G_{CE}
$G_{SB1} = G_{SE}$ @ G_{EB1}

Positions of Importance

$y_{m1} = G_{SB1}$ @ [0, 0, 0, 1] [index 1]
$y_{m2} = G_{SB2}$ @ [0, 0, 0, 1] [index 1]
posn_top = G_{SA} @ [0, 0, 0, 1] [0:2]