MATLAB Problems

5.21 A centrifugal pump has the nonlinear pressure-flow relation

$$P = 3.645(10^5)\sqrt{1 - \frac{Q}{0.019}} \text{ Pa}$$

where Q is the volumetric-flow rate (in m^3/s) and P is the pressure output of the pump (in Pa). The pump model is valid for $0 < Q \leq 0.0175\ m^3/s$. The nominal (operating) volumetric-flow rate is $0.008\ m^3/s$. Derive a linear model for the pump pressure about the operating (nominal) point. Plot the true (nonlinear) pump pressure and approximate (linearized) pump pressure vs. volumetric-flow rate for $0 < Q < 0.0175\ m^3/s$. Comment on the range of accuracy for the linear pump model.

5.22 The inductance of a solenoid actuator varies with armature position (or stroke) x and can be modeled by the nonlinear expression

$$L(x) = \frac{L_0}{1 - x/d}$$

For a particular solenoid coil, the constant $d = 7.8$ mm and the inductance at zero stroke is $L_0 = 0.006$ H. Note that inductance $L(x)$ increases with stroke x as the armature moves toward the center of the coil.

a. Develop a linearized approximation for inductance $L(x)$ about a nominal stroke $x^* = 1$ mm.

b. Plot the (true) nonlinear inductance $L(x)$ and the approximate (linearized) inductance for a stroke $0 < x < 3$ mm.

c. Plot the percent error between the nonlinear and linear inductances vs. stroke and comment on the accuracy of the linear approximation.

Engineering Applications

Review Class

5.23 Figure P5.23 shows the hydromechanical actuator from Example 4.2 in Chapter 4. Obtain a complete set of state-variable equations for this system (note that the piston position is redefined as z so that x may be used as the state variable). Identify the state and input variables.

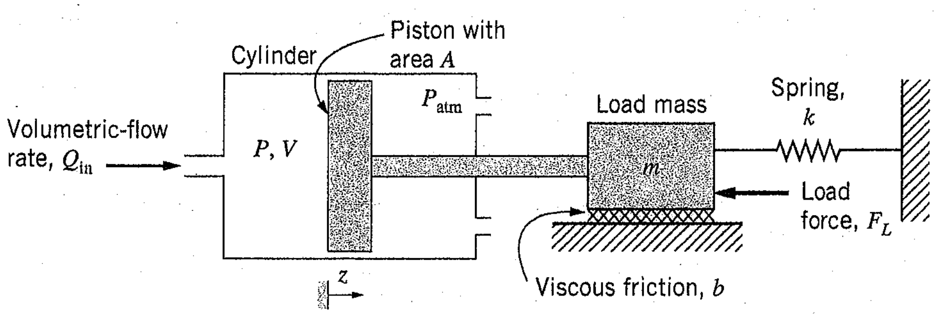
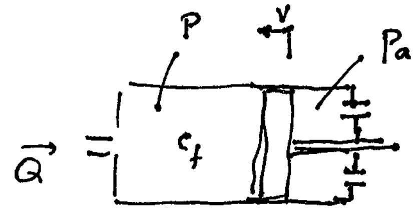
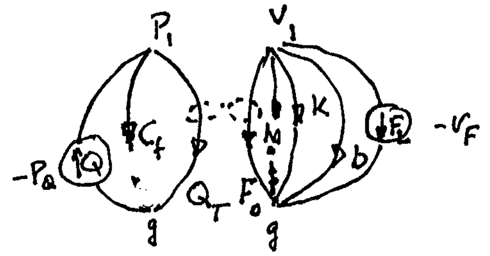


Figure P5.23

5.24 Figure P5.24 shows an electrical system known as a *buck converter*, which is a circuit used to step the source voltage $e_{in}(t)$ "down" to a lower desired output voltage (see Problem 3.27 in Chapter 3). The step-down voltage converter uses a switch to connect and disconnect the voltage supply $e_{in}(t)$ from the remainder of the circuit until output voltage $e_O = e_C$ is equal to the desired voltage. Obtain a complete SSR of the buck



This problem
IF the fluid side of piston cylinder has capacitance $C_f = V/\beta$ $\quad \beta$ = bulk modulus



$b=8 \quad s=2 \quad n=4 \quad p=2$

<u>b-s=6</u>

$Q_c = C_f \frac{dp_{1g}}{dt}$

$F_m = m \frac{dv_{1g}}{dt}$

$F_b = b v_{1g}$

$\frac{dF_K}{dt} = k v_{1g}$

$F_o = p_{1g} \cdot A$

$Q_T = -v_{1g} \cdot A$

<u>n-p=2</u>

$Q - Q_c - Q_T = 0$

$F_o + F_m + F_K + F_b + F_L = 0$

<u>b-(n-p)=6</u>

$-P_Q + P_{1g} = 0$

$-P_{1g} + P_{1g} = 0$

$-v_{1g} + v_{1g} = 0 \quad \times 3$

$-v_{1g} - v_F = 0$

$Q = Q_{c_f} + Q_T$

$Q_{c_f} = C_f \frac{dP_{1g}}{dt}$

$Q - Q_T = C_f \frac{dP_{1g}}{dt}$

$= \frac{V}{\beta} \frac{dP_{1g}}{dt}$

$Q_T = -v \cdot A$

$F_o = P_{1g} A = -F_k - F_b - F - F_m$

$P_{1g} A = F_o = -kx - b\dot{x} - F - m\ddot{x}$

$m\ddot{x} + b\dot{x} + kx = -F - p_{1g}A = -F - (P_1 - P_g)A$

<u>SV + Sources</u>

v_{1g}, p_{1g}, F_K; Q & F_L

$\frac{dv_{1g}}{dt} = \frac{F_m}{m} = \frac{1}{m}\left[-F_o - F_K - F_b - F_L\right]$

$= \frac{1}{m}\left[-Ap_{1g} - F_K - bv_{1g} - F_L\right]$

$\frac{dp_{1g}}{dt} = \frac{Q_c}{C_f} = \frac{[Q - Q_T]}{C_f} = \left[\frac{Q + v_{1g}A}{C_f}\right]$

$\frac{dF_K}{dt} = k v_{1g}$

Note problem in class review had no ~~[illegible]~~ fluid capacitance

Note line graph for C_f is ~~[illegible]~~ dotted since fluid is not in contact with ref. pressure