EXAMPLE 8.4 (*Multistage countercurrent extraction*) It is planned to extract diphenyl hexane (DPH) from a solution in docosane (*A*) using 'pure' furfural (*B*) as the solvent. The feed enters the extractor cascade at a rate of 2000 kg/h with 45% DPH (*C*) that has to be reduced to 4% in the final raffinate. The solvent rate is 2500 kg/h. Determine the number of theoretical stages required. Extraction is to be carried out at 45°C. Several compositions on the extract and the raffinate arms and the tie-line data in mass% of the components at 45°C are given below.

Equilibrium data

A:	96.0	84.0	67.0	52.5	32.6	21.3	13.2	7.7	4.4	2.6	1.5	1.0	0.7
B:	4.0	5.0	7.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	99.3
C:	0	11.0	26.0	37.5	47.4	48.7	46.8	42.3	35.6	27.4	18.5	9.0	0.0

Tie-line data

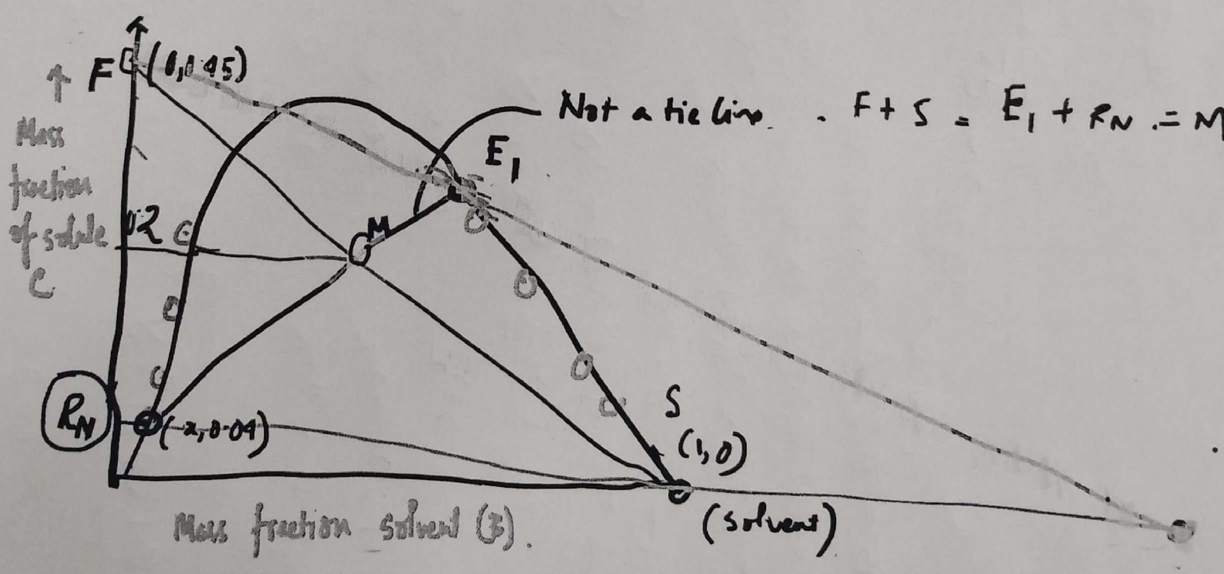
Raffinate (Docosane) phase, mass%			Extract (Furfural) phase, mass%		
A	*B*	*C*	*A*	*B*	*C*
85.2	4.8	10.0	1.1	89.1	9.8
69.0	6.5	24.5	2.2	73.6	24.2
43.9	13.3	42.6	6.8	52.3	40.9

1. Plot the LLE Data and tie lines in Right Angle Triangle Co-ordinates. [Provided to you]

2. Locate **M point**. Plot the **E1 point and delta point and locate R1.** Calculate the number of stages required for the given separation level for countercurrent operation (**solvent =2800 kg/h).** [25]

3. Show all the calculations/ graph points for calculation of the composition of the raffinate and extract from each stage. [25]. From the given equations, can you calculate the flow rate for E1

Homework: Perform the graphical construction of stages for crosscurrent operation (for the same 4 % solute in the raffinate and same solvent rate). [in a new graph paper]



$F + S = M$

$\boxed{M = 4800}$

$F x_F + S y_s = M x_M$

$(2000)(0.45) + (2500)(0) = 4800(x_M)$

$\boxed{x_M = 0.1875}$

mass balance $R_N + E_1 = F + S = 2000 + 2800$

$R_N + E_1 = 4800$ — ①

mnc balance $R_N x_{cN} + E_1 y_{c1} = F x_{cF} + S y_s$

$0.04 R_N + 0.24 E_1 = 2000(0.45) + 2800(0)$

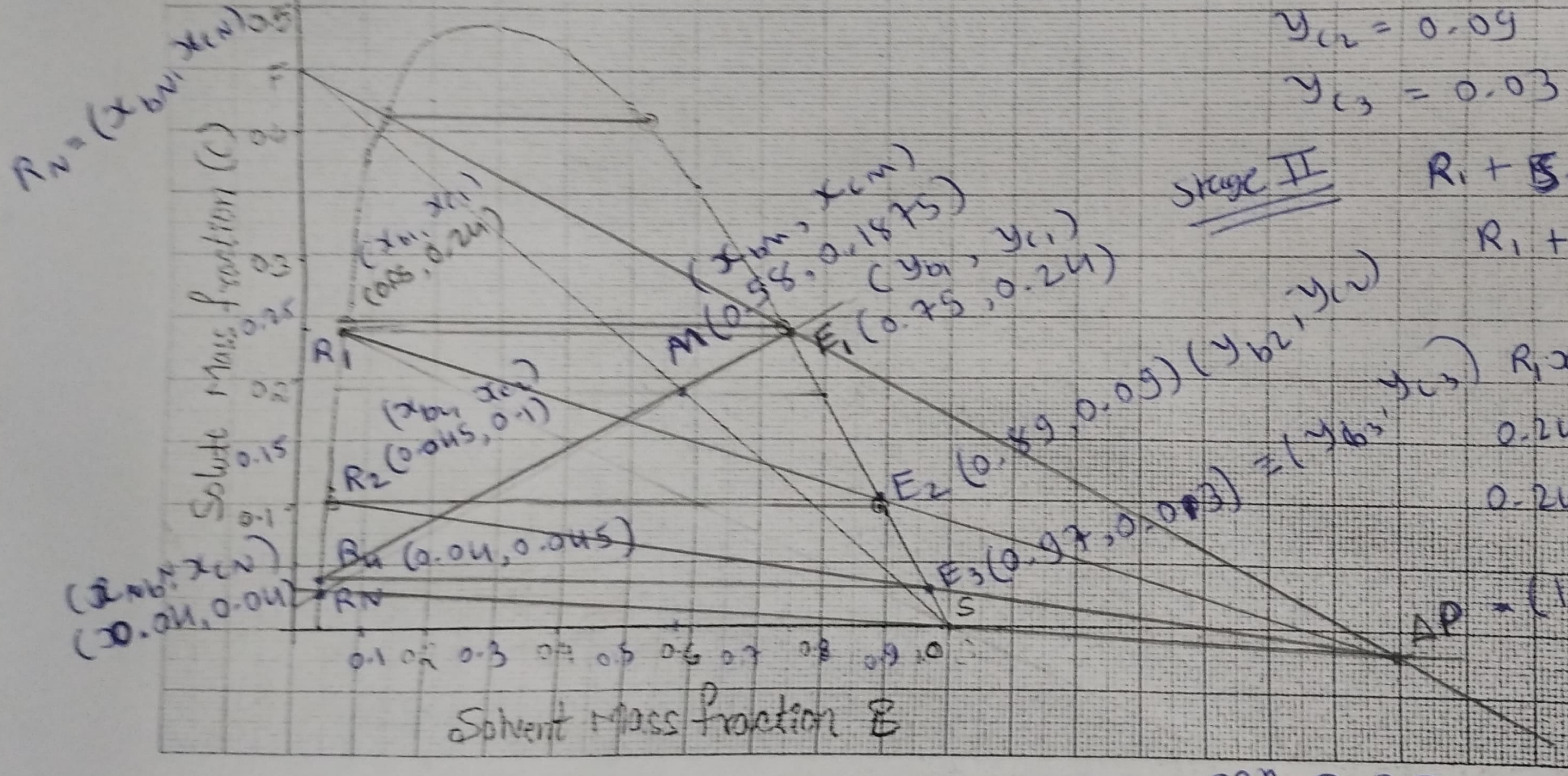
$0.04 R_N + 0.24 E_1 = 900$ — ②

From eq ① & ② $\boxed{E_1 = 3540\ kg/s}$ $\boxed{R_N = 1260\ kg/s}$

$S = 2800$

$F = 2000$

$y_s = 0$



$y_{c1} = 0.24$ $x_{1c} = 0.24$

$y_{c2} = 0.09$ $x_{2c} = 0.1$

$y_{c3} = 0.03$ $x_{3c} = 0.045$

stage II $R_1 + S = E_2 + R_N$

$R_1 + (2800) = E_2 + 1260$

$R_1 - E_2 = -1540$ — ③

$R_1 x_{c1} + S y_s = E_2 y_{c2} + R_N x_{cN}$

$0.24 R_1 + 2800(0) = E_2(0.09) + 1260(0.04)$

$0.24 R_1 - 0.09 E_2 = 50.4$ — ④

-0.025

from eqⁿ ③ & ④

$R_1 - E_2 = -1540$

$-R_1 \mp 0.375 E_2 = 210$

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ADDITIONAL SHEET

ROLL NO. :

$$-0.625 E_2 = -1750$$

$$\boxed{E_2 = 2800 \text{ kg/s}}$$

$$\boxed{R_1 = 1260 \text{ kg/s}}$$

Stage III

$$R_2 + S = E_3 + R_N$$

$$R_2 + 2800 = E_3 + 1260 \quad \text{—— (5)}$$

$$R_2 x_{c2} + S y_S = y_{c3} E_3 + x_{cN} R_N$$

$$0.1 R_2 + 0 = 0.03 E_3 + 50.4$$

$$0.1 R_2 - 0.03 E_3 = 50.4 \quad \text{—— (6)}$$

from eqn (5) & (6)

$$R_2 - E_3 = -1540$$

$$R_2 - 0.3 E_3 = 504$$

$$- \quad + \quad -$$

$$0.7 E_3 = 2044$$

$$\boxed{E_3 = 2920} \text{ kg/s}$$

$$\boxed{R_2 = 1380 \text{ kg/s}}$$