

- HW 6 due today
- Lab 3 due Friday
- Choose lab partner for 4 and 5
- Lab 4 covered this week
- HW 7 due Monday

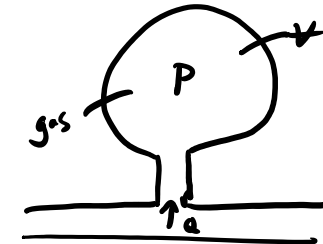
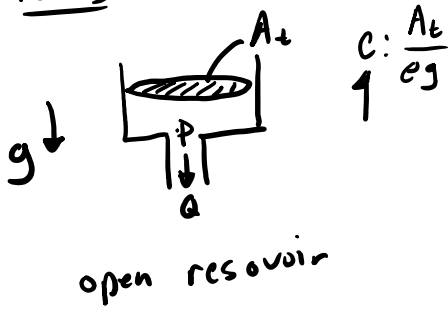
Hydraulic, Pneumatic, Quasi-Static Fluid Systems

* based on assumptions of hydrostatic (high pressure / low fluid velocities)

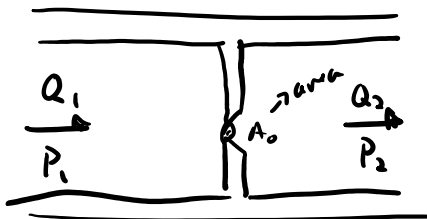
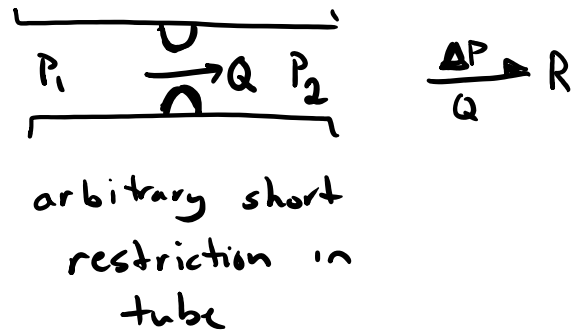
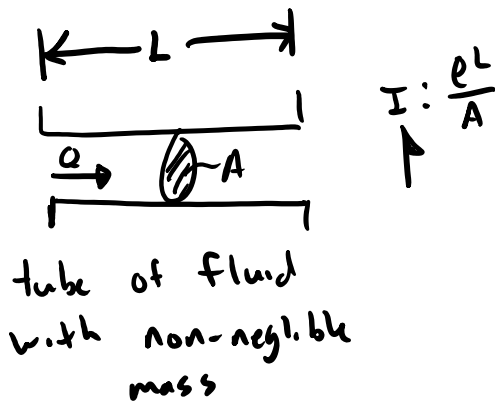
$$Re < 5000$$

laminar flow

Parts



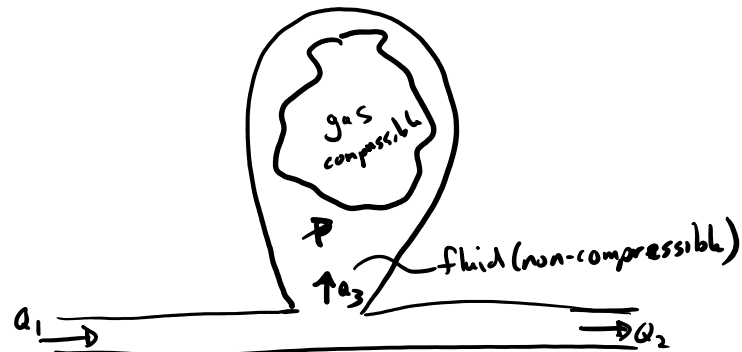
"acoustic approximation"



$$P_1 - P_2 = P_3 \uparrow \begin{matrix} R \\ Q_3 \\ \downarrow \\ P_2 \\ Q_2 \end{matrix}$$

$$P_3 = \frac{\rho Q_3 |a_3|}{2 C_d^2 A_0^2}$$

$$P_3 = \frac{\rho Q_3 |a_3|}{2 C_d(x)^2 A_d(x)^2}$$



$$c = \frac{P_3}{\rho a_3} \quad \begin{matrix} P_1 \\ \downarrow \\ Q_1 \end{matrix} \quad \begin{matrix} P_2 \\ \downarrow \\ Q_2 \end{matrix}$$

$$P_3 = P_0 \left(\frac{v}{c_s} \right)^2$$

$$C = \frac{C_d^2 A_0^2}{2}$$

discharge coefficient

$$C(x) = \frac{C_d^2(x) A_d(x)^2}{2}$$

size of the valve opening

$$P_3 = \frac{P_0 V_0^\gamma}{(V_0 - V_3)^\gamma}$$

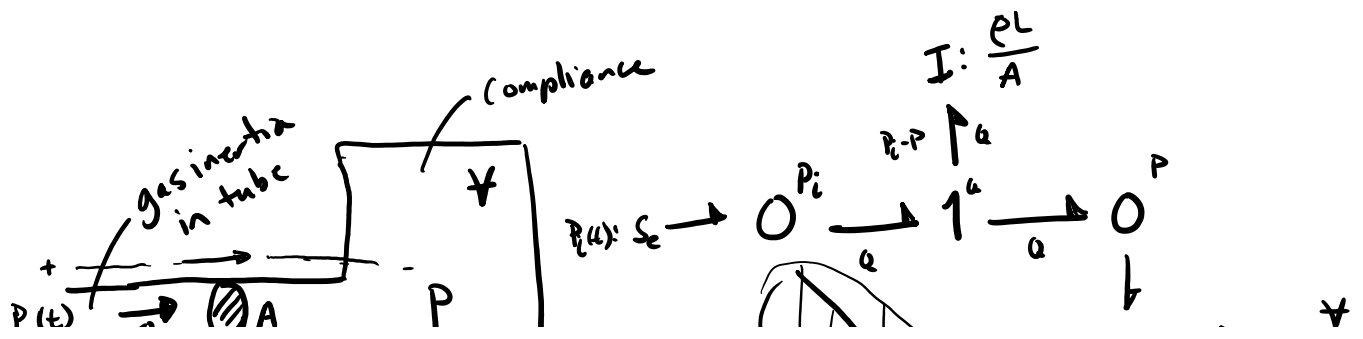
γ specific heat ratio
 $P_0, V_0 \Rightarrow$ initial pressure and volume
 $P_3, V_3 \Rightarrow$ changing pressure and volume

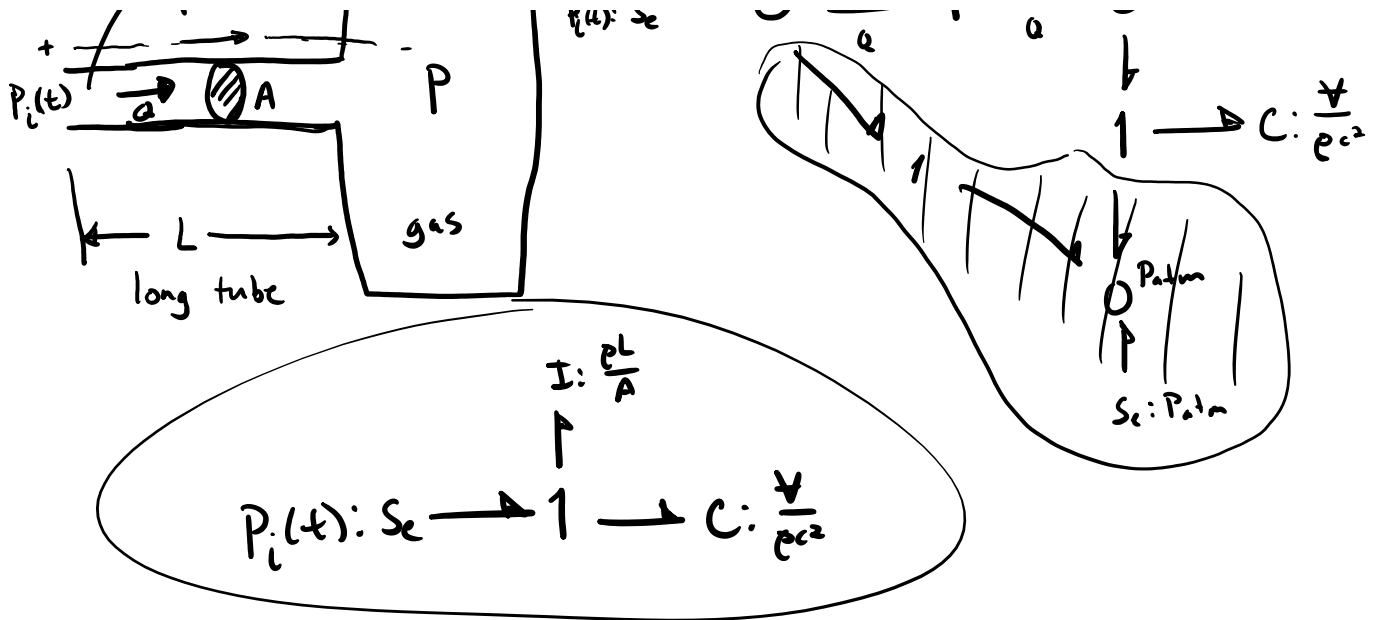
Steps for hydraulic systems (similar to electric circuits)

1. Show positive directions of flow and pressure on diagrams.
 2. For each distinct pressure establish a 0-junction and attach elements that act on that absolute pressure. Include a 0-junction for atmospheric pressure.
 3. Insert R, C, and I junctions between appropriate 0-junctions for an associated pressure drops.
 4. Eliminate 0-junction for atmospheric pressure if gage pressure is desired.
5. Simplify.

Example: Helmholtz Oscillator

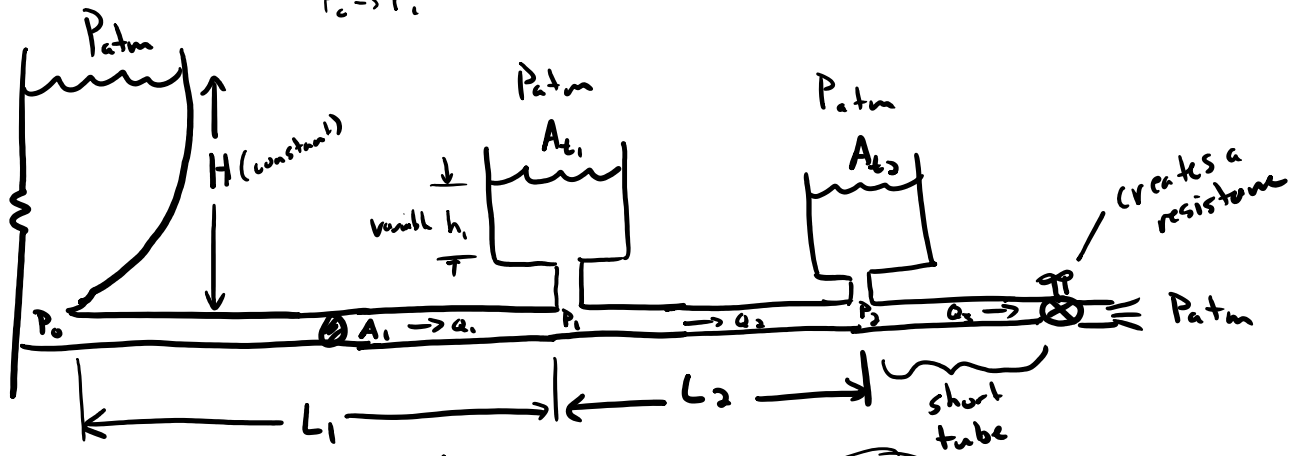
equivalent to a mass-spring or LC circuit system



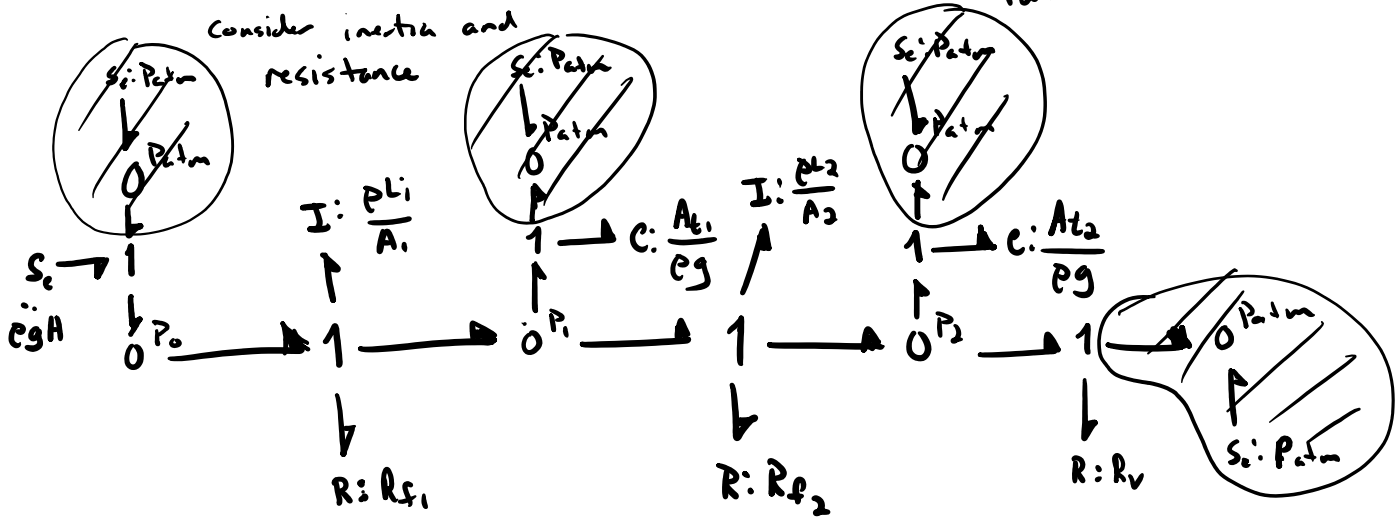


Example

$P_0^+ \rightarrow P_{atm}$
 $P_c^+ \rightarrow P_i$
 $P_i^+ \rightarrow P_{atm}$



Consider inertia and resistance



R_f for laminar flow in a pipe a reasonable linear coefficient:

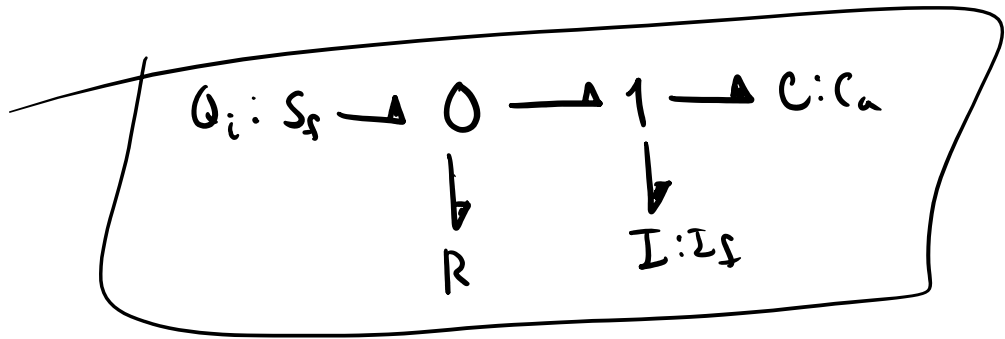
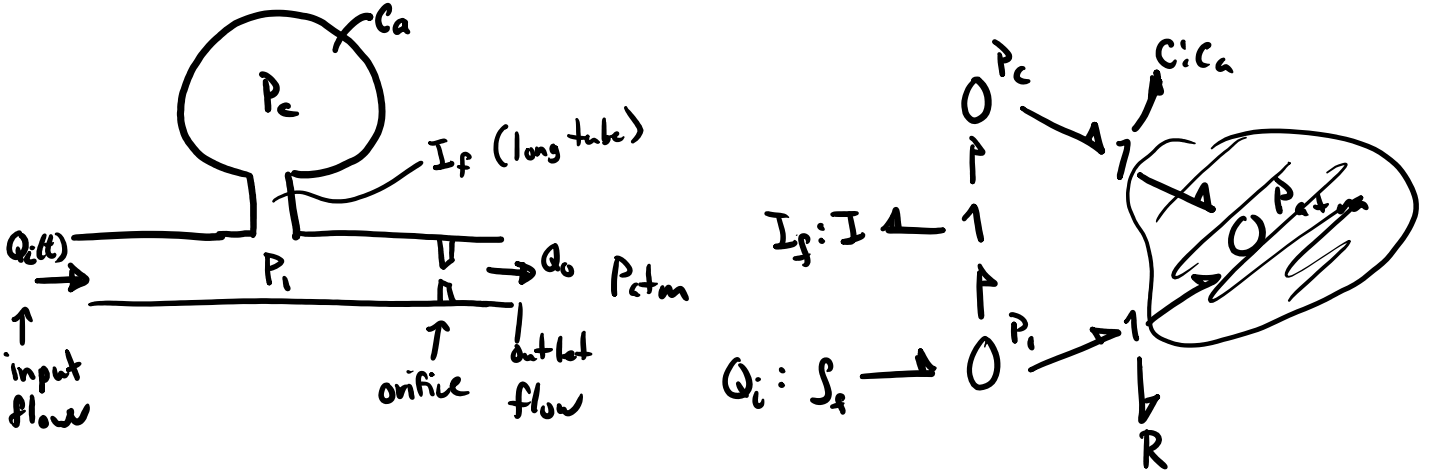
$R_f = \frac{128 \mu L}{\pi d^4}$ d : pipe ϕ

Reynolds number

$$R_f = \frac{128 \mu l}{\pi d^4}$$

d : pipe ϕ
 μ : viscosity of the fluid
 l : length

Exercise



Lumped Mass Model of Fluid in a Line

