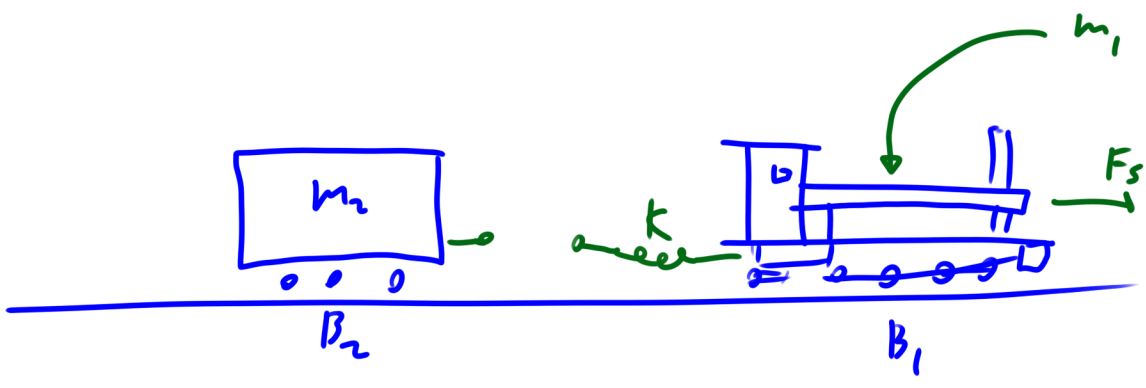
RW 13.13

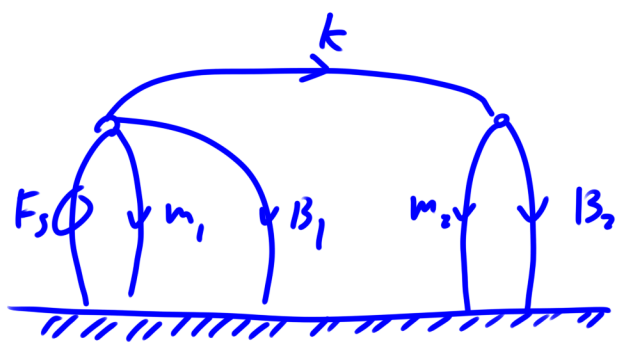


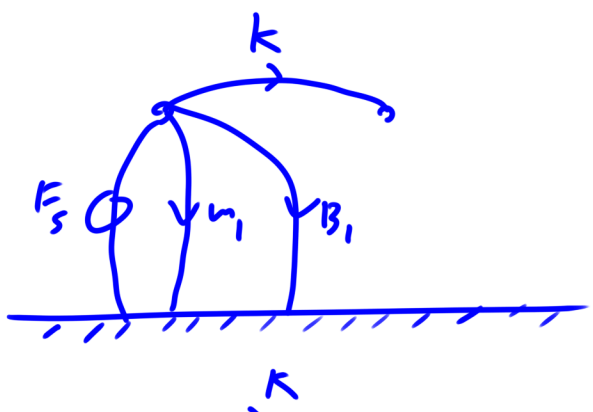
✓ a) linear graph

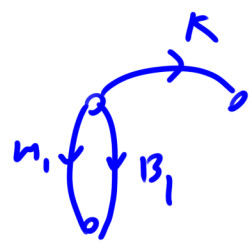
✓ b) Thevinin equivalent for locomotive

✓ c) linear graph

d) $V_{m_2}(s) / F_s(s)$







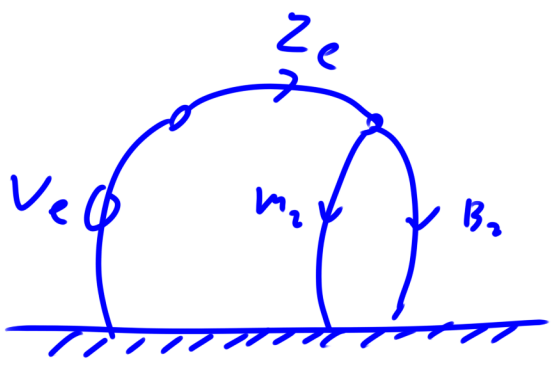
$$Z_e = \frac{1}{\frac{1}{Z_{m_1}} + \frac{1}{Z_{B_1}}} + Z_k$$

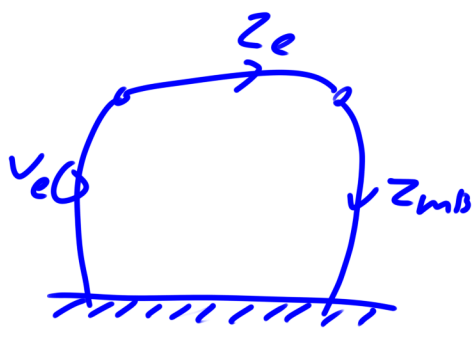
$$= \frac{1}{m_1 s + B_1} + \frac{s}{k}$$

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

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

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





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

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

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

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

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

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

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