# CHBE 344 Homework Assignment #5

Due: 30 November 2018 at 4pm

## Problem 1 (20 points):

Process cooling water is being pumped from an open reservoir to a heat exchanger. The pump is located 5.00 m below the liquid level in the reservoir, the heat exchanger is located 2.75 m above the pump and requires an input gauge pressure of 325 kPa. The pump is connected to the reservoir by 125 m of 4 inch (inner diameter) pipe with 7 regular $90^o$ threaded elbows and to the heat exchanger by 6.50 m of 1.00 inch (inner diameter) pipe with 1 long radius $90^o$ threaded elbow and 1 long radius $90^o$ flanged elbow. You may assume a relative roughness of 0.001 for all pipes.

a) If the pump is consuming 6.25 kW and is 63.5% efficient, what will be the mass flow rate and Reynolds number of the water entering the heat exchanger?

There has been some debate amongst the plant engineers regarding the benefits of rerouting pipelines for a more convenient spatial layout of the plant vs. minimizing the pumping energy by reducing frictional losses.

b) For the same mass flow rate calculated above, plot the brake horsepower (in hp) of the pump as a function of the number of elbows (regular $90^o$ threaded) in the pipeline between the reservoir and the pump from 0 to 50 elbows using the following assumptions?
   i) Adding or subtracting an elbow results in the addition or subtraction of 3 m of pipe respectively.
   ii) The pump efficiency can be approximated by the following equation:
   $e[\%] = -0.48 * (P[kW])^2 + 8.2 * (P[kW]) + 31$

c) Based on your plotted results, which side of the debate would you take and why?

## Problem 2 (15 points):

It is proposed to pump 9,750 kg/h of toluene at 115C ($\rho = 786$ kg/m$^3$; $\mu = 0.278$ cP) and 1.15 atm absolute pressure from the reboiler of a distillation tower to a second distillation unit operating at the same pressure without cooling the toluene before it enters the pump. The frictional loss in the line between the reboiler and pump and between the pump and the second reboiler have been measured at 7.5 kPa and 18.9 kPa respectively.

a) Calculate how far above the pump the liquid level in the reboiler must be maintained to give a net positive suction head of 2.5 m

b) Plot the minimum liquid level needed as a function of the pressure in the reboiler varying from 0.50 atm to 1.50 atm absolute pressure. You may assume that the liquid properties do not change.

## Problem 3 (15 points):

a) Explain the difference between a positive displacement pump and a centrifugal pump.

b) State which type you would recommend using in the following scenarios and give a brief justification. If your recommendation is a positive displacement pump, state the type of positive displacement pump as well.
   i) Pumping water to the top of a municipal water reservoir (see `https://en.wikipedia.org/wiki/Water_tower`)
   ii) Pumping waste water with a high solids content
   iii) Evacuating the headspace of an evaporator to maintain a pressure below atmospheric pressure
   iv) Pumping process water to a high pressure steam generator