1. **(60 pts)** 500 kg/hr of a feed solution containing a solute (C) mass fraction of 0.24, diluent mass fraction (A) of 0.76, is to be extracted using a recycled solvent stream (solute C mass fraction = 0.04, solvent mass fraction B = 0.90. The exiting raffinate shall be 0.11 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.
   a. Use the McCabe-Thiele method to determine the required number of stages if 1.5 times the minimum solvent flow is used.
   b. What is the recycled solvent stream flow rate used? (This will include all three components of the solvent stream flow.)
   c. What are the Extract and Raffinate compositions and flow rates?

Diluent Rich (Raffinate)		**Solvent Rich (Extract)**	
x (x_B)	**y (x_C)**	**x (x_B)**	**y (x_C)**
0.13	0.30	0.40	0.42
0.11	0.24	0.46	0.39
0.09	0.18	0.51	0.35
0.08	0.12	0.57	0.30
0.07	0.08	0.61	0.26
0.068	0.04	0.66	0.20

2. **(40 pts)** A 1000 kg/hr feed of 45 mass percent ethylbenzene and 55 mass percent toluene enters a continuous distillation tower (fitted with a partial condenser) operating at a reflux ratio which is 2.0 times the minimum. (Minimum reflux is based on actual equilibrium curve.) There is a 95 percent recovery of toluene in the distillate and 97 percent recovery of ethylbenzene in the bottom product. Feed enters as a saturated liquid. Assume a Murphree Efficiency, η_M = 0.75.

   MW Toluene = 92.14 g/mol
   MW Ethylbenzene = 106.17 g/mol

   a. How many plates will be required?
   b. What plate is optimum for the feed to enter?

3. (60 pts) A stream of gas has the composition 95 mole % air and 5 mole % of Elroy's proprietary Zapple®. The gas stream enters at 5000 pounds per hour at 20 C and 1 atmosphere. It is required to remove 90% of the Zapple® from the gas stream by absorbing it into a stream of pure water. The liquid stream is to be 1.5 times the minimum flow. The tower is packed with 1.5" plastic Pall rings.

The tower diameter shall be determined to give ΔP/ft of packing equal to 50% that of ΔP_{flood}/ft. The tower operates at 20 C (= 527.67 R) and 1 atmosphere total pressure. The equilibrium curve at these conditions is **y = 0.7 x**. You may regard the operating line as being straight.

Data:

Air:

MW = 28.9

Zapple®:

MW = 15.0

Sc = 0.75 in air

Sc = 350 in water

Water:

MW = 18

ρ = 62.4 lb/ft^3

ν = 1 cSt

μ = 0.891 cP

Packing:

Table included in attachments

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

R is degrees Rankine

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

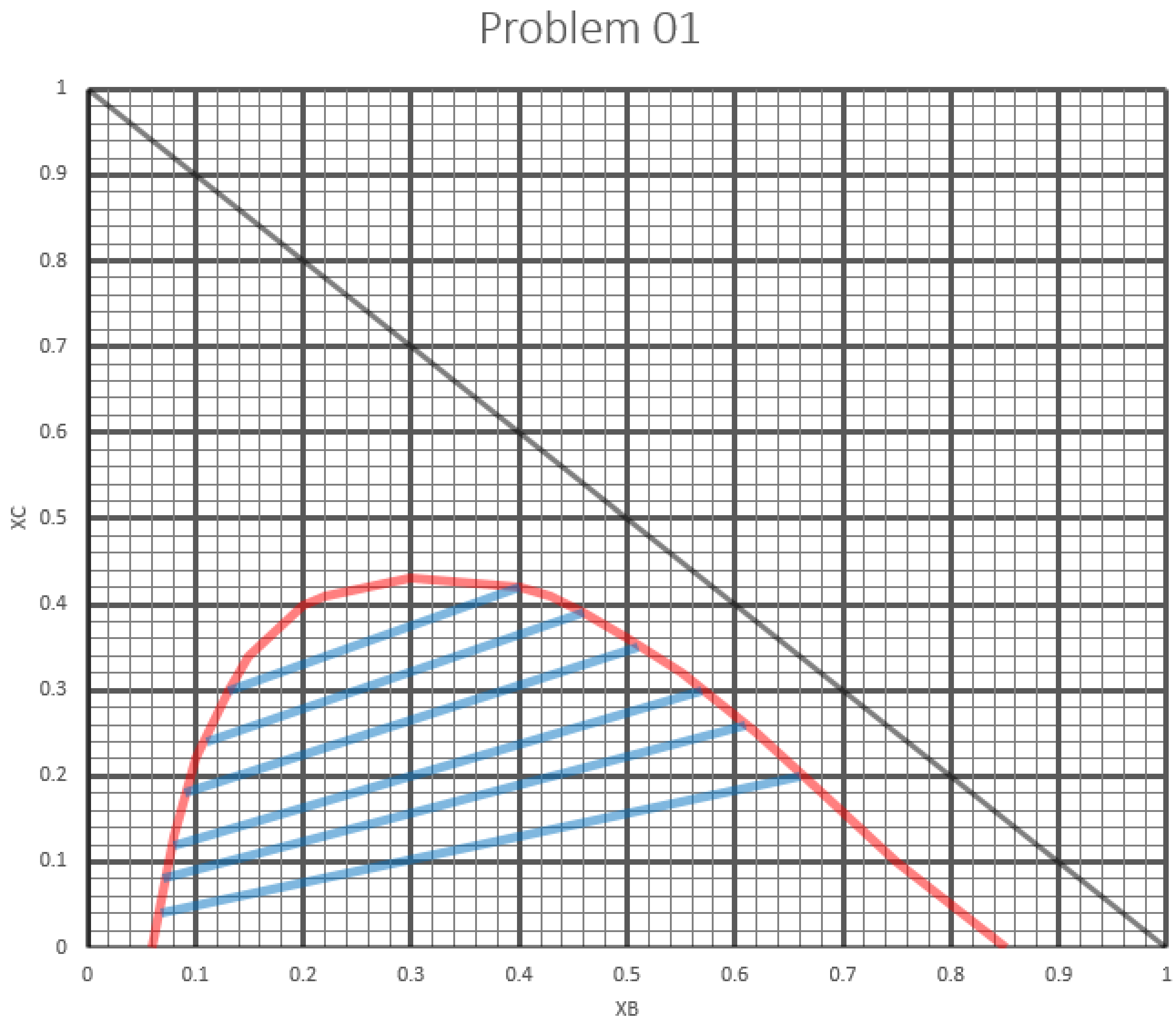
b. What height of packing is required? Base your solution on y – y*. Use the correlations from lecture to determine H_x and H_y. Base your calculations on flow rates at the bottom of the tower.

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

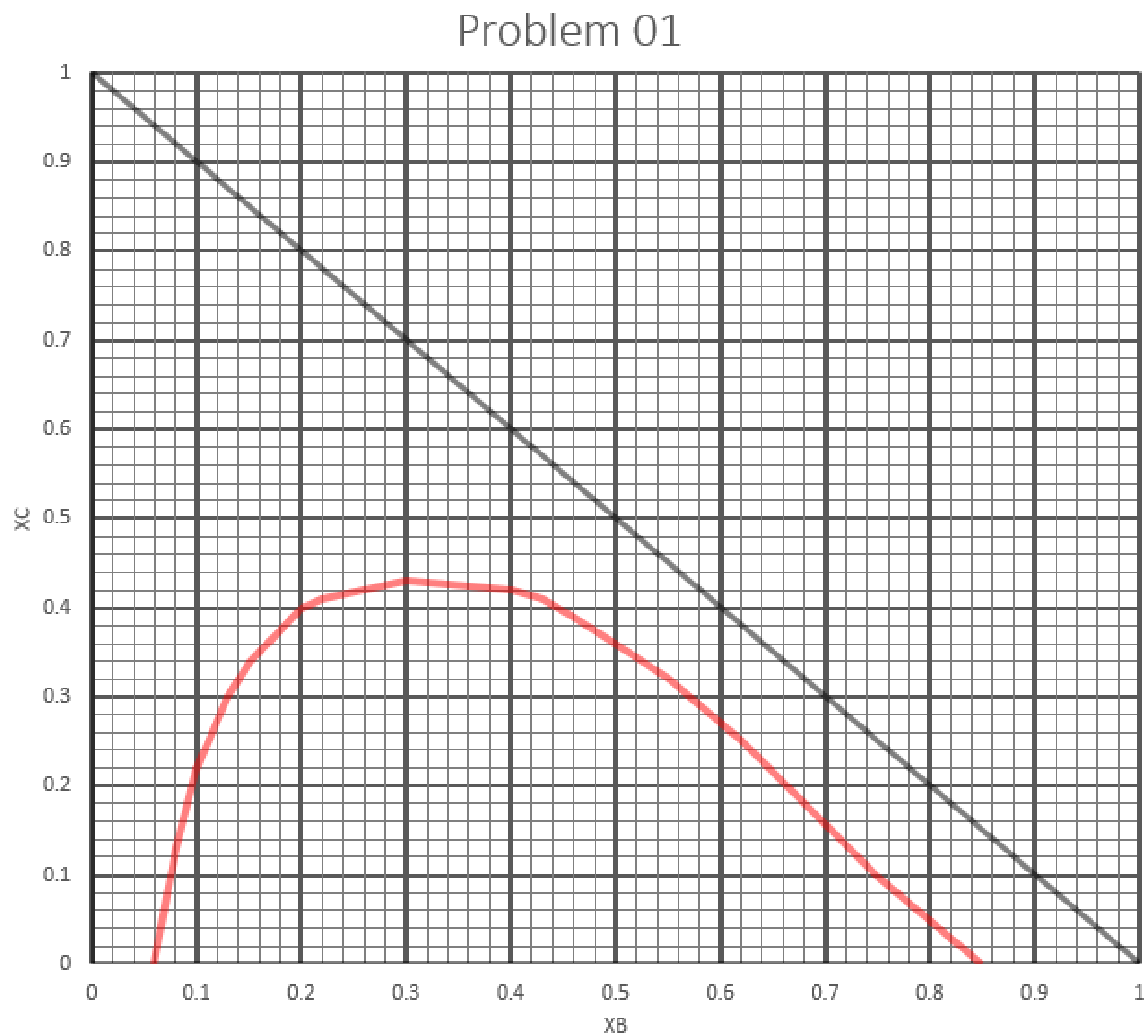
4. **(40 pts)** A 100 mol/min feed stream comprising 30 mole percent benzene and 70 mole percent ethylbenzene is separated by continuous distillation at atmospheric pressure in a column fitted with a total condenser. Process specifications require a mole fraction of 0.999 benzene in the distillate and a mole fraction 0.05 benzene in the bottoms. The feed enters as a saturated liquid. The reflux ratio $R_D = 1.5$. Use the analytical procedure (Kremser equation) for $x > 0.9$ and the graphical (McCabe-Thiele method) for $x < 0.9$.

   Note that one point on the equilibrium curve is **(x,y) = (0.9000000, 0.9815065)**.

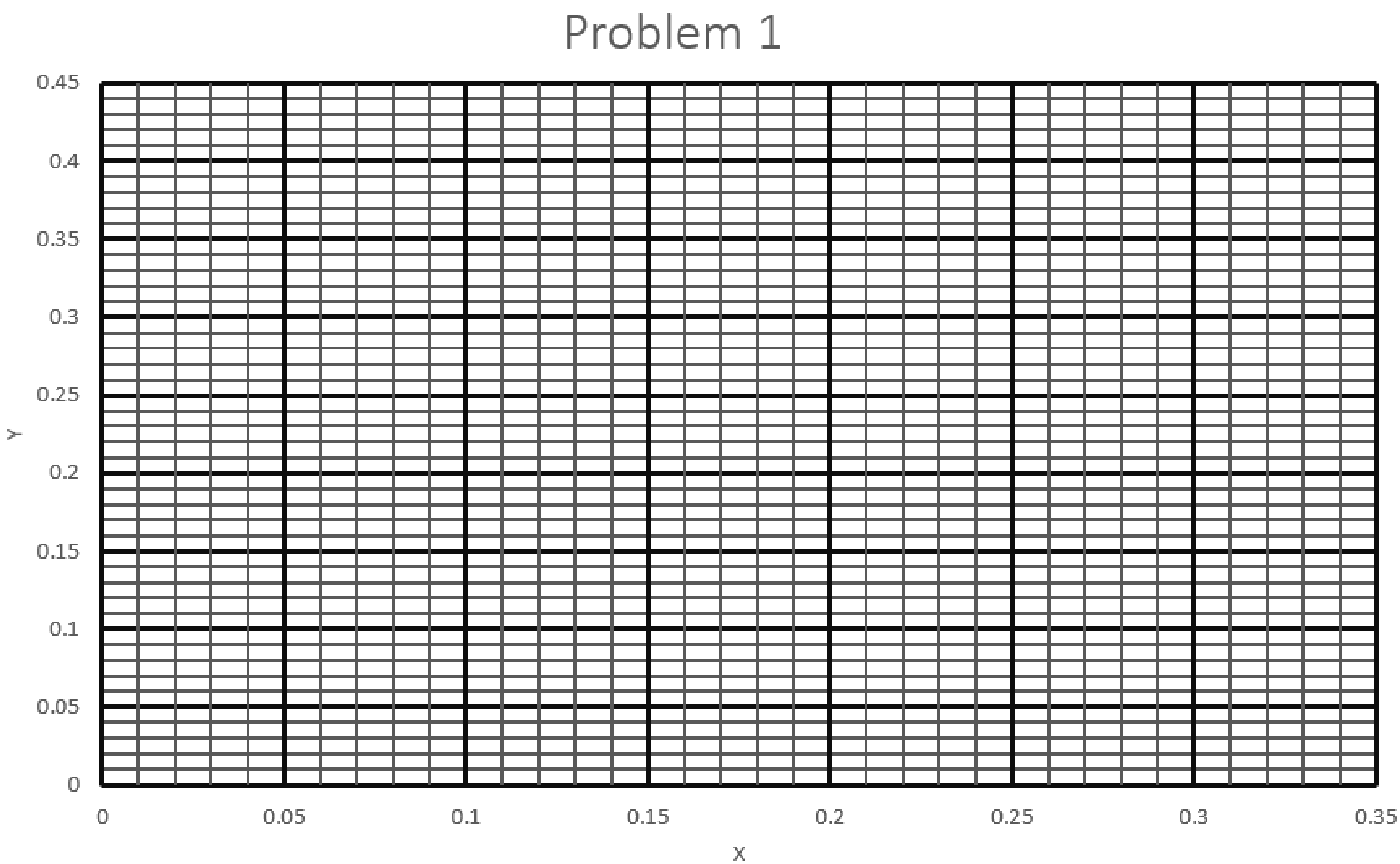
   a. What are the flow rates of the distillate and bottoms streams?
   b. How many stages are required?
   c. What is the optimal stage to introduce the feed?



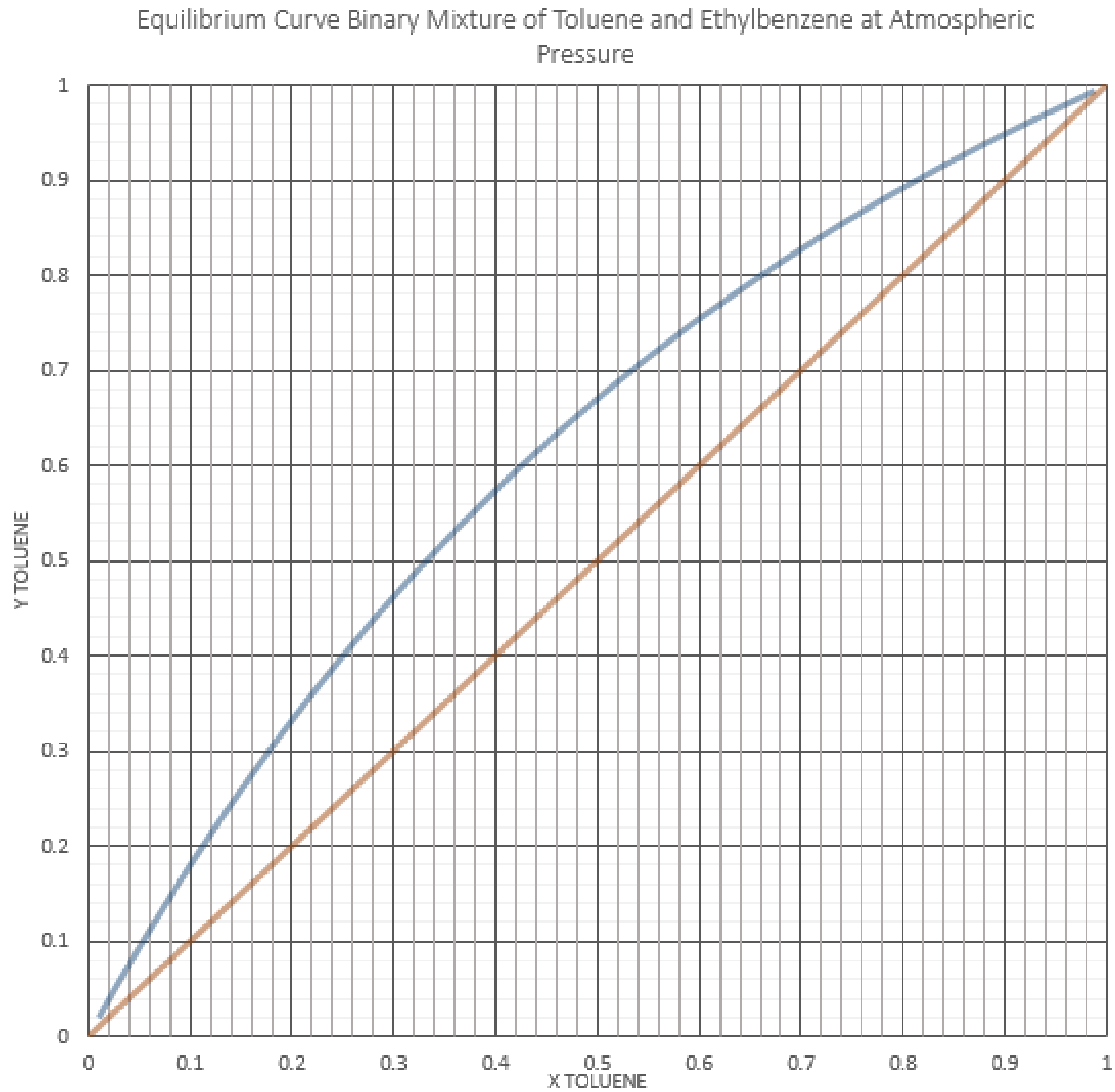
Problem 01
XC
XB
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1



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


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

Problem 2

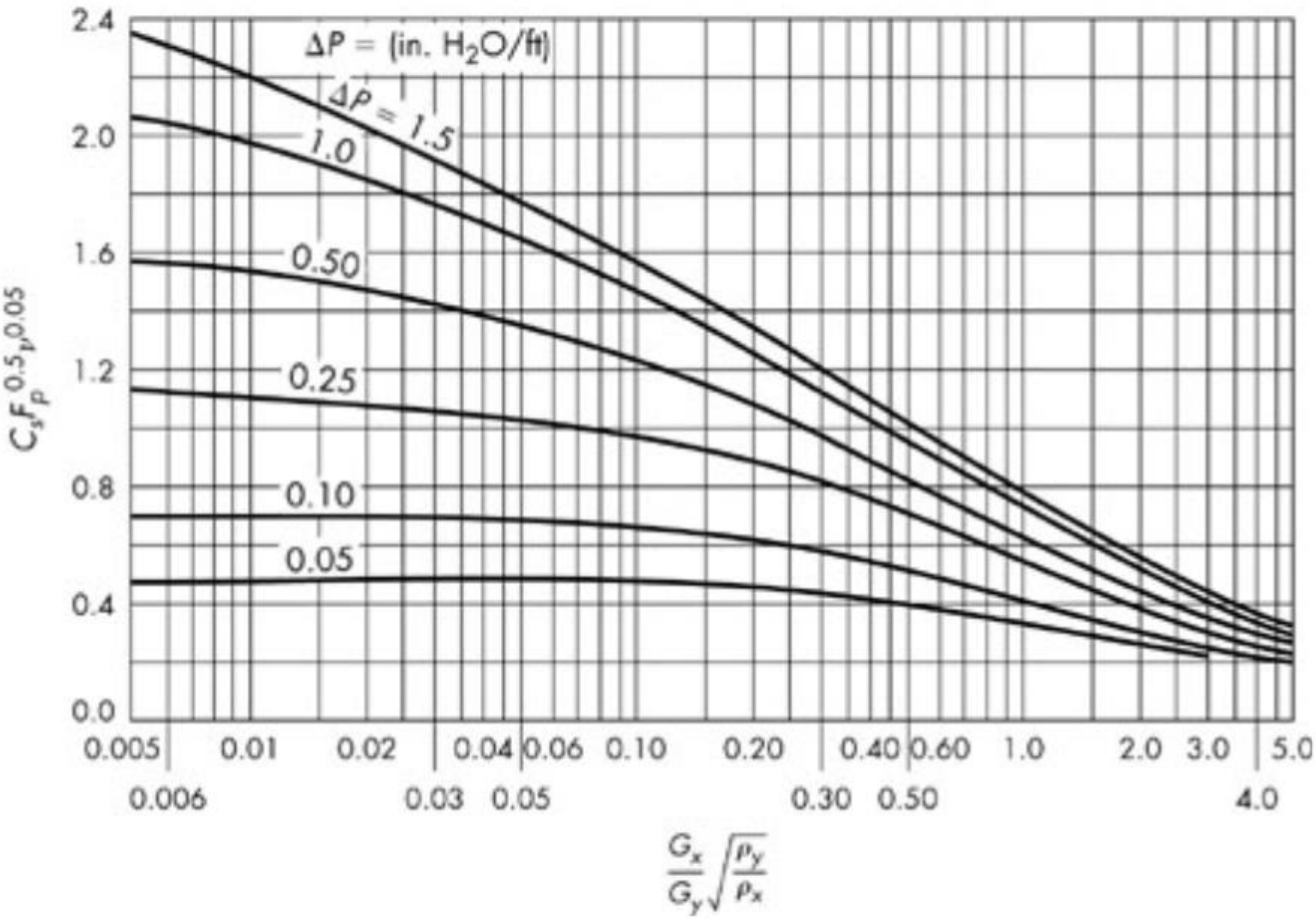


Equilibrium Curve Binary Mixture of Toluene and Ethylbenzene at Atmospheric Pressure
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Y TOLUENE
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
X TOLUENE

Problem 3

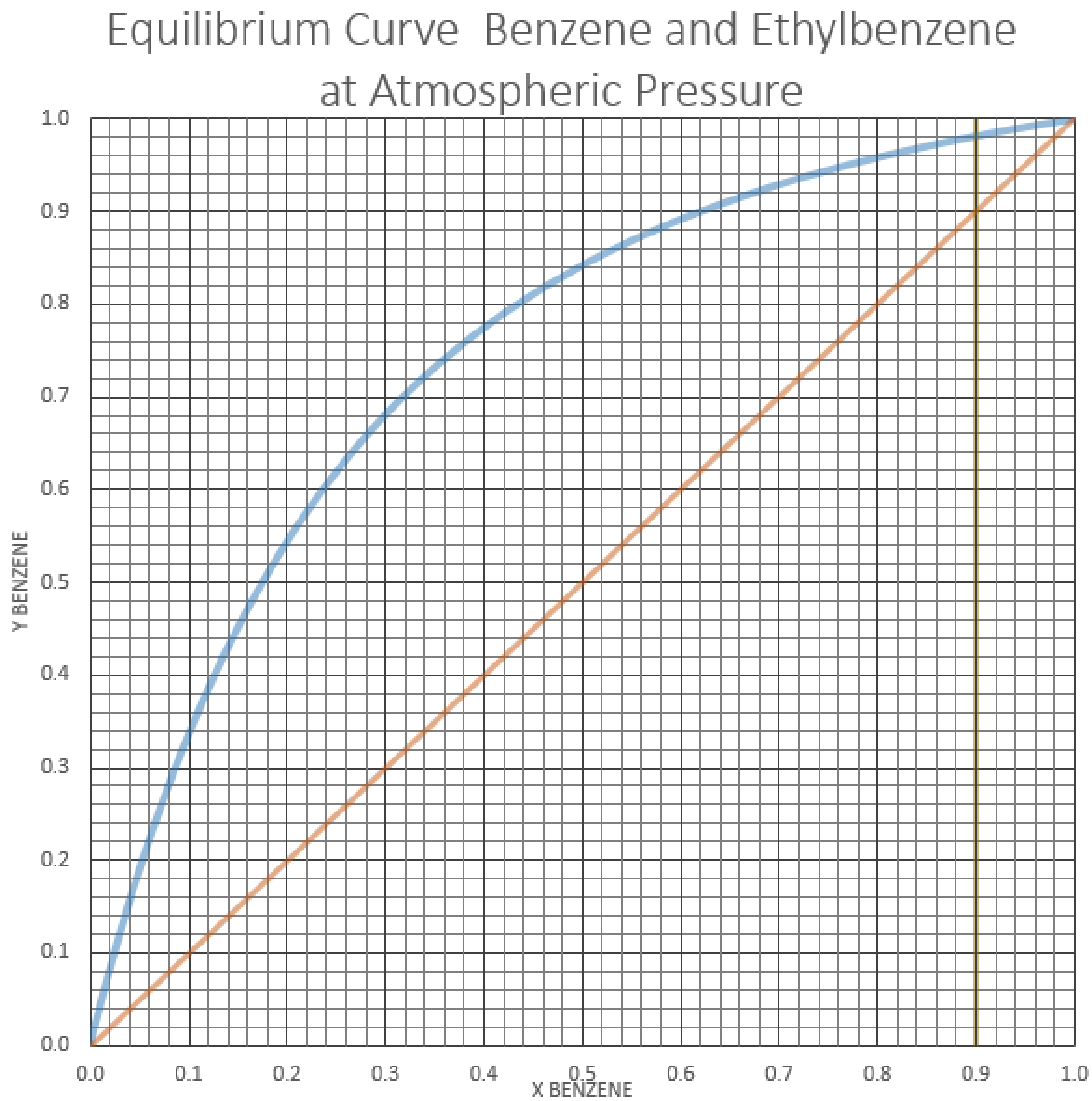
TABLE 18.1
Characteristics of dumped tower packings[12,15b,27]

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
$C_s F_p^{0.5} \nu^{0.05}$
0.005
0.01
0.02
0.04
0.06
0.10
0.20
0.40
0.60
1.0
2.0
3.0
5.0
0.006
0.03
0.05
0.30
0.50
4.0
$\frac{G_x}{G_y}\sqrt{\frac{\rho_y}{\rho_x}}$

Problem 4


Equilibrium Curve Benzene and Ethylbenzene
at Atmospheric Pressure
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Y BENZENE
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
X BENZENE