ChE 263

HW #1

Note: Use Excel for all problems and review the Python solutions. For each problem please use a separate worksheet and highlight your answers.

1. Review the materials at https://apmonitor.com/che263 to obtain an overview of the course. The first section is to learn a spreadsheet program (Excel). The CL1, CL2…, CL6 are the same Excel homework problems but with Python. Visit the Homework Help link to see video solutions. Record short answers to the following in an Excel sheet:
   a. What is your level of experience with spreadsheets like Excel?
   b. What is your level of experience with programming with Python?
   c. What is your level of experience with other programming languages?
   d. How are problem solving and programming related?
   e. What do you hope to learn from this class?

2. In the second worksheet in the workbook complete the following. The rate of heat transfer (q) from a heated flat plate with a cool fluid stream flowing across it can be found by:

$$q = h\,\Delta T$$

   where h is the heat transfer coefficient and ΔT is the change in temperature between the cool fluid and the plate. The heat transfer coefficient is related to Nu, the dimensionless Nusselt number, through

$$Nu = \frac{hL}{k} = 0.332 \cdot \sqrt[3]{\mathrm{Pr}}\sqrt{\mathrm{Re}}$$

   where L is the plate length, k is the fluid's thermal conductivity, Pr is the dimensionless Prandtl number and Re the dimensionless Reynolds number.

   The last two quantities are calculated according to $\mathrm{Re} = \frac{\rho L v}{\mu}$ and $\mathrm{Pr} = \frac{\mu c_p}{k}$ where μ is the fluid viscosity, c_p is the fluid heat capacity, v is the fluid velocity and ρ is the density of the fluid.

   What is the heat transfer rate, in W/m^2, from a flat plate 2 meter long and temperature 343 K, if a stream of water passes over it at a velocity of 1.45 meters per second? The temperature of the water is 294 K, the. Water properties are: $\mu = 9.79\times10^{-4}$ Pa·s, $\rho = 998$ kg/m^3, k = 0.601 W·m^{-1}·K^{-1}, and $c_p = 4.18\times10^{3}$ J·kg^{-1}·K^{-1}.
   Hint: Begin by giving all the known quantities names, then calculate Nu. h can be obtained once Nu is known.

3. In the third worksheet in the workbook complete the following. Your team is tasked with designing the operational protocol for a batch reactor (basically a tank) for a particular reaction that must be carried out in the absence of oxygen to reduce the formation of byproducts. You have an idea to first fill the tank with nitrogen and then add the liquid mixture. As the liquid mixture is added, part of the nitrogen gas will be removed to prevent pressure buildup.

   To flush the oxygen out, the tank will initially be filled so that the nitrogen is at 298.15 K and 1.25 atm. To keep oxygen out, you want to make sure that the pressure inside the tank remains greater than 1.0 atm after the liquid is added; however, the pressure should not become greater than 2.5 atm in order to keep the cost of the tank to a minimum. The tank has a capacity of 4000 L, and depending upon the amount of product needed, the volume of liquid in the tank can range from 3000 to 3500 L. **In all cases, twenty-five percent of the nitrogen initially placed in the container remains after the tank is filled with the liquid.** Given these constraints determine for your boss the range of possible operating conditions (temperatures, volumes, and pressures) so that appropriate heat transfer and control equipment can be designed.

   Hints:

   - You may assume nitrogen and the liquid mixture are at the same temperature & pressure.
   - You may assume that nitrogen is an ideal gas described by the equation **PV=nRT**.
   - One of the first things you need to do is calculate the amount of nitrogen that is placed into the empty tank. I would also suggest setting up the spreadsheet with a column of possible temperatures and a row of possible volumes.
   - You may assume that changes in the volume of liquid due to changes in temperature and pressure is negligible and the volatility of the liquid is low such that nitrogen is essentially the only component of the gas phase.
   - Remember that the number of moles, temperature, pressure, and volume of the gas are related. You can only set three of the four independently.
   - The hardest part of this problem is figuring out what is needed. Remember, you are the engineer trying to present some data to your boss that can be used for future design. The Excel portion of this problem is fairly easy (especially if you make careful use of dollar signs ($) in your equations).