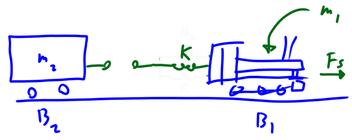
RW 13.13

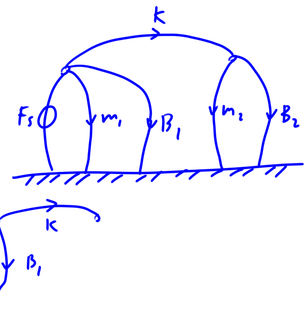


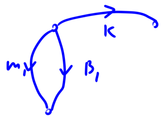
✓a) Linear Graph

✓b) Thevenin for the locomotive

✓c) Linear Graph

d) $\frac{V_{m_2}(s)}{F_s(s)}$



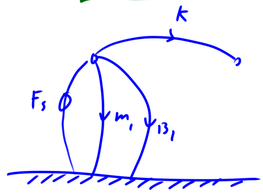


$$Z_e = \frac{1}{\frac{1}{Z_{m_1}} + \frac{1}{Z_{B_1}}} + Z_K$$

$$= \frac{1}{m_1 s + B_1} + \frac{s}{K}$$

$$= \frac{k}{K m_1 s + K B_1} + \frac{m_1 s^2 + B_1 s}{K m_1 s + K B_1}$$

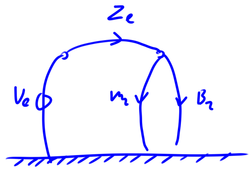
$$= \boxed{\frac{k + m_1 s^2 + B_1 s}{K m_1 s + K B_1}}$$

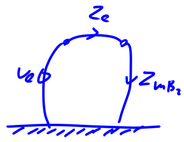


$$Z_{in} = \frac{1}{\frac{1}{Z_{m_1}} + \frac{1}{Z_{B_1}}}$$

$$= \frac{1}{m_1 s + B_1}$$

$$\boxed{V_e = \frac{F_s}{m_1 s + B_1}}$$





$$Z_{mB_2} = \frac{1}{\frac{1}{m_2} + \frac{1}{B_2}} = \frac{1}{m_2 s + B_2}$$

$$V_{m_2} = \frac{Z_{mB_2}}{Z_{mB_2} + Z_e} V_e$$

$$= \frac{Z_{mB_2}}{Z_{mB_2} + Z_e} \frac{F_s}{m_1 s + B_1}$$

$$= \frac{\frac{1}{m_2 s + B_2}}{\frac{1}{m_2 s + B_2} + \frac{k + m_1 s^2 + B_1 s}{K m_1 s + K B_1}} \frac{F_s}{m_1 s + B_1}$$

$$= \frac{1}{1 + \frac{(k + m_1 s^2 + B_1 s)(m_2 s + B_2)}{K m_1 s + K B_1}} \frac{F_s}{m_1 s + B_1}$$

$$= \frac{K m_1 s + k B_1}{K m_1 s + k B_1 + (k + m_1 s^2 + B_1 s)(m_2 s + B_2)} \frac{F_s}{m_1 s + B_1}$$

$$= F_s \frac{k}{K m_1 s + K B_1 + (k + m_1 s^2 + B_1 s)(m_2 s + B_2)}$$

$$\frac{V_{m_2}(s)}{F_s(s)} = \boxed{\frac{k}{K m_1 s + K B_1 + (k + m_1 s^2 + B_1 s)(m_2 s + B_2)}}$$