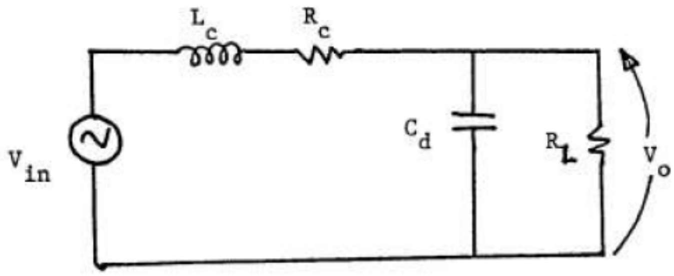
7.4 This system is the same as that of Example 7.1. Thus we have $f_n$ = 91 Hz and $\zeta = 0.033$ for the system without a leak. The system with a leak may be modeled as shown below.




This circuit is similar to the circuit in Fig. 7.8 with $R_L$ connected in parallel to $C_d$. $R_L$ represents the pinhole leak at the junction of the catheter and sensor. We need to find new relationships for $f_n$ and $\zeta$ for this circuit.

$$V_0\ (j\omega)/V_i\ (j\omega) = \frac{(1/C_d L_c)}{-\omega^2 + j\omega\left(\frac{R_L R_c C_d + L_c}{R_L C_d L_c}\right) + \frac{R_L + R_c}{R_L C_d L_c}}$$

The standard form for a second order system is

$$V_0(j\omega)/V_i\ (j\omega) = \frac{K\,\omega_n^2}{-\omega^2 + 2\zeta\,\omega_n(j\omega) + \omega_n^2}$$

Thus $\omega_n = \sqrt{(R_L + R_c)/R_L C_d L_c}$

and $\zeta = (R_L R_c C_d)/(2\ R_L C_d L_c)\ \sqrt{(R_L C_d L_c/R_L + R_c)}$

The values for $R_L$, $R_c$, $C_d$ and $L_c$ must be determined

$C_d = 1/E_d = 2.04 \times 10^{-15}\ \mathrm{m^5/N}$

$L_c = \rho L/\pi r^2 = (1\times10^3)(1)/\pi\ (0.046\times10^{-2})^2 = 1.5 \times 10^9\ \mathrm{Pa \bullet s^2/m^3}$

$R_c = 8\eta L/\pi r^4 = 8(0.001(1)/\pi\ (0.046\times10^{-2})^4 = 4.69 \times 10^{10}$ Pa•s/m$^3$

$R_L$ = Pressure/Flow = 13.3 kPa/ (0.4 ml/min)(1 min/60 s)

$\times$ (1 $\times$ $10^{-3}$m$^3$/1000 ml)

= 2 $\times$ $10^{12}$Pa•s/m$^3$

Thus for the system with a leak

$\omega_n$ = 580 r/s or $f_n$ = 92.4 Hz

and

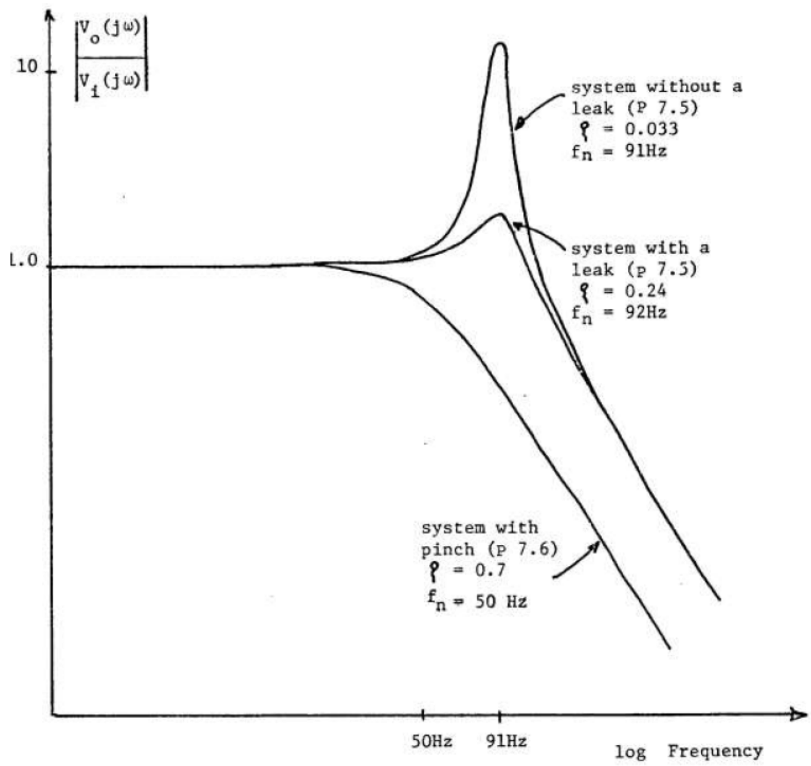
$\zeta = 0.24$

For reference the parameters for the system without a leak

$f_n$ = 91 Hz

$\zeta = 0.033$

The frequency response curves for the system with and without the leak are given below.



8.4

$$F = \frac{Q}{\rho_b c_b \int_0^{t_1} \Delta T_b dt} = \frac{V_i\ T_i\ \rho_i\ c_i}{\rho_b c_b \int_0^{t_1} \Delta T_b dt}$$

$$= \frac{(10\text{ml})(-30\text{K})(1.005\ \text{g/ml})(4.172\ \text{J/(g•K}}{(1.060\ \text{g/ml})(3.640\ \text{J/(g•K)}(-5.0\ \text{s•K)}}$$

= 65.2 ml/s

(62.5 ml/s)(60 s/min) = 3912 ml/min = 3.9 l/min

8.7

$e = Blu$

$= (0.03\ \text{T})(0.015\ \text{m})(1\ \text{m/s})$

$= 0.00045\ \text{V} = 450\ \mu\text{V}$