Mass transfer 2: Endsem exam **February 14, 2022**

INSTRUCTIONS: (Please follow the instructions strictly), Full marks= 200

1. Save the m-file as: your Name_question_number (ex:swetha_1b) **without any spaces in between. Keep all the .m files in a folder with the name as your roll number.**
2. Mention the **title and axis** for each of the plot. Also show the name of the model used for fitting in the plot. Show the legends if you have multiple plots in a figure.
3. Save the m-file as: your name_question number_quiz number (ex:swetha_1b_quiz1) **without any spaces in between.**
2. Mention the **title and axis** for each of the plot. Also show the name of the model used for fitting in the plot. Show the legends if you have multiple plots in a figure.
3. **Upload your files** (with answer) strictly by **1.40 pm**. Any submission/updation after 1.40 will not be considered as exam answer. If there in google classroom, we will collect it from your laptop.

Question 1: Solid-liquid System:Countercurrent multistage operation using Ponchon Savarit diagram [80 markes]

9.4 (***Countercurrent liquid–solid contact***)[3] Experimental 'equilibrium data' on extraction of oil from a meal by using benzene are given below:

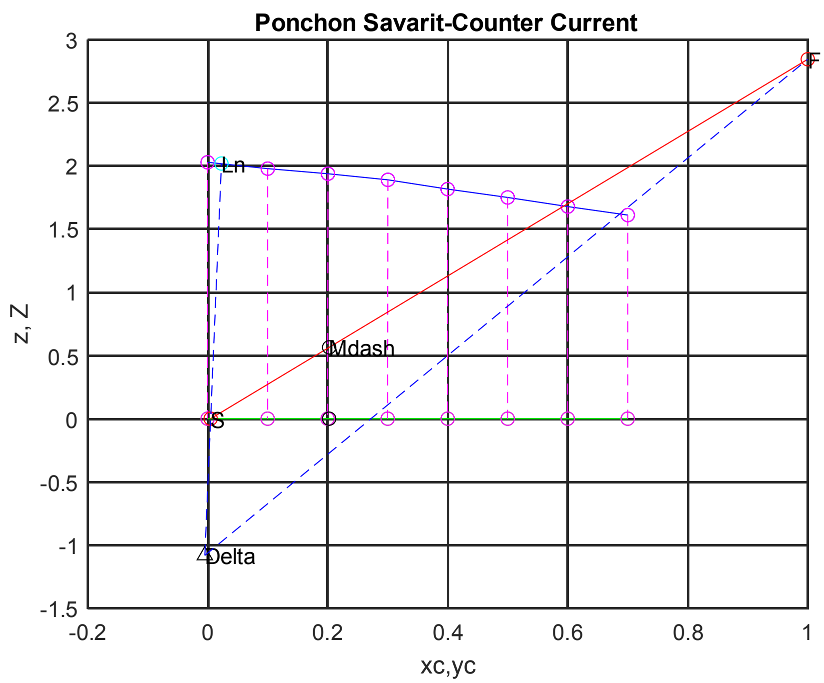
Mass fraction of oil (C) in solution	*Mass fractions in the underflow*		
y_C	x_C	x_A	x_B
0	0	0.67	0.33
0.1	0.0336	0.664	0.302
0.2	0.0682	0.660	0.272
0.3	0.1039	0.6541	0.242
0.4	0.1419	0.6451	0.213
0.5	0.1817	0.6366	0.1817
0.6	0.224	0.6268	0.1492
0.7	0.268	0.6172	0.1148

Two thousand kilograms per hour of the meal containing 26 mass% oil is extracted with 2100 kg/h of benzene. The underflow leaving the countercurrent cascade must not contain more than 0.015 mass fraction of oil. The feed benzene has 0.005 mass fraction oil in it. The overflow is essentially solid-free. Calculate the mass fraction in the rich extract leaving the cascade and the number of ideal stages required.

Countercurrent operation in Ponchon Savarit Diagram [L- Underflow, V-Overflow]
Print the answer of the questions separately for all the questions.

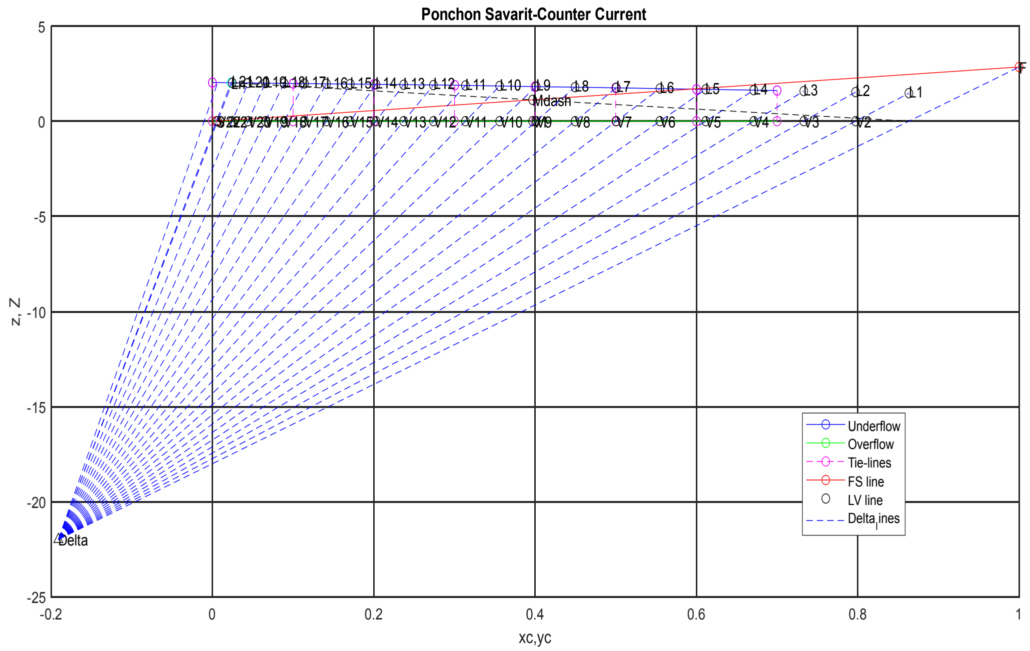
1. **Figure 1**: Calculate the mass fraction of A and B in overflow from the given conditions in the problem and plot the SLE data using Poncon Savarit diagram (Z vs X/Y). Also plot the data for right angled triangle co-ordinate. This should show only the SLE data plots. [5+5]
   From 2 to end, Use PS diagram for answering the questions.

2. **Figure 2:** Locate S and F point, mention who is the underflow and who is the overflow. Calculate the concentration of the solute in mixture x_m from the material balance and locate the M point. Draw the FM line and the tie lines. This should show the SLE data +FM line. [5]
3. **Figure 3**:Locate the delta point. Join F and S and locate M. Join Ln and M and extend it to meet the overflow line at V1. LnS and FV1 are joined and extended to meet delta point. Show the delta point as the intersection point [5]
4. **Figure 4:** Draw the tie line through V1 to find L1 to get ZL1 and Xc1, ZV1 and Yc1. This should show the construction of only one stage and print the stage 1 details, **without any loop**. [15]
5. Calculate the flow rate **<u>LN (underflow from last stage) and V1(overflow for first stage)</u>** [15].



6. Figure 5: Create a while loop to calculate the number of stages to have the underflow containing no more than 0.015 mass fraction of oil, when Solvent amount is 800 kg, you can do extrapolation for locating stages [5]
7. Figure 6: Plot the **concentration of oil at various stages in underflow and overflow <u>and flow rate of overflow and underflow</u>** if solvent level is 1500, using a heatmap representation [one for composition, one for flow rate]. [20]
8. Figure 7: Plot the number of stages as a function of solvent level (example: 800 to 2100).[10]

[**Hint:** ***Underflow should be such that level of C=0.015. calculate the level of B from given data***]



Underflow: wB_dash = [0.33 0.302 0.272 0.242 0.213 0.1817 0.1492 0.1148];

__________wC_dash = [0 0.0336 0.0682 0.1039 0.1419 0.1817 0.224 0.268];

Overflow: wC = [0 0.1 0.2 0.3 0.4 0.5 0.6 0.7];

Question 2. Crystallizer data analysis (Parameter estimation from experimental data) [30]

One liter suspension from a crystallizer containing 161.07 g yielded the following results on sieve analysis. Determine crystal size distribution function and the nucleation rate of crystals.

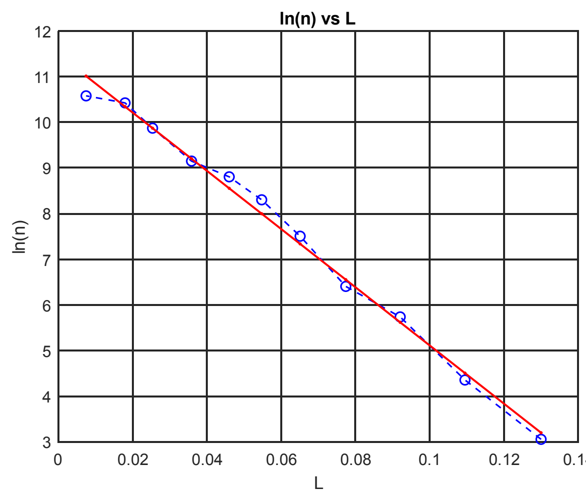
Tyler mesh size details	12/14	14/16	16/20	20/24	24/28	28/32	32/35	35/48	48/65	65/100	<100
Mass	4.44	8.41	16.65	16.28	24.32	27.24	22.5	23.13	11.9	5.15	1.05

Solid density =2163 kg/m^3, shape factor, =2.0, residence time =0.9 hour.

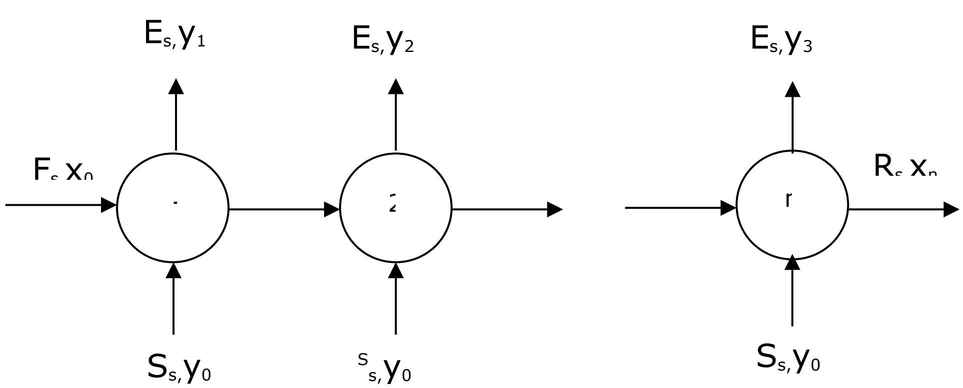
1. Calculate the average opening, L_{avg} and ΔL from given data [5]
2. Calculate the number of particles n in each size range. [4]

3. Plot ln(n) vs **<u>average size of the particl</u>**e L avg and fit a straight line through the curve using polyfit function. Calculate G and n0 through parameter estimation. Calculate the **RMSE** (root mean square error) for this fitting and report the parameters estimated. [10+3]
4. Using G and n0, Plot n vs L from using population distribution function (n= n^0 exp(-GL) and the nucleation rate B^0 . [4]
5. Plot the scatter plot for model results and the experimental data. [x axis, experimental data, y axis is , simulated data]. Analyze the goodness of fit using correlation coefficient [4]
Mesh size details are as follows in mm.
For [12 14 16 20 24 28 32 35 48 56 100]

```
MSI = [1.41 1.19 1 0.841 0.707 0.595 0.5 0.42 0.297 0.21 0.149 ];  %INITIAL MESH SIZE
MSF = [1.19 1 0.841 0.707 0.595 0.5 0.42 0.297 0.21 0.149 0];      %FINAL MESH SIZE
Hint:
L = (MSF + MSI ) * 10^-1 /2;     %Average passing mesh size in cm
L_diff = (MSI - MSF) * 10^-1 ;  %delta L in cm
```



<u>Question 3.Liquid-liquid extraction: multistage crosscurrent extraction, insoluble liquid [40]</u>



The equilibrium distribution of the solute C between solvents A and B (upto 20% of C in solution of A) is given by, Y=3.7 X. X and Y are concentration of C in A and B respectively, both in the mass ratio unit (**i.e. mass of the solute per unit mass of solute free solvent**). The solvent B is solute free.

Suppose we need to design a multistage crosscurrent system where a feed liquid 1000 kg/hr having 15% solute needs to be handled. The extraction process should be designed such that 95% removal of C is possible using the solvent.

a) Plot the **solvent rate** as a function of number of stages[choose the range of solvent rate [10-450]. [10]
b) **Automation:** Create a MATLAB program from which you can automatically calculate the amount of solvent for a specific stage number. If you want to perform the extraction (95% removal) using 6 stages, what is the amount of solvent to be used for each stage (S1)? Also, calculate the solvent level required for a 15-stage operation (S2). **Assume that each stage uses the same amount of solvent**. [10]
   (***Hint:*** fit an equation to the plot obtained from (a) and find S1 and S2. [Do not return the solvent amount from the graph]
c) Plot the equilibrium line, operating lines and construct the stages using MATLAB simulation [for 6 stage and 15 stage operation with S1 and S2]. [5+5]
d) Calculate the **amount of C** in raffinate in every stage for the 6-stage operation. [10]

Question 4:Liquid =Liquid Extraction: Countercurrent operation [50]

The following is the MEK (B), ethylene glycol (C)-water (A) system.

Extract (MEK phase)			Raffinate (water)		
y_A	y_B	y_C	x_A	x_B	x_C
0.884	0.111	0.005	0.208	0.697	0.095
0.871	0.112	0.017	0.21	0.656	0.134
0.849	0.113	0.038	0.221	0.583	0.196
0.827	0.116	0.057	0.236	0.524	0.240
0.806	0.118	0.076	0.261	0.461	0.278
0.50	0.205	0.295		Plait point	

Prepare a right-angled triangle system and plot the LLE diagram. Mention the plait point clearly. Show the tie-lines. A solution of ethylene glycol in water (30% glycol, 70% water), is extracted with the solvent MEK. The feed rate is 500 kg/hr and MEK rate is 500 kg/hr.

a. Construct the conjugate line (and find the conjugate curve) based on given 5 tie lines, **using the existing code**. [10]
b. Based on the conjugate line created, interpolate 30 tie lines that cover the two-phase region in the LLE curve. [15].
c. If you want to have xc=0.04 in raffinate phase (for the final stage), using countercurrent multistage operation, **calculate the M point co-ordinate and E1 point co-ordinate** [10].

d. Draw a tie line through E1, (**using the equation of conjugate line**), and find the co-ordinate of R1. [15]

```
xb=[0.111 0.112 0.113 0.116 0.118 0.205];
xc=[0.005 0.017 0.038 0.057 0.076 0.295];

yb=[0.697 0.656 0.583 0.524 0.461 0.205];
yc=[0.095 0.134 0.196 0.240 0.278 0.295];
```