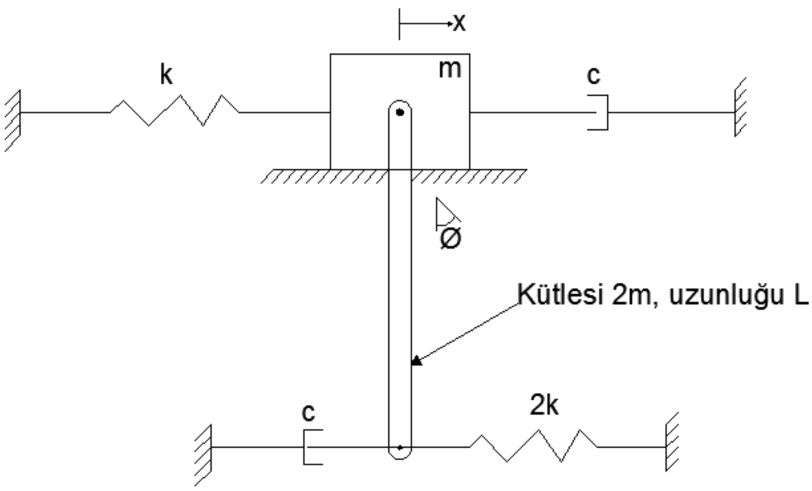
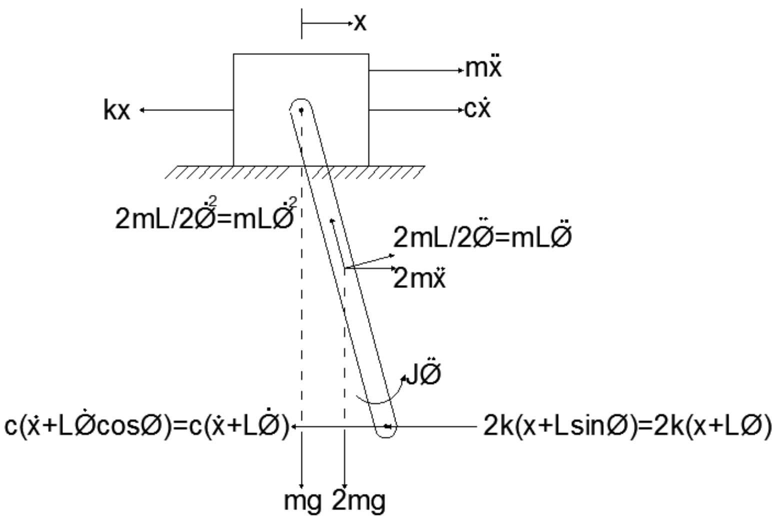
SORULAR ve CEVAPLAR

1 Aşağıdaki sistemin hareket denklemini elde ediniz.



Cevap
Newton Yöntemi ile çözüm
Verilen sistemin SCD'sini çizelim.



Küçük θ değerleri için $\sin\theta=\theta,\ \cos\theta=1,\ \tan\theta=\theta$

m kütlesi için Newton Kanunu

$$\sum F = m.a \ (+\rightarrow)$$

$$m\ddot{x}+2m\ddot{x}=-kx-2k(x+L\theta)-c\dot{x}-c(\dot{x}+L\dot{\theta})-mL\ddot{\theta}\cos\theta+mL\dot{\theta}^2\sin\theta$$

$$3m\ddot{x}+mL\ddot{\theta}+2c\dot{x}+cL\dot{\theta}+3kx+2kL\theta-mL\dot{\theta}^2\theta=0$$

$mL\dot{\theta}^2\theta$ *ihmal edilirse*

$$3m\ddot{x}+mL\ddot{\theta}+2c\dot{x}+cL\dot{\theta}+3kx+2kL\theta=0 \text{..}(1)$$

2m kütlesi için Newton Kanunu

$$\sum M = J\ddot{\theta} \quad (\textit{Saat tersi yönü} +)$$

$$J\ddot{\theta}+mL\ddot{\theta}\frac{L}{2}+2m\ddot{x}\frac{L}{2}=-c(\dot{x}+L\dot{\theta})L\cos\theta-2k(x+L\theta)L\cos\theta-2mg\frac{L}{2}\sin\theta$$

$$J=\frac{1}{12}2mL^2 \quad J=\frac{mL^2}{6}$$

$$mL\ddot{x}+(\frac{mL^2}{6}+\frac{mL^2}{2})\ddot{\theta}+c\dot{x}+cL^2\dot{\theta}+2kx+(2kL^2+mgL)\theta=0 \quad ....(2)$$

1 ve 2 nolu denklemleri matris formatında yazarsak

$$\underbrace{\begin{bmatrix} 3m & mL \\ mL & \dfrac{2mL^2}{3} \end{bmatrix}}_{\textit{Kütle Matrisi}}\begin{Bmatrix}\ddot{x}\\ \ddot{\theta}\end{Bmatrix}+\underbrace{\begin{bmatrix} 2c & cL \\ cL & cL^2 \end{bmatrix}}_{\textit{Sönüm Matrisi}}\begin{Bmatrix}\dot{x}\\ \dot{\theta}\end{Bmatrix}+\underbrace{\begin{bmatrix} 3k & 2kL \\ 2kL & (2kL^2+mgL) \end{bmatrix}}_{\textit{Rijitlik Matrisi}}\begin{Bmatrix}x\\ \theta\end{Bmatrix}=\begin{Bmatrix}0\\ 0\end{Bmatrix}$$

Lagrange Yöntemi ile çözüm

Sistemin Kinetik Enerjisi:

m kütleli cisim öteleme hareketi yapmaktadır. 2m kütleli çubuk ise hem dönme hemde öteleme hareketi yapmaktadır

$$T=\underbrace{\frac{1}{2}m\dot{x}^2}_{m\text{ kütlesi öteleme}}+\underbrace{\frac{1}{2}2m(\dot{x}+\frac{1}{2}L\dot{\theta})^2}_{2m\text{ kütlesi öteleme}}+\underbrace{\frac{1}{2}\frac{1}{12}2mL^2\dot{\theta}^2}_{2m\text{ kütlesi dönme}} \quad ....(3)$$

Sistemin potansiyel enerjisi:

$$U=\frac{1}{2}kx^2+\frac{1}{2}2k(x+L\theta)^2-2mg\frac{L}{2}\cos\theta \quad ....(4)$$

Vizkoz sönüm elemanının yaptığı iş

$$\begin{aligned}\delta W&=-c\dot{x}\delta x-c(\dot{x}+L\dot{\theta})\delta(x+L\theta)\\ &=-c(2\dot{x}+L\dot{\theta})\delta x-cL(\dot{x}+L\dot{\theta})\delta\theta\end{aligned}$$

Lagrange denkleminin uygulanması

$$L=T-U$$

$$\frac{d}{dt}\left(\frac{\delta L}{\delta\dot{x}}\right)-\frac{\delta L}{\delta x}=Q_1$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta\dot{x}}\right)-\frac{\delta T}{\delta x}+\frac{\delta U}{\delta x}=Q_1$$

$$\frac{d}{dt}\left[m\dot{x}+2m\left(\dot{x}+\frac{L}{2}\dot{\theta}\right)(1)\right]+\left[kx+2k\left(x+L\theta\right)(1)\right]=-2c\dot{x}-cL\dot{\theta}$$

$$3m\ddot{x}+mL\ddot{\theta}+2c\dot{x}+cL\dot{\theta}+3kx+2kL\theta=0 \quad ....(5)$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta\dot{\theta}}\right)-\frac{\delta T}{\delta\theta}+\frac{\delta U}{\delta\theta}=Q_2$$

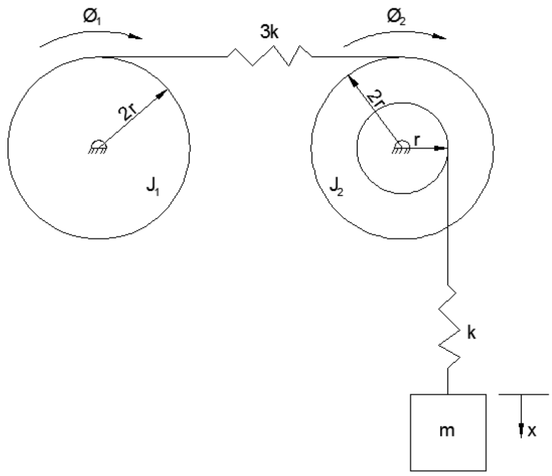
$$\frac{d}{dt}\left[2m\left(\dot{x}+\frac{1}{2}L\dot{\theta}\right)\left(\frac{L}{2}\right)+\frac{1}{12}2mL^2\dot{\theta}\right]+2k\left(x+L\theta\right)\left(L\right)+mgL\sin\theta=-cL\dot{x}-cL^2\dot{\theta}$$

$$mL\ddot{x}+\frac{2mL^2}{3}\ddot{\theta}+cL\dot{x}+cL^2\dot{\theta}+2kLx+\left(2kL^2+mgL\right)\theta=0 \quad ....(6)$$

5 ve 6 nolu denklemleri matris formatında yazarsak

$$\underbrace{\begin{bmatrix} 3m & mL \\ mL & \dfrac{2mL^2}{3} \end{bmatrix}}_{\textit{Kütle Matrisi}}\begin{Bmatrix}\ddot{x}\\ \ddot{\theta}\end{Bmatrix}+\underbrace{\begin{bmatrix} 2c & cL \\ cL & cL^2 \end{bmatrix}}_{\textit{Sönüm Matrisi}}\begin{Bmatrix}\dot{x}\\ \dot{\theta}\end{Bmatrix}+\underbrace{\begin{bmatrix} 3k & 2kL \\ 2kL & (2kL^2+mgL) \end{bmatrix}}_{\textit{Rijitlik Matrisi}}\begin{Bmatrix}x\\ \theta\end{Bmatrix}=\begin{Bmatrix}0\\ 0\end{Bmatrix}$$

2 Aşağıdaki sistemin hareket denklemini elde ediniz.



Cevap
Newton Yöntemi ile çözüm
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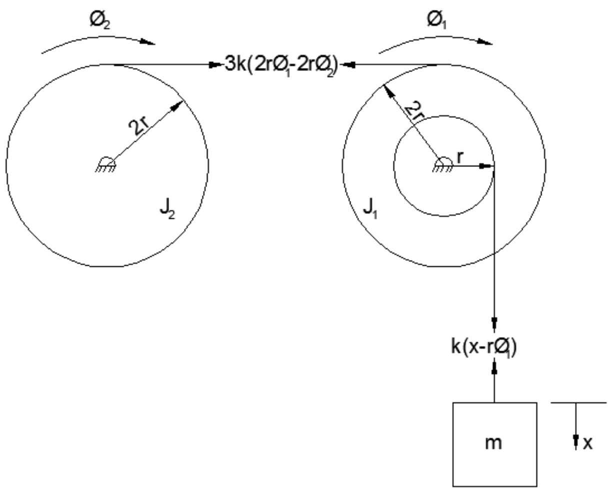


$$Küçük\ \theta\ değerleri\ için \sin\theta=\theta,\ \ \cos\theta=1,\ \ \tan\theta=\theta$$

m kütlesi için Newton Kanunu

$$\sum F = m.a\ (\downarrow +)$$

$$m\ddot{x} = -k\left(x - r\theta_1\right)$$

$$m\ddot{x} + kx - kr\theta_1 = 0 \text{...}(1)$$

$$\sum M = J_1\ddot{\theta}_1\ \ (Saat\ yönü\ +)$$

$$J_1\ddot{\theta}_1 = -6kr\left(2r\theta_1 - 2r\theta_2\right) + kr\left(x - r\theta_1\right)$$

$$J_1\ddot{\theta}_1 = -12kr^2\theta_1 + 12kr^2\theta_2 + krx - kr^2\theta_1$$

$$J_1\ddot{\theta}_1 + 13kr^2\theta_1 - 12kr^2\theta_2 - krx = 0 \text{...}(2)$$

$$\sum M = J_2\ddot{\theta}_2\ \ (Saat\ yönü\ +)$$

$$J_2\ddot{\theta}_2 = 6kr\left(2r\theta_1 - 2r\theta_2\right)$$

$$J_2\ddot{\theta}_2 + 12kr^2\theta_2 - 12kr^2\theta_1 = 0 \text{...}(3)$$

1,2 ve 3 nolu denklemleri matris formatında yazarsak

$$\underbrace{\begin{bmatrix} m & 0 & 0 \\ 0 & J_1 & 0 \\ 0 & 0 & J_2 \end{bmatrix}}_{\text{Kütle Matrisi}} \begin{Bmatrix} \ddot{x} \\ \ddot{\theta}_1 \\ \ddot{\theta}_2 \end{Bmatrix} + \underbrace{\begin{bmatrix} k & -kr & 0 \\ -kr & 13kr^2 & -12kr^2 \\ 0 & -12kr^2 & 12kr^2 \end{bmatrix}}_{\text{Rijitlik Matrisi}} \begin{Bmatrix} x \\ \theta_1 \\ \theta_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix}$$

Lagrange Yöntemi ile çözüm

Sistemin Kinetik Enerjisi:

$$T = \frac{1}{2} J_1 \dot{\theta}_1^2 + \frac{1}{2} J_2 \dot{\theta}_2^2 \frac{1}{2} m \dot{x}_1^2 \ldots\ldots (4)$$

Sistemin potansiyel enerjisi:

$$U = \frac{1}{2} k \left(x - r\theta_1 \right)^2 + \frac{1}{2} 3k \left(2r\theta_1 - 2r\theta_2 \right)^2 \ldots\ldots (5)$$

Lagrange denkleminin uygulanması

$$L = T - U$$

$$\frac{d}{dt}\left(\frac{\delta L}{\delta \dot{x}} \right) - \frac{\delta L}{\delta x} = 0$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{x}} \right) - \frac{\delta T}{\delta x} + \frac{\delta U}{\delta x} = 0$$

$$\frac{d}{dt}\left(m\dot{x} \right) + \left[k\left(x - r\theta_1 \right)(1) \right] = 0$$

$$m\ddot{x} + kx - kr\theta_1 = 0 \ldots\ldots (6)$$

$$\frac{d}{dt}\left(\frac{\delta L}{\delta \dot{\theta}_1} \right) - \frac{\delta L}{\delta \theta_1} = 0$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{\theta}_1} \right) - \frac{\delta T}{\delta \theta_1} + \frac{\delta U}{\delta \theta_1} = 0$$

$$\frac{d}{dt}\left(J_1 \dot{\theta}_1 \right) + \left[k\left(x - r\theta_1 \right)\left(-r \right) + 3k\left(2r\theta_1 - 2r\theta_2 \right)\left(2r \right) \right]$$

$$J_1 \ddot{\theta}_1 - krx + 13kr^2\theta_1 - 12kr^2\theta_2 = 0 \ldots\ldots (7)$$

$$\frac{d}{dt}\left(\frac{\delta L}{\delta \dot{\theta}_2} \right) - \frac{\delta L}{\delta \theta_2} = 0$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{\theta}_2} \right) - \frac{\delta T}{\delta \theta_2} + \frac{\delta U}{\delta \theta_2} = 0$$

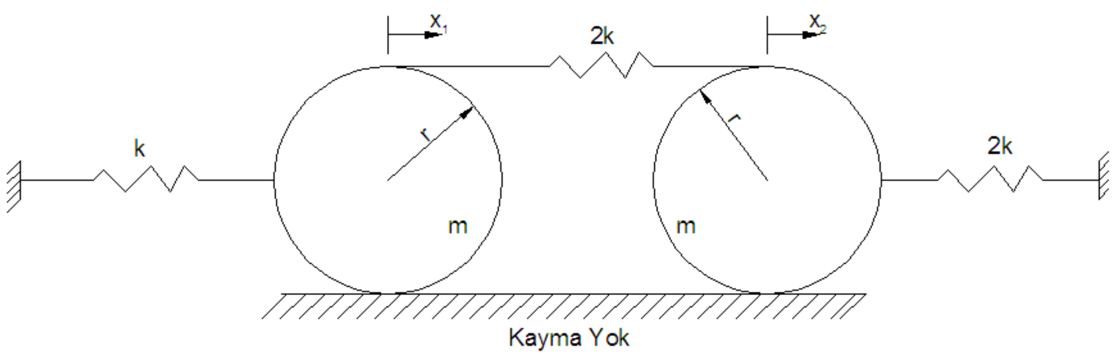
$$\frac{d}{dt}\left(J_2 \dot{\theta}_2 \right) + \left[3k\left(2r\theta_1 - 2r\theta_2 \right)\left(-2r \right) \right]$$

$$J_2 \ddot{\theta}_2 - 12kr^2\theta_1 + 12kr^2\theta_2 = 0 \ldots\ldots (8)$$

6,7 ve 8 nolu denklemleri matris formatında yazarsak

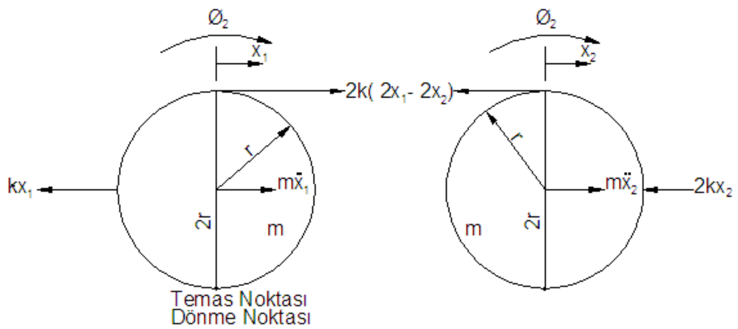
$$\underbrace{\begin{bmatrix} m & 0 & 0 \\ 0 & J_1 & 0 \\ 0 & 0 & J_2 \end{bmatrix}}_{\text{Kütle Matrisi}} \begin{Bmatrix} \ddot{x} \\ \ddot{\theta}_1 \\ \ddot{\theta}_2 \end{Bmatrix} + \underbrace{\begin{bmatrix} k & -kr & 0 \\ -kr & 13kr^2 & -12kr^2 \\ 0 & -12kr^2 & 12kr^2 \end{bmatrix}}_{\text{Rijitlik Matrisi}} \begin{Bmatrix} x \\ \theta_1 \\ \theta_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix}$$

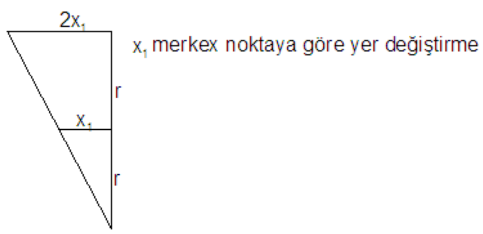
3 Aşağıdaki sistemin hareket denklemini elde ediniz.



Cevap
Newton Yöntemi ile çözüm

Verilen sistemin SCD'sini çizelim.





$$\theta_1 = \frac{x_1}{r} \quad \theta_2 = \frac{x_2}{r} \qquad J = \frac{1}{2}mr^2$$

$$\sum M = J_1\ddot{\theta}_1 \ \ (Saat\ yönü +)(Dönme\ Noktasına\ Göre)$$

$$\frac{1}{2}mr^2\frac{\ddot{x}_1}{2} + m\ddot{x}_1 r = 2k(2x_2 - x_1)2r - kx_1 r$$

$$\frac{3}{2}m\ddot{x}_1 = 8kx_2 - 8kx_1 - kx_1$$

$$\frac{3}{2}m\ddot{x}_1 + 9kx_1 - 8kx_2 = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\sum M = J_2\ddot{\theta}_2 \ \ (Saat\ yönü +)(Dönme\ Noktasına\ Göre)$$

$$\frac{1}{2}mr^2\frac{\ddot{x}_2}{2} + m\ddot{x}_2 r = -2k(2x_2 - x_1)2r - 2kx_2 r$$

$$\frac{3}{2}m\ddot{x}_1 = -10kx_2 + 8kx_1$$

$$\frac{3}{2}m\ddot{x}_1 - 8kx_1 + 10kx_2 = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

1 ve 2 nolu denklemleri matris formatında yazarsak

$$\underbrace{\begin{bmatrix} \frac{3m}{2} & 0 \\ 0 & \frac{3m}{2} \end{bmatrix}}_{\text{Kütle Matrisi}} \begin{Bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \end{Bmatrix} + \underbrace{\begin{bmatrix} 9k & -8k \\ -8k & 10k \end{bmatrix}}_{\text{Rijitlik Matrisi}} \begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$

Lagrange Yöntemi ile çözüm

Sistemin Kinetik Enerjisi:

m kütleli cisimler hem öteleme hem dönme hareketi yapmaktadır.

$$T = \underbrace{\frac{1}{2}m\dot{x}_1^2}_{m\ \text{kütlesi}\ x_1\ \text{öteleme}} + \underbrace{\frac{1}{2}\frac{1}{2}mr^2(\frac{\dot{x}_1}{r})^2}_{m\ \text{kütlesi}\ \theta_1\ \text{dönme}} + \underbrace{\frac{1}{2}m\dot{x}_2^2}_{m\ \text{kütlesi}\ x_2\ \text{öteleme}} + \underbrace{\frac{1}{2}\frac{1}{2}mr^2(\frac{\dot{x}_2}{r})^2}_{m\ \text{kütlesi}\ \theta_2\ \text{dönme}} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Sistemin potansiyel enerjisi:

$$U = \frac{1}{2}kx_1^2 + \frac{1}{2}2kx_2^2 + \frac{1}{2}2k(2x_2 - 2x_1)^2 \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Lagrange denkleminin uygulanması

$$L = T - U$$

$$\frac{d}{dt}\left(\frac{\delta L}{\delta \dot{x}_1}\right) - \frac{\delta L}{\delta x_1} = 0$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{x}_1}\right) - \frac{\delta T}{\delta x_1} + \frac{\delta U}{\delta x_1} = 0$$

$$\frac{d}{dt}\left[m\dot{x}_1 + \frac{1}{2}m\dot{x}_1(1)\right] + \left[kx_1 + 2k\left(2x_2 - 2x_1\right)\left(2\right)\right] = 0$$

$$\frac{3}{2}m\ddot{x}_1 + 9kx_1 - 8kx_2 = 0 \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$\frac{d}{dt}\left(\frac{\delta L}{\delta \dot{x}_2}\right) - \frac{\delta L}{\delta x_2} = 0$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{x}_2}\right) - \frac{\delta T}{\delta x_2} + \frac{\delta U}{\delta x_2} = 0$$

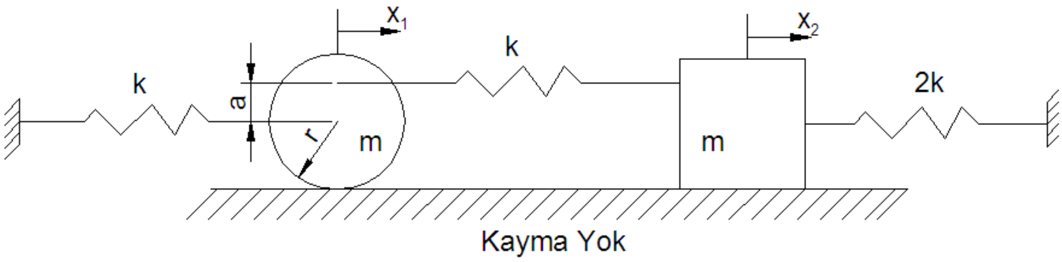
$$\frac{d}{dt}\left[m\dot{x}_2 + \frac{1}{2}m\dot{x}_2(1)\right] + \left[2kx_2 + 2k\left(2x_2 - 2x_1\right)\left(2\right)\right] = 0$$

$$\frac{3}{2}m\ddot{x}_2 - 8kx_1 + 10kx_2 = 0 \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

5 ve 6 nolu denklemleri matris formatında yazarsak

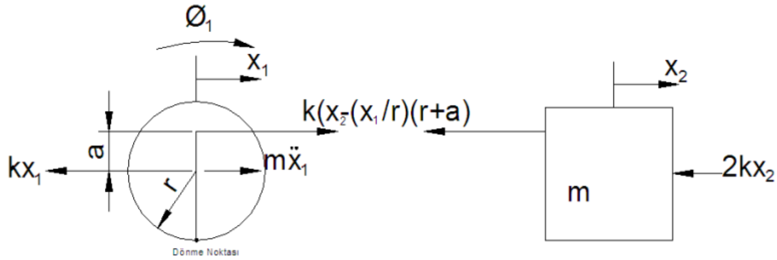
$$\underbrace{\begin{bmatrix} \frac{3m}{2} & 0 \\ 0 & \frac{3m}{2} \end{bmatrix}}_{\text{Kütle Matrisi}} \begin{Bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \end{Bmatrix} + \underbrace{\begin{bmatrix} 9k & -8k \\ -8k & 10k \end{bmatrix}}_{\text{Rijitlik Matrisi}} \begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$

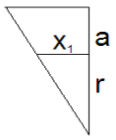
4 Aşağıdaki sistemin hareket denklemini elde ediniz.



Cevap
Newton Yöntemi ile çözüm

Verilen sistemin SCD'sini çizelim.





$$x_1 = \theta r \ Benzerlikten$$

$$\frac{r}{(r+a)} = \frac{\theta r}{y} \quad y = \theta(r+a), \ y = \frac{x_1}{r}(r+a) \ , \qquad \theta_1 = \frac{x_1}{r} \quad , \ J = \frac{1}{2}mr^2$$

$$\sum M = J\ddot{\theta} \ \ (Saat \ yönü +)(Dönme \ Noktasına \ Göre)$$

$$\frac{1}{2}mr^2\frac{\ddot{x}_1}{2} + m\ddot{x}_1 r = -kx_1 r + k\left(x_2 - \frac{x_1}{r}(r+a)\right)(r+a)$$

$$\frac{3}{2}m\ddot{x}_1 = -kx_1 + kx_2\left(1 + \frac{a}{r}\right) - kx_1\frac{(r+a)^2}{r^2}$$

$$\frac{3}{2}m\ddot{x}_1 = -kx_1\left(1 + \frac{r^2 + 2ar + a^2}{r^2}\right) + kx_2\left(1 + \frac{a}{r}\right)$$

$$\frac{3}{2}m\ddot{x}_1 + kx_1\left(1 + \frac{r^2 + 2ar + a^2}{r^2}\right) - kx_2\left(1 + \frac{a}{r}\right) = 0 \ldots\ldots\ldots\ldots(1)$$

$$\sum F = m\ddot{x}_2 \ \ (+\rightarrow)$$

$$m\ddot{x}_2 = -2kx_2 - k\left(x_2 - \frac{x_1}{r}(r+a)\right)$$

$$m\ddot{x}_2 = -2kx_2 - kx_2 + kx_1\left(1 + \frac{a}{r}\right)$$

$$m\ddot{x}_2 - kx_1\left(1 + \frac{a}{r}\right) + 3kx_2 = 0 \ldots\ldots\ldots\ldots(2)$$

1 ve 2 nolu denklemleri matris formatında yazarsak

$$\underbrace{\begin{bmatrix} \frac{3m}{2} & 0 \\ 0 & m \end{bmatrix}}_{Kütle \ Matrisi}\begin{Bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \end{Bmatrix} + \underbrace{\begin{bmatrix} k\left(2 + \frac{2a}{r} + \frac{a^2}{r^2}\right) & -k\left(1 + \frac{a}{r}\right) \\ -k\left(1 + \frac{a}{r}\right) & 3k \end{bmatrix}}_{Rijitlik \ Matrisi}\begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$

Lagrange Yöntemi ile çözüm

Sistemin Kinetik Enerjisi:

m kütleli disk hem öteleme hem dönme hareketi yapmaktadır.

$$T = \underbrace{\frac{1}{2}m\dot{x}_1^{\,2}}_{m\ k\ddot{u}tlesi\ x_1\ \ddot{o}teleme} + \underbrace{\frac{1}{2}\frac{1}{2}mr^2(\frac{\dot{x}_1}{r})^2}_{m\ k\ddot{u}tlesi\ \theta_1\ d\ddot{o}nme} + \underbrace{\frac{1}{2}m\dot{x}_2^{\,2}}_{m\ k\ddot{u}tlesi\ x_2\ \ddot{o}teleme} \quad \ldots\ldots(3)$$

Sistemin potansiyel enerjisi:

$$U = \frac{1}{2}kx_1^{\,2} + \frac{1}{2}k\left(x_2 - \frac{x_1}{r}(r+a)\right)^2 + \frac{1}{2}2kx_2^{\,2} \ldots\ldots(4)$$

Lagrange denkleminin uygulanması

$$L = T - U$$

$$\frac{d}{dt}\left(\frac{\delta L}{\delta \dot{x}_1}\right) - \frac{\delta L}{\delta x_1} = 0$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{x}_1}\right) - \frac{\delta T}{\delta x_1} + \frac{\delta U}{\delta x_1} = 0$$

$$\frac{d}{dt}\left[m\dot{x}_1 + \frac{1}{2}m\dot{x}_1(1)\right] + \left[kx_1 - k\left(x_2 - \frac{x_1}{r}(r+a)\right)\frac{(r+a)}{r}\right] = 0$$

$$\frac{3}{2}m\ddot{x}_1 + kx_1 - kx_2\left(1+\frac{a}{r}\right) + kx_1\left(1+\frac{2a}{r}+\frac{a^2}{r^2}\right) = 0$$

$$\frac{3}{2}m\ddot{x}_1 + kx_1\left(2+\frac{2a}{r}+\frac{a^2}{r^2}\right) - kx_2\left(1+\frac{a}{r}\right) = 0 \ldots\ldots(5)$$

$$\frac{d}{dt}\left(\frac{\delta L}{\delta \dot{x}_2}\right) - \frac{\delta L}{\delta x_2} = 0$$

$$\frac{d}{dt}\left(\frac{\delta T}{\delta \dot{x}_2}\right) - \frac{\delta T}{\delta x_2} + \frac{\delta U}{\delta x_2} = 0$$

$$\frac{d}{dt}\left[m\dot{x}_2\right] + k\left(x_2 - \frac{x_1}{r}(r+a)\right)(1) + 2kx_2 = 0$$

$$m\ddot{x}_2 + kx_2 - kx_1\left(1+\frac{a}{r}\right) + 2kx_2 = 0$$

$$m\ddot{x}_2 - kx_1\left(1+\frac{a}{r}\right) + 3kx_2 = 0 \ldots\ldots(6)$$

5 ve 6 nolu denklemleri matris formatında yazarsak

$$\underbrace{\begin{bmatrix} \frac{3m}{2} & 0 \\ 0 & m \end{bmatrix}}_{K\ddot{u}tle\ Matrisi}\begin{Bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \end{Bmatrix} + \underbrace{\begin{bmatrix} k\left(2+\frac{2a}{r}+\frac{a^2}{r^2}\right) & -k\left(1+\frac{a}{r}\right) \\ -k\left(1+\frac{a}{r}\right) & 3k \end{bmatrix}}_{Rijitlik\ Matrisi}\begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$