

Quiz 3 L02

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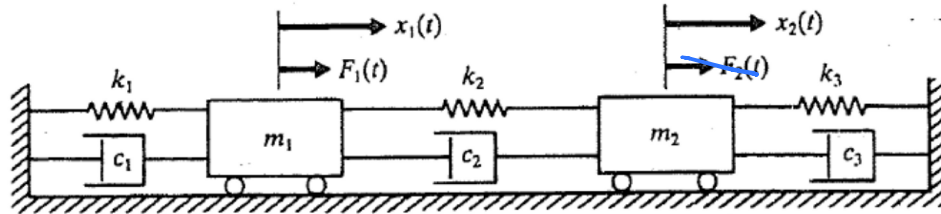
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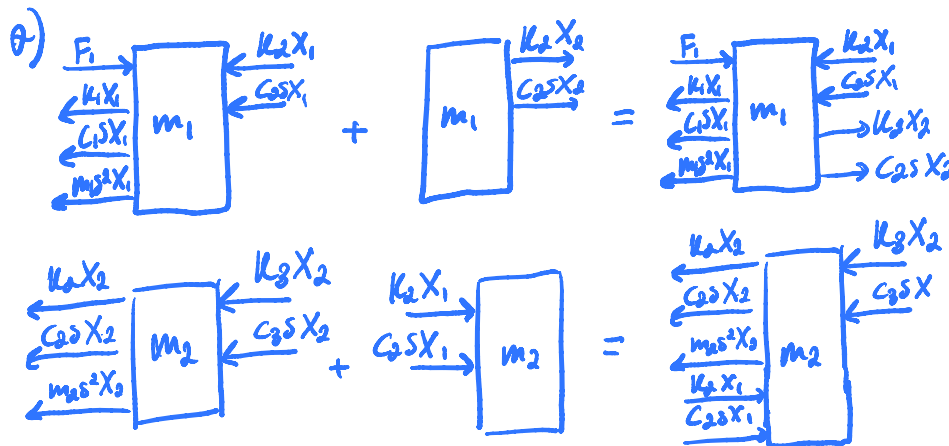
MECHTRON 3DX4 Tutorial Quiz 3 L02: Mechanical Systems

1. Linear Mechanical Systems Models (10 marks)

Consider the system show below where the wheels are friction-less:



- a) (5 marks) Assume that $F_2(t) = 0$. What are the equations of motion for the system? Show your work deriving the equations to get full marks.
- b) (5 marks) Solve for $\frac{X_1(s)}{F_1(s)}$ assuming that $F_2(t) = 0$.



$$m_1: X_1(m_1 s^2 + (c_1 + c_2)s + k_1 + k_2) - X_2(c_2 s + k_2) = F_1$$

$$m_2: -X_1(c_2 s + k_2) + X_2(m_2 s^2 + (c_2 + c_3)s + k_2 + k_3) = 0$$

b)

$$\begin{bmatrix} m_1 s^2 + (c_1 + c_2)s + k_1 + k_2 & -(c_2 s + k_2) \\ -(c_2 s + k_2) & m_2 s^2 + (c_2 + c_3)s + k_2 + k_3 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} F_1 \\ 0 \end{bmatrix}$$

$$\det(A_1) = \det \begin{bmatrix} F_1 & -(c_2 s + k_2) \\ 0 & m_2 s^2 + (c_2 + c_3)s + k_2 + k_3 \end{bmatrix}$$

$$= F_1 (m_2 s^2 + (c_2 + c_3)s + k_2 + k_3)$$

$$\det(A) = (m_1 s^2 + (c_1 + c_2)s + k_1 + k_2)(m_2 s^2 + (c_2 + c_3)s + k_2 + k_3) + (c_2 s + k_2)^2$$

$$X_1 = \frac{\det(A_1)}{\det(A)} = \frac{F_1 (m_2 s^2 + (c_2 + c_3)s + k_2 + k_3)}{\left[s^4(m_1 m_2) + s^3(c_1 m_2 + c_2 m_1 + c_2 m_2 + c_3 m_1) + s^2(k_1 m_2 + k_2 m_1 + k_2 m_2 + k_3 m_1 + c_1 c_2 + c_1 c_3 + c_2 c_3) + s(c_1 k_2 + c_2 k_1 + c_1 k_3 + 4c_2 k_2 + c_3 k_1 + c_2 k_3 + c_3 k_2) + (k_1 k_2 + k_1 k_3 + k_2 k_3 + 2k_2^2) \right]}$$

$$\frac{X_1}{F_1} = \frac{m_2 s^2 + (c_2 + c_3)s + k_2 + k_3}{\left[s^4(m_1 m_2) + s^3(c_1 m_2 + c_2 m_1 + c_2 m_2 + c_3 m_1) + s^2(k_1 m_2 + k_2 m_1 + k_2 m_2 + k_3 m_1 + c_1 c_2 + c_1 c_3 + c_2 c_3) + s(c_1 k_2 + c_2 k_1 + c_1 k_3 + 4c_2 k_2 + c_3 k_1 + c_2 k_3 + c_3 k_2) + (k_1 k_2 + k_1 k_3 + k_2 k_3 + 2k_2^2) \right]}$$