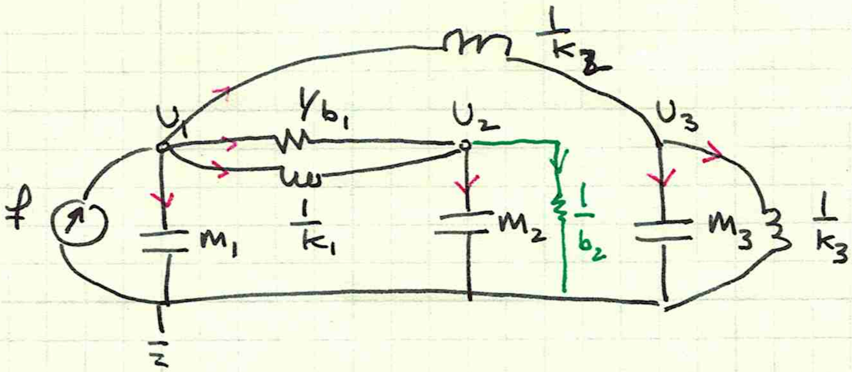
1.

(a)



(b)

U_1: $$F = \frac{U_1}{\frac{1}{M_1 s}} + \frac{(U_1 - U_3)}{\frac{s}{k_2}} + \frac{(U_1 - U_2)}{\frac{1}{b_1}} + \frac{(U_1 - U_2)}{\frac{s}{k_1}}$$

U_2: $$\frac{U_1 - U_2}{\frac{1}{b_1}} + \frac{U_1 - U_2}{\frac{s}{k_1}} = \frac{U_2}{\frac{1}{M_2 s}} + \frac{U_2}{\frac{1}{b_2}}$$

U_3: $$\frac{U_1 - U_3}{\frac{s}{k_2}} = \frac{U_3}{\frac{1}{M_3 s}} + \frac{U_3}{\frac{s}{k_3}}$$

(c)

$$U_1 \frac{k_2}{s} = U_3 \left[\frac{k_2 + k_3}{s} + M_3 s \right]$$

$$\frac{U_3}{U_1} = \frac{\frac{k_2}{s}}{\left[\frac{k_2 + k_3}{s} + M_3 s \right]} = \frac{k_2}{M_3 s^2 + k_2 + k_3}$$

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(2)

(a) $E = X - YH$

$$\left.\begin{aligned} \frac{E}{X} &= 1 - \frac{Y}{X}H \\ \frac{Y}{X} &= \frac{G}{1+GH} \end{aligned}\right\} \quad \frac{E}{X} = \frac{1}{1+GH}$$

$$\frac{E}{X} = \frac{1}{1 + H\left[\frac{s+4}{s(s+5)}\right]}$$

(b) $X = \frac{1}{s^2}$

$$E = \frac{1}{s^2 + Hs^2\left[\frac{s+4}{s(s+5)}\right]}$$

$$e(\infty) = \lim_{s \to 0} sE = \lim_{s \to 0} \frac{1}{s + sH\left[\frac{s+4}{s+5}\right]} = 0 \qquad \boxed{H = \frac{k}{s}}$$

$$1 + GH = 0 \Rightarrow 1 + \frac{k}{s}\left[\frac{s+4}{s(s+5)}\right] = 0$$

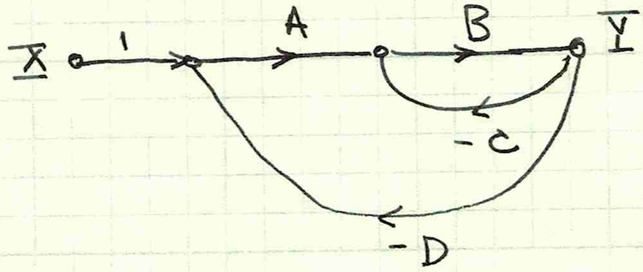
$$s^3 + 5s^2 + ks + k4 = 0$$

$$\begin{array}{c|cc} s^3 & 1 & k \\ s^2 & 5 & k4 \\ s & \frac{5k - k4}{5} & \\ s^0 & k4 & \end{array} \qquad \begin{array}{l} \\ \\ k > 0 \\ k4 > 0 \end{array}$$

stable for $k > 0$

3

(a)



(b) Forward Path

$P_1 = AB$

Loops

$L_1 = -BC$

$L_2 = -ABD$

$\Delta = 1 - L_1 - L_2$

$\Delta_1 = 1$

$$\frac{Y}{X} = \frac{P_1 \Delta_1}{\Delta}$$