CE407 Exam 02 July 03, 2020

1. **(40 pts)** 500 kg/hr of a feed solution containing a solute (C) mass fraction of 0.25 is to be extracted using 125 kg/hr of a recycled solvent stream (solute C mass fraction = 0.04, solvent mass fraction B = 0.95. The exiting raffinate shall be 0.10 mass fraction solute on a solvent free basis. Use the following equilibria data and phase diagrams on next pages to determine how many extraction stages are required. ***Use the McCabe-Thiele method to determine the required number of stages.***

Diluent Rich (Raffinate)		Solvent Rich (Extract)	
x (x_B)	**y (x_C)**	**x (x_B)**	**y (x_C)**
0.07	0.22	0.30	0.42
0.06	0.17	0.40	0.39
0.045	0.12	0.52	0.30
0.04	0.06	0.64	0.18
0.038	0.04	0.685	0.12
0.035	0.02	0.73	0.06

2. (40 pts) Benzene will be stripped from a valuable oil by countercurrent contact with air in a tower packed with 2.0" ceramic Raschig rings. The contaminated oil (composition 98 mole % oil and 2 mole % benzene) will enter the tower at 2500 mol/hr and 95% of the entering benzene is to be removed. The flow rate of the incoming air will be 37,500 mol/hr. The density and viscosity of the dilute oil/benzene solution are well approximated by the properties of pure oil. The vapor phase behaves ideally. The tower will operate isothermally at 25 C and at a total pressure of 1 atm. The tower diameter shall be determined to give ΔP/ft of packing equal to 50% that of ΔP_{flood}/ft. The equilibrium curve at these conditions is **y = 0.125 x**. You may regard the operating line as being straight. Calculation of the flooding velocity should be based on flow rates at the **top** of the tower, where they are largest. The density of the vapor at the top of the column can be approximated as that of air.

Data:

Air:

MW = 28.9

Benzene:

MW = 78.11

Sc = 1.76 in air

Sc = 3500 in oil

Oil:

MW = 106

ρ = 0.83 g/cm^3

ν = 2.84 cSt

μ = 2.36 cP

Packing:

Table included in attachments

Gas Constant = 0.73024 ft^3 atm / (R lbmol) R is degrees Rankine

Gas Constant = 82.05745 cm^3 atm / (K mol)

a. What is the required diameter for the tower? Use the following graph and the correlation $\Delta P_{flood}/ft = 0.115\ F_P^{0.7}$ inches water column per foot of packing

b. What height of packing is required? Base your solution on y – y*. Use the correlations from lecture to determine H_x and H_y.

$$H_{Oy} = H_y + m \frac{V}{L} H_x$$

3. (20 pts) *n*-Heptane undergoes mass transfer from a bulk gas (air + n-heptane) phase, where its mole fraction $y = 0.03$,to a bulk liquid (mineral oil + n-heptane) phase, where its mole fraction $x = 0.005$, through a gas-liquid interface. Temperature and pressure are 35 C and 1.0 atmosphere. The vapor pressure of n-Heptane at this temperature is 74.02 mm Hg. Mass transfer coefficients are as follows:

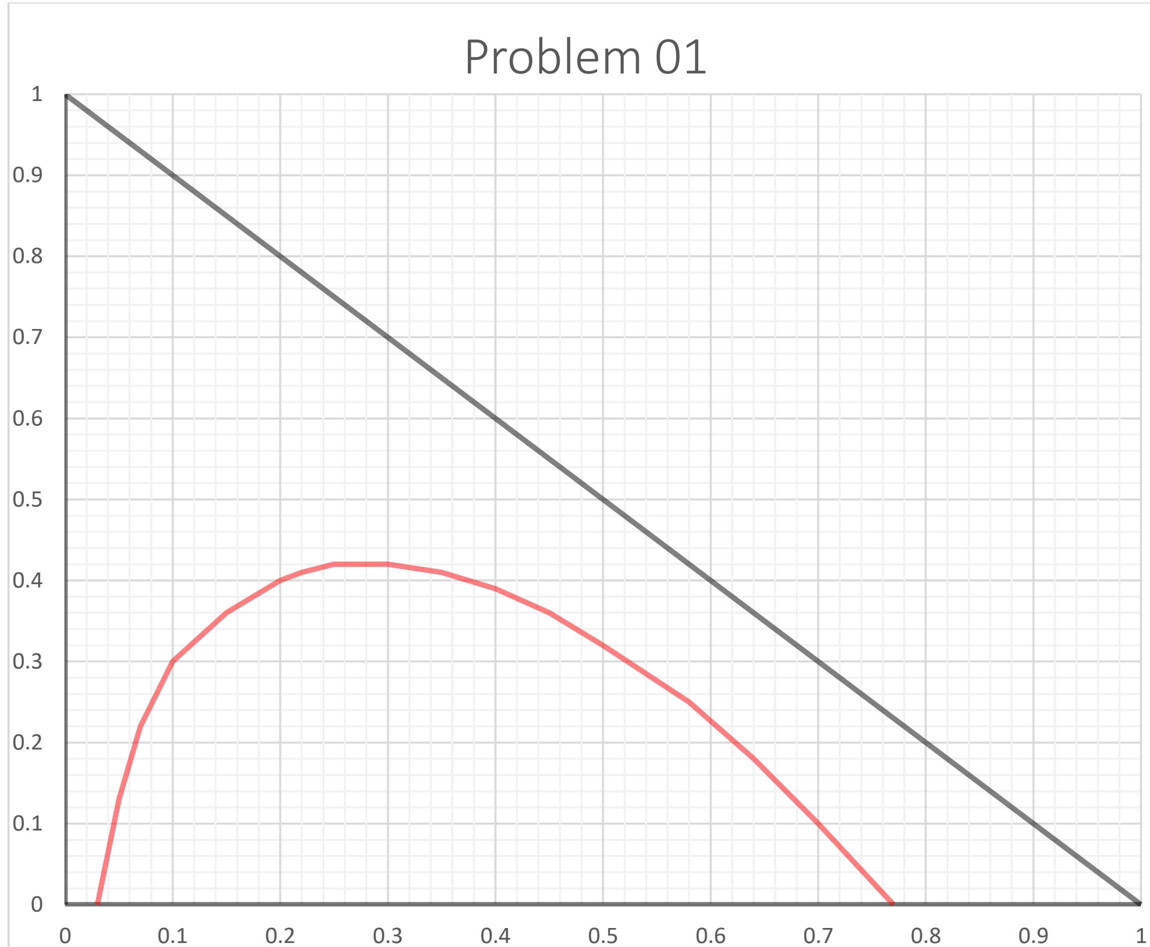
$$k_y = 7.0 * \ 10^{-6} \ \frac{mol}{cm^2 s}$$

$$k_x = 3.5 * \ 10^{-6} \ \frac{mol}{cm^2 s}$$

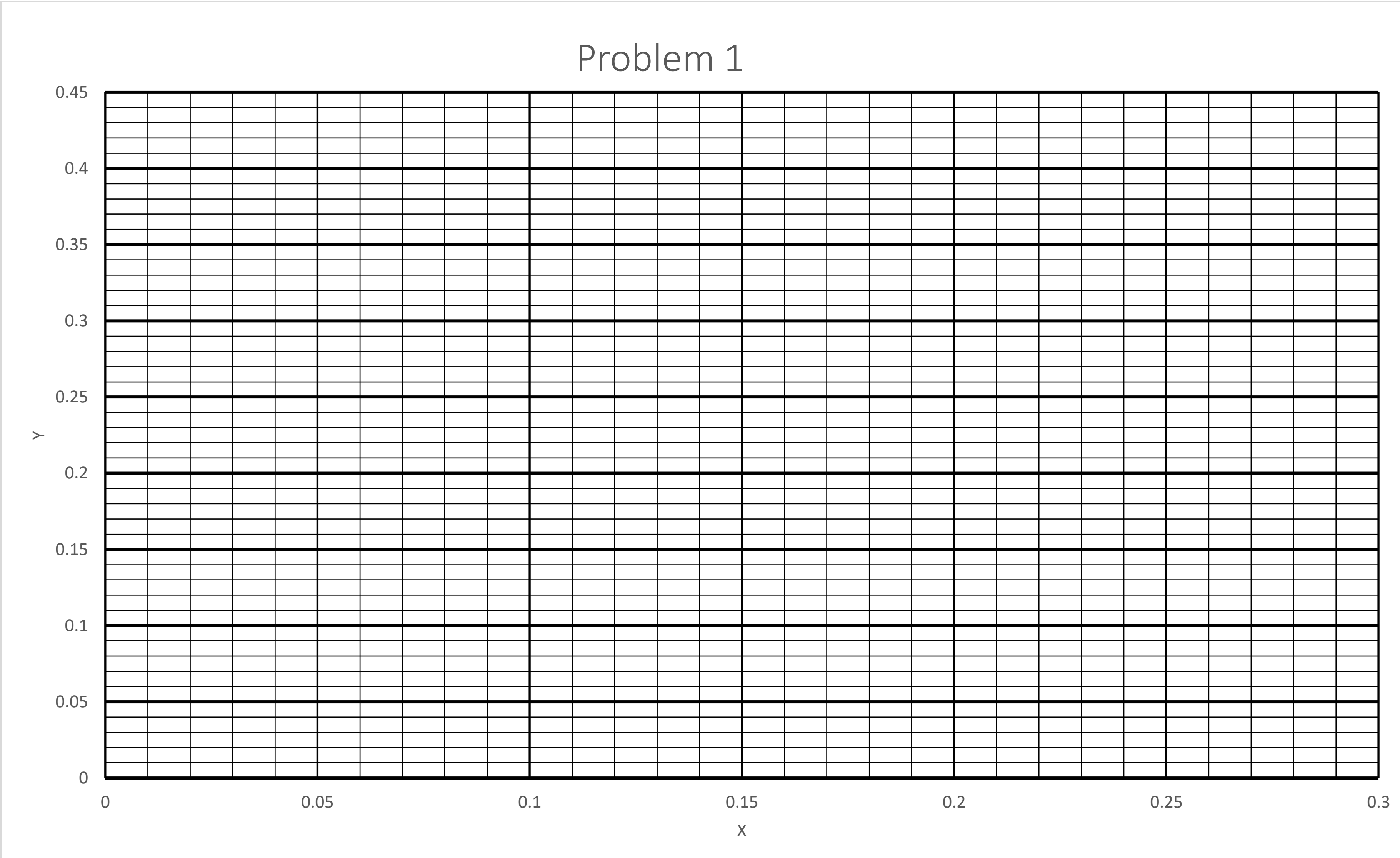
Assuming validity of Raoult's Law for the equilibrium relation,

a. What are the overall mass transfer coefficients K_y and K_x?
b. What is the molar flux of n-heptane from gas to liquid?

Problem 01
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1



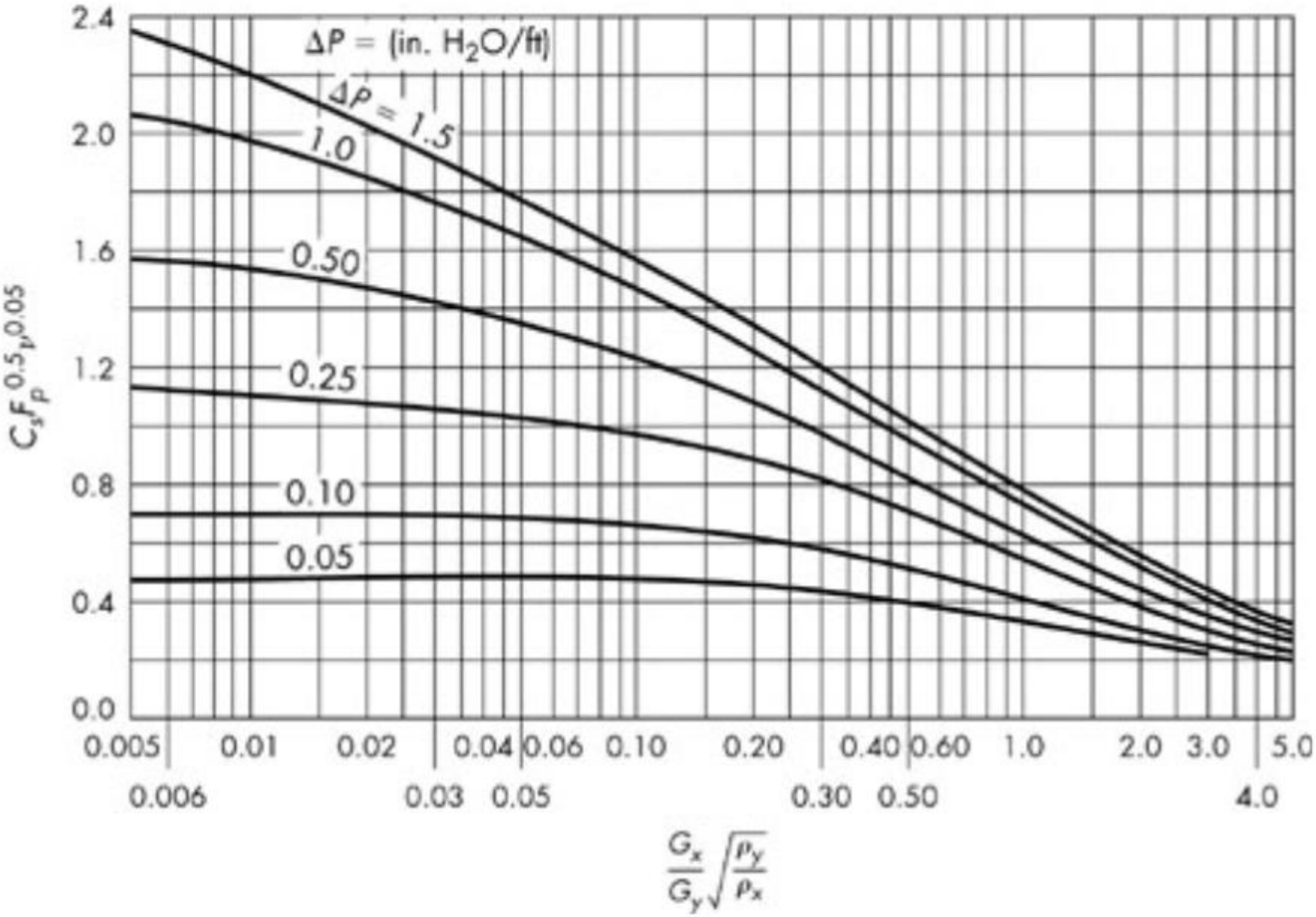
Problem 01
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1



Problem 1
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Y
0
0.05
0.1
0.15
0.2
0.25
0.3
X

TABLE 18.1
Characteristics of dumped tower packings[12,15b,27]

Type	Material	Nominal size, in.	Bulk density,† lb/ft³	Total area,† ft²/ft³	Porosity ε	Packing factors† F_p	f_p
Raschig rings	Ceramic	$\frac{1}{2}$	55	112	0.64	580	1.52§
		1	42	58	0.74	155	1.36§
		$1\frac{1}{2}$	43	37	0.73	95	1.0
		2	41	28	0.74	65	0.92§
Pall rings	Metal	1	30	63	0.94	56	1.54
		$1\frac{1}{2}$	24	39	0.95	40	1.36
		2	22	31	0.96	27	1.09
	Plastic	1	5.5	63	0.90	55	1.36
		$1\frac{1}{2}$	4.8	39	0.91	40	1.18
Berl saddles	Ceramic	$\frac{1}{2}$	54	142	0.62	240	1.58§
		1	45	76	0.68	110	1.36§
		$1\frac{1}{2}$	40	46	0.71	65	1.07§
Intalox saddles	Ceramic	$\frac{1}{2}$	46	190	0.71	200	2.27
		1	42	78	0.73	92	1.54
		$1\frac{1}{2}$	39	59	0.76	52	1.18
		2	38	36	0.76	40	1.0
		3	36	28	0.79	22	0.64



ΔP = (in. H2O/ft)
ΔP = 1.5
1.0
0.50
0.25
0.10
0.05
2.4
2.0
1.6
1.2
0.8
0.4
0.0
CsFp0.5ν0.05
0.005
0.006
0.01
0.02
0.03
0.04
0.05
0.06
0.10
0.20
0.30
0.40
0.50
0.60
1.0
2.0
3.0
4.0
5.0
Gx/Gy √(ρy/ρx)