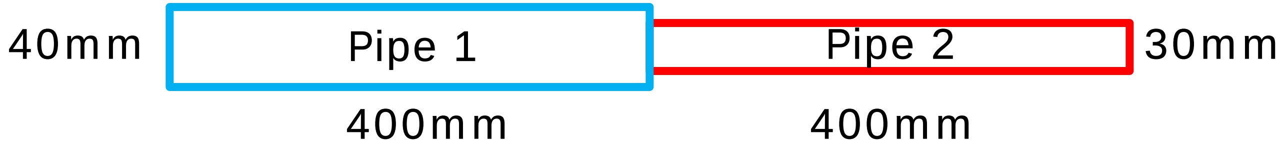
Tutorial – 1



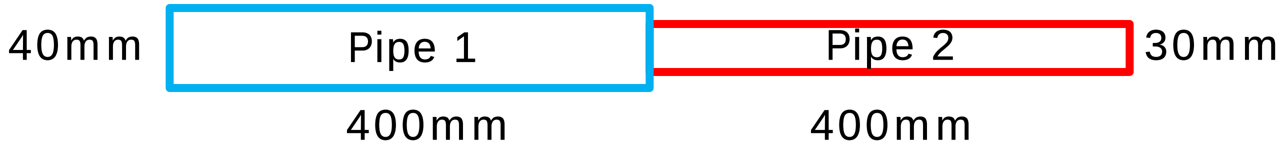
- Calculate the overall conductance of the pipe assembly shown above. The pressure on the right end of the 40 mm tube is 150 mPa, while the pressure on the left end of 30mm pipe is 10 mPa. The ambient temperature is 300 K. The molecular weight and viscosity of air are 28.95 g/mol and 18.47 μPa-s.

Tutorial – 1

Given	
Apparatus : Series Combination of pipes	
Working Fluid : Air (mol. wt. 28.95 g/mol)	
Temperature : 300 K	
Dimensions	Pipe 1 – 40mm dia., 400mm Length Pipe 2 – 30mm dia., 400mm Length

Calculate
Overall Conductance (**C_o**)

Tutorial – 1



Calculation of Flow Regime

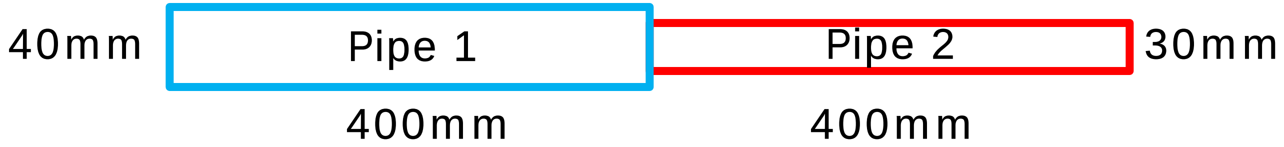
- $\mathbf{N_{Kn}}$ for pipe 1: D=0.04m, L=0.4m, T=300 K, R=8314/28.95, μ=18.47 μPa-s, p=0.15Pa.

$$N_{Kn} = \frac{\lambda}{D} = \frac{\mu}{Dp}\left(\frac{\pi RT}{2}\right)^{0.5}$$

$$N_{Kn} = \frac{18.47\left(10^{-6}\right)}{(0.04)(0.15)}\left(\frac{\pi(287.14)(300)}{2}\right)^{0.5}$$

$$N_{Kn} = 1.132$$

Tutorial – 1



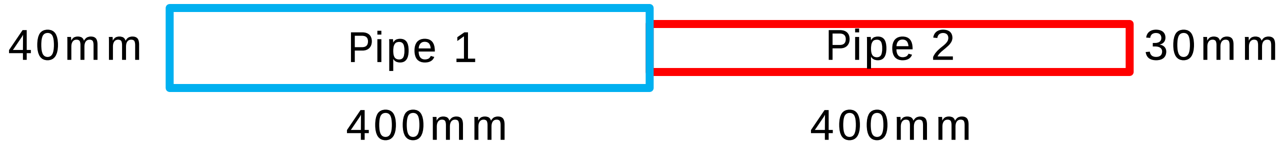
Similarly, calculating $\mathbf{N_{Kn}}$ for Pipe 2, we have

- $\mathbf{N_{Kn}}$ for pipe 1: 1.132
- $\mathbf{N_{Kn}}$ for pipe 2: 22.65

- The Knudsen numbers for both the pipes are greater than 0.3. Therefore, the flow is free molecular through out the series combination.

- The **L / D** ratios of each of these pipes being less than 30, these are classified as Short Pipes.

Tutorial – 1



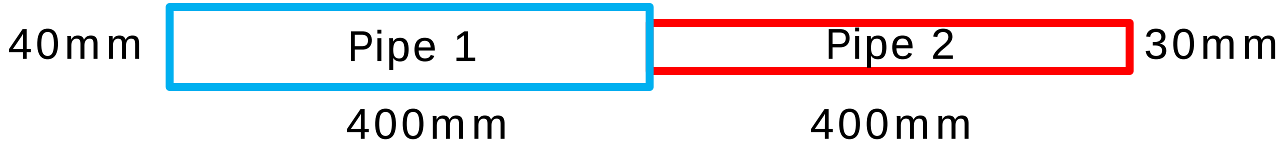
Conductance for pipe 1: D_1=0.04m, D_2=0.04m, L=0.4m, T=300 K, $\mathcal{R}$=8314, M=28.95 gm/mol.

$$C_1 = \frac{D_1^2 \sqrt{\left(\pi \Re T / 18M\right)}}{L/D_1 + (4/3)\left(1 - \left(D_1/D_2\right)^2\right)}$$

$$C_1 = \frac{(0.04)^2 \sqrt{\left(\pi \Re (300)/18(28.95)\right)}}{0.4/0.04 + (4/3)\left(1 - (0.04/0.04)^2\right)}$$

$$C_1 = 0.0173 m^3 / s$$

Tutorial – 1



Similarly, calculating conductance for Pipe 2, we have

- Pipe 1 ($\mathbf{C_1}$) : 0.0173
- Pipe 2 ($\mathbf{C_2}$) : 0.0079

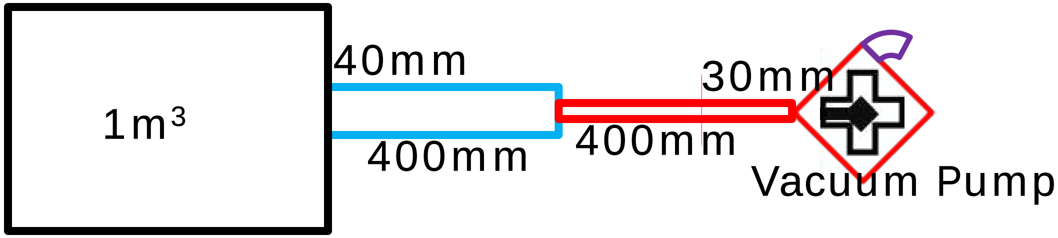
- The Overall Conductance ($\mathbf{C_o}$) for a series combination is given by

$$\frac{1}{C_o} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C_o} = \frac{1}{0.0173} + \frac{1}{0.0079}$$

$$C_o = 0.00542 m^3 / s$$

Tutorial – 2



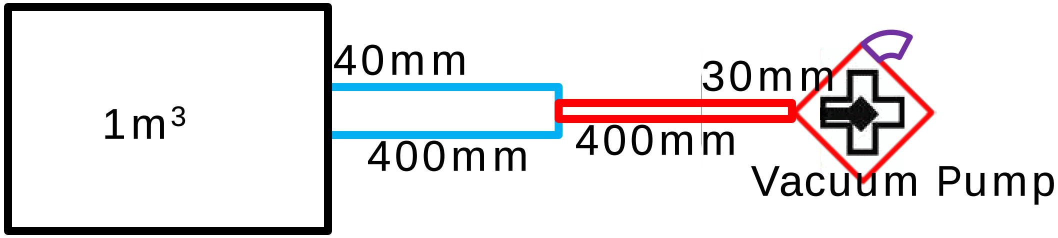
- Consider a vacuum vessel of $1 m^3$ with an initial pressure of 1 atm at 300 K. It is connected to a vacuum pump via a connecting pipe as shown above. The ultimate pressure of the system is 0.1 mPa. Determine the system pumping speed, if the required vacuum in the cavity is 1 kPa in 1 hour.

Tutorial – 2

Given	
Apparatus	Vacuum Pump
Working Fluid	Air at 1 atm
Vacuum	1 kPa
Temperature	300 K
Connecting Pipe	Pipe 1 : 40mm (D), 400mm (L) Pipe 2 : 30mm (D), 400mm (L)
Time	1 Hour
Volume	1 m^3
Ultimate Pr.	0.1 mPa

Calculate
System Pumping Speed (S_p)

Tutorial – 2



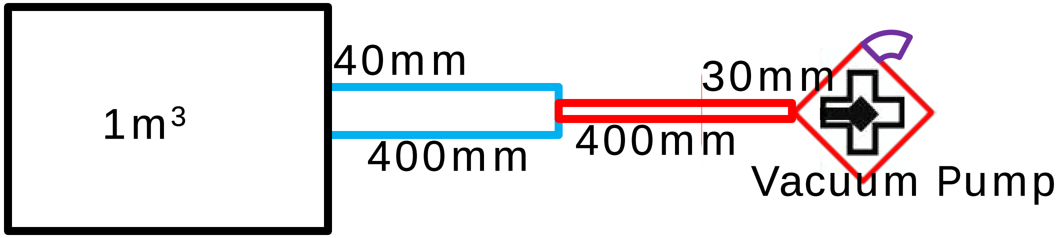
Calculation of $\mathbf{S_s}$

- $V=1m^3$, $p_1 = 1.013\times10^5$ Pa, $p_2 = 1000$ Pa, $p_u = 0.1\times10^{-3}$ Pa, $t_p = 3600$ s.

$$S_s = \frac{V}{t_p}\ln\left(\frac{p_1 - p_u}{p_2 - p_u}\right)$$

$$S_s = \frac{1}{3600}\ln\left(\frac{101300 - 0.1\left(10^{-3}\right)}{1000 - 0.1\left(10^{-3}\right)}\right) = 0.0012 m^3 / s$$

Tutorial – 2



From the earlier tutorial, we have

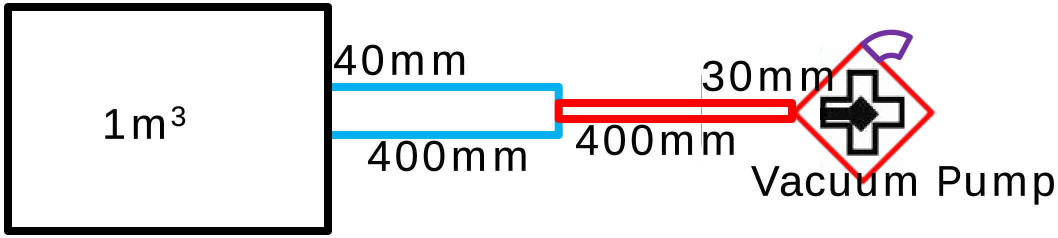
- $\mathbf{N_{Kn}}$ for pipe 1: 1.132, $\mathbf{N_{Kn}}$ for pipe 2: 22.65.

- $\mathbf{N_{Kn}}$>0.3, the flow is free molecular flow.

- The conductance of these Short Pipes
- Pipe 1 ($\mathbf{C_1}$) : 0.0173, Pipe 2 ($\mathbf{C_2}$) : 0.0079.

- The Overall Conductance ($\mathbf{C_o}$) is 0.00542 m^3/s.

Tutorial – 2



Calculation of $\mathbf{S_p}$

- $\mathbf{C_o}$ = 0.00542, $\mathbf{S_s}$=0.0012.

$$\frac{1}{S_s} = \frac{1}{S_p} + \frac{1}{C_o}$$

$$\frac{1}{S_p} = \frac{1}{S_s} - \frac{1}{C_o}$$

$$\frac{1}{S_p} = \frac{1}{0.0012} - \frac{1}{0.00542}$$

$$S_p = 0.00154 m^3 / s$$

$$S_p = 92.4 Lit / \min$$