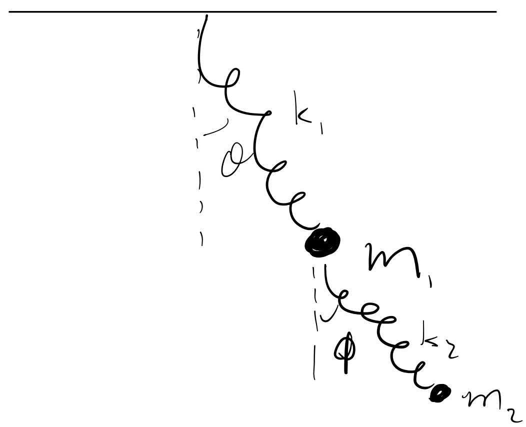

$$x_1 = (l_1 + r_1)\sin\theta_1$$

$$y_1 = -(l_1 + r_1)\cos\theta_1$$

$$T = \frac{1}{2} m ((l_1 + r_1)\dot{\theta})^2$$

$$x_2^{(1)} = (l_1 + r_1)\sin\theta + x_2 \sin\phi$$

$$U = -mg(l_1 + r_1)\cos\theta + \frac{1}{2} k(r_1)^2$$

$$= x_1 + (l_2 + r_2)\sin\phi$$

For m_2

$$y_2 = y_1 - (l_2 + r_2)\cos\phi$$

$$T = \frac{1}{2} m_2 ($$

Generally:

$$T_1 = \frac{1}{2} m (x_1^2 + y_1^2)\dot{\theta}_1^2 = \frac{1}{2} m(\dot{x}_1^2 + \dot{y}_1^2)$$

$$U_1 = mgy_1 + \frac{1}{2} k r_1^2$$

$$T_2 = \frac{1}{2} m(x_2^2 + y_2^2)\dot{\theta}_2^2 = \frac{1}{2} m_2(\dot{x}_2^2 + \dot{y}_2^2)$$

$$U_2 = mgy_2 + \frac{1}{2} k_2 r_2^2$$

$$T_N = \frac{1}{2} m_N(\dot{x}_N^2 + \dot{y}_N^2)$$

$$y_N = y_{N-1} + y_{N-2} + \dots + y_1 - (l_N + r_N)\cos\phi_N$$

$$x_N = x_{N-1} + x_{N-2} + \dots + x_1 + (l_N + r_N)\sin\phi_N$$

$$U_N = m_N g y_N + \frac{1}{2} k_N r_N^2$$

$$T_{total} = \frac{1}{2} \sum_{i=1}^{N} m_i (\dot{x}_i^2 + \dot{y}_i^2)$$

$$U_{Total} = \sum_{i=1}^{N} m_N g y_N + \frac{1}{2} k_N r_N^2$$

$$\mathcal{L}_N = T_{total} - U_{total}$$

$$T_{total} = \frac{1}{2} m \left(\sum_{i=1}^{N} \dot{x}_i^2 + \sum_{i=1}^{N} \dot{y}_i \right)$$

assuming m is same for all bobs

Create length N array of r_i, ϕ_i, $\dot{r}_i$, $\dot{\phi}_i$, $\ddot{r}_i$, $\ddot{\phi}_i$

then derive arrays of x, y

$$x_i = (l_1 + r_1)\sin\phi_1 + (l_2 + r_2)\sin\phi_2 + \dots + (l_i + r_i)\sin\phi_i$$

$$y_i = -(l_1 + r_1)\cos\phi_1 - (l_2 + r_2)\cos\phi_2 + \dots - (l_i + r_i)\sin\phi_i$$