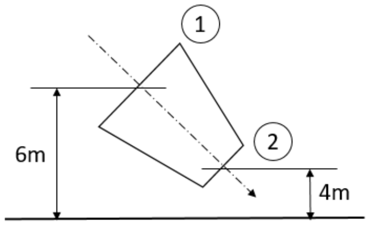
Introduction to Transport Phenomena: Exercises Module 1

Exercise 1.1

(Application of Bernoulli's equation)

Water flows through a conical nozzle with an input diameter of $d_1 = 20cm$ and an output diameter of $d_2 = 10cm$. The volumetric flow is $Q = 0.035\frac{m^3}{s}$. The inlet pressure is given by $p_1 = 3.924\ bar$. Calculate the outlet pressure p_2 in bar.

Tip: Water can be assumed as an incompressible fluid with a density of $\rho = 1\frac{g}{cm^3}$



****

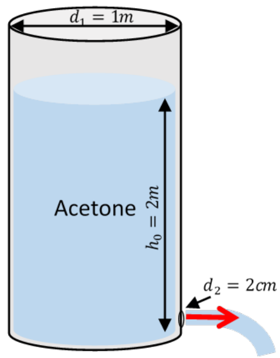
Exercise 1.2

(Application of the Torricelli's Theorem)

A cylindrical tank of diameter $d_1 = 1m$ has an orifice of diameter $d_2 = 2cm$ in its base. How long will it take an initial depth of acetone equal to $h_0 = 2m$ to drain completely from the tank? $\left(\rho_{acetone} = 0.701\frac{g}{cm^3}\right)$

a) Calculate the time assuming constant average velocity during the draining

b) Calculate the time considering variable velocity during the draining

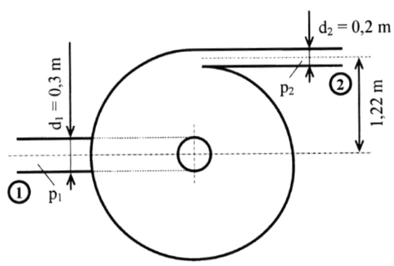


****

Exercise 1.3

(Bernoulli's equation including pump)

A pump delivers $Q = 9\ m^3/min$ of water. Its horizontal suction pipe has a diameter of $d_1 = 0.3m$. The pressure in the suction pipe is measured to be $p_1 = 2.63 * 10^4 Pa$ below atmospheric pressure. The exit pipe of the pump is $h = 1.22m$ higher than the suction pipe. The diameter of the exit pipe is $d_2 = 0.2m$. The pressure at this point is $p_2 = p_{atm} + 0.7263 * 10^5 Pa$. The mechanical efficiency of the pump is $\eta_{pump} = 80\%$. Calculate the mechanical power required to operate the pump.

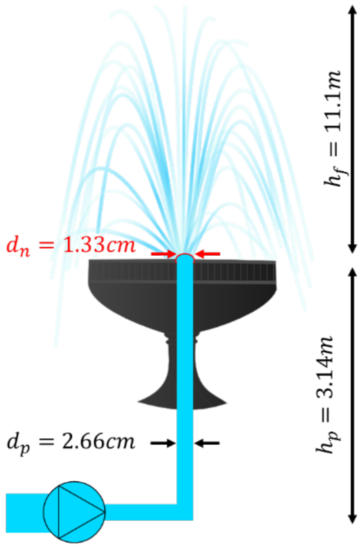


Note: Water is assumed to be an incompressible fluid

Exercise 1.4

(Bernoulli's equation including pump)

A water fountain designed to spray a column of water 11.1 m into the air has a 1.33 cm diameter nozzle at the ground of the fountain. The water pump is 3.14m below the nozzle. The pipe to the nozzle has a diameter of 2.66 cm. Find the pump pressure (in kPa) necessary if the fountain is to operate as designed. Assume that the water is at atmospheric pressure before entering the pump.



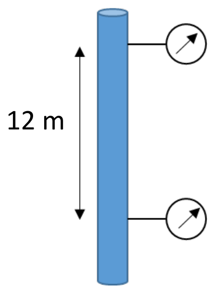
****

Exercise 1.5

(Bernoulli's equation including friction)

Two pressure gauges are mounted on a vertical water pipe 12 m apart, yet they read exactly the same pressure (7 bar).
a) Is the water flowing?
b) If so, in which direction? And why?

Note: There are no pumps involved.

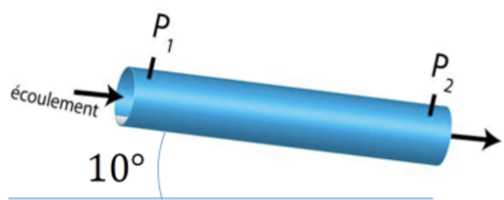


****

Exercise 1.6

(Bernoulli's equation including friction)

Oil, with the properties $\rho = 900\frac{kg}{m^3}$ and kinematic coefficient of viscosity $v = 1 * 10^{-5}\frac{m^2}{s}$, flows at $Q = 0.2\frac{m^3}{s}$ through 500m of a cast-iron pipe with a $d = 200mm$ diameter. The pipe is angled by $\alpha = 10°$ into flow direction. Estimate the pressure drop. ($\varepsilon \approx 0.5 * 10^{-3}m$ for a cast-iron pipe)



****

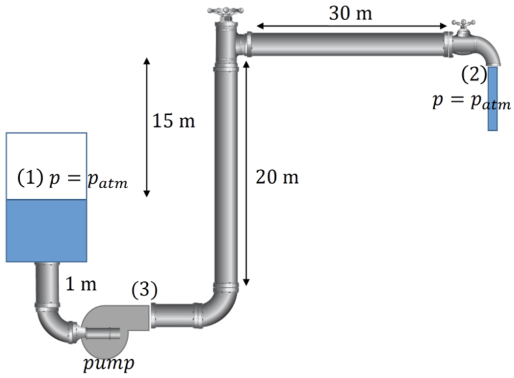
Exercise 1.7

(Bernoulli's equation including pump and pressure losses due to friction and to closed elements)

You need to purchase a pump to move water with a rate of $Q = 100\frac{L}{min}$ (at $20°C$) through the tubing system on the right. The diameter of the piping can be assumed to be $d = 2cm$ throughout the system. The pipes are in stainless steel with $\varepsilon = 0.015 * 10^{-3}m$. The efficiency of the pump is $\eta_{pump} = 65\%$. Considering the coefficient of kinematic viscosity as $\frac{\mu}{\rho} = 0.9 * 10^{-6}m^2/s$:

a) Calculate the pressure at the pump outlet p_3.

b) Calculate the pump input power required.



****