General information:

1. Name all function files and scripts using the notation *Q1_function_name* or *Q1_script_name* and so on.
2. **Do not define your functions within the script file**.
3. You do not need to add a separate report. For each question, provide your answers in the form of comments in the code itself. **Marks will be deducted if the comments do not contain answers and explanations, even if you have coded correctly**. Add proper axis labels to help identify what you are plotting.
4. Internet access will not be available during the session. However, you are free to access MATLAB documentation. Most, if not all, issues with your code can be fixed if you go through the documentation.
5. TAs will not help clear your conceptual questions. Do not ask them if you are getting the correct answers or not.
6. **Keep all your codes in a single zip file with file name *Name_Roll_number_CHE213_3*.** You will have to upload this zip file either on HelloIITK or to USB drive carried by the TA.
7. **Submissions will start from 4:40 pm. All submissions must be done by 4:50 pm**. No submissions will be entertained after that.

Recovery of ethyl alcohol from sugarcane molasses – Part 2

As the world continues to transition towards sustainable fuel alternatives, the production of biofuels or fuels from biological sources has gained tremendous attention in recent years. One prominent example of biofuel family is ethanol-gasoline blend in which ethanol is combined with gasoline at different compositions.

A common source of the ethanol used in biofuels is sugarcane molasses. The liquid byproduct remaining in the sugarcane juice after extraction of sugar is known as sugarcane molasses. Molasses is rich in fermentable sugars and is a suitable feedstock for fermentation. During the fermentation process, yeast (e.g., *Saccharomyces cerevisiae*) is added to the molasses which converts the sugar into ethanol along with the production of CO_2.

Assume a fermentation process in which the production of gaseous ethanol-CO_2 feedstock, containing 15% mol fraction of ethanol, is 2000 kg/hr. **The ethanol is to be recovered from the ethanol-CO_2 mixture by absorption with pure water** in **(i)** a stage-wise column and **(ii)** a packed bed column. In Part I of this task, we focused on determining the operating conditions for the column. **Part II of the task** will determine the number of stages, number, and height of ideal transfer units, which would aid the design of the two columns.

Questions (i) is same as the previous assignment. You do not need to solve them again. Start from question (ii).

Assume that the column is operated under isothermal, isobaric conditions and that the water absorbs only ethanol. Use the relevant information provided below.

(i) The ethanol-water equilibrium solubility data is given below. Here x and y are in mole fractions of ethanol. Since, we will be working on a solute-free basis, convert this data to obtain equilibrium data between X and Y, where X and Y are mole ratios. Use your favourite fitting function in MATLAB to fit the X - Y data to the functional form:

$$Y = \frac{aX}{1 + bX}$$

Use this fitted curve for all subsequent calculations. Show both the tabulated and the fitted curve in the same plot (**Name this Figure 1**).

$\boldsymbol{x}$	0	0.0186	0.0476	0.0673	0.0881	0.1102	0.1424	0.1894	0.2069
$\boldsymbol{y}$	0	0.0105	0.0272	0.0375	0.0492	0.0624	0.0809	0.1078	0.1182

(ii) Revisit the operating line derived for 94% recovery. Plot this operating line in **Figure 1**. Using the guideline given below, determine the **number of stages**, n_t required in a **stagewise column** for the desired separation. **(30 points)**

1. Start with $Y = Y_1$, $X = X_1$ and $n_t = -1$. These values will be updated within a loop.
2. While ($Y \geq Y_2$)

   Store current values of X and Y in X_{old} and Y_{old} respectively.

   Update $Y \rightarrow \frac{aX}{1+bX}$

   Update X such that X and Y (updated above) lie on the operating line

   Update $n_t \rightarrow n_t = n_t + 1$ (where n_t= number of stages)

   line([X_{old} X_{old}], [Y_{old} Y]);

   line([X_{old} X], [Y Y]);

   End
3. To calculate the fractional stage, after the above loop ends: $n_t = n_t + \frac{Y_{old}-Y_2}{Y_{old}-Y}$

(iii) Repeat the same for 98% recovery. Make a separate **Figure 2** for this part. How does n_t vary with recovery? **(20 points)**

Parts (iv) and (v) will be used to design a packed bed column for the same separation.

(iv) If the overall gas-phase mass transfer coefficient $K_Y\bar{a} = 130 \frac{kmol}{m^3 hr.(\Delta Y)}$ and the cross-sectional area available for the column is 0.8 m^2, calculate $H_{tOG} = \frac{G_S'}{K_Y\bar{a}}$.

(v) To determine N_{tOG}, we need to determine the value of the integral

$$\int_{Y_2}^{Y_1} \frac{dY}{Y - Y^*},$$

where Y and Y^* refers to the gas phase mole ratios based on the operating and equilibrium lines respectively. Y_2 and Y_1 are the outlet and inlet gas phase mole ratios. This integration needs to be performed numerically. Use your favourite integration tool in MATLAB and determine N_{tOG} for 94% and 98% recoveries. How does N_{tOG} vary with ethanol recovery? **(40 points)**

Here is a reminder of what you solved in the 2nd practice session:

Next, we will perform a more complex integration problem. Consider the following functions:

$$y_1(x) = 2x + 1,$$

$$y_2(x) = \frac{2x}{1 + 0.2x}$$

Your task is to evaluate the following integral:

$$\int_0^{15} \frac{dy_1}{y_1 - y_2}.$$

(vi) The theoretical height of the column will be given by $h_T = H_{tOG} \times N_{tOG}$. Plot the variation of h_T as a function of ethanol recovery (Plot 2b). Explain your observations. **(10 points)**