ORDRE DES INGÉNIEURS DU QUÉBEC

MAI 2017 SESSION

Open-book examination **Calculator : only authorized models** **Duration : 3 hours**

16-CH-A2 Unit operations and separation processes

This examination consists of 6 questions.

Questions	Value	Score
1. Binary distillation	20 points	
2. Absorption of alcohol	15 points	
3. Pumping	25 points	
4. Sedimentation	15 points	
5. Fast questions	10 points	
6. Pressure drop in a packed tower	15 points	
Total	**100 points**	

1. Binary distillation *(20 points)*

The feed to a distillation column contains 55 mol% of phenol and 45 mol% of ethylbenzene and has a flow rate of 13 kmol/h. The feed is at its bubble point and the reflux ratio corresponds to 1.8 times the minimum reflux ratio. It is desired to obtain a distillate containing 90% ethylbenzene and a residue containing 5% ethylbenzene. An overall efficiency of 73% was calculated previously. The distillation unit use a total condenser and a partial reboiler. The equilibrium curve of the phenol / ethylbenzene mixture is shown below.

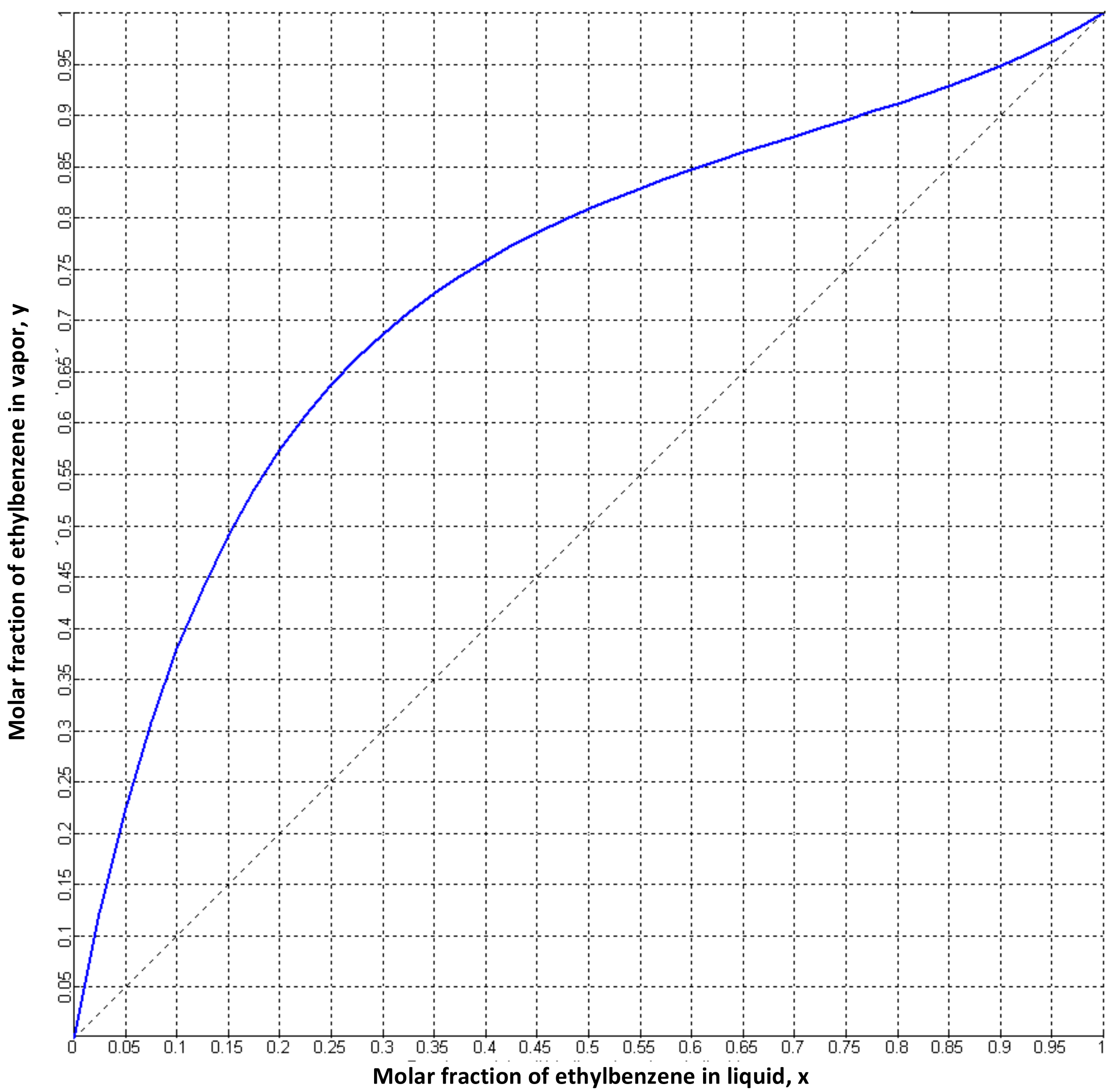

Figure 1 – Equilibrium curve for phenol/ethybenzene system at P = 1 atm

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For this binary mixture, calculate :

A) distillate and residue flow rates (kmol/h).
B) the minimum reflux ratio, R_{min}.
C) the reflux ratio, R.
D) the number of theoretical plates.
E) the optimal position of the feed.
F) the number of actual trays.
G) the composition of the liquid and vapor streams emerging from the top plate of the column.
H) If the flow of vapor is too great, what problem could occur in the column?

2. Absorption of alcohol *(15 points)*

The following equations respectively represent the operating line of an absorption column and the equilibrium line for the absorption of an alcohol in water. A schematic of the column is presented below. Determine the molar ratio of alcohol in the vapor leaving stage 2 (X_2).

$$Y_{N+1} = 0.0006 + 0.8288X_N$$

$$Y = \frac{0.57X}{1 + 0.43X}$$

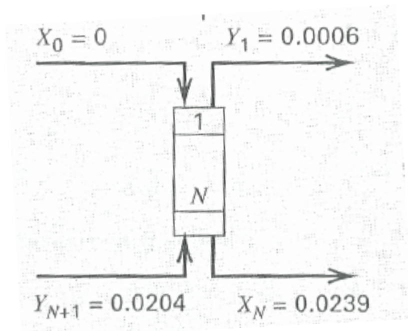


Figure 2 – Absorption column diagram

3. Pumping *(25 points)*

From the hydraulic network shown below:

A) Calculate the Reynolds number in the pipeline if a water flow of 7200 m^3 / day is to be pumped.
B) Calculate the developed load (ΔH) that the pump should have, assuming that the friction factor in the pipes is $f_m = 0.016$.
C) Calculate the NPSHA value in meters.

The vapor pressure of the water at 20 ^oC is 2336.8 Pa and its viscosity is 0.001 Pa.s.

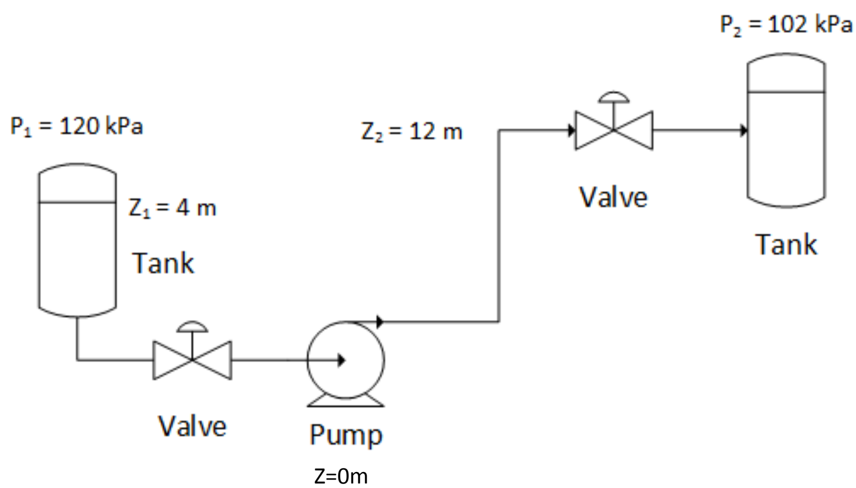


Figure 3 – Hydraulic network

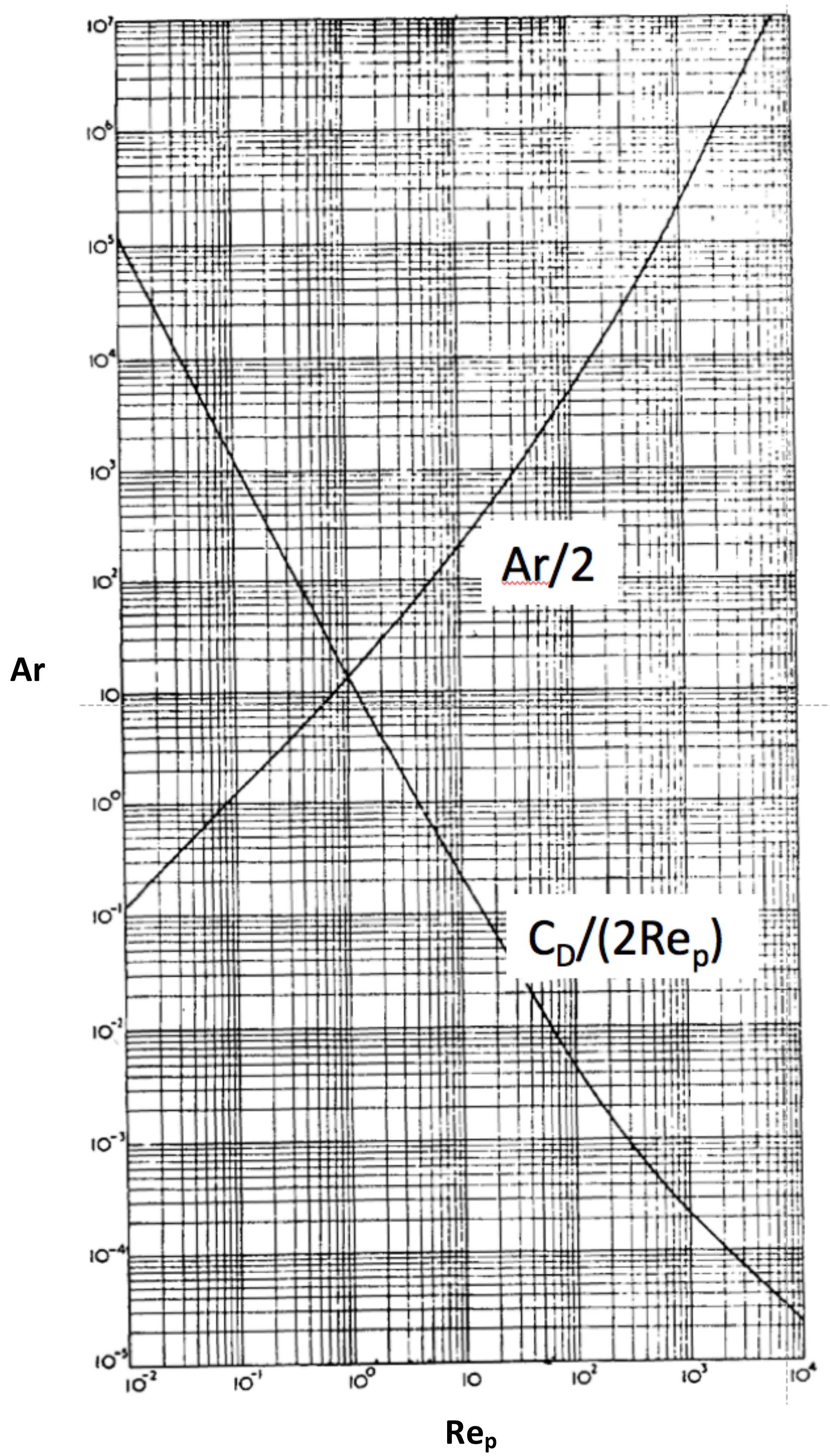
Hydraulic network information :

Suction	Discharge
L = 17 m (piping)	L = 42 m (piping)
d_{pipe} = 150 mm	d_{pipe} = 150 mm
1 elbow 90^o, K = 0,24	2 elbows 90^o, K = 0,24
Globe valve, L_{eq} = 4 m	Globe valve, L_{eq} = 4 m
	Swing check valve L_{eq} = 4 m

4. Sedimentation *(15 points*)

Calculate the terminal velocity of falling of spherical droplets of an unknown substance into the air. The droplets have a diameter of 400 µm and are free-falling into the air. The density of the droplets is 1.03 and the air is at a temperature of 149 ^{o}C. The viscosity of the air is 2.3 x 10^{-5} Pa.s. You can use the graph on the next page to help you.

Note : $Ar = \frac{4D_p^3}{3\mu^2}(\rho_p - \rho)\rho g$ is the number of Archimedes and Re_p is the number of particulate Reynolds for particles having reached their terminal velocity of falling.



Ar vs Re_p graph for sedimentation of spherical particles

5. Fast questions *(10 points)*

I. Which of the following statements is correct for laminar flow of a liquid in a tube of unknown roughness ? Explain your answer.

A) The transition from laminar to turbulent flow occurs at a Reynolds number of 210.
B) The friction factor decreases when the Reynolds number increases.
C) The friction factor depends on the relative roughness.
D) The friction factor is independant of velocity.

II. The pressure drop in a 6 in pipe (ID = 6,065 in) of lenght *L* is 1 psi with the flow in the highly turbulent region. If the same liquid flows at the same volumetric flow rate in a 3 in pipe (ID = 3,068 in) with lenght *L*, the pressure drop (psi) is most nealy :

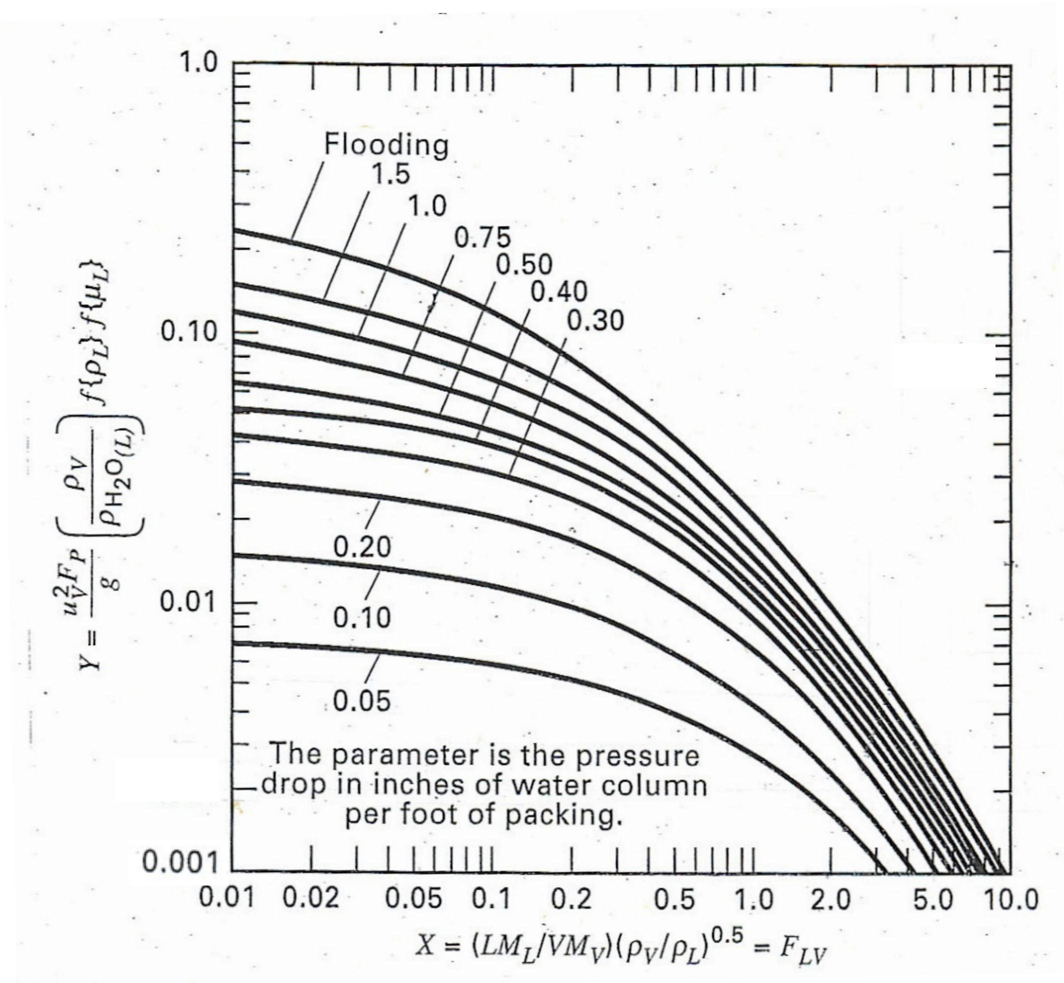
A) 0,033
B) 2,0
C) 7,7
D) 30

Explain your answer.

6. Pressure drop in a packed tower *(15 points)*

A packed tower is to be used to remove acetone (C_3H_6O) from an air stream with pure water. The gas flow rate is 3,78 kg/s and density is 0,0909 lb/ft^3. The liquid density is 62,4 lb/ft^3.

One inch Intalox packing (F_p = 32 ft^{-1}) is selected for the column. The design is for a pressure drop of 1,0 in. of water per foot of packing. For a water flow rate of 4,69 kg/s, calculate the gas velocity (ft/s) in the column.



Generalized flooding and pressure-drop correlation for packing

Legend :

L	Liquid mass flowrate	F_p	Packing factor
V	Gas mass flowrate	u_v	Gas velocity
M_L	Molecular weight of liquid	g	Gravitational constant (32,2 ft/s^2)
M_V	Molecular weight of gas	$\rho_{H2O(l)}$	Liquid water density
ρ_v	Gas density	$f(\rho_l)$	Ratio of density of water to the density of liquid
ρ_L	Liquid density	$f(\mu_L)$	Correction factor for viscosity **$f(\mu_L)$ = 1 if water is used**