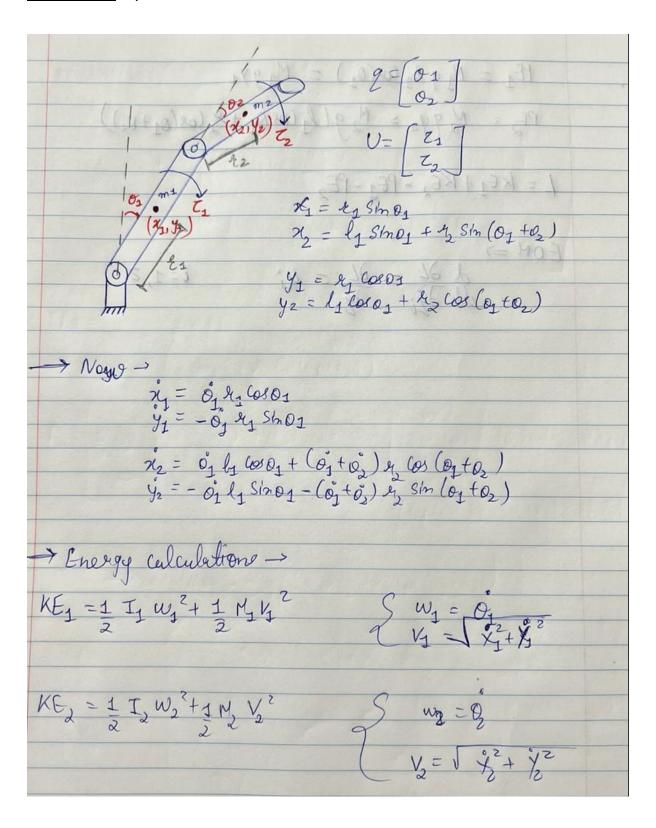
## **Problem a:** Equations of Motion



$$PE_{1} = M_{1}g A_{1} cos(O_{1}) = M_{1}g y_{1}$$

$$PE_{2} = M_{2}g y_{2} = M_{2}g (l_{1} cos O_{1} + l_{2} cos(O_{1} + O_{2}))$$

$$L = kE_{1} + kE_{2} - PE_{1} - PE_{2}$$

$$EON = 3$$

$$l = 2L - 2L = 4i$$

$$l = 1, 2$$

$$l = 1, 2$$

## **Equations of Motion -**

$$\begin{array}{l} \textit{tau1} = \text{I1}* \text{theta1}_{\text{ddot}} + \text{L1}^2* \text{M2}* \text{theta1}_{\text{ddot}} + \text{M1}* \text{r1}^2* \text{theta1}_{\text{ddot}} + \\ \text{M2}* \text{r2}^2* \text{theta1}_{\text{ddot}} + \text{M2}* \text{r2}^2* \text{theta2}_{\text{ddot}} - \text{M2}* \text{g}* \text{r2}* \text{sin}(\text{theta1} + \text{theta2}) \\ - \text{L1}* \text{M2}* \text{g}* \text{sin}(\text{theta1}) - \text{M1}* \text{g}* \text{r1}* \text{sin}(\text{theta1}) - \\ \text{L1}* \text{M2}* \text{r2}* \text{theta2}_{\text{dot}}^2* \text{sin}(\text{theta2}) + 2* \text{L1}* \text{M2}* \text{r2}* \text{theta1}_{\text{ddot}}* \text{cos}(\text{theta2}) \\ + \text{L1}* \text{M2}* \text{r2}* \text{theta2}_{\text{ddot}}* \text{cos}(\text{theta2}) - \\ 2* \text{L1}* \text{M2}* \text{r2}* \text{theta1}_{\text{dot}}* \text{theta2}_{\text{dot}}* \text{sin}(\text{theta2}) \end{array}$$

$$tau2 = I2 * theta2_{ddot} + M2 * r2^2 * theta1_{ddot} + M2 * r2^2 * theta2_{ddot} - M2 * g * r2 * sin(theta1 + theta2) + L1 * M2 * r2 * theta1_{dot}^2 * sin(theta2) + L1 * M2 * r2 * theta1_{ddot} * cos(theta2)$$

## Problem b: State Space Representation of E.O.M

Here states X(1) = theta1, X(2) = theta2,  $X(3) = theta1_{dot}$ ,  $X(4) = theta2_{dot}$ 

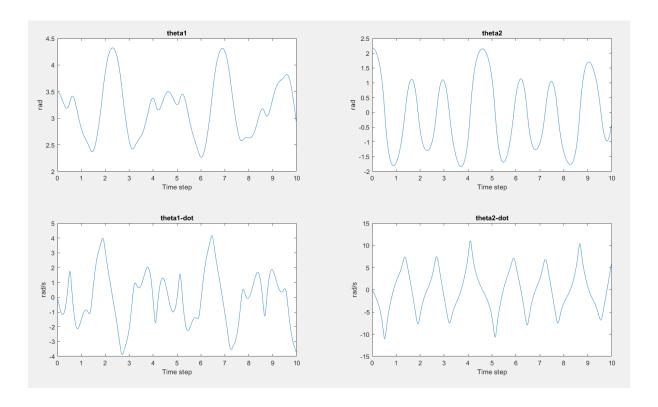
$$X(1)_{dot} = X(3) = theta1_{dot}$$

$$X(2)_{dot} = X(4) = theta2_{dot}$$

$$I2*tau1 + M2*r2^2*tau1 - M2*r2^2*tau2 + L1*M2^2*g*r2^2*\sin(theta1) + I2*M2*g*r2*\sin(theta1) + I2*M2*g*r2*\sin(theta1) + I2*M2*g*\sin(theta1) + I2*L1*M2*g*\sin(theta1) + I2*M1*g*r2*theta1^2_{dot}*\sin(2*theta2) + I2*M1*g*r1*\sin(theta1) - L1*M2*r2*tau2*\cos(theta2) + L1*M2^2*r2^3*theta1^2_{dot}*\sin(theta2) + L1*M2^2*r2^3*theta1^2_{dot}*\sin(theta2) + L1*M2^2*g*r2^3*theta2^2_{dot}*\sin(theta2) - L1*M2^2*g*r2^2*\sin(theta1 + theta2)*\cos(theta2) + I2*L1*M2*r2*theta2^2_{dot}*\sin(theta2) + M1*M2*g*r1*r2^2*\sin(theta1) + I2*L1*M2*r2*theta2^2_{dot}*\sin(theta2) + I2*L1*M2*r2*theta1^2_{dot}*theta2^2_{dot}*\sin(theta2) + I1*M2*r2^2*theta1^2_{dot}*theta2^2_{dot}*\sin(theta2) + I1*M2*r2^2*theta1^2_{dot}*theta2^2_{dot}*\sin(theta2) + I1*M2*r2^2+I2*L1^2*M2+I2*M1*r1^2+I1*M2*r2^2+I2*M2+I2*M1*r1^2+I1*M2*r2^2+I2*M2*r2^2+I2*M2*r2^2+I2*M1*r1^2+I1*M2*r2^2+I2*M2*r2^2+I2*M2*r2^2+I2*M1*r1^2+I1*M2*r1^2*r2^2-L1^2*M2^2*r2^2*\cos^2(theta2) + 2*I2*L1*M2*r2^2*cos(theta2)$$

```
M2 * r2^2 * tau1 - L1^2 * M2 * tau2 -
                M1 * r1^2 * tau2 - I1 * tau2 -
M2 * r2^2 * tau2 - L1^2 * M2^2 * g * r2 * sin(theta1 + theta2)
              + L1 * M2^2 * g * r2^2 * \sin(theta1) -
          I1 * M2 * g * r2 * sin(theta1 + theta2) +
         L1^2 * M2^2 * r2^2 * theta1_{dot}^2 * sin(2 * theta2)
      +\frac{L1^2*M2^2*r2^2*theta2_{dot}^2*\sin(2*theta2)}{2}+
              L1 * M2 * r2 * tau1 * cos(theta2) -
            2 * L1 * M2 * r2 * tau2 * cos(theta2) +
          L1 * M2^2 * r2^3 * theta1_{dot}^2 * sin(theta2) +
          L1^{3} * M2^{2} * r2 * theta1_{dot}^{2} * sin(theta2) +
          L1 * M2^2 * r2^3 * theta2_{dot}^2 * sin(theta2) -
 L1 * M2^2 * q * r2^2 * \sin(theta1 + theta2) * \cos(theta2) +
       L1^2 * M2^2 * g * r2 * \cos(theta2) * \sin(theta1) -
       M1 * M2 * g * r1^2 * r2 * \sin(theta1 + theta2) +
         I1*L1*M2*r2*theta1^2_{dot}*\sin(theta2) +\\
            M1 * M2 * a * r1 * r2^2 * \sin(theta1) +
 L1^2 * M2^2 * r2^2 * theta1_{dot} * theta2_{dot} * sin(2 * theta2) +
  2 * L1 * M2^{2} * r2^{3} * theta1_{dot} * theta2_{dot} * sin(theta2) +
     L1 * M1 * M2 * r1^2 * r2 * theta1_{dot}^2 * sin(theta2) +
    L1 * M1 * M2 * g * r1 * r2 * cos(theta2) * sin(theta1)
         I1 * I2 + L1^2 * M2^2 * r2^2 + I2 * L1^2 * M2 +
                 I2 * M1 * r1^2 + I1 * M2 * r2^2
             + I2 * M2 * r2^{2} + M1 * M2 * r1^{2} * r2^{2}
              -L1^2 * M2^2 * r2^2 * \cos^2(theta2) +
               2 * I2 * L1 * M2 * r2 * cos(theta2)
```

## **Problem b:** Simulation



Please toggle the visualization flag on line 3 of main.m file in the submission to "true" see the RRbot (the two-link robot) in action. !!!