# ENGR 292 Fluids and Thermodynamics

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## Pump and Pipe Example

***Design a Pump and Pipe System for the starter problem of Technologist***

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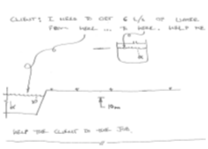
## Step 1

***Rough Layout***



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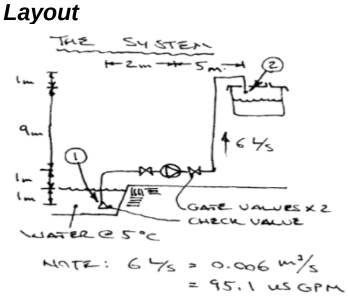
## Step 1 (cont'd)

***Rough Layout***

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## Step 2

***Pipe Size (Discharge):***

- $Q = \mathrm{v}A$ → $A = \frac{Q}{\mathrm{v}}$
- $A = \frac{\pi D^2}{4}$ → $D = \sqrt{\frac{4A}{\pi}}$
- $\mathrm{v}$ ***: Recommended Velocity***
  - ***We choose*** $v = 3m/s$ ***(Design)***
  - ***So*** $A = \frac{Q}{v} = \frac{0.006\ m^3/s}{3\ m/s} = 0.002m^2$

$$\therefore\ D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{(4)(0.002)}{\pi}} \approx 0.050463m = 50.463mm$$

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## Step 2 (cont'd)

***Pipe Size:***

- ***Choose a close real size***
- ***http://www.engineeringtoolbox.com/asme-steel-pipes-sizes-d_42.html***
- ***SCH 40 … ID=52.501mm***
- ***That is for 2" SCH 40 Pipe***
- $D_{Discharge} = 52.501 \times 10^{-2}m$
- $A_{Discharge} = 21.648 \times 10^{-4}m^2$

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## Step 3

***Suction Line Size:***

- ***One standard size larger than the discharge***
- ***Choose 2 1/2" SCH 40***
- ***ID=62.713mm***
- $D_{Suction} = 62.713 \times 10^{-2} m$
- $A_{Suction} = 30.889 \times 10^{-4} m^2$

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## Step 4

***Calculate Actual Flow Velocity of Discharge***

$$\mathrm{v}_{Discharge} = \frac{Q}{A_{Discharge}} = \frac{0.006 m^3/s}{21.648 \times 10^{-4} m^2}$$

$$= 2.77\ m/s$$

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## Step 4 (cont'd)

***Calculate Actual Flow Velocity of Suction***

$$\mathrm{v}_{Suction} = \frac{Q}{A_{Suction}} = \frac{0.006 m^3/s}{30.889 \times 10^{-4} m^2}$$

$$= 1.94\ m/s$$

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## Step 5

***Determine the Reynolds Number***

$$N_R = \frac{\mathrm{v} D \rho}{\mu}$$

$$at\ 5℃\ \ldots$$

$$\rho = 999.9\ kg/m^3$$

$$\mu = 1.519 \times 10^{-4} kg/(ms)$$

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## Step 5 (cont'd)

***Reynolds Number (Discharge)***

$$N_{R\_Discharge} = \frac{\mathrm{v}_{Discharge} D_{Discharge} \rho}{\mu}$$

$$= \frac{(2{,}77)(52.501 \times 10^{-3})(999.9)}{1.519 \times 10^{-4}} = 9.6 \times 10^4$$

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## Step 5 (cont'd)

***Reynolds Number (Suction)***

$$N_{R\_Suction} = \frac{\mathrm{v}_{Suction} D_{Suction} \rho}{\mu}$$

$$= \frac{(1.94)(62.713 \times 10^{-3})(999.9)}{1.519 \times 10^{-4}} = 8.0 \times 10^4$$

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## Step 6

**Pipe Material: Commercial Steel**

http://www.pipeflow.com/sitemap/pipe-roughness

**Roughness:**

$$\varepsilon = 0.0045\ (mm)$$

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## Step 7

**Relative Roughness:**

**Discharge Pipe:**

$$\frac{\varepsilon}{D_{Discharge}} = \frac{0.0045}{52.501} = 0.00086$$

**Suction Pipe:**

$$\frac{\varepsilon}{D_{Suction}} = \frac{0.0045}{62.713} = 0.00072$$

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## Step 7

**Relative Roughness:**

**Discharge Pipe:**

$$\frac{D_{Discharge}}{\varepsilon} = \frac{52.501}{0.0045} = 11666.89$$

**Suction Pipe:**

$$\frac{D_{Suction}}{\varepsilon} = \frac{62.713}{0.0045} = 13936.22$$

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## Step 8

**Friction Factor:**

**From Moody Diagram**

$$f_{Discharge} = f_{Suction} \approx 0.0217$$

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## Step 9

**Pipe Length:**

$$L_{Discharge} = 9 + 1 + 1 + 5 = 16\ (m)$$
$$L_{Suction} = 1 + 1 + 2 = 4\ (m)$$

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## Step 10

**Pipe Friction Head Loss:**

$$h_L = f\frac{L}{D}\frac{\mathrm{v}^2}{2g}$$

$$h_{L\_Discharge} = (0.0217)\frac{16}{52.501 \times 10^{-3}}\frac{(2.77)^2}{2(9.81)} = 2.59\ (m)$$

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## Step 10 (cont'd)

**Pipe Friction Head Loss:**

$$h_L = f\frac{L}{D}\frac{v^2}{2g}$$

$$h_{L\_Suction} = (0.0217)\frac{4}{62.713\times10^{-3}}\frac{(1.94)^2}{2(9.81)} = 0.266\ (m)$$

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## Step 11

**Fitting Head Loss: Minor Losses:**

$$h_L = \left[\sum K\right]\frac{v^2}{2g}$$

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## Step 11 (cont'd)

**Fitting Head Loss: Minor Losses**

**Discharge:**

- *2 gate valves:* $K = 0.16$ *each*
- *3 elbows:* $K = 0.39$ *each*
- *Discharge:* $K = 1.0$

$$h_{L\_Discharge} = [(0.16)\times2 + (0.39)\times3 + (1.0) + 0]\frac{1.94^2}{2\times9.81} = 0.974\ (m)$$

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## Step 11 (cont'd)

**Fitting Head Loss: Minor Losses**

**Suction:**

- *1 check valve:* $K = 2.0$ *each*
- *1 elbow:* $K = 0.39$ *each*

$$h_{L\_Suction} = [(2.0) + (0.39)]\frac{1.94^2}{2\times9.81} = 0.458\ (m)$$

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## Step 12

**Determine the pump head:**

**Reorder the general energy equation:**

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_R - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

**To:**

$$h_A = \frac{p_2 - p_1}{\gamma} + z_2 - z_1 + \frac{v_2^2 - v_1^2}{2g} + h_R + h_L$$

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## Step 12 (cont'd)

**Determine the pump head:**

$$p_1 = \rho g h = (999.9)(9.81)(1) = 9.81\ \text{kpa (gage)}$$

$$p_2 = 0\ \text{kpa (gage)}$$

$$\gamma = \rho g = 999.9\times9.81 = 9.81\ kN/m^3$$

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## Step 12 (cont'd)

***Determine the pump head:***

***So***

$$h_A = \frac{p_2 - p_1}{\gamma} + z_2 - z_1 + \frac{v_2^2 - v_1^2}{2g} + h_R + h_L$$
$$= \frac{0 - 9.81}{9.81} + [(1 + 1 + 9) - 0] + \frac{2.77^2 - 1.94^2}{2 \times 9.81} + 0$$
$$+[0.266 + 0.458 + 2.59 + 0.974] = 14.49\ (m)$$

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## Step 13

***Pump Selection – Pump Curves***

$$Q = 95.1\ \ (US\ GPM)$$
$$h_A = 14.49\ (m) = 47.54\ (ft)$$

*After a little searching …*

*B&G Model 1510 – 2E at 1150 PRM can be an option*

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## Step 14

***Check Suction Design:***

$$\boldsymbol{NPSH_A > NPSH_R}$$

***Or Change Design !***

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