ME 466 Final Exam Soln, SP 2005

1) a) flow source: rate of drug injection is the important variable to control (maintain dosage)
   b) potential source: temperature can be maintained precisely, heat flow will adjust as needed
   c) potential source: applies necessary rotation regardless (ideally) of resistance
   d) potential source: (mgh
   e) potential energy storage and perhaps energy dissipation. low flow means little energy dissipation can occur.

2) a) Max resisting torque with power
   b) Max resisting torque with no electrical power
   c) Angle between stable points in rotation. Angle traveled for one pulse
   d) Maximum resistive torque that can be overcome in an instantaneous rate (usually ~ 10 pps)
   e) Absolute torque that can be applied an a given speed

3) Presume N means gear ratio

$$I_{eff} = (I_m + I_{G1}) + N_1^2 (I_{G2} + I_{G3}) + N_1^2 N_2^2 (I_{G4} + I_{rod})$$

$$I_{rod} = \frac{1}{3} m \left(\frac{L}{2}\right)^2 = \frac{1}{12} m L^2$$

$$T = i K_T = I_{eff} \dot{\omega} + C \omega$$

$$v_a = i R_a + \frac{di}{dt} L_a + K_e \omega$$

$$\begin{bmatrix} \frac{di}{dt} \\ \dot{\omega} \end{bmatrix} = \begin{bmatrix} -\frac{R_a}{L_a} & -\frac{K_e}{L_a} \\ \frac{K_T}{I_{eff}} & -\frac{C}{I_{eff}} \end{bmatrix} \begin{bmatrix} i \\ \omega \end{bmatrix} + \begin{bmatrix} \frac{1}{L_a} \\ 0 \end{bmatrix} v_a$$

4) $\dot{y} + a y = u(t)$

$$y(t) = 1 - e^{-at} = 1 - e^{-\frac{t}{\tau}}$$

1 time constant is at ~63% decay $\left(1 - \frac{1}{e}\right)$

$\tau \approx 2$

$$\dot{y} + \frac{1}{2} y = u(t)$$

5) Section I (left end)

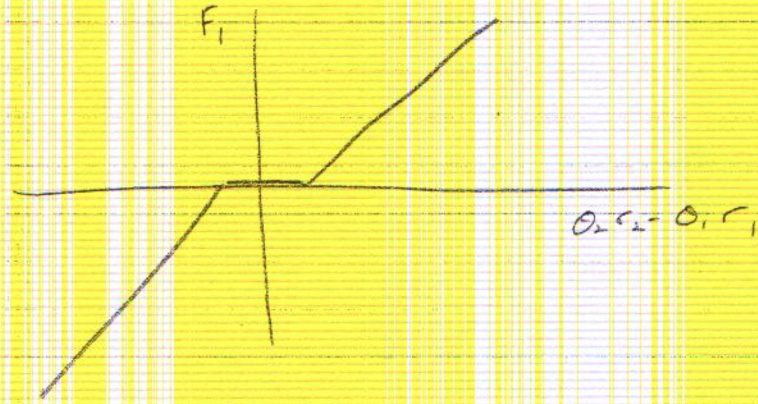
$$I_1 \ddot{\theta}_1 = T_1 - r F_1$$

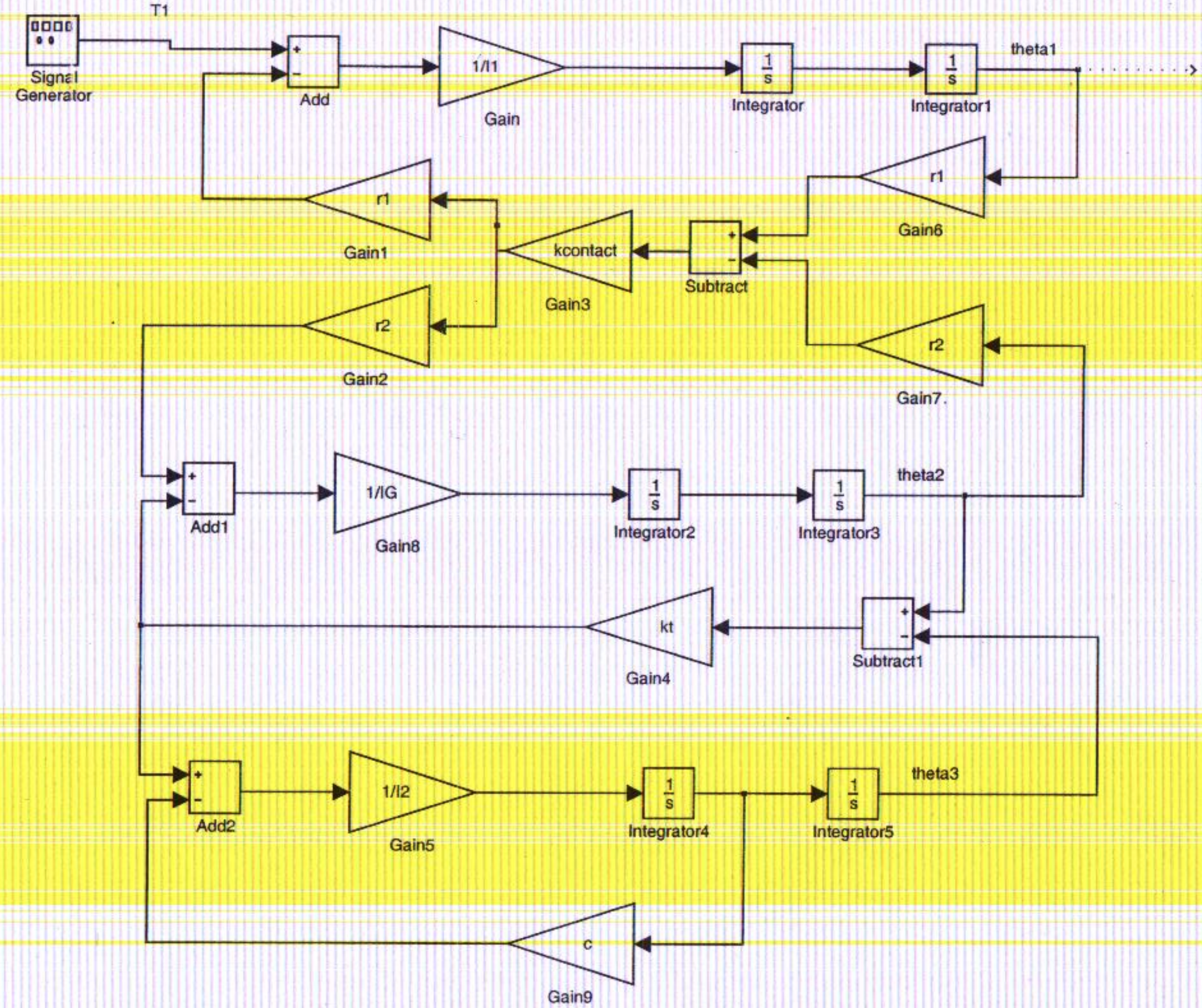
Gear 2

$$I_G \ddot{\theta}_2 = F_1 r_2 - k(\theta_2 - \theta_3)$$

Mass w/ damper

$$I_2 \ddot{\theta}_3 = -k(\theta_3 - \theta_2) - c\dot{\theta}_3$$




Signal Generator
T1
Add
1/I1
Gain
Integrator
Integrator1
theta1
r1
Gain1
kcontact
Gain3
Subtract
r1
Gain6
r2
Gain2
r2
Gain7.
Add1
1/IG
Gain8
Integrator2
Integrator3
theta2
kt
Gain4
Subtract1
Add2
1/I2
Gain5
Integrator4
Integrator5
theta3
c
Gain9

6) ① $p_1 = \rho g h_1$ $\qquad\qquad p_2 = \rho g h_2$

② $q_1 = \frac{1}{R_1} p_1$ $\qquad\qquad q_2 = \frac{1}{R_2} p_2$

$$q_3 = \frac{1}{R_3}(p_1 - p_2)$$

③ $A_1 \dot{h}_1 \rho = q_{in} - q_1 - q_3$ $\qquad\qquad A_2 \dot{h}_2 \rho = q_3 - q_2$

Combining

a) $$\begin{bmatrix} \dot{h}_1 \\ \dot{h}_2 \end{bmatrix} = \begin{bmatrix} \frac{-g}{A_1}\left(\frac{1}{R_1} + \frac{1}{R_3}\right) & \frac{g}{A_1 R_3} \\ \frac{g}{A_2 R_3} & \frac{-g}{A_2}\left(\frac{1}{R_3} + \frac{1}{R_2}\right) \end{bmatrix} \begin{bmatrix} h_1 \\ h_2 \end{bmatrix} + \begin{bmatrix} \frac{1}{A_1 \rho} \\ 0 \end{bmatrix} q_{in}$$

b) ② become

$$q_1 = \sqrt{\frac{p_1}{R_1}} \qquad q_2 = \sqrt{\frac{p_2}{R_2}}$$

$$q_3 = \sqrt{\frac{p_1 - p_2}{R_3}}$$

$$\begin{bmatrix} \dot{h}_1 \\ \dot{h}_2 \end{bmatrix} = \begin{bmatrix} \frac{-1}{A_1 \rho}\left(\sqrt{\frac{\rho g (h_1 - h_2)}{R_3}} + \sqrt{\frac{\rho g h_1}{R_1}}\right) \\ \frac{1}{A_2 \rho}\left(\sqrt{\frac{\rho g (h_1 - h_2)}{R_3}} - \sqrt{\frac{\rho g h_2}{R_2}}\right) \end{bmatrix} + \begin{bmatrix} \frac{1}{A_1 \rho} \\ 0 \end{bmatrix} q_{in}$$

Note, when one has $h_1 - h_2$ inside a square root, $\sqrt{h_1 - h_2}$ means $\mathrm{sgn}(h_1 - h_2)\sqrt[4]{(h_1 - h_2)^2}$.