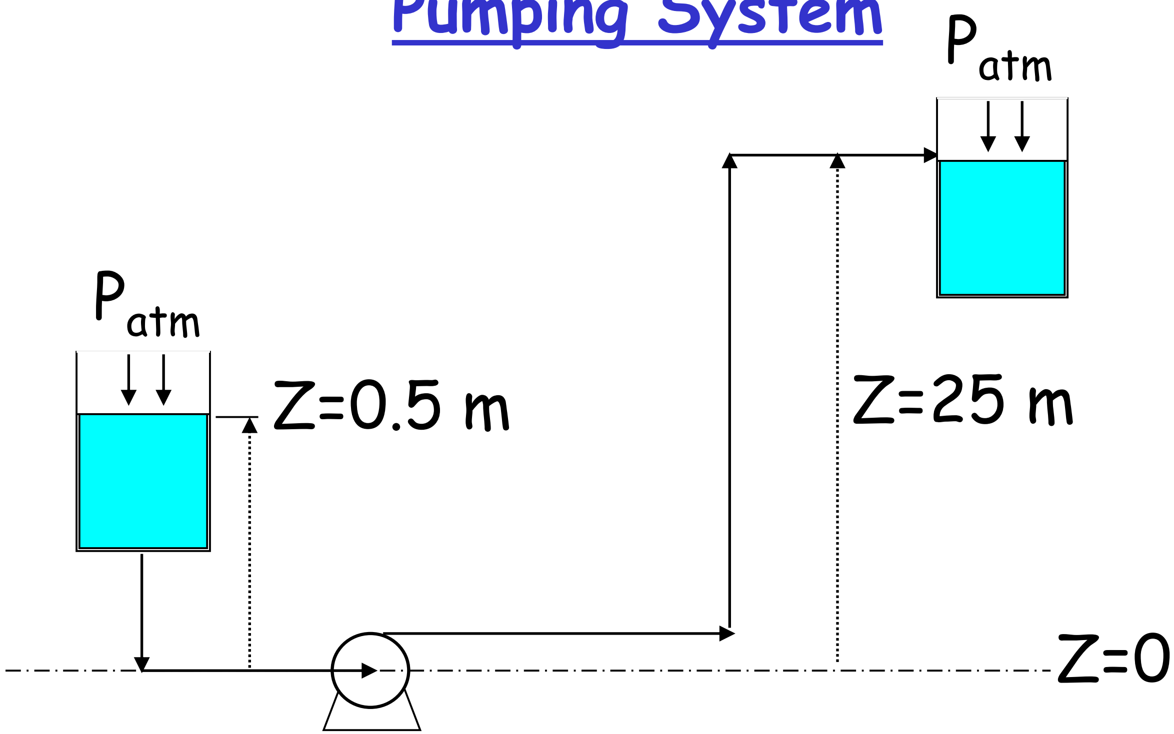
Pumping System



Suction line length (including fittings equivalent lengths) 12.0 m
Discharge line length (including fittings equivalent lengths) 50.0 m
ID of the suction pipe 0.4064 m, ID of the discharge line 0.3556 m
Water flow at 0.75 m^3/min.

The Fanning friction factor can be assumed at 0.008.

Pumping System

(a) Find the friction loss in the suction side of the pump.

(b) What is the pump inlet pressure?

(c) What is the power necessary to drive the pump?

1 atm= 101,325 Pascal. ρ=1,000 kg/m^3, g=9.81 m/s^2.

Use the Bernoulli Equation:

$$g(Z_2 - Z_1) + \left(\frac{p_2}{\rho_2} - \frac{p_1}{\rho_1}\right) + \left(\frac{V_2^{\,2} - V_1^{\,2}}{2}\right) = \Delta W_o - \sum F$$

Pumping System

(a) Find the friction loss in the suction side of the pump.

The friction loss is given by:

$$F = \frac{2V^2 f}{D} L$$

Need to calculate velocity:

$V=(4/\pi D^2)\ Q = (4/\pi\ 0.4064^2)\ .75\ m^3/min = 0.09636\ m/s$

and $F=2 * .09636^2 * 0.008 * 12 / 0.4064 = 0.0044\ m^2/s^2$

Pumping System

(b) What is the pump inlet pressure?

Use the Bernoulli Equation for the suction line:

$$g(Z_2 - Z_1) + \left(\frac{p_2}{\rho_2} - \frac{p_1}{\rho_1}\right) + \left(\frac{V_2^{\,2} - V_1^{\,2}}{2}\right) = \Delta W_o - \sum F$$

So, $g*(-0.5)+(p_2 - p_1)/\rho + V_2^2/2 = - F$

and $p_2 = 1{,}000\ (-0.0044+9.81*0.5 - .09636^2/2)\ \text{kg}/(\text{m s}^2) +$

$101{,}325\ \text{Pa} = 106216\ \text{Pa}$ or $106.216\ \text{kPa}$ absolute.

Think about cavitation!

Pumping System

(c) What is the power necessary to drive the pump?

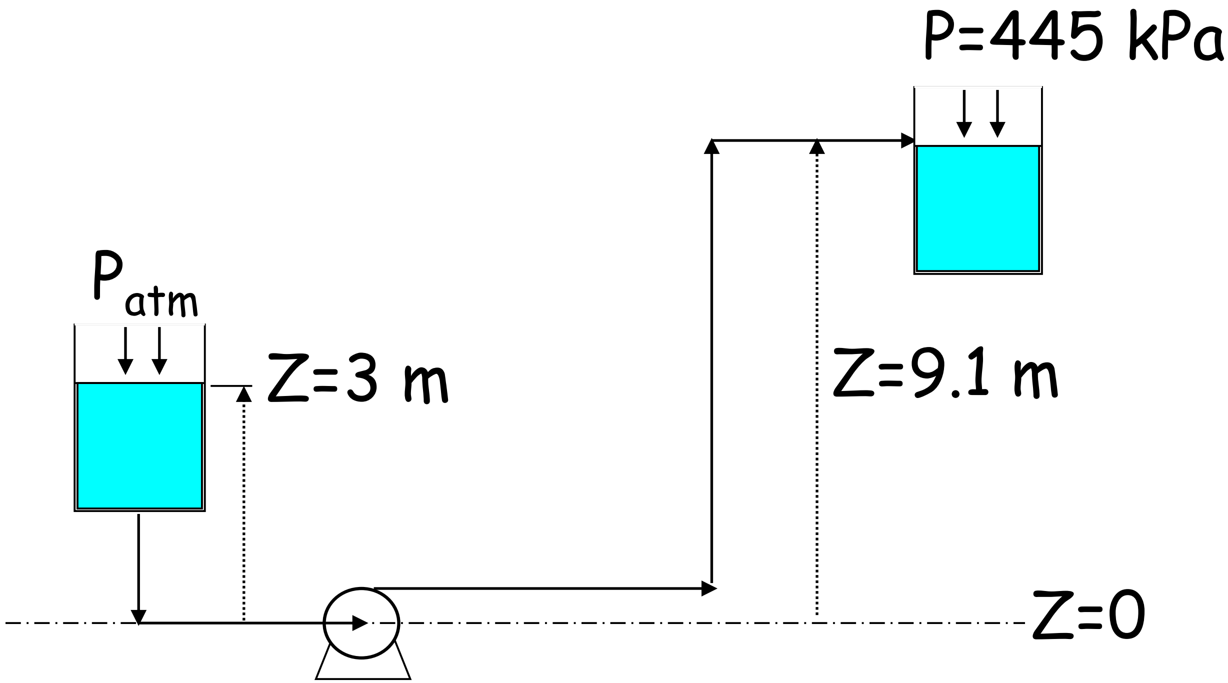
Use the Bernoulli Equation between the end points:

$$g(Z_2 - Z_1) + \left(\frac{p_2}{\rho_2} - \frac{p_1}{\rho_1}\right) + \left(\frac{V_2^{\;2} - V_1^{\;2}}{2}\right) = \Delta W_o - \sum F$$

So, $g*24.5 = \Delta W_o - (F_s + F_d)$

$F_d = 2*.125^2*50*0.008/0.3556 = 0.0356\ m^2/s^2$
and $\Delta W_o = 9.81*24.5 + (0.0044+0.0356) = 240.38\ m^2/s^2$
But Bernoulli above is per unit mass, so:
$240.38\ m^2/s^2 * 1{,}000\ kg/m^3 * 0.75\ m^3/\ 60\ s = 3.004\ kW$
Actual power with 75% efficiency: P=3.004/0.75=4.00 kW

Pumping System



Suction and discharge lines combined length of 46.0 m
Five 90^{O} elbows in the lines,
ID of the pipe 0.078 m,
Lean oil flow at 2.7 kg/s.
Viscosity 15 cP, density 857 kg/m^3

What is the pump motor power, when the efficiency is 40% ?.

Pumping System

(a) Find the friction loss in the pipe system.

The friction loss is given by:

$$F = \frac{2V^2 f}{D} L$$

Need to calculate the Fanning factor and the equivalent lengths.

$V=(4/\pi D^2)\ Q = (4/\pi\ 0.078^2) * 2.7 / 857$ m/s = 0.659 m/s

So, Reynolds number = $D\ V\ \rho / \mu$ = 2,937
From Moody diagram (Fig 12-1) and steel : f=0.011
Equivalent length (Table 12-1): 5*32*0.078 + 46 = 58.5 m

and $F=2 * 0.659^2 * 0.011 * 58.5 / 0.078 = 7.17\ m^2/s^2$

Pumping System

(b) What is the power necessary to drive the pump?

Use the Bernoulli Equation between the end points:

$$g(Z_2 - Z_1) + \left(\frac{p_2}{\rho_2} - \frac{p_1}{\rho_1}\right) + \left(\frac{V_2^{\ 2} - V_1^{\ 2}}{2}\right) = \Delta W_o - \sum F$$

So,

$g*6.1 + (445{,}000 - 101{,}359)/857 + 0.659^2/2 = \Delta W_o - 7.17$

$\Delta W_o = 9.81*6.1 + 7.17 + 400.98 + 0.22 = 468.21\ m^2/s^2$

But Bernoulli is per unit mass, so:

$468.21\ m^2/s^2 * 2.7\ kg/s = 1.265\ kW$

Actual power with 40% efficiency: P=1.265/0.4=3.18 kW

Pressure loss

What is the pressure loss when 2.14 kg/s of benzene at 40° C flows in a 21 m long pipe with ID = 0.0409 m ?

The pipeline has six 90° elbows, one tee used as an elbow (equiv. resistance is 60 pipe diameters), one globe valve, and one gate valve.
Density 849 kg/m^3, viscosity at 40° C is 5x10^{-4} Pa·s

Pressure loss

Need to calculate the Fanning factor and the equivalent lengths.

Equivalent lengths (Table 12-1):

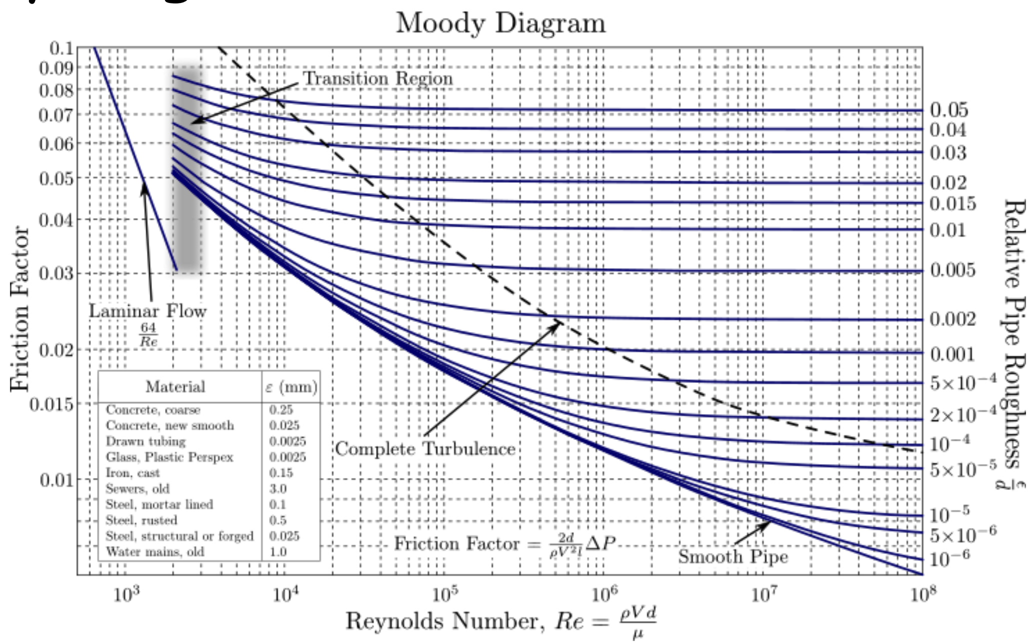
6	90^o elbows	192 D
1	Tee	60 D
1	Gate valve (open)	7 D
1	Globe valve (open)	300 D

So, L_{eq} = 559 * 0.0409 = 22.9 m, and L=22.9 + 21 =43.9
$V=(4/\pi D^2)\ Q = (4/\pi\ 0.0409^2) * 2.14 / 849$ m/s = 1.92 m/s

$Re = D\ V\ \rho / \mu = 1.33\times10^5$
From Moody diagram (Fig 12-1) and steel : f=0.0053
and $F=2 * 1.92^2 * 0.0053 * 43.9 / 0.0409$ =41.9 N m/kg
Finally, $\Delta P = F\ \rho$ =41.9 *849 = 35,575 Pa

Pressure loss

Re = D V ρ / μ = 1.33×10^5
From Moody diagram and steel :



f=0.0053
and F=2 * 1.92^2 * 0.0053 * 43.9 / 0.0409 =41.9 N m/kg
Finally, ΔP = F ρ =41.9 *849 = 35,575 Pa