Generalized Coordinates

```
% DispSysVar(sysvar.theta_1);
% DispSysVar(sysvar.theta_dot_1);
% DispSysVar(sysvar.theta_ddot_1);
% DispSysVar(sysvar.theta_2);
% DispSysVar(sysvar.theta_dot_2);
% DispSysVar(sysvar.theta_ddot_2);
```

Arm

```
DispSysVar(sysvar.x_1);
```

$$(x_1 = l_1 \cos(\theta_1)) = l_1 \cos(\theta_1)$$

```
DispSysVar(sysvar.y_1);
```

$$(y_1 = l_1 \sin(\theta_1)) = l_1 \sin(\theta_1)$$

```
DispSysVar(sysvar.x_dot_1);
```

$$\left(\dot{x}_1 = -l_1 \dot{\theta}_1 \sin(\theta_1)\right) = -l_1 \dot{\theta}_1 \sin(\theta_1)$$

```
DispSysVar(sysvar.y_dot_1);
```

$$\left(\dot{y}_1 = l_1 \dot{\theta}_1 \cos(\theta_1)\right) = l_1 \dot{\theta}_1 \cos(\theta_1)$$

```
DispSysVar(sysvar.V_1);
```

$$(V_1 = g\, m_1\, y_1) = g\, l_1\, m_1 \sin(\theta_1)$$

```
DispSysVar(sysvar.T_1);
```

$$\left(T_1 = \frac{m_1 \left(\dot{x}_1^{\,2} + \dot{y}_1^{\,2}\right)}{2}\right) = \frac{l_1^{\,2}\, m_1\, \dot{\theta}_1^{\,2}}{2}$$

Projectile

```
DispSysVar(sysvar.x_2);
```

$$(x_2 = x_1 + l_2 \cos(\theta_2)) = l_1 \cos(\theta_1) + l_2 \cos(\theta_2)$$

```
DispSysVar(sysvar.y_2);
```

$$(y_2 = y_1 + l_2 \sin(\theta_2)) = l_1 \sin(\theta_1) + l_2 \sin(\theta_2)$$

```
DispSysVar(sysvar.x_dot_2);
```

$$\left(\dot{x}_2 = \dot{x}_1 - l_2\,\dot{\theta}_2\,\sin(\theta_2)\right) = -l_1\,\dot{\theta}_1\,\sin(\theta_1) - l_2\,\dot{\theta}_2\,\sin(\theta_2)$$

```
DispSysVar(sysvar.y_dot_2);
```

$$\left(\dot{y}_2 = \dot{y}_1 + l_2\,\dot{\theta}_2\,\cos(\theta_2)\right) = l_1\,\dot{\theta}_1\,\cos(\theta_1) + l_2\,\dot{\theta}_2\,\cos(\theta_2)$$

```
DispSysVar(sysvar.x_ddot_2);
```

$$\left(\ddot{x}_2 = \ddot{x}_2\right) = \ddot{x}_2$$

```
DispSysVar(sysvar.y_ddot_2);
```

$$\left(\ddot{y}_2 = \ddot{y}_2\right) = \ddot{y}_2$$

```
DispSysVar(sysvar.V_2);
```

$$(V_2 = g\,m_2\,y_2) = g\,m_2\,\left(l_1\,\sin(\theta_1) + l_2\,\sin(\theta_2)\right)$$

```
DispSysVar(sysvar.T_2);
```

$$\left(T_2 = \frac{m_2\,\left(\dot{x}_2^{\,2} + \dot{y}_2^{\,2}\right)}{2}\right) = \frac{m_2\,\left(l_1^{\,2}\,\dot{\theta}_1^{\,2} + 2\,\cos(\theta_1 - \theta_2)\,l_1\,l_2\,\dot{\theta}_1\,\dot{\theta}_2 + l_2^{\,2}\,\dot{\theta}_2^{\,2}\right)}{2}$$

Potential Energy

```
DispSysVar(sysvar.V);
```

$$(V = V_1 + V_2 + V_3) = \frac{k\,\theta_1^{\,2}}{2} + g\,l_1\,m_1\,\sin(\theta_1) + g\,l_1\,m_2\,\sin(\theta_1) + g\,l_2\,m_2\,\sin(\theta_2)$$

Kinetic Energy

```
DispSysVar(sysvar.T);
```

$$(T = T_1 + T_2) = \frac{l_1^{\,2}\,m_1\,\dot{\theta}_1^{\,2}}{2} + \frac{l_1^{\,2}\,m_2\,\dot{\theta}_1^{\,2}}{2} + \frac{l_2^{\,2}\,m_2\,\dot{\theta}_2^{\,2}}{2} + l_1\,l_2\,m_2\,\dot{\theta}_1\,\dot{\theta}_2\,\cos(\theta_1 - \theta_2)$$

Lagrangian

```
DispSysVar(sysvar.L);
```

$$(L = T - V) = \frac{l_1^{\,2}\,m_1\,\dot{\theta}_1^{\,2}}{2} - \frac{k\,\theta_1^{\,2}}{2} + \frac{l_1^{\,2}\,m_2\,\dot{\theta}_1^{\,2}}{2} + \frac{l_2^{\,2}\,m_2\,\dot{\theta}_2^{\,2}}{2} - g\,l_1\,m_1\,\sin(\theta_1) - g\,l_1\,m_2\,\sin(\theta_1) - g\,l_2\,m_2\,\sin(\theta_2) -$$

Rope

```
DispSysVar(sysvar.F_x2_rope);
```

$$\left(F_{\mathrm{x2,rope}} = m_2\,\ddot{x}_2\right) = m_2\,\ddot{x}_2$$

```
DispSysVar(sysvar.F_y2_rope);
```

$$\left(F_{\mathrm{y2,rope}} = m_2\,\left(g + \ddot{y}_2\right)\right) = m_2\,\left(g + \ddot{y}_2\right)$$

Computed Parameters

must run LoadSolution.m first

```
DispSysVar(sysparam.discrete.phi_release, 4, 3);
```

$$\left(\phi_{\mathrm{rel}} = 135.0 \quad \mathrm{degrees}\right)$$

```
DispSysVar(sysparam.discrete.t_release, 5);
```

$$\left(t_{\mathrm{rel}} = 0.97 \quad \text{where} \quad -\phi_{\mathrm{rel}} + \mathrm{atan2}\left(\dot{y}_2(t_{\mathrm{rel}}), \dot{x}_2(t_{\mathrm{rel}})\right) = 0\right)$$

```
DispSysVar(sysparam.discrete.T_2_release);
```

$$\left(T_{2,\mathrm{rel}} = T_2(t_{\mathrm{rel}})\right) = 5.2$$