

University of Technology
Chemical Engineering Department



Subject: Combustion Engineering
Branch: Oil & Gas Refinery Engineering
Examiner: Zainab Y. Shnan

Final Examination

2011/2012

Class: Third
Time: 3 hours
Date : 7/6/2012

Attempt four questions only

Q1:- Liquid fuel (C_5H_{12} 36%, C_6H_{14} 64% by mole) is burned with 20% excess air. Determine the height of chimney if the draught is 10mm water, if the temperature of flue gas is $327^\circ C$ and the temperature of air is $23^\circ C$. (25 mark)

Q2:- A/Determine the adiabatic flame temperature for constant pressure combustion of a stoichiometric CH_4 -air mixture. Assuming reactant at 298 K. (Include your answer the assumption to calculate the flame temperature). Enthalpy at 298 K (kJ/kmole)

$$[CO_2 = -39354, CH_4 = -74831, H_2O = -241845] ,$$

$$C_p \text{ at } 1200 \text{ (kJ/kmole.K) for } [CO_2 = 56.21, H_2O = 43.87, N_2 = 32.71]$$

B/ The higher heats value of a dry ash. Free bituminous is 12500 Btu/lbm = 29.050 kJ/kg the cool containing 70%wt carbon and 5%wt hydrogen on adry ash. Free basis find the enthalpy of formation of this cool. ΔH (kJ/kmole) for $[CO_2 = -393520, H_2O = -285750]$. (25 mark)

Q3:- A/ what is the draught in the furnaces? Explain all the types of draught with the aid of a sketch.

B/ Define the furnace efficiency and state the factors influence on it.

C/ Give the factors which effect on flame temperature. (25 mark)

Q4:- A/ The higher heating value of gaseous methane and air at $25^\circ C$ is 55.5 MJ/kg. Find the heat of reaction at constant pressure of a stoichiometric mixture of methane and air if the reactant and products are at 500 K.

Enthalpy at 500 K (MJ/kgmole) $[CO_2 = 8.31, CH_4 = 8.20, H_2O = 6.92, N_2 = 5.91, O_2 = 6.09]$

H_{fg} of water at 500 K = 2394 (kJ/kg water) .

B/ propane is burned to completion in a furnace the fuel and air at $77^\circ F$. If 5% of the heat is loss through the walls of the furnace. The combustion product exits the furnaces to the stack at $340^\circ F$. What is the useful heat output of the furnace per pound of propane ?

HHV 953,480 Btu/lbmole

Enthalpy at $800^\circ R$ (kBtu/lbmole)

$[CO_2 = 2.528, H_2O = 2.142, N_2 = 1.838, O_2 = 1.882]$, H_{fg} of water = 1050 kBtu/lb. (25 mark)

Q5:- Decane $C_{10}H_{22}$ in gas phase is burned to completion in a furnace .the fuel and air at $25^\circ C$. There is no heat lost through the wall of the furnace and the stack gas temperature was $427^\circ C$ no blower was used. The fuel and air inlet the furnace at $25^\circ C$.Calculate the higher heating value and the operating efficiency of this furnace.

Enthalpy at 298 K (kJ/kmole) $[CO_2 = -393596, C_{10}H_{22} = -249659, H_2O = -285857]$

Enthalpy of product at 700 K (kJ/kmole) $[CO_2 = 5.88 \times 10^3, N_2 = 4.2 \times 10^3, H_2O = 4.9 \times 10^3]$

H_{fg} of water (kJ/kmole) = 1050 . (25 mark)

Q111 Basis = 100 mol of fuel

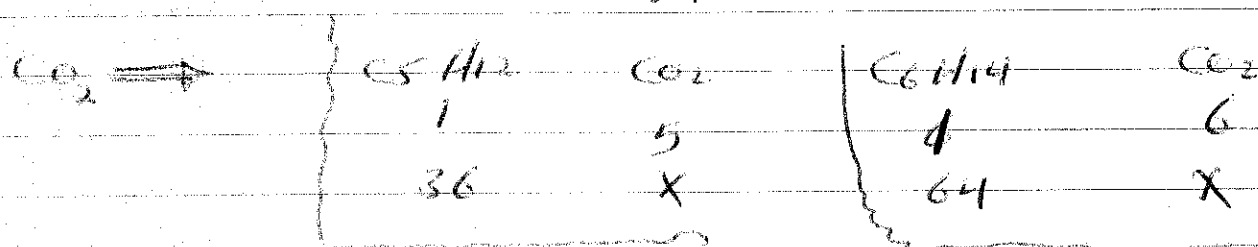


$$O_2 \text{ required} = 8 \times 36 + \frac{19}{2} \times 64 = 896 \text{ mole (theo)}$$

$$O_2 \text{ excess} = \% \text{ excess} \times O_2 \text{ theo} \\ = \frac{20}{100} (896) = 179.2 \text{ mole}$$

$$O_2 \text{ actual} = O_2 \text{ theo} + O_2 \text{ excess} \\ = 896 + 179.2 = 1075.2 \text{ mole}$$

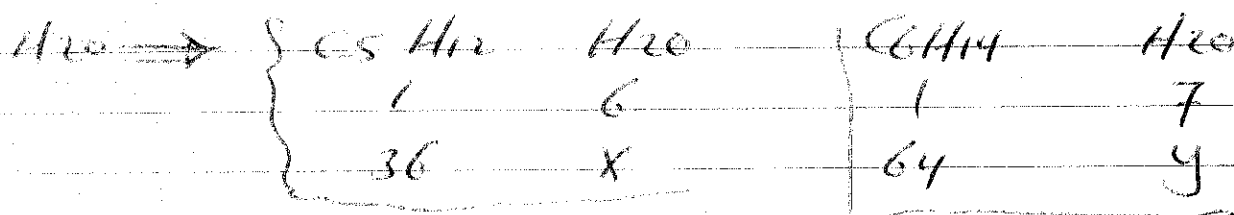
$$\text{inlet } N_2 = 1075.2 \times \frac{79}{21} = 4044.8 \text{ mole}$$



$$x = 180$$

$$x = 384$$

$$CO_2 = 180 + 384 = 564 \text{ mole}$$



$$H_2O = 6 \times 36 + 7 \times 64 = 664 \text{ mole}$$

$C_{O_2} \text{ excess} = 179.2 \text{ mole}$

$N_2 \text{ in} = N_2 \text{ out}$

Comp	<u>N (mole)</u>	<u>mwt</u>	<u>m kg</u>	<u>mass %</u>
CO_2	564	44	24816	0.159
H_2O	664	18	11952	0.076
O_2	179.2	32	5734.4	0.036
N_2	4044	28	113232	0.727
	<u>7064</u>		<u>155734.4</u>	

$$H = \frac{h}{353 \left[\frac{1}{T_1} - \frac{w+1}{w} * \frac{1}{T_2} \right]}$$

$$\text{air weight} = (N_{O_2} + N_{N_2}) * 29 = (179.2 + 4044) * 29 = 1178188.8 \text{ kg}$$

$$\text{fuel weight} = 36(72) + 64(86) = 8096 \text{ kg}$$

$$w = \frac{1178188.8}{8096} = 145.527 \text{ kg}$$

$$H = \frac{10}{353 [0.0033 - 0.00329]} = 2832.86 \text{ m}$$



$$H_{\text{react}}(T_{i,P}) = H_{\text{Prod}}(T_{ad,P})$$

$$H_{\text{react}} = \left(\sum N_i h_i \right)_{\text{react}} = H_{\text{Prod}} = \left(\sum N_i h_i \right)_{\text{Prod}}$$

$$H_{\text{react}} = 1(-74831) + (2 \times 0) + (2 \times 3.76 \times 0) \\ = -74.831 \text{ kJ} \quad \text{--- (1)}$$

$$H_{\text{Prod}} = \left[\sum N_i h_i + C_P(T_{ad} - 298) \right]$$

$$= 1[-393546 + 56.21(T_{ad} - 298)] + 2[-24184 \\ + 43.87(T_{ad} - 298)] + 7.52[0 + 32.71(T_{ad} - 298)]$$

$$H_{\text{react}} = H_{\text{Prod}}$$

$$-74831 = 1[-393546 + 56.21(T_{ad} - 298)] + 2[-241845 + \\ 43.87(T_{ad} - 298)] + 7.52[0 + 32.71(T_{ad} - 298)]$$

$$T_{ad} = 2318^\circ\text{C}$$

Assumption

① Complete combustion the product mixture consists only of CO_2 , H_2O and N_2

② the Product mixture enthalpy estimated using specific heats evaluated at $1200 = 0.5(T_i + T_{ad})$ where T_{ad} is guessed to be about 2600°K .

Shiggi

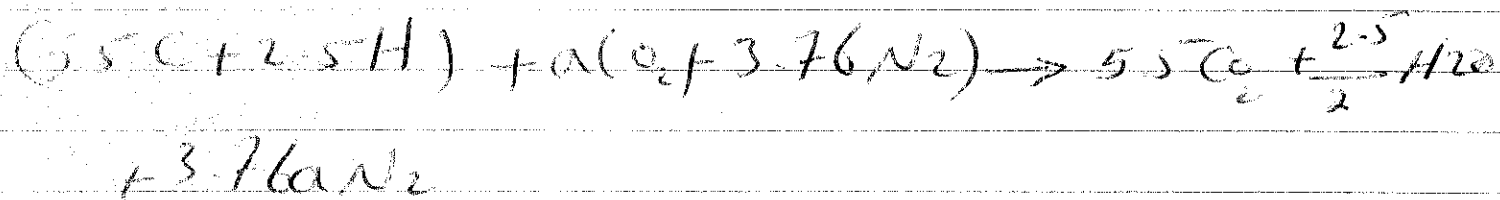
Q211(B)

$$HHV = \Delta H_c = -\Delta H_R = (H_{prod} - H_{react})$$

for $\text{C}_2 \rightarrow \text{fuel}$, $\text{H}_2\text{O} \rightarrow \text{product}$

$$(m \Delta H)_{\text{coal}} - (m \Delta H)_{\text{C}_2} - (m \Delta H)_{\text{H}_2\text{O}} = (m HHV)_{\text{coal}}$$

$$\Delta H_{\text{coal}} = HHV + \left(\frac{m \text{C}_2}{m_{\text{coal}}} \right) \Delta H_{\text{C}_2} + \left(\frac{m \text{H}_2\text{O}}{m_{\text{coal}}} \right) \Delta H_{\text{H}_2\text{O}}$$



$$\left(\frac{m \text{C}_2}{m_{\text{coal}}} \right) = Y_{\text{C}_2} \times \frac{\text{mwt C}_2}{\text{mwt C}} = \left(\frac{70}{100} \times \frac{44}{12} \right)$$

$$\frac{m \text{H}_2\text{O}}{m_{\text{coal}}} = Y_{\text{H}_2\text{O}} \times \frac{\text{mwt H}_2\text{O}}{\text{mwt H}} = 0.05 \times \frac{18}{2}$$

$$\Delta H_{\text{coal}} = 29.05 \text{ kJ/kg} + 2.57 \left(\frac{-393520 \text{ kJ/kmol}}{44} \right)$$

$$+ 0.45 \left(\frac{-285750 \text{ kJ/kmol}}{18} \right)$$

$$= -1079 \text{ kJ/kg}$$

Q3/1/11

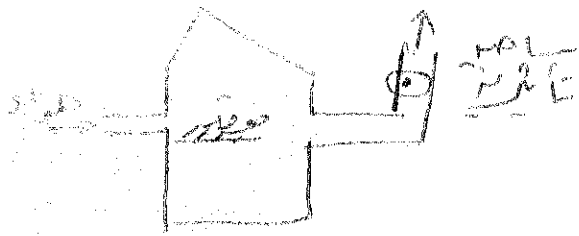
نقد مفهوم اختيار السحب في الافرام والوقود على Draught
 (م) في زويد الهواء الذي يعبره او الوقود الذي لا يعبره لوقود وسوقه في الهواء
 المحترق في هذه الحالة السحب هو الوقود على كيم الهواء يدفعه ذلك في وقت
 الامتصاص

(ن) لان السحب غازات الامتصاص التي تعبر في الهواء او الوقود
 سحر السحب هو يعرف به الضغط في وقت اللغات عند نقطة من جري الهواء
 والضغط الجوي يحصل اختيار عند زو الضغط اقل لنيت السحب في الهواء
 او غازات الامتصاص وقدر اختيار السحب هو مقدار الضغط في الامتصاص
 (د) سحر السحب الطبيعي Natural draught

مبدأ نظام سحر السحب
 الصورة عند استخدام السحب
 ضغط زويد السحب وتحدث لسحر السحب
 مرة الضغط بين جوي الغازات الساخنة داخل
 الامتصاص وجوي الهواء الخارجي وسوقه في السحب الساخنة على السطح
 معدل وزيد الحرارة في السحب في الافرام والضغط في السحب في الافرام
 المصنوع نسب

(هـ) سحر السحب الميكانيكي mechanical draught هو نظام الامتصاص
 في الافرام بالرافل للسحب والسحب في الهواء سحر السحب الميكانيكي هو
 اختراع في ارتفاع الضغط في كفة الحزام السحب على سحر السحب الميكانيكي
 اوت السحب في تأثيرات اخرى

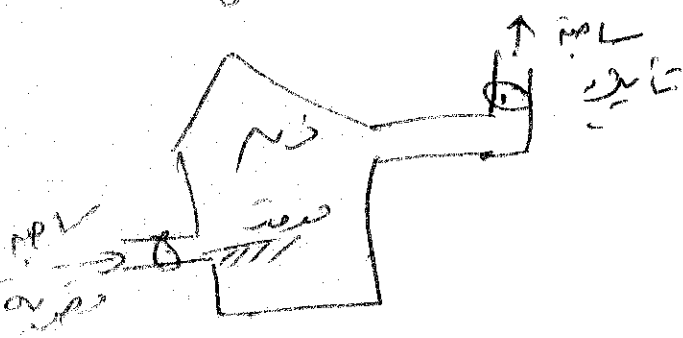
(و) سحر السحب في تأثير السحب عند قامة السحب في الافرام
 لسحب الهواء في السحب الجاهل عند السحب في السحب في السحب في السحب
 في الافرام اختراع السحب السحب في السحب في السحب في السحب في السحب
 غازات الامتصاص في الافرام في السحب في السحب في السحب في السحب في السحب
 التأثير في السحب في السحب في السحب في السحب في السحب في السحب في السحب
 الامتصاص في السحب في السحب في السحب في السحب في السحب في السحب في السحب



٢٠) تيار الهواء العفوي: تنشأ إصابات في أسفل أرضه عند قدمه فوق السطح
عند ضغط الهواء في الكهنة الجوى، وتزيد داخل الجدران الجوفية فلا تخرج
الوقود كجاء إلى البيت أو فوق المدخل كجاء الهواء، والضغط الجاهل يدع الهواء
الأقراص فلا تخرج الهواء، حين الأقراص، لا بد من تدخين، مثل تيار الهواء
المضرب عند طامات الأقراص الكبيرة في مواد التقديم في أسفل.



٢١) تيار الهواء المتوازن: يتكون تيار الهواء المتوازن عند موازنة الهواء
العفوي والتهار التنازلي وذلك عند تثبيت السطح عند قدمه الجوفية
عند قاعه المدخن، عند تدخين موازنة بين الضغط، التنازل، والتهار
تحت ما يتأرجح الكهنة المتعددة.



Furnace efficiency

The efficiency of the Furnace is defined as the relation of the useful heat output to the energy input. In general for any type of fuel

$$\eta = \frac{q}{m_f HHV + w_{in}}$$

$$\eta = \frac{h_{sf} + h_{sa} \left(\frac{N_a}{N_f} \right) + HHV - \frac{N_p}{N_f} \sum X_i h_{si} - \frac{N_{H_2O}}{N_f} h_{fi} - \frac{q_L}{N_f}}{HHV + w_{in}/N_f}$$

The furnace efficiency can be increased by the following measures

- ① Decrease the temperature of the exhaust products.
- ② reduce the excess air which will reduce the moles of products per mole of fuel and also reduces the blower power.
- ③ reduce the extraneous heat loss
- ④ reduce the blower power requirements.

where $\frac{N_p}{N_f} = \frac{N_p}{N_c} \times \frac{N_c}{N_f} = \frac{N_c/N_f}{X_{CO_2} + X_{CO}}$

Q3/C

المواد التي تترك على درجة حرارة الذهب

① حمض ديسيد الخوا الزاكن

② كبريتات البوتاسيوم المتفرقة

③ الخوا المتفرقة في الذهب بدرجة الإشعاع

④ فصلت درجة حرارة العزم

⑤ درجة الحرارة لهذا CO_2 والمواد

⑥ كبريتات تفاعل بين جدار الذهب ودرجة الحرارة

⑦ تفاعل الذهب في ذلك في طابع معطارات العزم

$\frac{C_p}{M} (H_2V)_{CH_4} = 55.5 \text{ MJ/kg}$

A $\frac{Q_{41A}}{Q_{41A}}$

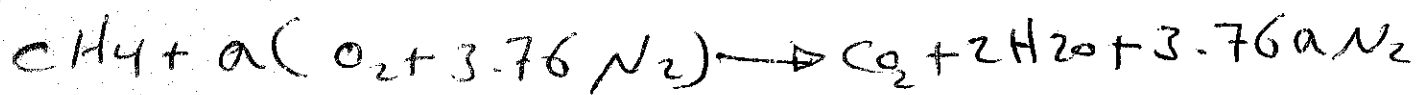
$$Q_p = C_p(T_0) + m(hs_2 - hs_1) \div m$$

$$\frac{Q_p}{m} = \frac{C_p(T_0)}{m} + (hs_2 - hs_1)$$

① hs_1 من hs_1 موجود است

$$hs_1 = \frac{hs_i}{(Mwt)_{mix}}$$

مطلوبه است



$$a = x + \frac{y}{4} = 1 + \frac{4}{4} = 2$$

$$hs = \sum x_i hs_i$$

Comp	N_i	$X_i = \frac{N_i}{N_T}$	$hs_i \text{ (MJ/kmol)}$	M_i	y_i
CH ₄	1	0.095	8.2	16	0.095
O ₂	2	0.19	6.09	32	0.22
N ₂	7.52	0.715	5.91	28	0.72
	$N_T = 10.52$	$\sum = 1$			

(hs_i) موجود است در جدول

$$y_i = X_i \cdot \frac{M_{wi}}{(Mwt)_{mix}}$$

$$\begin{aligned} (Mwt)_{mix} &= \sum X_i \cdot M_{wi} \\ &= 0.095(16) + 0.19(32) + 0.715(28) \\ &= 27.6 \end{aligned}$$

$$hs = 0.095(8.2) + 0.19(6.09) + 0.715(5.91) = 6.16 \frac{MJ}{kg}$$

$$hs_1 = \frac{6.16}{27.6} = 223 \text{ kJ/kg}$$

$$hs_2 = \frac{hs_2}{(Mwt)_{mix}} \quad \text{جاء في (hs}_2\text{) للخليط} \quad \text{ⓐ}$$

Comp	N_i	$X_i = \frac{N_i}{N_T}$	hs_i	M_i
CO ₂	1	0.095	8.31	44
H ₂ O	2	0.19	6.92	18
N ₂	7.52	0.715	5.91	28

$$hs_2 = \sum X_i hs_i$$

$$= 0.095(8.31) + 0.19(6.92) + 0.715(5.91)$$

$$= 6.33 \text{ MJ/kmole}$$

$$hs_2 = \frac{6.33}{27.6} = 229 \text{ kJ/kg}$$

$$(Mwt)_{mix} = 0.095(44) + 0.19(18) + 0.715(28)$$

$$= 27.6 \text{ kg/kmole}$$

$$P = \frac{m_{fuel}}{m_{air}} = \frac{y_{fuel}}{y_{air}} = \frac{0.055}{(0.22 + 0.725)} = 0.0582 \quad \text{COP(TD) جاء في ⓑ}$$

$$LHV = HHV - \frac{m_{H_2O}}{m_{fuel}} \times h_{fg}$$

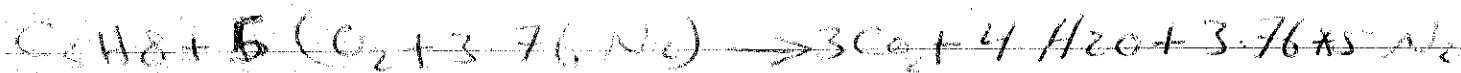
$$= 55,000 - \frac{2(18)}{1(16)} \times 2394$$

$$= 50,113 \text{ kJ/kg} \Rightarrow \frac{COP(TD)}{COP(TD)} = \frac{-P}{1+P} (LHV)$$

$$\frac{COP(TD)}{COP(TD)} = \frac{0.0582}{0.0582 + 1} (50,113) \Rightarrow COP = -2747 \text{ kJ/kg} \rightarrow COP = -2741 \text{ kJ/kg}$$

MEMO

C4H10



$$\text{HHV} = 953480 \text{ Btu/lbmole}$$

Product	N/NP	KBtu/lbmole	KJtu/lbmole Fuel
CO ₂	3	2.528	7.584
H ₂ O	4	2.142	8.568
N ₂	18.8	1.838 1.838	6.1 34.554

$$q_{\text{L/NP}} = \left[h_{\text{sf}} + \text{HHV} + \frac{N_{\text{A}}}{N_{\text{P}}} h_{\text{sa}} - \sum \frac{N_{\text{S}}}{N_{\text{P}}} h_{\text{si}} - \frac{N_{\text{H}_2\text{O}}}{N_{\text{P}}} h_{\text{H}_2\text{O}} \right] - q_{\text{L/NP}}$$

$$= 0 + 953480 + 0 - 50.7064 - (4 \times 1050 \times 18)$$

$$= \frac{-0.05 q_{\text{h}}}{N_{\text{P}}}$$

$$q_{\text{Wf}} = 783,490 \text{ Btu/lbmole}$$

RS11



$$(1) HHV = \Delta H_c = -\Delta H_r - H_{react} - H_{prod}$$

$$H_{react} = (\sum N_i h_i)_{react}, H_{prod} = (\sum N_i h_i)_{prod}$$

$$\Delta H_c = HHV = (1 \times h_{f_{C_{10}H_{22}}} + 15.5 \times h_{f_{O_2}} + 15.5 \times 3.76 \times h_{f_{N_2}}) - (10 \times h_{f_{CO_2}} + 11 \times h_{f_{H_2O}} + 15.5 \times 3.76 \times h_{f_{N_2}})$$

$$HHV = h_{f_{C_{10}H_{22}}} - 10 h_{f_{CO_2}} - 11 h_{f_{H_2O}}$$

$$h_{fg} = h_{f, vap} - h_{f, liq} \rightarrow -241,845 - (-44,010) = -285,855 \frac{kJ}{kmol}$$

$$HHV = (1 \times -249,659) - (10 \times -393,596) - (11 \times -285,857)$$

$$= 6,809,096 \text{ kJ}$$

$$HHV = \frac{6,809,096 \text{ kJ}}{1 \text{ kmol}} = 6,809,096 \text{ kJ/kmol}$$

$$(2) \eta = \frac{q_h}{m \cdot HHV + q_a}$$

$$\eta = \left[h_{sp} + HHV \frac{N_a}{N_f} h_{sa} - \sum \frac{N_j}{N_f} h_{sj} - \frac{N_{H_2O}}{N_f} h_{H_2O} \right] - q_{L/NF}$$

Product	\dot{M}/\dot{M}_F	KJ/kmole	$\text{KJ}/\text{kmole Fuel}$
CO_2	10	5.00×10^3	58800
H_2O	11	4.9×10^3	53900
O_2	58.28	4.2×10^3	244776
N_2	10.28		
			<u>357476</u>

$$\frac{\dot{Q}}{\dot{M}_F} = [0 + 6,380,96 + 0 - (357476) - (11 \times 1050 \times 18)]$$

$$\dot{Q}/\dot{M}_F = [6,380,96 - 357476 - 207900]$$

$$= 72720 \text{ KJ}/\text{kmole}_{\text{fuel}}$$

$$\eta = \frac{72720 \text{ KJ}}{6,380,96 \text{ kmole}_{\text{fuel}}}$$

$$6,380,96$$

$$\eta = 0.1139$$



University of Technology
Chemical Engineering Department



Subject: Statistics
Branch: both branches
Examiner: Ebtisam H.

Final Examination

2011/2012

Class: third
Time: 3 hours
Date: 11 June

Attempt four questions only

Q1/ The following table show corresponding values of three variables X_1, X_2 , and X_3 .

X_1 : 2.0 3.5 4.5 2.5 8.5 10.5 13.5
 X_2 : 18.0 16.5 10.5 2.5 9.0 4.5 1.5
 X_3 : 27.5 28.0 28.8 29.1 30.0 31.0 32.0

A. Find the Least Square regression equation of X_3 on X_1 and X_2 . (10 Marks)

B. Find the standard error of estimate of X_3 on X_1 and X_2 . (15 Marks)

Q2/ The following data represent the level of happiness and health for a random sample:

Happiness	Health				
		Excellent	Good	Fair	Poor
	Very happy	271	261	82	20
	Pretty happy	247	567	231	53
	Not too happy	33	103	92	36

Test the null hypothesis (H_0) at a significance level of 0.05 (Given: $\chi^2_{0.95} = 12.6$). (25 Marks)

Q3/ It is known that the soil permeability (x) of type A follows a normal distribution.

If $\Pr(x > 7.2) = 30\%$ and $\Pr(x < 5.6) = 5\%$.

A. Find the mean and standard deviation of x . (10 Marks)

B. If 40% of the total plot has soil type (A) and 60% has type (B) with mean of 7.5 and standard deviation of 0.45. For what percentage of the plot is x greater than 7.35. (One unit in L.S.D. = 0.1). (15 Marks)

Q4/ A sample of (11) electric bulbs is drawn every day from those manufactured at a plant. The probability of finding no defective bulb is 0.57.

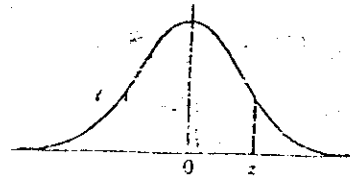
A. What is the probability of finding exactly 3 defective bulbs. (10 Marks)

B. What is probability of finding 3 or more defective bulbs. (15 Marks)

Q5/ Explain the following: A. Temperature measurement by electric methods. B. Classification of measurements. C. Industrial manometer. D. Diaphragm gauge. E. Classification of flow meters. (25 Marks)

With my best wishes for success

AREAS
under the
STANDARD
NORMAL CURVE
from 0 to z



z	0	1	2	3	4	5	6	7	8	9
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0754
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2258	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2518	0.2549
0.7	0.2580	0.2612	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2996	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990
3.1	0.4990	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995	0.4995	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997
3.4	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4998
3.5	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998
3.6	0.4998	0.4998	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999
3.7	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999
3.8	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999
3.9	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000

" حلل ايهو وقياسات "

حلل النسخة الاولى

$$Q1 \quad X_3 = f_n(X_1, X_2) \Rightarrow X_3 = b_{31.2}X_1 + b_{32.1}X_2$$

$$\sum X_3 X_1 = b_{31.2} \sum X_1^2 + b_{32.1} \sum X_1 X_2$$

$$\sum X_3 X_2 = b_{31.2} \sum X_1 X_2 + b_{32.1} \sum X_2^2$$

$$\sum X_1 = 45$$

$$\sum X_2 = 62.5$$

$$\sum X_3 = 206.4$$

$$\bar{X}_1 = 6.43$$

$$\bar{X}_2 = 8.93$$

$$\bar{X}_3 = 29.49$$

$$x_1 = X_1 - \bar{X}_1$$

$$x_2 = X_2 - \bar{X}_2$$

$$x_3 = X_3 - \bar{X}_3$$

x_1	x_2	x_3	$x_3 x_1$	$x_3 x_2$	$x_2 x_1$	x_1^2	x_2^2
4.43	9.07	-1.99	8.8	-18.05	-40.2	19.6	82.3
-2.93	7.57	-1.49	4.4	-11.3	-22.2	8.6	57.3
-1.93	1.57	-0.69	1.3	-1.08	-3.07	3.7	2.5
-3.93	-6.43	-0.39	1.5	+2.5	+25.3	15.4	41.3
2.07	0.07	0.51	1.06	+0.036	+0.145	4.3	0.0049
4.07	-4.43	1.51	6.1	-6.69	-18	16.6	19.6
7.07	-7.43	2.51	17.7	-18.6	-52.5	49.9	55.2
$\sum x_1 = -0.01$	$\sum x_2 = -0.01$	$\sum x_3 = -0.03$					

$$\sum x_3 x_1 = 40.9, \quad \sum x_3 x_2 = -53.23, \quad \sum x_1 x_2 = -110.5$$

$$\sum x_1^2 = 118.2, \quad \sum x_2^2 = 258.2$$

$$40.9 = b_{31.2} \times 118.2 + b_{32.1} \times (-110.5) \quad \text{--- ①}$$

$$-53.23 = b_{31.2} \times (-110.5) + b_{32.1} \times (258.2) \quad \text{--- ②}$$

solve ① and ② to get:

$$b_{32.1} = 0.206, \quad b_{31.2} = 0.54$$

subst in

$$\bar{X}_3 = b_{31.2} \bar{X}_1 + b_{32.1} \bar{X}_2 \text{ to get:}$$

$$b_{31.2} = 24.2$$

Q.2

	X_1	X_2	X_3	X_4	total
Y_1	271	261	82	20	634
Y_2	247	567	231	53	1098
Y_3	33	105	92	36	264
total	551	931	405	109	

total of table = 1996

O_E	P_E	$(O-E)^2/E$
271	175	52.66
261	295.7	4.1
82	128.6	16.9
20	34.6	6.2
247	303.1	10.4
567	512.1	5.88
231	222.8	0.3
53	59.96	0.8
33	72.9	21.8
105	123.14	2.67
92	53.6	27.5
36	14.4	32.4

$$\chi^2 = 181.61$$

$$\chi^2 > \chi^2_{0.95}$$

therefore reject the null hypo.

this mean that happ. and health are dependent.

H_0 : the row variable and Col. are independent

P.3 (A) $y > 7.2 = 0.3$, $y < 5.6 = 0.05$

OR $Pr(X > 7.2) = 0.3$ $Pr(X < 5.6) = 0.05$

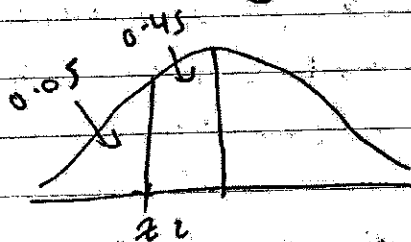
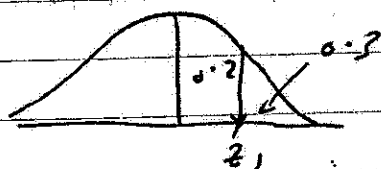
\Downarrow $Pr(Z > z_1) = 0.3$ $Pr(Z < z_2) = 0.05$

$z_1 = \frac{x_1 - \mu}{\sigma}$

$z_2 = \frac{x_2 - \mu}{\sigma}$

$z_1 = \frac{7.25 - \mu}{\sigma}$

$z_2 = \frac{5.55 - \mu}{\sigma}$



at $A_1 = 0.2 \rightarrow z_1 = 0.53$ at $A_2 = 0.45$

$z \rightarrow z_2 = 1.64$

$0.53 = \frac{7.25 - \mu}{\sigma}$ — (1)

$1.64 = \frac{5.55 - \mu}{\sigma}$ — (2)

Solve the (1) and (2) to get

$\mu = 6.8$

$\sigma = 0.78$

(B) $Pr(Z > z_1)$ (type B).

$z_1 = \frac{7.4 - 7.5}{0.45} = -0.22 \rightarrow A = 0.0871$

$Pr(Z > -0.22) = 0.587 \approx 60\%$

type (A) $z_1 = \frac{7.4 - 6.8}{0.78} = 0.77 \rightarrow A = 0.2794$

$Pr(Z > 0.77) = 0.5 - 0.2794 = 0.22$

\therefore type B.

no def. = 0.57

Q.4 / (A) $P_X(X=3)$ $p = 0.43$ $q = 0.57$

$$\begin{aligned} \Pr(X=3) &= \frac{N!}{x!(N-x)!} p^x q^{N-x} \\ &= \frac{11!}{3!(11-3)!} (0.43)^3 (0.57)^8 = 0.1456 \end{aligned}$$

$$\textcircled{13} \quad \begin{aligned} \Pr(X \geq 3) &= \Pr(3) + \Pr(4) + \dots + \Pr(11) \\ &= \Pr\{1 - (\Pr(0) + \Pr(1) + \Pr(2))\} \end{aligned}$$

$$Pr(0) = 0.00206$$

$$Pr(1) = 0.017 \quad \therefore Pr(X \geq 3) = 0.916$$

$$p_r(2) = 0.065$$

Q.5/ A. electrical methods: thermocouples:

يكون من عوصلين مختلفين المواد اذ من مواد مختلفة على عينة واحدة على وجه التحديد
كربا في دائرة الحقل اذا اختلفت درجة الحرارة فسيختلف قوة الالتصاق بها
التي على وجه التحديد تكون حقا للزيت في درجات الحرارة والخواص

1. The surface contact type
2. in section type
3. suction type.

B. Classification of measurements:

[illegible]

c. Industrial manometer:

يتمثل انما حروف القنقناتين (تتخلفا) ويكونان من جنس واحد
تختلفان في... ثم حولا ليس تحريا كل حرفا على حدة... التثنية
تكون احدى التثنية... واسمها الاخر... يكون
الجزء... الواحدة... التثنية...
التثنية... التثنية... التثنية...

Diaphragm gauge

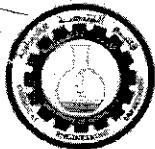
يستخدم القنطرة عملاً إما طرئاً فائزاً من عتف ترد فعل للقنطرة
وتنقل هذه الحركة عبر مجموعة توصيلات وعناصر الكاموستر
ويكون اللازم انما على صفة صفة صفة اربلا ستيكية تأفة
كل ضبط ارفقوع لزيادة الحاسم السطحية ، نيتت هاه
الصفتية صيد الحن الطيلة ديوصل المركز صلا ييليا بجوشر وتيتت بأفة
بين تلجيتن لوف دفع التاء وبشمل هذا الحواسر للكام
اللزيم اوالحتيلورة 0 - 16 mbar 0 - 25 mbar

E. Classification of Flow meters :

1. مقاييس التدفق ذات القنطرة التفاضلية التايث
2. مقاييس التدفق فاقوت السحيفة

وكذلك يمكن تقسيمها الى

1. مقاييس التكميم التدفق
2. معدل التدفق



University of Technology
Chemical Engineering Department



Subject: Environmental Eng
Branch: Chem. Processing Eng.
Examiner: Dr. Jenan A. Al-Najar

Final Examination

2011/2012

Class: Third
Time: 3 hours
Date: 7/June

Note: Answer only four questions.

Q1:

1. Define the acid rain. What are the effects of acid rain? Explain the chemical process of acid rain formation in the atmosphere.

Acid rain: the present of sulfuric acid or nitric acid in the atmosphere could lower the pH of rain droplets to value below 5.6 and such rain is considered acidic and it called "acid rain. These acids are mainly caused by the release of sulfur dioxide (SO₂) and oxide of nitrogen (NO_x) during fossil fuel combustion and the use sulfur coal and oil. When these gases are discharged into atmosphere they react with water, oxygen, and other gases in the atmosphere to form sulfuric acid, ammonium, and nitric acid. These acids then disperse over large areas because of wind patterns and fall back to the ground with rainwater as acid rain.

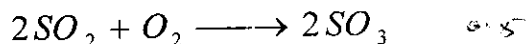
Effects of acid rain

The harmful effects caused by acid deposition can be categories under many effects:

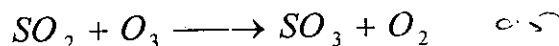
- 1- Effects on water bodies: acid rain causes acidulation of lack and streams and contributes to damage of tree at high elevation and much sensitive forest.
- 2- Effect on material: acid rain accelerates the decay of building, bridge, and other structures may by corrosion.
- 3- Effect of human health: acid rain caused acidification of air, water and food that damage the human health. It can also release heavy metals from the pipes of the distribution systems into the potable water supply.

Chemical processes of acid formation in atmosphere

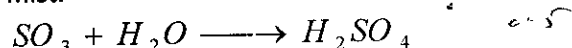
A large part of SO₂ in the atmosphere is oxidized to sulfur trioxide SO₃:



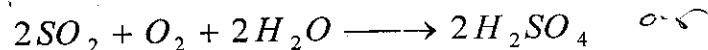
Also SO₂ reacted with atmospheric ozone to give sulfur trioxide SO₃:



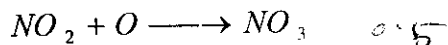
Sulfur trioxide SO₃ is then quickly combined with moisture (water) in the atmosphere to form sulfuric acid mist:



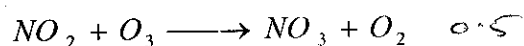
The overall reaction is:



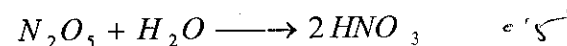
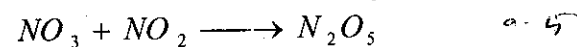
Nitrogen dioxide reacts with atomic oxygen to give nitrogen trioxide:



Also NO₂ reacted with atmospheric ozone to give nitrogen trioxide NO₃:



NO₃ reacted with NO₂ forming N₂O₅, which react with moisture (water) forms nitric acid:



2. What are the advantages and disadvantages of the wet scrubbers? Numerate the major types of the wet scrubbers.

Wet scrubbers

Wet scrubber is one of the particulate control equipment in which water is used to capture particulate dust. The resulting solids are removed from the gas stream by water as slurry. The principle mechanism involved impact (impingement) of the dust particles and water droplet in order to achieve good contact time.

-The advantages of wet scrubbers 3 1x3

- 1- Simultaneously removal of gases and particulate.
- 2- Can effectively remove fine particulate, both liquid and solid, ranging from $0.1-20 \mu$ from gas stream.
- 3- Equipment occupies only a moderate amount of space compared to dry collectors such as bag house.

-The disadvantages of wet scrubbers 5

- 1- Relatively high energy costs.
- 2- Problem of wet sludge disposal.
- 3- Corrosion problems
- 4- The wet sludge causes water pollution and there is need to treatment method to remove particles from the water.
- 5- Very small particles (sub-micron sizes) may not captured.

The major types of wet scrubbers are: 4.5 1.5x3

- 1- Spray scrubbers
- 2- centrifugal scrubbers
- 3- Venture scrubbers

Q2: Calculate the 50% cut-off diameter for particles of CaO suspended in an air stream at 100°C and at atmospheric pressure for a gravitational settling chamber of 8m long and 2 m height, when the gas velocity in the collector is 1.2 m/s. The CaO particle density is 3310 kg/m^3 and the air density 1.2 kg/m^3 and viscosity $2.17 \times 10^{-5} \text{ kg/m s}$.

Solution

at

$$\eta = 0.5$$

$$dp = ?$$

$$\rho_p = 3310 \text{ kg/m}^3$$

$$L = 8 \text{ m} \quad u = 1.2 \text{ m/s}$$

$$H = 2 \text{ m}$$

$$\rho_g = 1.2 \text{ kg/m}^3$$

$$\mu_g = 2.17 \times 10^{-5}$$

$$\eta = 15$$

$$V_L = 15$$

$$\eta = 3$$

$$\eta = 2$$

using Stokes law

$$\eta = \frac{V_L L}{H u}$$

$$\eta = \frac{g dp^2 (\rho_p - \rho_g) L}{18 \mu_g H u}$$

$$dp = \left[\frac{18 \mu_g H u \eta}{g (\rho_p - \rho_g) L} \right]^{1/2} = \left[\frac{18 (2.17 \times 10^{-5}) (2) (1.2) (0.5)}{(9.81) (3310 - 1.2) (8)} \right]^{1/2}$$

$$= 42.5 \times 10^{-6} \text{ m}$$

$$= 42.5 \mu\text{m}$$

Q3: Answer the following:

1. Define the solid waste and what are the classifications of solid wastes?

Solid waste is that material which arises from various human activities and which is normally discharged as useless or unwanted. It consists:

- Highly heterogeneous mass of discharged materials from the urban community.
- The more homogeneous accumulation of agricultural, industrial and mining waste.

Classification of solid wastes

Solid wastes may be classified based partly on content and partly on moisture and heating value. A typical classification is as follows:

- (a) Garbage (النفايات الصلبة القابلة للتلف): Refers to the putrescible solid waste constituents produced during the preparation or storage of meat, fruit, vegetables etc. These wastes have a moisture content of about 70% and heating value of about 6×10^6 J/kg.
- (b) Rubbish (القمامة غير المتعفنة): Refers to non-putrescible solids waste constituents, either combustible or non-combustible. Combustible wastes would include paper, wood scrap, rubber, leather etc. Non-combustible wastes are metals, glass, ceramics etc. These wastes contain a moisture content of about 25% and heating value of the waste is around 15×10^6 J/kg.
- (c) Pathological wastes (النفايات المرضية): Dead animals, human waste, etc. The moisture content is 85% and there are 5% non-combustible solids. The heating value is around 2.5×10^6 J/Kg.
- (d) Industrial wastes (النفايات الصناعية): Chemicals, paints, sand, metal ore processing, fly ash, sewage treatment sludge etc.
- (e) Agricultural wastes (النفايات الزراعية): Farm animal manure (السماد), crop residues etc.

2. Explain the oxygen sag curves with sketch and drive the equation of:

1. The oxygen deficit D in time t .
2. The critical oxygen deficit D_c

Oxygen sag curves

The discharge of waste into a body of water results in the depletion of dissolved oxygen level (deoxygenation) as the wastes oxidized by bacteria. Opposite of this drop in dissolved oxygen (depletion) is reaeration which replaces oxygen through the surface of water, at a rate which is proportional to the rate of depletion of oxygen below the saturation value. The simultaneous action of deoxygenation and reaeration produces a typical pattern in the dissolved oxygen concentration of aquatic system. This pattern is known as the dissolved-oxygen sag and the typical curve is shown in the figure below

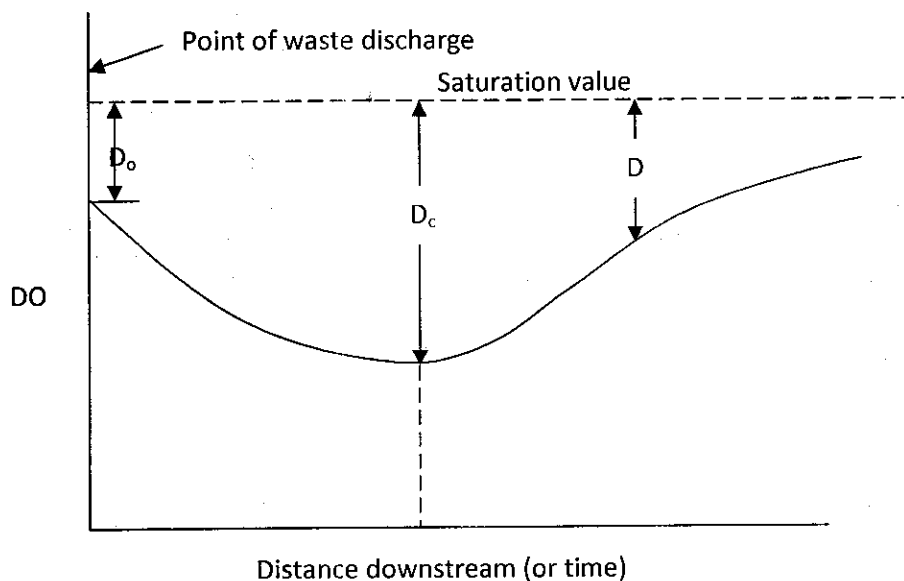


Fig.1 Oxygen sag curve

The following conclusion can be seen from oxygen sag curve:

1. Initially the sag curve drops as the waste deplete the oxygen faster than it can be replaced.
2. At the point where the dissolved oxygen (DO) is a minimum, the rate of reaeration becomes equal to the rate of deoxygenation. This point is the critical point.
3. Beyond the critical point, the rate of reaeration exceeds the rate of deoxygenation and dissolved oxygen levels (DO) begin to increase and eventually return to normal.
- 4.

1. The oxygen deficit D in time t .

The simultaneous action of deoxygenation and reaeration can be described by the equation:

$$\frac{dD}{dt} = k_1 L - k_2 D \quad (1)$$

where

D = dissolved oxygen deficit, mg/l or kg/m³

L = concentration of organic material (the BOD remaining in time t), mg/l or kg/m³

k_1 = deoxygenation constant, day⁻¹

k_2 = reaeration constant, day⁻¹

L can be expressed in terms of ultimate BOD, L_u as:

$$L = L_u e^{-k_1 t} \quad (2)$$

Substituting Eq.2 into Eq.1 and integrating we get:

$$D = \frac{k_1 L_u}{k_2 - k_1} (e^{-k_1 t} - e^{-k_2 t}) + D_0 e^{-k_2 t} \quad (3)$$

2. The critical oxygen deficit D_c

The critical dissolved oxygen deficit D_c , where the rate of oxygen utilized for waste material decomposition equals to the rate of atmosphere reaeration, and this can be evaluated by simply setting $dD/dt = 0$ in Eq.1 and $D = D_0$, as:

$$k_1 L - k_2 D_c = 0$$

$$L = L_u e^{-k_1 t}$$

and

then

$$k_2 D_c = k_1 L = k_1 L_u \exp(-k_1 t_c) \quad (6)$$

$$D_c = \frac{k_1}{k_2} L_u \exp(-k_1 t_c) \quad (7)$$

ملامحة الصفحات ومناقشة المعادلات في التوضيح المرفقة رقم (1)

Q4:

a. A town discharges $21600 \text{ m}^3/\text{day}$ of sewage into a nearby stream. The stream is with depth of 2 m and a velocity of 4 km/h and has flow of $0.5 \text{ m}^3/\text{s}$. Other information are:

	Temp. ($^{\circ}\text{C}$)	DO (mg/l)	BOD ₅ (mg/l)
Stream	22	5	7
sewage	28	2	180

The deoxygenation constant (k_1) evaluated at 20°C is 0.4 day^{-1} . The saturation concentration of dissolved oxygen at average temperature is given by:

Mixing

$$DO_s = 14.6 - 0.394 T + 0.007714 T^2 - 0.000064 T^3$$

Determine the critical oxygen deficit, D_c and its location, x_c .

solution

$$\text{Sewage flow} = Q_{se} = 21600 \frac{\text{m}^3}{\text{day}} \times \frac{\text{day}}{24 \text{ hr}} \times \frac{\text{hr}}{3600} = 0.25 \text{ m}^3/\text{s}$$

$$\text{Stream flow} = 0.5 \text{ m}^3/\text{s} = Q_{st}$$

$$\begin{aligned} \text{Temp. after mixing (stream + sewage)} &= T_m \\ T_m &= \frac{Q_{se} T_{se} + Q_{st} T_{st}}{Q_{se} + Q_{st}} = \frac{0.25(28) + 0.5(22)}{0.25 + 0.5} \\ &= 24^{\circ}\text{C} \end{aligned}$$

$$\begin{aligned} \text{DO after mixing} &= DO_m \\ DO_m &= \frac{Q_{se} DO_{se} + Q_{st} DO_{st}}{Q_{se} + Q_{st}} = \frac{0.25(2) + 0.5(5)}{0.25 + 0.5} \\ &= 4 \text{ mg/l} \end{aligned}$$

$$\text{BOD}_5 = Y_{5,m} \text{ after mixing}$$

$$\begin{aligned} Y_{5,m} &= \frac{Q_{se} Y_{5,se} + Q_{st} Y_{5,st}}{Q_{se} + Q_{st}} = \frac{0.25(180) + 0.5(7)}{0.25 + 0.5} \\ &= 64.7 \text{ mg/l} \end{aligned}$$

$$k_1 \text{ at } T = 20^\circ\text{C} = 0.4 \text{ day}^{-1}$$

$$\therefore k_{1,T_m} = k_{1,20} \theta^{\frac{T-20}{24-20}} \quad \theta = 1.056 \quad T_m = 24^\circ\text{C}$$

$$= 0.4 (1.056)$$

$$k_{1,T_m} = 0.5 \text{ day}^{-1}$$

$$Y_{s,m} = L_{u,m} (1 - e^{-5k_{1,m}})$$

$$\therefore L_{u,m} = \frac{Y_{s,m}}{1 - e^{-5k_{1,m}}} = \frac{64.7}{1 - e^{-5(0.5)}}$$

$$= 70.5 \text{ mg/l}$$

* DO_s = saturation oxygen deficit at T_m

From the following equation

$$DO_s = 14.6 - 0.394T + 0.007714T^2 - 0.000064T^3$$

$$= 14.6 - 0.394(24) + 0.007714(24)^2 - 0.000064(24)^3$$

$$= 8.7 \approx 9 \text{ mg/l}$$

The initial oxygen deficit = D_0

$$D_0 = DO_{sat} - DO_{max}$$

$$= 9 - 4 = 5 \text{ mg/l}$$

$$k_2 = 3.9 \frac{V^{0.5}}{H^{1.5}}$$

$$V = 4 \frac{\text{km}}{\text{hr}} \times \frac{1000\text{m}}{\text{km}} \times \frac{\text{hr}}{3600\text{s}} = 1.11 \text{ m/s}$$

(2.5)

Q.4.a

$$H = 2m$$

$$k_2 = 3.9 \frac{(1.11)^{0.5}}{(2)^{1.5}} = 1.45 \text{ day}^{-1}$$

at 20°C

$$1 \quad k_{2,T_m} = 1.45 (1 - 0.47)^{24-20} = 1.74 \text{ day}^{-1}$$

$$2 \quad t_c = \frac{1}{k_2 - k_1} \ln \left[\frac{k_2}{k_1} \left(1 - D_0 \frac{k_2 - k_1}{k_1 L_u} \right) \right]$$
$$= \frac{1}{1.74 - 0.5} \ln \left[\frac{1.74}{0.5} \left(1 - 5 \frac{1.74 - 0.5}{0.5 (70.5)} \right) \right]$$
$$= 0.85 \text{ day}$$

$$2 \quad D_c = \frac{k_1}{k_2} L_u \exp(-k_1 t_c)$$
$$= \frac{0.5}{1.74} (70.5) \exp(-0.5 \times 0.85)$$
$$= 13.2 \text{ mg/l}$$

$$2 \quad X_c = V t_c = \frac{4 \text{ km}}{\text{hr}} \times \frac{24 \text{ hr}}{\text{day}} \times 0.85 \text{ day}$$
$$= 96 \text{ km}$$

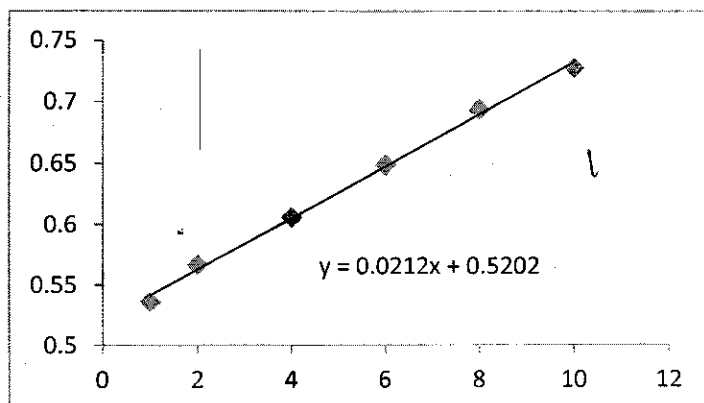
b. The BOD results given below are observed on a sample of wastewater at 20°C:

t (days)	0	1	2	4	6	8	10
Y (BOD, mg/l)	0	6.5	11	18	22	24	26

1. Plot BOD curve.
2. Calculate the parameters k_1' and L_u

Solution

t (days)	1	2	4	6	8	10
(t/y) ^{1/3}	0.54	0.57	0.61	0.65	0.69	0.73



Slop= $b = 0.0212$
Intercept = $a = 0.5202$

$$k_1' = 2.61 \frac{b}{a}$$

$$k_1' = 2.61 \frac{0.0212}{0.5202} = 0.106 \text{ day}^{-1}$$

$$L_u = \frac{1}{2.3 k_1' a^3}$$

$$L_u = \frac{1}{2.3(0.106)(0.5202)^3} = 29 \text{ mg/l}$$

$$C = D_0 - \frac{k_1 L_u}{k_2 - k_1} \quad \text{--- (5)}$$

Sub. equation (5) into equation (4)

$$D = \frac{k_1 L_u}{k_2 - k_1} e^{-k_1 t} + \left[D_0 - \frac{k_1 L_u}{k_2 - k_1} \right] e^{-k_2 t}$$

$$D = \frac{k_1 L_u}{k_2 - k_1} e^{-k_1 t} + D_0 e^{-k_2 t} - \frac{k_1 L_u}{k_2 - k_1} e^{-k_2 t}$$

$$\therefore D = \frac{k_1 L_u}{k_2 - k_1} (e^{-k_1 t} - e^{-k_2 t}) + D_0 e^{-k_2 t}$$

$$D_0 \frac{k_1}{k_2} = L_u \exp(-k_1 t_c)$$

2. The critical oxygen deficit and the critical time t_c

differentiating Eq-3

$$D = \frac{k_1 L_u}{k_2 - k_1} (e^{-k_1 t} - e^{-k_2 t}) + D_0 e^{-k_2 t}$$

$$\frac{dD}{dt} = \frac{k_1 L_u}{k_2 - k_1} (-k_1 e^{-k_1 t} + k_2 e^{-k_2 t}) + k_2 D_0 e^{-k_2 t}$$

$$\text{Let } \frac{dD}{dt} = 0 \quad \text{at } t = t_c$$

$$0 = \frac{k_1 L_u}{k_2 - k_1} (-k_1 e^{-k_1 t_c} + k_2 e^{-k_2 t_c}) + k_2 D_0 e^{-k_2 t_c}$$

crosses both sides,

$$t_c = \frac{1}{k_2 - k_1} \ln \left[\frac{k_2}{k_1} \left(1 - D_0 \frac{k_2 - k_1}{k_1 L_u} \right) \right]$$

(1)

Q2. 1. The oxygen deficit D in time t

حسب الاستحقاق السعوي، السكان كيبه القبول الى المعدل، ثم

(3)

substituting Eq. 2 into Eq. 1

$$\therefore \frac{dD}{dt} = k_1 L_u e^{-k_1 t} - k_2 D \quad \text{--- (1)}$$

$$\therefore \frac{dD}{dt} + \underbrace{k_2 D}_P = \underbrace{k_1 L_u e^{-k_1 t}}_\Phi \quad \text{--- (2)}$$

Integrating by integration factor R

$$R = e^{\int P dt}$$

$$\text{Let } P = k_2 \quad \& \quad \Phi = k_1 L_u e^{-k_1 t}$$

$$\therefore R = e^{\int k_2 dt} = e^{k_2 t} \quad \text{--- (3)}$$

$$RD = \int R \Phi dt$$

$$e^{k_2 t} D = \int e^{k_2 t} k_1 L_u e^{-k_1 t} dt$$

$$e^{k_2 t} D = k_1 L_u \int e^{(k_2 - k_1)t} dt$$

$$e^{k_2 t} D = \frac{k_1 L_u}{k_2 - k_1} e^{(k_2 - k_1)t} + C$$

$$D = \frac{k_1 L_u}{k_2 - k_1} e^{-k_1 t} + C e^{-k_2 t} \quad \text{--- (4)}$$

initial condition $t = 0 \quad D = D_0$

$$\therefore D_0 = \frac{k_1 L_u}{k_2 - k_1} + C$$

2- Try 4 cyclones in parallel

$\therefore D_c = 0.42 \text{ m}$

2 - Flow rate per cyclone = $\frac{4000}{4} = 1000 \text{ m}^3/\text{hr}$

negligible gas density compared with the solid density.

using scaling factor equation

2 - Scaling factor = $\left[\left(\frac{D_{c2}}{D_{c1}} \right)^3 \times \frac{Q_1}{Q_2} \times \frac{\Delta P_1}{\Delta P_2} \times \frac{\mu_1}{\mu_2} \right]^{1/2}$

$$= \left[\left(\frac{0.42}{0.203} \right)^3 \times \frac{223}{1000} \times \frac{2000}{2500} \times \frac{0.023}{0.018} \right]^{1/2}$$

$$= 1.42$$

$\therefore d_2 = 1.42 d_1$

$a = 0.15 D_c$
 $b = 0.2 D_c$

$d_1 = \frac{d_2}{1.42}$

مجموع الكسرات

d_p, μ	Wt%	$\frac{1.5}{d_2}$	$\frac{1.5}{d_1}$	77.15 Wt% $\times 1.5$	100
750	10	50	35	98	9.8
50-40	15	45	32	97	14.6
40-30	10	35	25	96	9.6
30-20	10	25	18	95	9.5
20-10	25	15	11	93	23.3
10-5	20	7.5	5	86	17.2
5-0	10	2.5	2	50	5
	100				89%

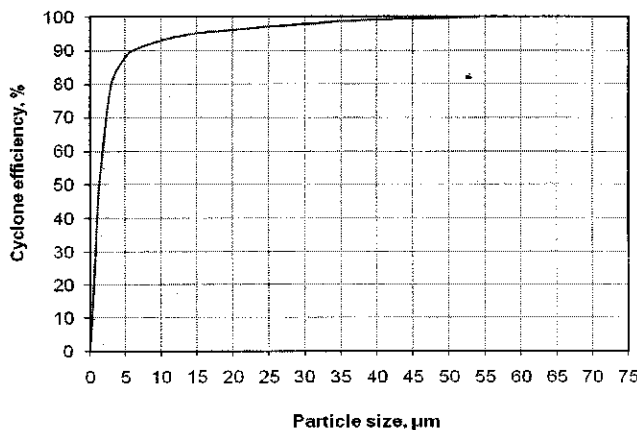
\therefore overall collection efficiency = 89%

Q5: Design a high efficiency cyclone to recover solids from a process gas stream. The particle size distribution in the inlet gas is given below. The density of the particles is 2500 kg/m^3 , and the gas is initially nitrogen at 150°C . The stream volumetric flow rate is $4000 \text{ m}^3/\text{h}$ and the operation is at atmospheric pressure. An 80 percent recovery of the solids is required.

Size range, $\text{dp}, \mu\text{m}$	>50	50-40	40-30	30-20	20-10	10-5	5-0
Weight percent, w%	10	15	10	10	25	20	10

$$d_2 = d_1 \left[\left(\frac{D_{C2}}{D_{C1}} \right)^3 \times \frac{Q_1}{Q_2} \times \frac{\Delta\rho_1}{\Delta\rho_2} \times \frac{\mu_2}{\mu_1} \right]$$

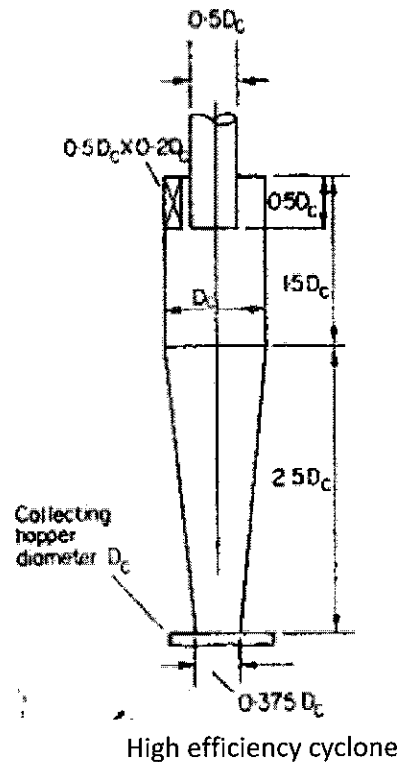
Standard conditions: $D_{C1} = 203 \text{ mm}$, $Q_1 = 223 \text{ m}^3/\text{h}$, $\Delta\rho_1 = 2000 \text{ kg/m}^3$, $\mu_1 = 0.018 \text{ mN}\cdot\text{s/m}^2$. The optimum velocity is 15 m/s . $\mu \text{ of } \text{N}_2 \text{ at } 150^\circ\text{C} = 0.023 \text{ mN}\cdot\text{s/m}^2$



(a) High efficiency Cyclone

$\rho = 2500 \text{ kg/m}^3$
gas = N_2 $T = 150^\circ\text{C}$
 $Q = 4000 \text{ m}^3/\text{h}$

Solution



High efficiency cyclone

Q2 - Flow rate = $4000 \frac{\text{m}^3}{\text{h}} \times \frac{1}{3600} = 1.11 \text{ m}^3/\text{s}$

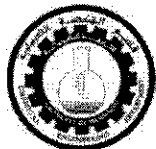
$u = 15 \text{ m/s}$

Q2 - duct & area inlet $A = \frac{Q}{u} = \frac{1.11}{15} = 0.07 \text{ m}^2$

duct inlet area = $0.5 D_c \times 0.2 D_c$

$0.07 = 0.5 D_c \times 0.2 D_c$

Q2 - $D_c = 0.84 \text{ m} > \text{standard design of } 0.203$



University of Technology
Chemical Engineering Department



Subject: Equipment Design
Branch: Chemical processing
Examiner: Zainab Y. Shnan

Final Examination

2011/2012

Class: Third
Time: 3 hours
Date : 5/6/2012

Attempt four questions only

Q1:- A/ Draw sketches symbology of six of the following:

- 1) Reverses flow bubble cap tray 2) Trapezoidal slot 3) One way valve
4) Pressure controller 5) Packed bed 6) spherical storage tank 7) Rotary kiln

B/ Explain the general design steps of Distillation Column that used for separation of a binary liquid feed mixture (Pentane "of low boiling point" & Heptane) ; with drawing of all required figures in your answer. (25 mark)

Q2:- A/ Define and give requirement for piping and instrumentation diagram (PID).

B/ write the steps of complete design procedure for shell and tube heat exchanger .assuming that the hot fluid is liquid benzene and the cold fluid is water .and write all necessary design equations. (25mark)

Q3:- A/Explain the general steps in designing of bubble cap trays.

B- What are the main principle requirements that determine the selection of site for a chemical plant. (25mark)

Q4:- A mixture of three components with the following specification:

Stream	Mass flow rate (kg/hr)	Density (kg/ m ³)	Viscosity, (cp)
Gas	$W_v = 166799$	$\rho_v = 12$	-
Hexane	$W_L = 6440$	$\rho_L = 900$	$\mu_L = 0.6$
Water	$W_h = 520$	$\rho_h = 990$	$\mu_h = 0.7$

The mixture was fed into a vapor-liquid-separator. The operating pressure was 50 bar and operating temperature of 47 °C. The vessel should have an extra surge time of (25min) for the hexane.

Take : Liquid-liquid separation constant = 0.026

Vapor-liquid separation constant = 0.106

Then calculate all design parameters of this unit under such conditions.

(25mark)

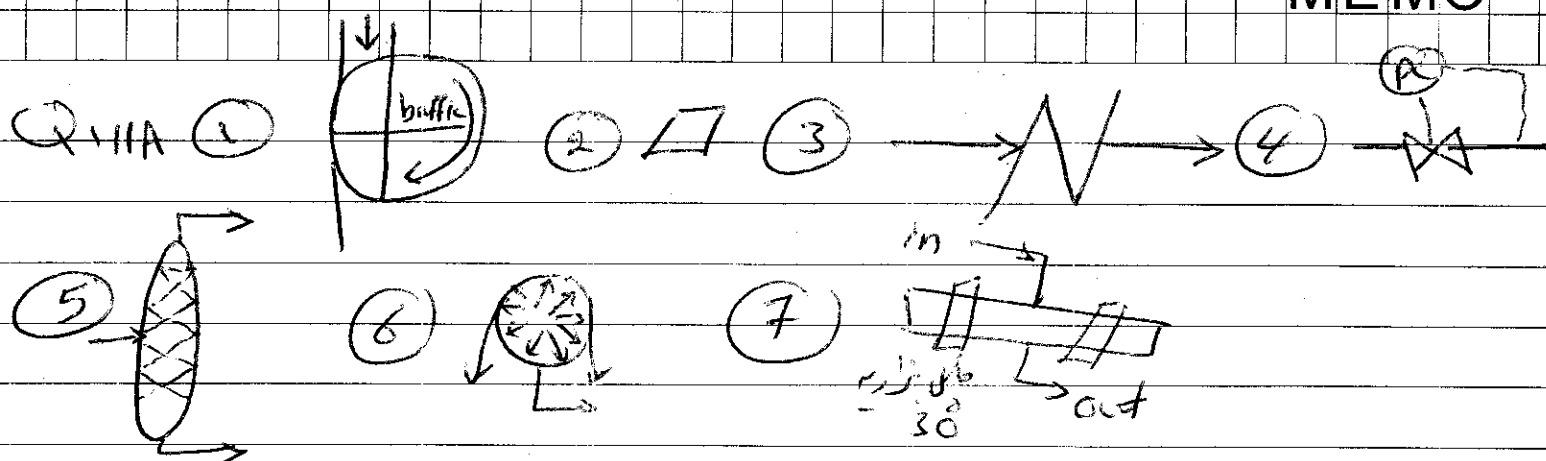
Q5:- Three liquid surge drums constructed from carbon steel and holding heavy naphtha.

- The 1st drum diameter is (1 m) with operating pressure (2 bar), located as a reflex drum in distillation column.
- The 2nd drum diameter is (2 m) and the operating pressure is (15 bar) located between two distillation column.
- The 3rd drum diameter is (2.5 m) and the operating pressure is (70 bar) located as a feeding reactor

Then, calculate:

- 1- The design and test pressures of each drum.
- 2- Thickness of material of construction for each drum, $f = 950 \text{ kg/cm}^2$ for carbon steel.
- 3- Make equipment summary (Data sheet) for the drums.

(25mark)



(B)

i Distillation column Components

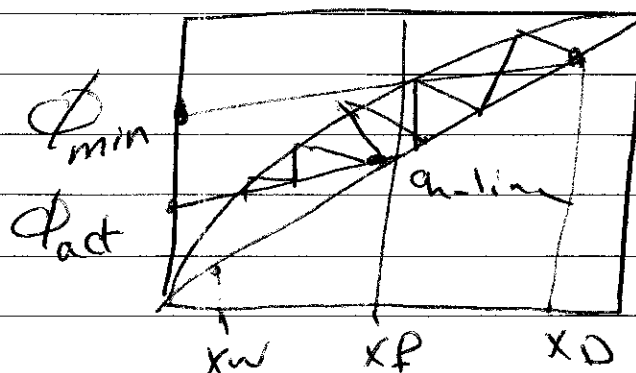
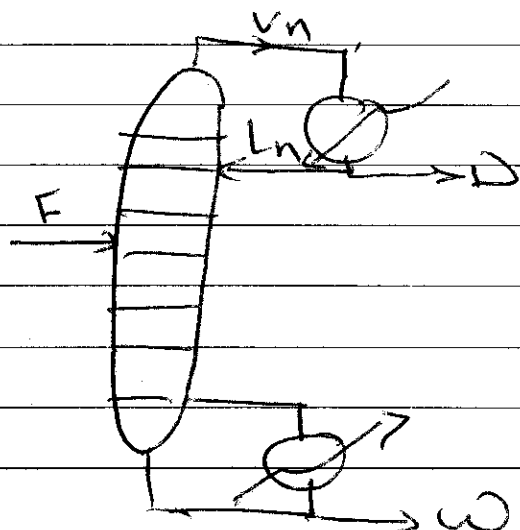
① Internals ② Reboiler (working by steam) ③ Condensor.

Design

① Height of D.C ② Diameter of D.C
③ select type of internals ④ Design of reboiler & condenser and select the best type of cooling or heating fluids ⑤ selection of material of construction
⑥ thickness of materials of construction ⑦ Control system
⑧ supports ⑨ Computer Program.

macabe-Thiele

① كل موازنة هي موازنة خاصة بالنظام
 ② أيام عدد النظير للموازن (تقريباً)
 ③ Equil-Data (نظم كبرياء)



$$\phi_{min} = \frac{XD}{R_{min} + 1} \Rightarrow R_{min} = ? , R_{act} = (1.2 - 1.5) R_{min}$$

$$\therefore \phi_{act} = \frac{XD}{R_{act} + 1} \Rightarrow \phi_{act} = ?$$

جواب: q_h is (Feed rate) q_h is
 $q_h = 1$ is sat liq feed

$$q_h = \frac{H_v - H_F}{H_v - H_L} = \frac{H_v - H_F}{\lambda}$$

lower operating line is upper operating line

calculation of quantities of coolant & heating fluids

Reboiler $q_{h, feed} = q_{h, steam}$

Condenser $q_{h, D} = q_{h, coolant}$

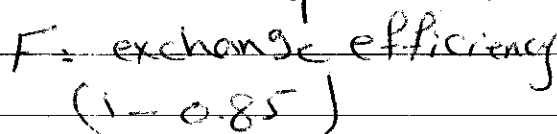
(Note 4) is a diagram showing the PFD Configuration.

- Q2//A ① Prepared by chemical engineer with the aid of mechanical and control engineers
- ② regarded as a data base for mechanical engineer for manufacturing of vessel, Heat exchanger, machines and controllers.
- ③ This diagram flows the PFD Configuration.
- ④ Show Piping details type construction, diamet. length, Design Pressure and Pipe Position in the Process
- ⑤ show the Position of measurement Points for T and P and Sample Point.
- ⑥ show all equipment in the Process with details.
- ⑦ used as data base for preparation of detailed design

MEMO

(A) $q_{\text{cold}} = q_{\text{hot}} = U A \Delta T_{\text{lm}}$

\bar{T}_{lm} : logarithmic mean temp $\bar{T}_{lm} = \frac{(T_1 - T_2) - (T_2 - T_1)}{\ln \frac{T_1 - T_2}{T_2 - T_1}}$



$$\ln \frac{T_1 - t_2}{T_2 - t_1}$$

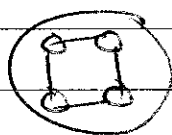
from table

select exchange length 3, 4, 5 m

No. of tube = Atotal

TTDL

$$D_s = d_o \left(\frac{\text{no. of tubes}}{K} \right)^{1/n} \quad \text{Tube bundle } \textcircled{c}$$



Trinagular square

$$\frac{1}{U_{\text{cal}}} = \frac{1}{h_o} + \frac{D_o}{D_i h_i} + \frac{D_o \ln \frac{D_o}{D_i}}{2k} \left(\frac{1}{h_{f_o}} + \frac{1}{h_{f_i}} \right) \quad \text{---} \quad (7)$$

امداد h_0 , h_1 ... حالات التي تتعامل مع التفرع في جدول
الحقبات التي توضع في ريع، كالم - ونوع الجزيئة ... ونحوها.

Design Procedure (bubble cap trays).

- ① Select cap diameter from table
- ② calculate minimum slot area, the slot area for fully loaded slot.

$$V_m = C_s \sqrt{H_s \left(\frac{\rho_L - \rho_v}{\rho_v} \right)} A_s$$

- ③ select cap spacing: one of standard spacing should be selected using table b
ratio of slot / allocated cap area. 25%, 31.25% and 37.5% and 50%

Determine required allocated cap area.

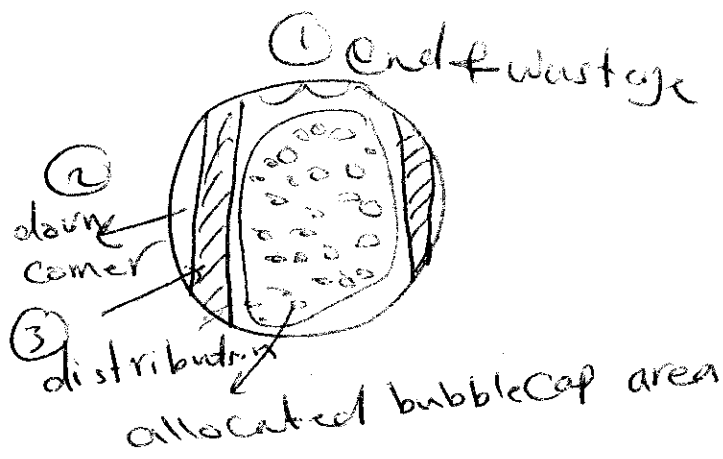
- ④ Utilizing table b for reading ratio of slot area to allocated cap area. This is achieved by dividing the required slot area by ratio read from table "b". $(A_s / \text{ratio}) = \text{allocated cap area}$.

- ⑤ Estimate tower size: For this purpose determination is made by dividing the required slot area by (0.6) as cap area approximately represent 60% of tower area. $\text{required cap area} = \frac{(A_s / \text{ratio})}{0.6} \Rightarrow A = \frac{\pi d^2}{4}$
 $d = ?$

- ⑥ select tray type: This is done as the basis of tower size and liquid loaded utilizing table c

- ⑦ reconsider cap selection: in view of the tower estimated size, it may be adequate to change the cap size Utilize table "e"

- ⑧ Estimate distribution of trays area utilize table "d" to estimate (down flow), (end/wast. (Distribution) and allocated bubble cap area as ratio of total area



⑨ reconsider tower size: The required tray area is estimated by dividing the required allocated cap area by the estimated ratio or the allocated to tower area.

⑩ select tray spacing: This is done utilizing table for tower size

<u>Tower size</u>	<u>Spacing</u>
2.5 - 4 ft	18"
5 - 20 ft	24"

- B// Site
- ① اختيار نوعية الأرض هل هي صلبة أو فضفاضة
 - ② صيانة التربة، والرياح (مساحات التفتت) هل تتحمل نقل الأحمال
 - ③ مستوى الأرض (ارتفاع الأرض) بالنسبة للأرض (توزيع التربة)
 - ④ توفير وسائل النقل (الطرق) هل يمكن نقل البضائع
 - ⑤ هل هناك مياه جوفية أو أنابيب مياه قريبة من المكان أم لا
 - ⑥ الحاسم، يجب توفير السمات الخاصة بالبيئة.

Q411

MEMO

solution ① Apply Sander's-Brown to calculate vapour velocity

$$V_a = K \sqrt{\frac{P_L - P_v}{P_v}} = 0.106 \sqrt{\frac{900 - 12}{12}}$$

$$= 0.91 \text{ m/sec}$$

② Q_v = volumetric flow rate for vapour.

$$Q_v = \frac{W_v}{P_v} = \frac{166799}{60 \times 12} = 231 \text{ m}^3/\text{min}$$

$$Q_L = \frac{W_L}{P_L} = \frac{6440}{60 \times 900} = 0.119 \text{ m}^3/\text{min}$$

$$Q_h = \frac{W_h}{P_h} = \frac{520}{60 \times 990} = 0.008 \text{ m}^3/\text{min}$$

③ Q_v = area \times vapour velocity

$$Q_v = \frac{\pi}{4} D^2 \times (V_a \times 60)$$

$$\therefore D = 2.3 \text{ m} \Rightarrow A = \frac{\pi}{4} (2.3)^2 \approx 4.0 \text{ m}^2$$

④ settling velocity

$$V_L = K_s \frac{P_h - P_L}{\mu_L} = 0.026 \frac{990 - 900}{0.6} = 3.9 \frac{\text{cm}}{\text{min}} = 10 \text{ kJ}$$

$$V_h = K_s \frac{P_h - P_L}{\mu_h} = 0.026 \frac{990 - 900}{0.7} = 3.3 \frac{\text{cm}}{\text{min}} = 10 \text{ kJ}$$

⑤ assume $h_L = 30 \text{ cm}$

$$t_L = \frac{h_L}{V_L} = \frac{30}{3.9} = 7.6 \text{ min}$$

assume $h_h = 30 \text{ cm}$, $t_h = \frac{h_h}{v_h} = \frac{30}{3.3} = 9.0 \text{ min}$

⑥ $Q_L = \frac{\text{volume of light phase}}{Q_L} = \frac{A \times 0.3}{0.119} = \frac{4 \times 0.3}{0.119}$

$= 10.0 \text{ min } (Q_L > t_h)$

$Q_h = \frac{A \times h_l}{0.008} = \frac{4 \times 0.3}{0.008} = 150 \text{ min}$, $Q_h > t_h$

\therefore Design ok

⑦ since, an extra surge drume time of 25 min is required for H.C

$h_s = \frac{Q_L \times t_s}{A_L} = \frac{0.119 \times 25 \text{ min}}{4 \text{ m}^2} = 0.743 \text{ m}$

⑧ Calculate L

$L = h_{bn} + h_l + h_h + h_s + h_v$

$h_v = 0.5(1.2) + 0.5(0.9) = 0.5(2.3) + 0.5(0.9)$

$h_{bn} = 0.5(0.9) + 0.6 = 1.05 \text{ m}$

$h_s = 0.743 \text{ m}$

$h_l = 0.3 \text{ m}$

$h_h = 0.3 \text{ m}$

$h_b = 0.15 \text{ m}$

$\therefore L =$

Q5 ① select surge time (t_s)

// ① $t_s = 5 \text{ min}$ (distillation reflux drum)

$$t_s = 5 \times 1.5 \times 1.5 = 15 \text{ min}$$

② $t_s = 8 \text{ min}$ (between two distillation)

$$t_s = 8 \times 1.5 \times 1.5 = 24 \text{ min}$$

③ $t_s = 12 \text{ min}$ (Feeding reactor).

$$= 12 \times 1.5 \times 1.5 = 36 \text{ min}$$

$$\begin{aligned} \text{② ① test Pressure} &= (\text{Operating Pressure} + 20\%) \times 2 \\ &= (2 \text{ bar} + 0.2) \times 2 \\ &= 4.4 \text{ bar} \end{aligned}$$

$$\text{② test Pressure} = (15 \text{ bar} + 0.2) \times 2 = 30.4 \text{ bar}$$

$$\text{③} = = = (70 \text{ bar} + 0.2) \times 2 = 140.4 \text{ bar}$$

$$\text{③ Thickness ① } t = \frac{PD}{2fS - P} + C$$

$$= \frac{2.2 \times 1 \times 1000}{2 \times 950 \times 1 - 2.2} + 3 = 4.1 \text{ mm}$$

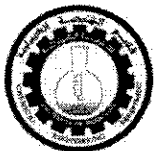
$$\text{② } t = \frac{15.2 \times 2 \times 1000}{2 \times 950 \times 1 - 15.2} + 3 = 19.1 \text{ mm}$$

$$\begin{aligned} \text{thickness } \textcircled{3} l &= \frac{70.2 \times 2.5 \times 1000}{2 \times 950 \times 1 - 70.2} + 3 \\ &= \frac{223322.5}{1829.8} + 3 \\ &= 125.0 \text{ mm} \end{aligned}$$

عمل قاعدة بيانات (هذا اسم البيانات) عند قاعدة الترخيص الاندفاع (4)
وقت عمل الترخيص (الوقت) وتستخدم لتعويض لبقائه عند (drum)

- ① length
- ② Diameter
- ③ material of construction
- ④ operating pressure
- ⑤ Test pressure
- ⑥ Thickness
- ⑦ internals (trays) or Packing.

length	Diam	material of Cast	Pressure	thickness	inter
	1	Carbon steel			
	2				
	2.5				



Attempt four questions only

الدرجات موزعة بالتساوي على جميع الاسئلة

Q1 Correct the following phrases

1. Liquid drums usually are placed vertically and gas-liquid separators horizontal
2. Double pipe heat exchanger is one of complex and costly type of heat exchanger
3. The space between the jacket and the vessel wall typically a range from 1000 mm to 5000 mm
4. Codes used in United States are a- BSI b- European Committee for standardization c- DN
5. The first trial in sieve tray design ,downcomer area may take 80%of the total column area

Q2 A- Explain types of packing's used in column

B- A Explain the advantages and disadvantages of plate heat exchangers

Q3 Numerates the information included in process flow diagram ,and draw symbols of Centrifugal pump ,open vessels, absorption vessel , compressor

B- Explain three types of valves used in chemical factories

Q4 A- Discuss factors effect on site selection and explain in details

Q5 It is need to design a cylindrical vessel (diam. 2 m)for lubricant oil at 250 C and 8 bar (absolute) the material of construction will be carbon steel ,weld will be fully radio graphed ,corrosion allowance should be used ,estimate

1- The thickness of the cylindrical wall

2- the thickness of the hemispherical bottom head ,

3- the flat top head

Note: $10 \text{ N/mm}^2 = 1 \text{ bar}$

Material	Tensile strength (N/mm ²)	Design stress at temperature °C (N/mm ²)									
		0 to 50	100	150	200	250	300	350	400	450	500
Carbon steel (semi-killed or silicon killed)	360	135	125	115	105	95	85	80	70		
Carbon-manganese steel (semi-killed or silicon killed)	460	180	170	150	140	130	115	105	100		
Carbon-molybdenum steel, 0.5 per cent Mo	450	180	170	145	140	130	120	110	110		
Low alloy steel (Ni, Cr, Mo, V)	550	240	240	240	240	240	235	230	220	190	170
Stainless steel 18Cr/8Ni unstabilised (304)	510	165	145	130	115	110	105	100	100	95	90
Stainless steel 18Cr/8Ni Ti stabilised (321)	540	165	150	140	135	130	130	125	120	120	115
Stainless steel 18Cr/8Ni Mo 2½ per cent (316)	520	175	150	135	120	115	110	105	105	100	95

①

Q₁ Correct the following:

1- Liquid drums usually are placed horizontally and gas-liquid

Separators Vertical.

2- Double pipe heat exchanger is one of simplest and cheapest type of heat exchanger

3- The space between the jacket and the vessel will typically a range from 50 mm to 300 mm.

4- Codes used in United states are 1- ASTM 2- ASME

3- API 4- ANSI

5- The first trial in sieve tray design, downcomer area may take 12% of the total column area.

Q₂ A. They can be divided into two broad classes

I Packing with a regular geometry, such as stacked rings, grids, and proprietary structured packings

II Random packings: - rings, saddles, and proprietary shapes with dumped into the column and take up a random arrangement

A - ~~Raschig~~ Raschig rings are oldests specially manufactured type of random ~~arrangement~~ packing.

B - Pall rings - are essentially Raschig rings in which openings have made by folding strips of the surface into the ring.

C - Berl saddles: were developed to give improved liquid distribution.

D. The Hypac and super Intalox packing can be

considered improved types of pall rings and Intalox saddles

(2)

Q2 B

Advantages of plate heat exchanger

- 1- Low approach temp. can be used as 1°C
- 2- The exchangers more flexible easy to add extra plates
- 3- Suitable for highly viscous materials
- 4- The temp. correction factor higher than shell & tube.

Disadvantages

- 1- The limitation of pressure not exceeds 30 bar
- 2- The selection of suitable gasket is critical.
- 3- The maximum operating temp. is limited to about 250°C
- 4- Expansion than other types.
- 5- The max. flowrate of fluid $2500\text{ m}^3/\text{hr}$.

Q3 Two types of Information

I - Essential Information

- 1- Stream Composition either (i) the flowrate of each individual component. kg/h ,
(ii) the stream composition as a weight fraction.
- 2- Total stream flowrate kg/h
- 3- Stream temp. degrees Celsius preferred
- 4- Nominal operating pressure.

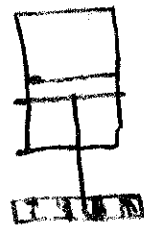
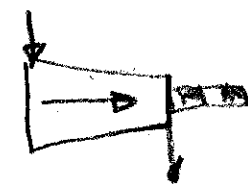
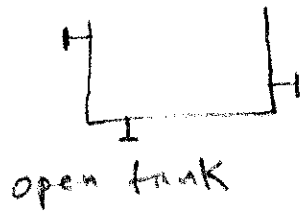
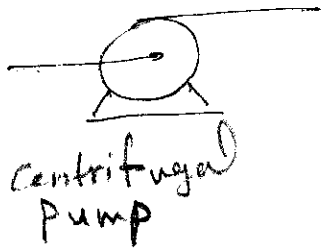
II - Optional information.

- 1- Molar percentages composition.
- 2- physical property data such as.
(i) density kg/m^3 (ii) Viscosity in Ns/m^2

~~3)~~

3) Stream Name

③



compressor

Q3 B ~~Stop~~ Valve
 or Globe Valve:- it is name derives from the globular shape of the valve body. inlet and outlet openings arranged in several ways to suit varying



b- Gate valve are used when a straight-line flow of fluid and minimum restriction is desired. The gate is usually wedge shaped.

c- Butterfly valves:- used in variety of systems can be used effectively in fresh water, saltwater, lub oil, chill water. butterfly valve is light in weight, relatively small, relatively quick-acting, provides positive shut-off.

d- Ball valves:- are stop valves. that use a ball to stop or start the flow of fluid.

e- Plug valves valves with cylindrical or conical-tapered plugs which can be rotated inside the valve body to control flow through the valve.

(4)

Q 4 :-

- 1- Location with respect to the marketing area.
- 2- Raw material supply
- 3- Transport facilities.
- 4- Availability of labour.
- 5- Availability of utilities water, fuel, power
- 6- Availability of suitable land.
- 7- Environmental impact and effluent disposal
- 8- Local Community Considerations.
- 9- Climate
- 10- Political and strategic considerations.

* Marketing Area :- If the production are in bulk quantities and product per tonne is low, and the cost of transport are significant of the sales price, the plant should locate near to primary market.

* Raw material The availability and price of suitable raw materials will often determine the site location.

* Transport :- transport of material & products to and from the plant must be considered.

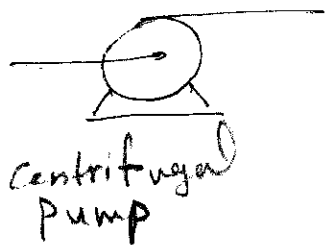
* Availability of labour :- Labour will be needed for construction and its operation.

* Utilities :- Chemical processes require large quantities of water for cooling and general process use. So, plant must locate near source of water.

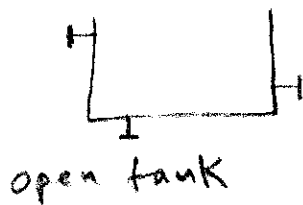
* Environmental impact and effluent disposal :-

~~The disj~~
All industrial processes produce waste products, and full considerations must be given to the difficulties and cost of their disposal.

3



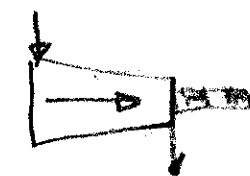
Centrifugal Pump



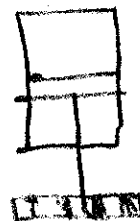
open tank



absorption vessel

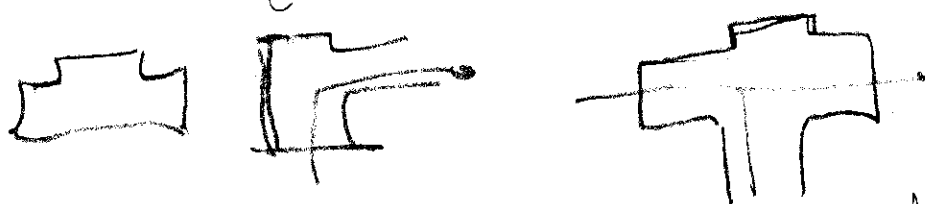


OR



compressor

Q3 B ~~stop~~ stop valve
OR Globe Valve :- it is name derives from the globular shape of the valve body .. inlet and outlet openings arranged in several ways to suit varying



b - Gate valve are used when a straight-line flow of fluid and minimum restriction is desired. The gate is usually wedge shaped.

c - Butterfly valves :- used in variety of systems can be used effectively in fresh water, saltwater, lub oil chill water. butterfly valve is light in weight relatively small, relatively quick-acting provides positive shut-off.

d - Ball valves :- are stop valves. that use a ball to stop or start the flow of fluid.

e - Plug valves :- valves with cylindrical or conical-tapered plugs which can be rotated inside the valve body to control flow through the valve.

⑤

* Local Community Considerations : The proposed plant must fit in with and be acceptable to the local community.

* Land = Sufficient suitable land must be available for the proposed plant and for future expansion.

* Climate = - Adverse climatic conditions at a site will increase costs

* Political and Strategic Considerations, - Capital grants, taxes, and other inducement are often given by governments to direct new investment to preferred locations.

$$10 \text{ N/mm}^2 = 10 \text{ bar}$$

$$(8 - 1) \times 1.1 = 7.7 \text{ bar}$$

$$\frac{7.7}{10} = 0.77 \text{ N/mm}^2$$

From table = 95 N/mm²

$$Q5 \quad t = \frac{P_i D_i}{2 S E - P_i}$$

$$t = \frac{0.77 \times 2 \times 10^3}{2 \times 95 \times 1 - 0.77}$$

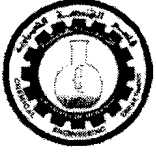
$$8.13 \text{ mm}$$

$$\text{Corrosion} = 2 \text{ mm} = 10.1 \text{ mm}$$

$$② \quad t = \frac{P_i D_i}{4 S E - 0.4 P_i} = \frac{0.77 \times 2 \times 10^3}{4 \times 95 \times 1 - 0.4 \times 0.77} = 4.0 \text{ mm}$$

$$t = D_c \sqrt{\frac{C P_i}{S E}} = 2.2 \times 10^3 \sqrt{\frac{0.25 \times 0.77}{95}}$$

$$99 \text{ mm}$$



Subject: Democracies
Branch: Both Branch
Examiner: Dr. Bushra

University of Technology
Chemical Engineering
Department
Final Examination
2011/2012



Class: Third
Time: 3 hours
Date: /may

ملاحظة: الإجابة على ثلاثة أسئلة.

س1_1 ممارسة الديمقراطية في الوطن العربي ممارسة أيديولوجية تعبوية ماذا نعني بذلك ؟

ب_ عدد أهم التحديات الخارجية التي تواجه عملية التحول الديمقراطي في الوطن العربي ؟ (20 درجة)

س2_1 وضح علاقة المثقف بالسلطة ؟ (20 درجة)

ب_ قارن بين الشريعة والديمقراطية؟

س3_1 ماهية محاسن الديمقراطية ؟

ب ماهية معوقات تطبيق الديمقراطية في الوطن العربي ؟ (20 درجة)

س4_1 ماهية جماعة الضغط وما هي الأحزاب السياسية ؟

ب_ ما علاقة البرجوازية بالديمقراطية ؟ (20 درجة)

امة عليا في عليا في اى به السكس في المدينه
 العربي هو الحارسه الايد بر ليه والتعبير به
 قمرنا في التمدد الفرديه وغلوصا الترميم
 الرهه مما يؤد به اى الاعمال القديه الإلهيه
 والسكس واحصتها به والتبريه وهذا
 خلق فلسفه الإصديه الي كانت سادك
 في المعينه العربي ولكن يتخلص المعينه
 هذا وذلك لايه في اى السكس السكس
 السكس الثاني وهو المتاع العربيه الي
 تحيل التخفي تعالى بالوقار والى ربح وتدفقها
 كذا الايدي في الكلا ولكن تنعم بالرب السكس
 لايه في وجود مؤسساتها الي تلب دور
 في استيعاب العربيه وجعلها في عتاد السكس

١ - تصدقت مصادر السجلات التاريخية

على ناس السجلات التي هي في أيدي العرب
وتسوزعت على هذه العواصم الداخلية وخارجها

فالتجارب التي هي في تلك السجلات

أ- في تاريخ وأصل الدولة الكبرى وفي تاريخها

المعروف في اللغة العربية والدينية قد نتج من هذه

الوقائع السجلات التي هي في أيدي العرب

التي هي في أيدي العرب

٢ - هم من بين الأحرار في استقراء وأصل

اللغة العربية

٣ - الخوفاة وهو السجلات التي هي في أيدي العرب

الكلمة هي من بين الأحرار في استقراء وأصل

٤ - هم من بين الأحرار في استقراء وأصل

سواء في اللغة العربية أو في غيرها

الثلث -

سأ ٢ - علامة الحقيقة بالله

الجواب

تحت هذه العناوين هناك أسئلة تفحصها نفس

مذاهب أديان وهو ؟

١ - هل الحقيقة دائماً ثابتة كقول الله عز وجل

وهو يخلق ما يشاء يريد لا يستتر الفكرة تحت شعار

تختلف

٢ - ما هي إشارات الله في خلقه الحقيقة بالله

وهل تختلف مع غيره الكائن ؟

الاستكالية المبرور اليوم هو علامة الحقيقة

بالله ومما في المعتقدات البرهانية

عليها أنهم استبدادهم حيث يجد في حقوق النعمة

الحققة من يؤمنها ويأول التبرير لها كتب

أعني شعار

والطبيعية الكال تختلف سمات العلامة بين

العلمية بين المتقين والسليمة من بلادهم
ومعهم من تاريخهم الكائنات. وعليه أخذ
فئتين من المستحقين رواد الحركة التنويرية الأولى

أولها فئة أولئك الذين كانوا قدامهم دعاء
إليه مع دعاء الكلم المخلوق المستبد به.

ثانيها فئة كانت معارضة السلطة الاستبدادية
الأولى حاولت الإصلاح داخل السلطة السليمة
بما قد مت قولها أنها نموذجاً للسلطة السليمة
في ديارهم قبل القرب وحسن تأسيه
نظام يعطي كهره يعقد له الكثرة بحيث يملأ
بكل جديد في الإصلاح.

ثالثها فئة الثائمين: أيقنت بأن نظام
الإصلاح السليم الذي أتت به القضاة على
الكلم الاستبدادي المخلوق وتأسيه نظام
دستوري وعقولي نظام الملك المستبد المخلوق

أَيُّ نَظَامٍ هَـذَا بَقَايَا نَظْمِ لُذَا ذَهَبِ السُّعْرَاءِ إِلَى السُّوَرِ
صَدِّ هَـذَا، الْأَرْضُ هَـذَا لَتَرَمِ الْوَصْرَ.

وَمَنْ هَـذَا السُّوَرِ بِمَكْتَابِهِ نَوَاسِيَانِ الْمَقَاتِ
ذَوِ مَرِيضَةٍ رَقِيعَةٍ لَا تَحِلُّ الْوَصْرَ إِلَى السُّوَرِ
وَيَدْرِفُ عَلَى عِيدِهِ وَهَيْهَ . فَأَذَا انْقَلَبَ
السُّوَرِ دَامِجِ الْمَقَاتِ بِمَكْتَابِهِ وَهَيْهَ إِلَى السُّوَرِ
فَمَنْ لَكُونِ وَهَيْهَ الْمَقَاتِ.

(هَذَا مَقَاتِ)

٢
١ - فاسد الدمع

٢ - الاستنزاف السريع

٣ - التيارات العقلية في اوقات الحروب

٤ - اكتنا صناعي النسا

٥ - اكتنا من فساد الارض

٦ - اكتنا من الفقر والحياة

٧ - اكتنا من الدمع

٨ - اكتنا من قتل النفس

٩ - اكتنا من

١٠ - اكتنا من

١١ - اكتنا من

في - - -
تحوّل وجهه من الإصبات
الأصباغ والأقلام في ورث خلف الدخول في
الوجه القوي .

هناك دلائل أثبتت أن الإصبات القوي
عما صرت بتأثيرات تجعل في / أي بولوس
فؤوسه /
لجسدي

ويمكن إجمال هذه الأشياء في

1 - اهتمام الفرد للقيمة الإصباتية فقط وحده والى
هو القيمة العليا وآدم كونه الذي يستند إليها

2 - التعلق المتصل بالجمي والفقر وقد حلت

الشفهم الحيوي وتحت دور المرأة الصفا

3 - تلك طازية الإصباتية في الذات
عما هي المعانيه / وهذا يمثل
ماتق اهتمام تنسيق الدخول

4 - عبارة القلم وحياته الحيوانية المستور

وتمت الإصبات في الشايد ولديهم

تفتت معامل من حيث عدم ادماج الفرد مع الشئ
كذلك أكتافه الموكلة المعاش والإصبات في عما يرد

الى قلبه ^٤ الى السكينة

٤ - ايتها ^٥ ذو الصفة الوسيطة المعية لكونه

عليه ^٦ كثر من شيء ^٧ عن عدم التكريم

المعنى ^٨ الحقيقى العزى

٥ - عدم تقاضى الصغار ^٩ الاصل ^{١٠} من التهو

الوقت ^{١١} من ^{١٢} كثر من ^{١٣} اللط ^{١٤} القريب ^{١٥} جدا

ما ^{١٦} يحل ^{١٧} هناك ^{١٨} حقوة ^{١٩} من ^{٢٠} صغار ^{٢١} الهاء

للتهو ^{٢٢} السق ^{٢٣} الهاء

٦ - وجود ^{٢٤} الطاهر ^{٢٥} العباد ^{٢٦} للكنز ^{٢٧} باصر ^{٢٨} كثر

اذا ^{٢٩} اقل ^{٣٠} اقل ^{٣١} واذا ^{٣٢} اود ^{٣٣} اود ^{٣٤} والتعظيم ^{٣٥} الى

الكنز ^{٣٦} من ^{٣٧} كثر ^{٣٨} من ^{٣٩} الحق

والله ^{٤٠} لقوله ^{٤١} امر ^{٤٢} المتكبر ^{٤٣} انه ^{٤٤} حمله ^{٤٥} انه ^{٤٦} منكر

ليس ^{٤٧} حراً ^{٤٨} حراً ^{٤٩} حراً ^{٥٠} حراً ^{٥١} حراً ^{٥٢} حراً ^{٥٣} حراً ^{٥٤} حراً ^{٥٥} حراً ^{٥٦} حراً ^{٥٧} حراً ^{٥٨} حراً ^{٥٩} حراً ^{٦٠} حراً

قل ^{٦١} كثر ^{٦٢} كثر ^{٦٣} كثر ^{٦٤} كثر ^{٦٥} كثر ^{٦٦} كثر ^{٦٧} كثر ^{٦٨} كثر ^{٦٩} كثر ^{٧٠} كثر

جماعة الصفا لا يصرح بها في كتابه فيه
عنه انما لم يبدئ بذكرها اكمال الاصل عقود
الشيخ رحمه الله في كتابه في الفقه.

وهم جماعة من الاصفهانيين من طائفة علماء
ذات صفة دالة او حافظة حيث تعرفوا بها
نفسا فعبارة السلفاء في - وكيفية هؤلاء
الاخرى قد نفوسهم في ذلك ووجودهم في
او صفة مشتركة وبيعه في الاصل في
السلفاء في النقلة لكما تتخذ قرابة في
وصال عنه في التقابيل والاعتبارات -
اما التميز بين جماعة الصفا والاصناف السنية
كما في

في الاصل في السنية في كتابه في الفقه
كلية. اما جماعة الصفا في كتابه في الفقه
في الفقه في الفقه في الفقه في الفقه
في الفقه في الفقه في الفقه في الفقه

هذه هي حكمة الله في خلقه
الذين هم في الدنيا
او في الآخرة
حكمة الله في خلقه
الذين هم في الدنيا
او في الآخرة

هذه هي حكمة الله في خلقه
الذين هم في الدنيا
او في الآخرة
حكمة الله في خلقه
الذين هم في الدنيا
او في الآخرة

هذه هي حكمة الله في خلقه
الذين هم في الدنيا
او في الآخرة
حكمة الله في خلقه
الذين هم في الدنيا
او في الآخرة

٥ - إذا تَقَاتُحَتْ فَعَلَهُ الزَّوْرُ فِي مَقْوَعَةٍ وَهِيَ بَابُ
عَنِ الْمَلِكِ الْعَامِ فَأَنْ لَا تَرَامَ بِالْمَلِكِ الْعَامِ
أَمْرًا لِيَدِيهِ إِذَا هُوَ إِسْرَافٌ يَدِيهِ (عَيْنًا تَكُونُ
الْكِبَارَةُ يَكُونُ مَشْرِعُ اللَّهِ)

٦ - التَّوْرَى لَا تَقْبَلُ فَعْلُ اللَّهِ عَنِ السَّيِّئَةِ وَلَا
يَقْبَلُ فَعْلُ السَّيِّئَةِ إِلَّا تَقْبَلُ وَهَذَا الْفَعْلُ هُوَ
الْعَيْنُ فِي الدَّعْوَى أَيْ

٧ - الْأَمْرُ هُوَ الْمَشْرِعُ فِي السَّيِّئَةِ الدَّعْوَى
فِي مَقْوَعَةٍ هُوَ السَّيِّئَةُ الْمَشْرِعُ

٨ - الْأَمْرُ يَدْعُو عَيْنَ الرَّدِّ لِلْعَامِ أَوْ الْمَقْبُولِ وَلَيْسَ
لَهُ عَيْنٌ كَمَا تَقَالُ فِي الدَّعْوَى أَيْ

٩ - فِي الدَّعْوَى أَيْ تَكُونُ أَيْ تَقْبَلُ كُلُّ أَيْ تَكُونُ
وَعَيْنُهَا يَدْعُو الْأَمْرَ فِي مَقْوَعَةٍ لَا تَقْبَلُ الْكِبَارُ
فِي الشَّرِّ نَحْوُ

والتاسعة هي التي تسمى أولئك الذين هم
مؤمنون بالله

١ - الحفصة ما له نقاط القاء ونظام
اقتراح بين الشريف والدكتوراه وهذا يعني
انها تلتزم بمبادئ نظام معين بينهما تناقض
افضل دمايك

٢ - لجنة الدكتوراه من مبادئ الاقتراح وعلى
الاعلى

٣ - السلطة، التقدير والسلطة الشريف
والقوانين سلطات وتقبله من بعضها
في هذه يكون السلطة والسلطة بيد المحاكم
المستقلة على القرائن الكريمة

٤ - لجنة الدكتوراه على الدستور والقانون
على تقبله اذا استبعد امر في هذه
المستوى على تقبله على القرائن الكريمة الذي هو
الدستور

٥ - في الشريف لا يورث الحكم انما الحفصة قد لا يكون
عليه راي الحمير وامام الجامعة قد لا يكون له راي



University of Technology
Chemical Engineering Department
Final Examination
2011/2012



Subject: Reactor Design

Class: Third
Time: 3 hours

Examiner: Dr. Mohammad Fadhil & Dr. Amer Aziz

Attempt (4) questions only

Q1) The homogenous gas phase reaction $A \rightarrow 3R$ using system of PFR, follows a second order kinetics. For a feed rate of $1 \text{ m}^3/\text{h}$ of pure A at 3 atm and 300°C , an experimental reactor consisting of a 30 cm inside diameter pipe and 3 m long gives 60% conversion of feed. Estimate the half life time of the reaction. (15 marks)

Q2) A gas-phase reaction $A \longrightarrow R+S$ is carried out in a batch reactor with initial conditions of $T_0 = 300 \text{ K}$, total pressure = 5 atm. and a constant volume of 0.5 m^3 . The feed contains 70 mole% A and the balance inert material. The reaction rate constant is:

$k = 10^{14} \exp(-10000/T) \text{ h}^{-1}$. The heat of reaction is $(-1500) \text{ kcal/kmol}$

And the heat capacity of A, R and S are 40, 35, and 30 kcal/kmol.K respectively.

a) Compute the time required for isothermal conditions if the conversion is 70%.

b) Compute the time required for adiabatic conditions if the conversion is 70%. (15 marks)

Q3) The production of methyl bromide (C) is an irreversible liquid phase reaction which is first order with respect to methylamine (A): $A + B \rightarrow C + D$, this reaction is carried out in a semi batch reactor. Methylamine (A) at a concentration of 0.025 mol/dm^3 is to be fed at a rate of $0.05 \text{ dm}^3/\text{s}$ to an aqueous solution of bromine cyanide (B) contained in a glass lined reactor. The specific rate constant is $K = 0.01 \text{ s}^{-1}$. The initial volume of fluid in the reactor to be 5 dm^3 . The initial moles of (A) in feed $N_{A0} = 0.01$ moles. Determine the conversion of A, assume time increment $(\Delta t) = 0.5 \text{ min}$ (15 marks)

Q4) The gas-phase reaction $A + 2B \longrightarrow 2D$ is to be carried out in an isothermal PFR at 5.0 atm and 55 C temperature. The mole fractions of the feed streams are: $A=0.2$, $B=0.5$ and inerts = 0.3. The volumetric feed rate is $50 \text{ dm}^3/\text{min}$, the activation energy 1.25 kcal/mol and the rate law at 75°C is:

$$(-r_A) = 2.5 C_A^{1/2} C_B \quad (\text{kmol/m}^3 \cdot \text{h})$$

How many numbers of 2.5 cm inside diameter pipes, 10 m length packed with a catalyst, are necessary to achieve 80 % conversion of A? (15 marks)

Q5) The liquid phase reversible reaction $A \rightleftharpoons B$ is carried out in a 120 liter CSTR. Two feed streams, one containing 2.5 mol A/liter and the other containing 1.5 mol A/liter, are to be introduced in equal volumetric flow rate into the reactor, and 50% of the equilibrium conversion is obtained. Assume a constant density throughout and given $k_1=7 \text{ liter/mol.min}$, $k_2=3 \text{ liter/mol.min}$:

a- What should be the flow rate of each stream?

b- If the effluent from the first reactor is charged to another CSTR where the irreversible reaction $A \rightarrow B$ takes place with $k=3 \text{ min}^{-1}$. Calculate the volume of CSTR needed to obtain 90% conversion of A. (15 marks)

$$R_g = 0.082 \text{ atm.lit/mol.K} = 1.987 \text{ cal/mol.K} = 8.314 \text{ J/mol.K}$$

GOOD LUCK

الحلول النموذجية للإمتحان رقم (1) (2011/2012)

$$Q_1) C_{A_0} = \frac{P_T y_{A_0}}{R_T} = \frac{3 \times 1}{0.082 \times 573} = 0.063 \text{ kmol/m}^3$$

$$V = \frac{\pi}{4} d^2 L = \frac{3.14}{4} (0.3)^2 \times 3 = 0.212 \text{ m}^3$$

$$C_A = C_{A_0} \left(\frac{1-x}{1+\epsilon x} \right), \quad \epsilon = y_{A_0} \delta = 1(3-1) = 2$$

$$C_A = C_{A_0} \left(\frac{1-x}{1+2x} \right)$$

$$V = F_{A_0} \int \frac{dx}{k C_{A_0}^2 \left(\frac{1-x}{1+2x} \right)^2}$$

X	$\left(\frac{1-x}{1+2x} \right)^2$	$\left(\frac{1-x}{1+2x} \right)^{-2}$
0	1	1
0.3	0.191	5.235
0.6	0.033	30.30

$$F(x) = \frac{0.3}{3} (1 + (4 \times 5.235) + 30.30)$$

$$F(x) = 5.224$$

$$V = \frac{V_0}{k C_{A_0}} \times F(x) \Rightarrow 0.212 = \frac{1 \times 5.224}{k \times 0.063}$$

$$k = \frac{5.224}{0.0133} \Rightarrow k = 392.782 \text{ m}^3/\text{kmol/hr}$$

For a second order, the half life time is:

$$t_{1/2} = \frac{1}{k C_{A_0}} = \frac{1}{392.782 \times 0.063} = \frac{1}{24.745}$$

$$t_{1/2} = \underline{\underline{0.04 \text{ hr}}} \quad \text{or} \quad \underline{\underline{2.42 \text{ min}}} \quad \text{or} \quad \underline{\underline{145.5 \text{ sec}}}$$

$$Q2) :- C_{A_0} = \frac{y_{A_0} P_T}{R T_0} = \frac{0.7 \times 5}{0.082 \times 300} = \frac{3.5}{24.6} = 0.1422$$

From the units of k , the reaction is of 1st order kinetic

$$(-r_A) = k C_A = k C_{A_0} (1-x)$$

$$t_r = C_{A_0} \int_0^x \frac{dx}{(-r_A)} = C_{A_0} \int_0^{0.7} \frac{dx}{k C_{A_0} (1-x)}$$

a) For isothermal $\therefore t_r = \frac{C_{A_0}}{k C_{A_0}} \int_0^{0.7} \frac{dx}{(1-x)}$ من القانون
 $k_{300^\circ C} = 0.33$

$$= -\frac{1}{k} \ln(1-x) \Big|_0^{0.7} = -\frac{1}{0.33} \ln(0.3) = \boxed{3.65 \text{ hr}}$$

b) For adiabatic,

$$-\Delta H_R C_{A_0} X = \sum C_j C_{P_j} \Delta T$$

$$-\Delta H_R C_{A_0} X = [C_{A_0} (1-x) C_{P_A} + C_{A_0} X C_{P_R} + C_{A_0} X C_{P_S}] (T - T_0)$$

$$-\Delta H_R X = [(1-x) C_{P_A} + X C_{P_R} + X C_{P_S}] (T - T_0)$$

$$-(-1500) X = [(1-x) 40 + X(35) + X(30)] (T - 300)$$

$$1500 X = [40 - 40 X + 35 X + 30 X] (T - 300)$$

$$T = 300 + \frac{1500 X}{40 + 25 X} \quad \text{--- (1)}$$

$$k = 10^{14} \exp(-10000/T) \quad \text{--- (2)}$$

$$t_r = \int_0^{0.7} \frac{dx}{k(1-x)}$$

X	T	k	$\frac{1}{k(1-x)}$	
0	300	0.33	3	$f(x)_0$
0.35	310.77	1.06	1.45	$f(x)_1$
0.7	318.26	2.26	1.47	$f(x)_2$

$$t_r = F(x) = \frac{0.35}{3} [3 + 4(1.45) + 1.47]$$

$$t_r = \boxed{1.2 \text{ hr}}$$

$$Q_3:- C_A = \frac{F_{A_0} t - N_{A_0} x}{V_0 + v_0 t}$$

$$-r_A = k \frac{(F_{A_0} t - N_{A_0} x)}{(V_0 + v_0 t)} \quad \text{--- (1)}$$

$$-r_A V = N_{A_0} \frac{dx}{dt} \Rightarrow (-r_A) = \frac{N_{A_0}}{V} \frac{dx}{dt}$$

$$(-r_A) = \frac{N_{A_0}}{V_0 + v_0 t} \cdot \frac{dx}{dt} \quad \text{--- (2)}$$

\therefore (2) & (1) solve

$$\frac{N_{A_0}}{V_0 + v_0 t} \frac{dx}{dt} = k \frac{(F_{A_0} t - N_{A_0} x)}{V_0 + v_0 t}$$

$$\frac{dx}{dt} = \frac{k}{N_{A_0}} (F_{A_0} t - N_{A_0} x)$$

$$k_1 = \Delta t * F(x_n, t_n)$$

$$k_2 = \Delta t * F\left(x_n + \frac{k_1}{2}, t_n + \frac{\Delta t}{2}\right)$$

$$k_3 = \Delta t * F\left(x_n + \frac{k_2}{2}, t_n + \frac{\Delta t}{2}\right)$$

$$k_4 = \Delta t * F(x_n + k_3, t_n + \Delta t)$$

The known quantities are:-

$$F_{A_0} = C_{A_0} v_0 = 0.025 * 0.05 = 1.25 * 10^{-3} \frac{\text{mol}}{\text{s}}$$

$$V_0 = 5 \text{ dm}^3, v_0 = 0.05 \frac{\text{dm}^3}{\text{s}}, k = 0.01 \text{ s}^{-1}$$

$$\frac{dx}{dt} = \frac{0.01}{0.01} (1.25 * 10^{-3} t - 0.01 x)$$

$$\frac{dx}{dt} = (1.25 * 10^{-3} t - 0.01 x)$$

$$\Delta t = 0.5 \text{ min} * 60 = 30 \text{ Sec.}$$

$$\text{when } t=0, x_0=0$$

$$x_1 = x_0 + \frac{1}{6} (k_1 + 2k_2 + 2k_3 + k_4)$$

$$k_1 = \Delta t * [F(x_0, t_0)]$$

$$= 30 (1.25 * 10^{-3} * 0 - 0.01 * 0)$$

$$k_1 = 0$$

$$k_2 = \Delta t * [F(x_0 + \frac{k_1}{2}, t_0 + \frac{\Delta t}{2})]$$

$$= 30 (1.25 * 10^{-3} * 15 - 0.01 * 0)$$

$$k_2 = 0.562 \text{ s}^{-1}$$

$$k_3 = \Delta t * [F(x_0 + \frac{k_2}{2}, t_0 + \frac{\Delta t}{2})]$$

$$= 30 (1.25 * 10^{-3} * 15 - 0.01 * 0.28)$$

$$= 30 (0.01875 - 0.0028)$$

$$k_3 = 0.4785 \text{ s}^{-1}$$

$$k_4 = \Delta t [f(x_0 + k_3, t_0 + \Delta t)]$$

$$k_4 = 30 [1.25 * 10^{-3} * 30 - 0.01 * 0.4785]$$

$$k_4 = 30 [0.0375 - 0.004785]$$

$$k_4 = 0.9814 \text{ s}^{-1}$$

$$X_1 = X_0 + \frac{1}{6} (k_1 + 2k_2 + 2k_3 + k_4)$$

$$X_1 = 0 + \frac{1}{6} (0 + 2(0.562) + 2(0.4785) + 0.9814)$$

$$X_1 = \frac{1}{6} (1.124 + 0.957 + 0.9814)$$

$$X_1 = 0.51$$

$$Q4) \quad C_{A0} = \frac{y_{A0} P_T}{R T} = \frac{0.2 \times 5}{0.082 \times 328} = 0.04 \frac{\text{kmol}}{\text{m}^3}$$

$$C_{B0} = \frac{y_{B0} P_T}{R T} = \frac{0.5 \times 5}{0.082 \times 328} = 0.09 \frac{\text{kmol}}{\text{m}^3}$$

$$C_A = C_{A0} \left(\frac{1-x}{1+\epsilon x} \right) \quad ; \quad \epsilon = y_{A0} \delta = 0.2(2-3) = -0.2$$

$$C_A = C_{A0} \left(\frac{1-x}{1-0.2x} \right) \quad ; \quad C_B = C_{A0} \left(\frac{\frac{C_{B0}}{C_{A0}} - x}{1-0.2x} \right)$$

$$C_B = C_{A0} \left(\frac{2.25 - x}{1-0.2x} \right)$$

$$V = F_{A0} \int_0^{0.8} \frac{dx}{k C_{A0}^{1/2} \left(\frac{1-x}{1-0.2x} \right)^{1/2} \cdot C_{A0} \left(\frac{2.25-x}{1-0.2x} \right)}$$

$$= \frac{V_0 \times C_{A0}}{k C_{A0}^{3/2}} \int_0^{0.8} \frac{dx}{\left(\frac{1-x}{1-0.2x} \right)^{1/2} \left(\frac{2.25-x}{1-0.2x} \right)}$$

$$= \frac{V_0}{k C_{A0}^{1/2}} \int_0^{0.8} \frac{dx}{\left(\frac{1-x}{1-0.2x} \right)^{1/2} \left(\frac{2.25-x}{1-0.2x} \right)}$$

← $F(x)$

$$V_0 = 50 \frac{dm^3}{min} = 3 m^3/hr$$

$$\ln \frac{k_{55+273}}{k_{75+273}} = \frac{E}{R} \left(\frac{1}{T_{75+273}} - \frac{1}{T_{55+273}} \right)$$

$$\ln \frac{k_1}{2.5} = \frac{1250}{1.987} \left(\frac{1}{348} - \frac{1}{328} \right)$$

$$\ln \frac{k_1}{2.5} = 629 (2.87 \times 10^{-3} - 3.04 \times 10^{-3})$$

$$\ln \frac{k_1}{2.5} = 629 (-1.7 \times 10^{-4}) \Rightarrow \ln \frac{k_1}{2.5} = -0.107$$

$$\frac{k_1}{2.5} = 0.898 \Rightarrow k_1 = 2.246 \text{ hr}^{-1}$$

X	$\left(\frac{1-x}{1-0.2x} \right)^{1/4} \left(\frac{2.25-x}{1-0.2x} \right)$
0	0.444
0.4	0.616
0.8	1.19

$$F(x) = \frac{0.4}{3} [0.444 + 4(0.616) + 1.19]$$

$$F(x) = 0.546$$

$$V = \frac{3}{2.246 \times (0.04)^{1/2}} \times 0.546 \Rightarrow V = 6.66 m^3$$

$$V = N \times \frac{\pi}{4} \times D^2 \times L \Rightarrow N = \frac{4 \times V}{\pi \times D^2 \times L}$$

$$N = \frac{4 \times 6.66}{3.14 \times (0.025)^2 \times 10} \Rightarrow N = 1361 \text{ pipes}$$

Q5) If the two streams are mixed just before feeding to the reactor; then:-

$$C_{A_0} = \frac{2.5 + 1.5}{2} = 2 \text{ mol/lit}_{\text{mix.}}$$

$$\textcircled{a} (-r_A) = k_1 C_A^2 - k_2 C_B^2 = k_1 [C_{A_0}(1-x)]^2 - k_2 [x C_{A_0}]^2$$

at equilibrium, $(-r_A) = 0$ & $x = x_e$

$$0 = k_1 (1 - x_e)^2 - k_2 x_e^2$$

$$4 x_e^2 - 14 x_e + 7 = 0, \text{ for } x_e < 1$$

$$\because x_e = 0.6 \Rightarrow x = 0.5 x_e \Rightarrow x = 0.3$$

$$\therefore (-r_A) = 7 [2(1 - 0.3)]^2 - 3 [2(0.3)]^2$$

$$(-r_A) = 5.78 \text{ mol of A/lit. min.}$$

$$\therefore V = \frac{V_0 C_{A_0} x}{(-r_A)}$$

$$120 = \frac{V_0 \times 2 \times 0.3}{5.78}$$

$$V_0 = 1156 \text{ lit/min}$$

$$(V_0)_A = 578 \text{ lit/min}; (V_0)_B = 578 \text{ lit/min.}$$

⑥ For the 2nd reactor:-

$$V = \frac{V_0 (C_{A_0} - C_A)}{-r_A}$$

المركب 2.3.1

$$C_A = C_{A0}(1 - x_1) = 2(1 - 0.3) = 1.4 \text{ mol/lit}$$

المركب 2.3.2

المركب 2.3.3

$$C_A = C_{A0} = 1.4 \text{ mol/lit}$$

المركب 2.3.4

$$C_A = C_{A0}(1 - X_2)$$

$$C_A = 1.4(1 - 0.9) \Rightarrow C_A = 0.14 \text{ mol/lit}$$

$$(-r_A) = k C_A \Rightarrow 3 * 0.14 \Rightarrow (-r_A) = 0.42 \frac{\text{mol}}{\text{lit} \cdot \text{min}}$$

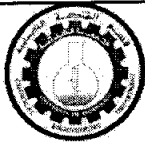
$$\therefore V = \frac{v_0(C_{A0} - C_A)}{(-r_A)}$$

$$V = \frac{1156(1.4 - 0.14)}{0.42}$$

$$V = \frac{1456.56}{0.42}$$

$$V = 3468 \text{ lit}$$

الأسئلة الامتحانية مع حلولها الدور الثاني



University of Technology
Chemical Engineering
Final Examination



Subject: Applied mathematics
Branch: Gas & Oil Refinery and
Unit Operations
Examiner: Dr Ghanim Alwan

2011/2012

Class: 3rd
Time: 3 hours
Date:

Attempt four questions only

Q1) Two CSTRs are connected in series carried out first order chemical reaction ($A \xrightarrow{k} B$). If the inlet concentration (C_1) of reactor (1) is changed by unit step .find the response equation of concentration into reactor (2) as function of time , i.e. , $c_3 = f(t)$

(20 marks)

Q2) Find the solution of the following equation:

$$X \frac{d^2y}{dx^2} + (X-1) \frac{dy}{dx} - y = 0$$

(20 marks)

Q3) Obtain the solution of the mass diffusion equation :

$$\frac{\partial^2 C}{\partial x^2} - \frac{\partial C}{\partial y} = 0$$

With B.cs of: $C(0, y) = C(2, y) = 0$ $y > 0$

$C(x, 0) = f(x)$ $0 \leq x \leq 2$

(20 marks)

Q4) Solve (numerically) the following equation:

$$X dy = (X^2 - y) dx$$

If $x_0 = y_0 = 1$,find the value of y at $x=3$. Discuss your results. What is the value of % error.

(20 marks)

Q5) Consider a fluid is flowing with linear velocity (V) along a pipe of length (L) and diameter (D). Find the temperature distribution of the fluid as a function of time and distance $T(x,t)$.

Where:

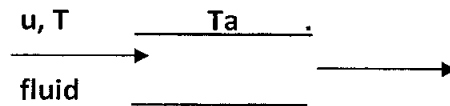
A : surface area of pipe, c_p : specific heat

w : mass rate of flow .

h : over all heat transfer coeff.

T : Temperature of fluid

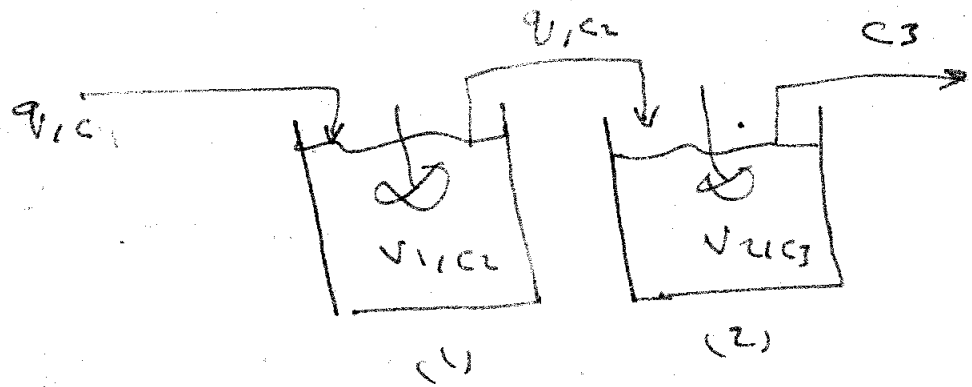
T_a : ambient temperature



(20 marks)

Good Luck

Q1)



M.B on reactor (1)

$$q_1 c_1 - q_2 c_2 - k V_1 c_2 = V_1 \frac{dc_2}{dt} \quad (1)$$

M.B on reactor (2)

$$q_2 c_2 - q_3 c_3 - k V_2 c_3 = V_2 \frac{dc_3}{dt} \quad (2)$$

$$C_1 = 1 \rightarrow C_1(s) = \frac{1}{s}$$

By taking L.T to eqs 1 & 2 $C_2(0) = 0, C_3(0) = 0$

$$q_1 C_1(s) - q_2 C_2(s) - k V_1 C_2(s) = V_1 (s C_2(s)) \quad (3)$$

$$q_2 C_2(s) - q_3 C_3(s) - k V_2 C_3(s) = V_2 (s C_3(s)) \quad (4)$$

From eq (3): $q_2 C_2(s) + s V_1 C_2(s) - k V_1 C_2(s) = \frac{q_1}{s}$

$$C_2(s) [q_2 + s V_1 - k V_1] = \frac{q_1}{s}$$

$$\therefore C_2(s) = \frac{q_1}{s (q_2 + s V_1 - k V_1)} \quad (5)$$

subst. eq (5) into eq (4)

$$q_2 \cdot \frac{q_1}{s (q_2 + s V_1 - k V_1)} = (q_3 + k V_2 - V_2 s) C_3(s)$$

$$\therefore C_3(s) = \frac{q_1 q_2}{s (q_2 + s V_1 - k V_1) (q_3 + k V_2 - V_2 s)}$$

$$C_3(t) = \int_0^t \frac{q_1 q_2}{s (q_2 + s V_1 - k V_1) (q_3 + k V_2 - V_2 s)} ds$$

$$Q_2) \quad x \frac{d^2 y}{dx^2} + (x-1) \frac{dy}{dx} - y = 0$$

$$y = \sum a_n x^{n+c} \quad , \quad y' = \sum a_n (n+c) x^{n+c-1}$$

$$y'' = \sum a_n (n+c)(n+c-1) x^{n+c-2}$$

$$\text{Indicial equation} = a_0 c(c-1) - a_0 c = 0$$

$$c^2 - c - c = 0 \rightarrow c^2 - 2c = 0 \quad c(c-2) = 0$$

$$c_1 = 0, \quad c_2 = 2$$

$$a_2(c+2)c + a_0 c = 0$$

$$\frac{a_2}{a_1} = \frac{-c}{(c+2)c} = \frac{-1}{c+2}$$

$$\frac{a_2}{a_1} = \frac{a_2}{a_1} \cdot \frac{a_1}{a_0} = \frac{1}{4!} = \frac{(-1)^2}{(n+2)!}$$

$$c = 2 \quad \therefore y_1 = \sum_{n=0}^{\infty} \frac{(-1)^n}{(n+2)!} 2a_0 x^{n+2}$$

$$y_1 = 2a_0 \left(\frac{x^2}{2!} - \frac{x^3}{3!} + \frac{x^4}{4!} - \dots \right)$$

$$\text{as } c = 0 \quad y_2 = a_0 - a_0 x + a_2 x^2 - \frac{a_2 x^3}{3} + \frac{a_1 x^4}{3+4}$$

$$\therefore y = y_1 + y_2$$

$$y = A(1-x) + B e^{-x}$$

$$= 2a_0 \left(\frac{x^2}{2!} - \frac{x^3}{3!} + \frac{x^4}{4!} - \dots \right) + a_0(1-x) + 2a_2(e^{-x} - 1)$$

$$Q_3) \quad \frac{\partial^2 c}{\partial x^2} - \frac{\partial c}{\partial y} = 0 \quad \text{--- (1)}$$

$$\text{BCs:} \quad c(0, y) = c(2, y) = 0 \quad y > 0 \quad \text{--- (2)}$$

$$c(x, 0) = f(x) \quad 0 < x < 2 \quad \text{--- (3)}$$

$$c(x, t) = X(x) T(t) \quad \text{--- (4)}$$

$$\therefore \frac{1}{X} \frac{d^2 X}{dx^2} = \frac{1}{T} \frac{dT}{dt} \quad (5)$$

$$\frac{1}{X} \frac{d^2 X}{dx^2} = -\omega^2 \quad (6)$$

$$\frac{1}{T} \frac{dT}{dt} = -\omega^2 \quad (7)$$

$$\therefore X = A \cos \omega x + B \sin \omega x \quad (8)$$

and $T = C e^{-\omega^2 t} \quad (9)$

A, B & C are constants.

$$\therefore C(x, t) = (A' \cos \omega x + B' \sin \omega x) e^{-\omega^2 t} \quad (10)$$

$$0 = A' e^{-\omega^2 t} \quad (11)$$

for all $t \therefore A' = 0 \quad (12)$

putting $x = \frac{z}{2}$

$$0 = (B' \sin \omega z) e^{-\omega^2 t} \quad (13)$$

$$\sin 2\omega = 0$$

$$\omega = \frac{r\pi}{2} \text{ where } r = 1, 2, 3, \dots$$

$$\therefore C(x, t) = \sum_{r=1}^{\infty} B_r e^{-r^2 \pi^2 t / 4} \sin \frac{r\pi x}{2} \quad (14)$$

$$B_r = \text{constant}$$

$$f(x) = \sum_{r=1}^{\infty} B_r \sin \frac{r\pi x}{2} \quad (15)$$

$$B_r = \frac{2}{\pi} \int_0^2 f(x) \sin \frac{r\pi x}{2} dx \quad (16)$$

$$\therefore C(x, t) = \sum_{r=1}^{\infty} \left[\frac{2}{\pi} \int_0^2 f(x') \sin \frac{r\pi x'}{2} dx' \right] e^{-r^2 \pi^2 t / 4} \cdot \sin \frac{r\pi x}{2} \quad (17)$$

(Q.1) Solve (numerically) :

$$x dy = (x^2 - y) dx \quad , \quad x_0 = 1, y_0 = 1$$

Find value of y at $x = 3$?

By using Runge-Kutta method $\rightarrow \frac{dy}{dx} = \frac{x^2 - y}{x} = f(x, y)$

$$\Delta x = h = 1$$

$$k_1 = f(1, 1) = 0$$

$$k_2 = f\left(1 + \frac{1}{2}, 1\right) = \frac{\left(\frac{3}{2}\right)^2 - 1}{\frac{3}{2}} = 5/6$$

$$k_3 = f\left(2, 2 + \frac{2}{3}\right) = \frac{2^2 - 2\frac{2}{3}}{2} = \frac{2}{3}$$

$$y = y_0 + \frac{1}{6} (k_1 + 4k_2 + k_3) \\ = 1 + \frac{1}{6} \left(0 + 4\frac{5}{6} + \frac{2}{3}\right) = \frac{5}{3}$$

by using integration:

$$\frac{dy}{dx} + \frac{y}{x} = x$$

$$y = \frac{x^3}{3} + \frac{C}{x} \quad \rightarrow \quad \text{at } x_0 = 1 \rightarrow y = 1 \rightarrow C = \frac{2}{3}$$

$$y = \frac{1}{3} x^3 + \frac{2}{3} x^{-1} \quad \rightarrow \quad y = \frac{5}{3}$$

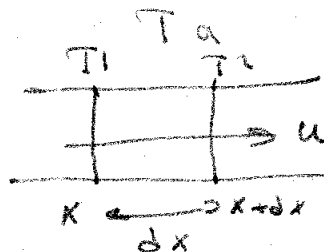
$$\% \text{ error} = \frac{y_{\text{act}} - y_{\text{num}}}{y_{\text{act}}} \times 100 = \frac{1/3}{5/3} \approx 20\%$$

Discussion

numerical method is approach method. It is needed to improvement by ~~ways~~ reduce Δx and increase the number of Iteration. Also ~~also~~ increase the number of k 's to k_4 or k_5 .

Q5)

w/T
→



Heat balance over element dx

Input - output - heat losses = accumulated heat

$$wcpT - wcp\left(T + \frac{\partial T}{\partial x} dx\right) - UA(T - T_a) = Mcp \frac{\partial T}{\partial t} \quad (1)$$

$$M = \rho V, w = \rho A u$$

$$V = A \cdot dx, A = \frac{D^2 \pi}{4}$$

$$\left(\frac{\pi}{4} D^2 dx\right) \rho cp \frac{\partial T}{\partial t} = - \left[\left(\frac{\pi}{4} D^2 u\right) \rho cp \frac{\partial T}{\partial x} dx - U(\pi D dx)(T - T_a) \right] \quad (2)$$

$$\therefore -\frac{\partial T}{\partial t} = -u \left(\frac{\partial T}{\partial x}\right) - \alpha (T - T_a), \text{ where } \alpha = \frac{4u}{\rho cp D}$$

$$\therefore \frac{\partial T}{\partial t} = -u \left(\frac{\partial T}{\partial x}\right) - \alpha (T - T_a) \quad (4)$$

By L.T:

$$sT(s) = -u \frac{dT(s)}{dx} - \alpha (T(s) - T_a)$$

Rearranging:

$$-u \frac{dT(s)}{dx} = (s + \alpha) T(s) - T_a \quad (5)$$

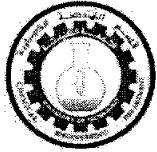
$$\frac{dT(s)}{(s + \alpha) T(s) - T_a} = \frac{-dx}{u} \quad (6)$$

Integrating from $T = T_1$ at $x = 0$ to $T = T_2$ at $x = x$

$$\frac{(s + \alpha) T_2(s) - T_a}{(s + \alpha) T_1(s) - T_a} = \exp \left[-\frac{(x/u)(s + \alpha)}{\alpha} \right] \quad (7)$$

$$\therefore \frac{T_2(s)}{T_1(s)} = \exp \left[-\frac{(x/u)(s + \alpha)}{\alpha} \right] \quad (8)$$

$$= \exp \left[-\frac{(x/u)s}{\alpha} - \frac{x/u}{\alpha} \right]$$



University of Technology
Chemical Engineering Department



Subject: Biochem. Eng.
Branch: Chemical Processing Eng.
Examiner: Lecturer Nagham A.A.

2nd attempt Examination

2011/2012

Class: 3rd
Time: 3 hours
Date : 3/September

Note :Answer four questions only

Q.1 Achemostat study was performed with yeast .The medium flow rate was varied and the steady state concentration of glucose in fermenter were measured and recorded. The inlet concentration of glucose was set at ($C_{s0} = 100 \text{ gm/L}$) .

The volume of the fermenter contents was (500 ml).The inlet stream was sterile

Flow rate F , (ml/hr):	31	50	71	91	200
Substrate con. C_s , (gm/L):	0.5	1.0	2.0	4.0	100

Find the rate equation for cell growth .

(15marks)

Q.2 A specific enzyme acts as catalyst in the enzyme reaction of substrate (A) as the reactant .At a given enzyme concentration in the aqueous feed stream (25 L/min),find the volume of mixed flow reactor (CSTR) needed for 95% conversion of reactant A, ($CA_0=2 \text{ mol/L}$) .The kinetic of the enzyme reaction at this enzyme concentration is given by :



(15marks)

Q.3 Define the following terms:-

- | | |
|----------------------------|-----------------------------|
| 1- Activation energy | 2- Continuous sterilization |
| 3- Inhibitor | 4- Damköhler number |
| 5- Transition state theory | |

(15marks)

Q.4 What are the most common aerobic biological treatment processes? Explain them with sketch.

(15marks)

Q.5 A) Derive the relationship show how the substrate concentration is changing with respect to time in batch bioreactor.

B) What are the methods of heat transfer in biological reactors?

(15marks)

find the rate equation by evaluation of Monod kinetic Q1

$$\mu = \frac{\mu_{max} \cdot C_s}{K_s + C_s} \quad \text{monod eq.}$$

$$\frac{1}{\mu} = \frac{K_s + C_s}{\mu_{max} \cdot C_s}$$

$$\frac{1}{\mu} = \frac{K_s}{\mu_{max} \cdot C_s} + \frac{1}{\mu_{max}}$$

$$\frac{1}{\mu} = \frac{1}{\mu_{max}} + \frac{K_s}{\mu_{max}} \cdot \frac{1}{C_s}$$

$$\text{slope} = \frac{K_s}{\mu_{max}}$$

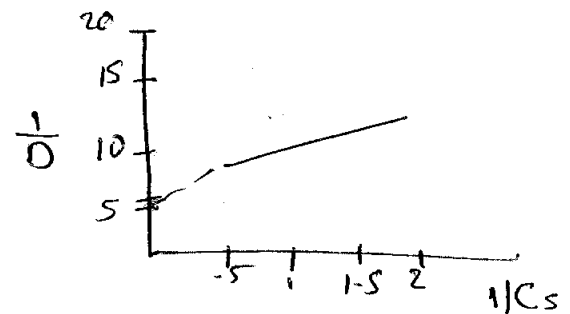
$$\text{Int} = \frac{1}{\mu_{max}}$$

Let assume that the growth rate can be expressed by monod kinetic. If this assumption is reasonable the plot of $(1/\mu)$ vs $(1/C_s)$ will result in a straight line according to the equation.

$$D = \mu = \frac{F}{V} = \frac{31}{500} = 0.062 \text{ hr}^{-1}$$

$$\frac{1}{D} = \frac{1}{\mu} = 16.12 \text{ hr}$$

D	$1/D$	$1/C_s$
0.062	16.12	2
0.1	10	1
0.14	7.04	0.5
0.182	5.44	0.25
0.4	2.5	0.01



$$\text{Int} = \frac{1}{\mu_{max}} = 3.8$$

$$\text{slope} = \frac{K_s}{\mu_{max}} = 5.2$$

$$\mu_{max} = 0.26 \text{ hr}^{-1}$$

$$K_s = 1.37 \text{ g/L}$$

∴ The rate eq. of cell growth

$$\mu_x = \frac{0.26 \cdot C_s \cdot C_x}{1.37 + C_s}$$

المعادلة هي معادلة مونود
Monod
وتكتب كالآتي

①

Solution Q2

$$v = F = 25 \text{ L/min}$$

$$\text{conversion} = 95\% \quad C_{A0} = 2 \text{ mol/L}$$

find the Vol of CSTR

$$-r_A = \frac{0.1 C_A}{1 + 0.5 C_A} \text{ mol/L} \cdot \text{min}$$

$$C_A = C_{A0}(1 - x)$$

$$= 2(1 - 0.95)$$

$$C_A = 0.1 \text{ mol/L}$$

mole balance.

$$F \cdot C_{A0} - F \cdot C_A - r_A V = 0 \text{ at S-S}$$

$$\left[\begin{aligned} F(C_{A0} - C_A) &= r_A \cdot V \\ \frac{F}{V}(C_{A0} - C_A) &= \frac{0.1 C_A}{1 + 0.5 C_A} \end{aligned} \right]$$

~~→~~

$$F(C_{A0} - C_A) - r_A V = 0$$

$$25(2 - 0.1) - \frac{0.1 C_A}{1 + 0.5 C_A} \cdot V = 0$$

$$V \left(\frac{0.1 C_A}{1 + 0.5 C_A} \right) = 25(2 - 0.1)$$

$$V = \frac{25(2 - 0.1)}{\frac{0.1 \times 0.1}{(1 + 0.5 \times 0.1)}}$$

$$V = 5 \text{ m}^3$$

$$= 4987.5 \text{ L}$$

2

2

Q3

1-A-E = Colliding molecules must possess a certain amount of energy to cross the potential barrier in order for the reaction to take place. The A-E of a reaction can be calculated by ~~A~~ Arrhenius Eq.

$$k = k_0 \exp\left(\frac{-E}{RT}\right).$$

k = rate constant

k_0 = Arrhenius constant

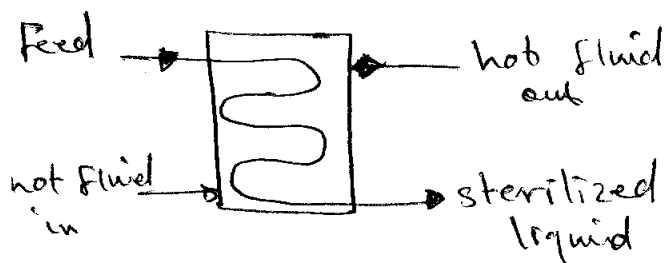
R = gas constant

T = Temp.

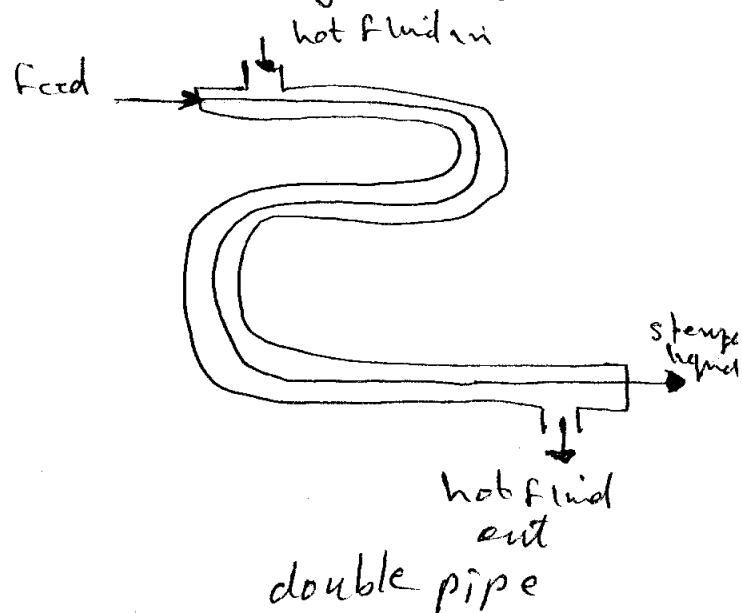
E = Activation energy.

2- Continuous sterilization

Are a tubular design with high temp. and short residence time. The liquid flows through the tube at high velocity and the wall is heated by heating fluid.



Shell and tube



3

1 - Inhibitor = Is a substance which can combine with enzyme to alter their catalytic activities. It can decrease the rate of reaction either

a - competitively .

b - non competitively .

c - partially competitively .

4 - N_{Da} = is the ratio of the maximum reaction rate over the max mass transfer rate $N_{Da} = \frac{V_{max}}{K_s - a \cdot C_{sb}}$

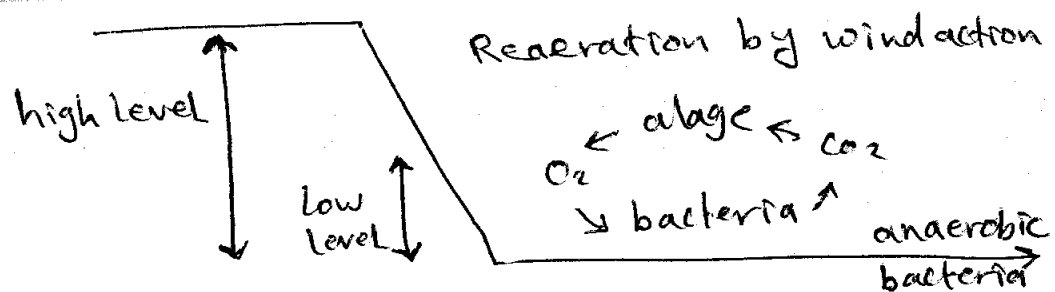
5 - Transition state theory :-

According to the transition state theory, chemical reactions proceed via the formation of an unstable intermediate between reactants and products. This unstable intermediate disintegrates to a more stable one and so must possess more free energy than stable compound.

Q 11
The most common aerobic biological treatment processes are :-

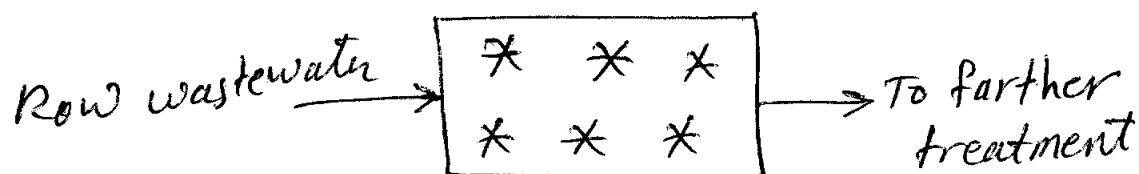
1- Oxidation pond

Oxidation pond are systems for storage and treatment of w.w. The natural combination of O_2 using bacteria and O_2 producing algae present in such ponds converts the organic waste into stable end products and produce a final effluent which can be discharged to the nearest acceptable drainage course.



2- Aerated lagoon

The aerated lagoon system consist of a large pond or tank that is equipped with mechanical aerators to maintain an aerobic environment and to prevent settling of the suspended biomass.

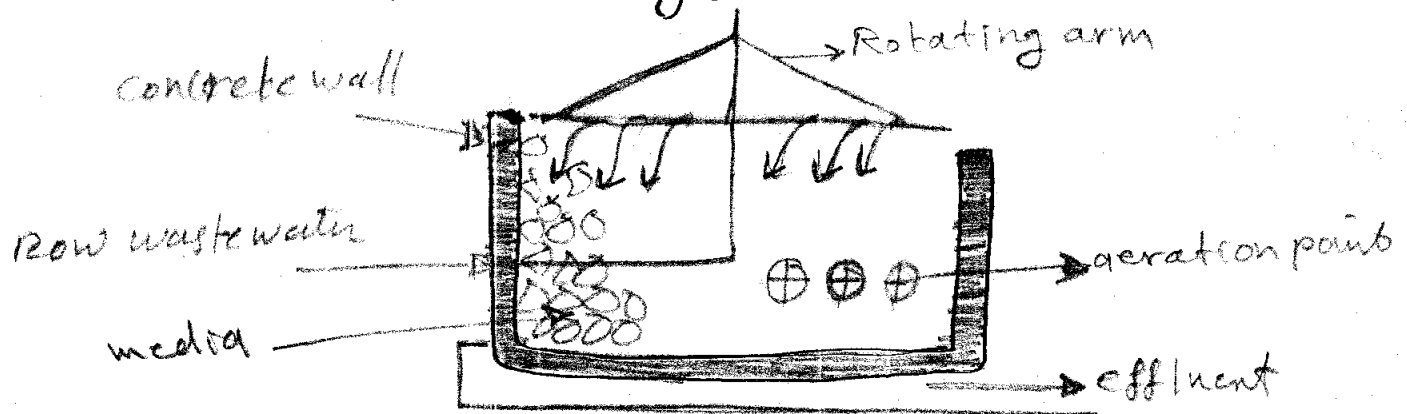


Trickling filter

Is an attached growth biochemical treatment process.

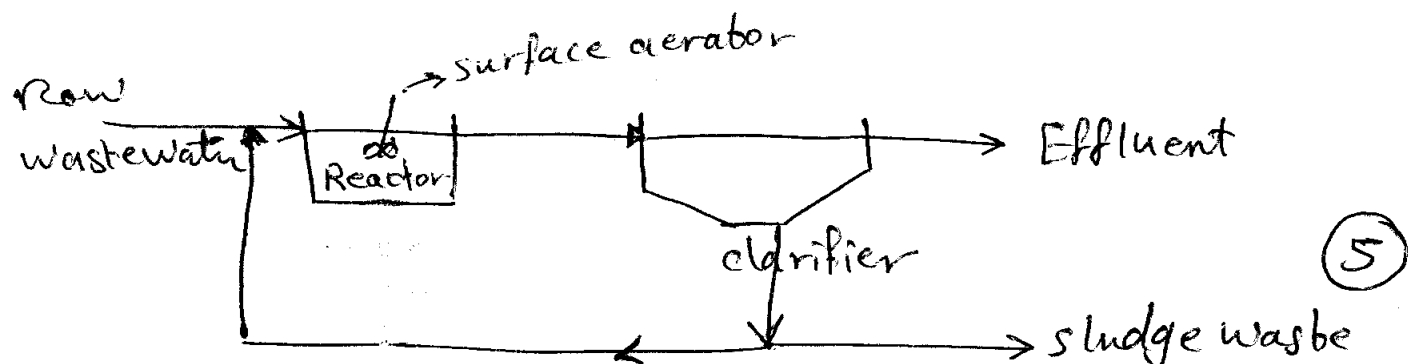
The filter medium consists of a bed of an inert material to which microorganisms attach themselves and through which the wastewater is percolated.

(Rocks or plastic rings).



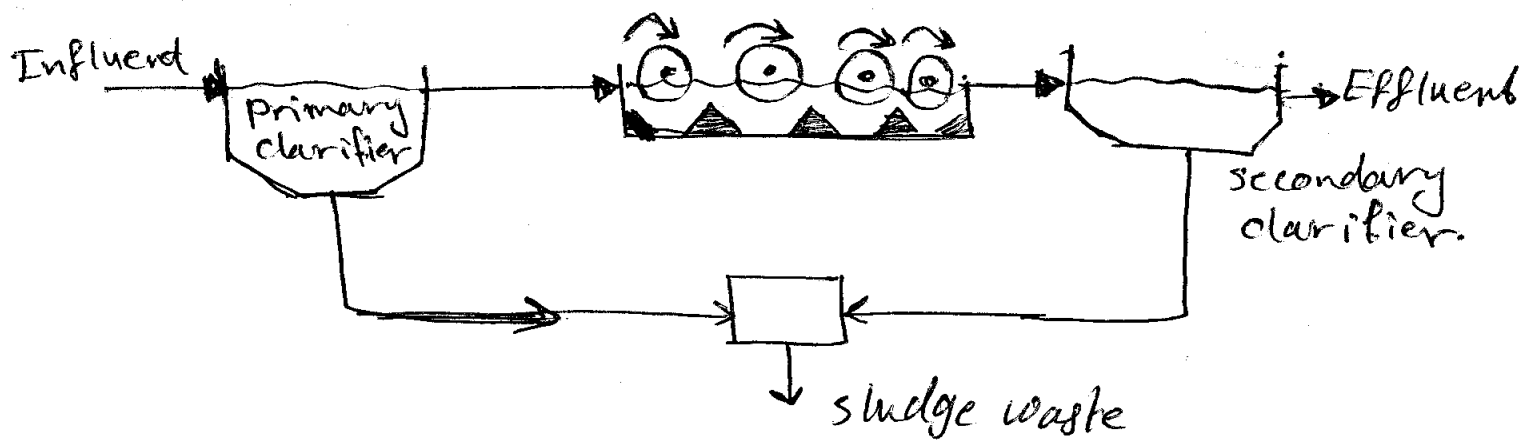
4- Activated sludge -

The activated sludge is a suspended-culture. The settled sludge containing living or active microorganisms is returned to the reactor to increase the available bio mass and speed up the reactions. The process is aerobic, with oxygen being supplied by dissolution from entrained air.



2 Rotating biological contactor (RBC)

The rotating biological contactor consist of a series of closely spaced, paralalled disks that rotate at an average rate from (1-2) r/min. The disks are submerged in the wastewater to about 40% of their diameter and rotated by power supplied to the shaft. Each disk covered with a biological slim that degrades dissolved organic that are present in wastewater.



Q5 - A

From M.M.E

$$-\frac{dC_s}{dt} \propto \frac{V_{max} \cdot C_s}{K_m + C_s}$$

$$\left[-(K_m + C_s) \cdot dC_s = V_{max} \cdot C_s \cdot dt \right] \div C_s$$

$$-\left(\frac{K_m + C_s}{C_s} \right) \cdot dC_s = V_{max} \cdot dt$$

$$-\left(\frac{K_m}{C_s} + 1 \right) \cdot dC_s = V_{max} \cdot dt$$

$$-\left[K_m \frac{dC_s}{C_s} + dC_s \right] = V_{max} \cdot dt$$

$$-\left[K_m \int_{C_{s0}}^{C_s} \frac{dC_s}{C_s} + \int_{C_{s0}}^{C_s} dC_s \right] = V_{max} \int_0^t dt$$

$$K_m \cdot \ln \frac{C_{s0}}{C_s} + (C_{s0} - C_s) = V_{max} \cdot t$$

this equation show how C_s changing with respect to time. (reaction time).

Q5-B

what are the methods of heat transfer in Biological Reactors

- 1- Externally jacketed vessels.
- 2- Coils inserted in a large vessels
- 3- Flow through a heat exchanger
- 4- Evaporation and condensation



University of Technology
Chemical Engineering Department



Subject: Combustion Engineering
Branch: Oil & Gas Refinery Engineering
Examiner: zainab Y. Shnan

Final Examination

2011/2012

Class: Third
Time: 3 hours
Date: 7/6/2012

Attempt four questions only

Q1:- A natural gas with the composition by volume $\text{CH}_4 = 98\%$ and $\text{N}_2 = 2\%$ burnt with 200 % by volume excess air. If 80% from methane change to CO_2 and 15% to CO and 5% not burned determine:-

1. Composition of flue gas.
2. The operating air fuel ratio.
3. The height of chimney if the draught is 15 mm water and the temperature of flue gases is 300°C and the temperature of air is 20°C . (25 mark)

Q2 :- Stack gas analysis of a natural gas-fired furnaces gave the following analysis 4% O_2 , 10% CO_2 , 17% H_2O , 86% N_2 all a dry basis the fuel was 75% C_2H_6 , 25% C_3H_8 by volume and the higher heating value was 23.3 Btu/lbm the fuel and air entered the furnace at 77°F and the stack gas temperature was 340°F . No blower was used and heat losses were negligible what the operating efficiency of this furnaces is and what is the excess air? (25 mark)

Enthalpy at 340°F (kBtu/lbmole)

[$\text{CO}_2 = 2.528$, $\text{H}_2\text{O} = 2.142$, $\text{N}_2 = 1.838$, $\text{O}_2 = 1.882$], H_{fg} of water = 1050 kBtu/lb

Q3:- A/ what is the flammability limits (with details).

B/In a flow calorimeter 36 mg/s of graphite particulate reacts completely with oxygen initially at 25°C to form carbon dioxide at 1 atm and 25°C . the rate of heat absorbed by the calorimeter water is 420 W. Find the heat of formation of CO_2 . (25 mark)

Q4:- A/Determine the upper and lower heating values at 298 K of gaseous n-decane $\text{C}_{10}\text{H}_{22}$ per kmole of fuel and per kg of fuel. The molecular weight of n-decane is 142.28.

B/ If the enthalpy of vaporization of n-decane is 359 kJ/kg fuel at 298 K. what are the upper and lower heating values of liquid n-decane. (25 mark)

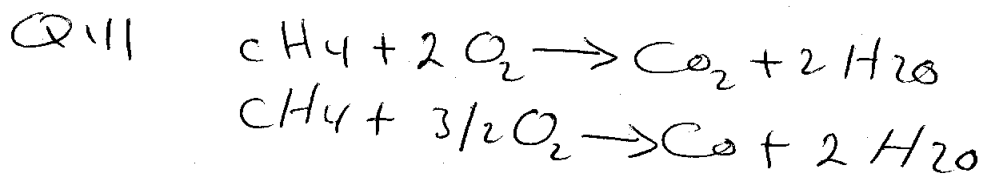
Enthalpy at 298 K (kJ/kmole)

$\text{CO}_2 = -393,596$, $\text{C}_{10}\text{H}_{22} = -249,659$, $\text{H}_2\text{O} = -241,847$, H_{fg} of $\text{H}_2\text{O} = -285,857$ kJ/kmole

Q5:- A/ Calculate the adiabatic flame temperature using the approximate equation. For bituminous coal is burned to completion with 50% excess air. The as received ultimate analysis of the coal is 70% wt carbon, 5% hydrogen, 15% oxygen, 5% moisture and 5% ash.

$\text{LHV} = 10100$ kJ/kg $C_p = 1.17$ kJ/kg.k.

B/ Explain the effect of reactant pressure and temperature on laminar burning velocity and how can calculate the critical velocity for any gas at any temperature. (25 mark)



Basis: 100 mole of Fuel gas

eq(1): moles of O_2 required for complete combustion

$$\frac{98}{\text{mole } \text{CH}_4} \times \frac{2 \text{ mole } \text{CO}_2}{1 \text{ mole } \text{CH}_4} = 196$$

$$\% \text{ excess } \text{O}_2 = \% \text{ excess air} = \frac{\text{excess } \text{O}_2}{\text{required } \text{O}_2} \times 100$$

$$\therefore \text{excess } \text{O}_2 = \frac{200}{100} \times 196 \text{ moles } \text{O}_2 = 392 \text{ mole } \text{O}_2$$

$$\text{inlet } \text{O}_2 = 196 + 392 = 588 \text{ mole } \text{O}_2$$

$$\text{inlet } \text{N}_2 = 588 \text{ mole } \text{O}_2 \times \frac{79 \text{ mole } \text{N}_2}{21 \text{ mole } \text{O}_2}$$

$$\begin{aligned} \text{eq(1) moles of } \text{CO}_2 &= 98 \text{ moles } \text{CH}_4 \times \frac{1 \text{ mole } \text{CO}_2}{1 \text{ mole } \text{CH}_4} \times \frac{80}{100} \\ &= 78.4 \text{ mole } \text{CO}_2 \\ &= \text{H}_2\text{O} = 98 \text{ moles } \text{CH}_4 \times \frac{2 \text{ mole } \text{H}_2\text{O}}{1 \text{ mole } \text{CH}_4} \times \frac{80}{100} \\ &= 156.8 \text{ mole } \text{H}_2\text{O} \\ &= \text{O}_2 = 98 \text{ moles } \text{CH}_4 \times \frac{2 \text{ mole } \text{O}_2}{1 \text{ mole } \text{CH}_4} \times \frac{80}{100} \\ &= 156.8 \text{ mole } \text{O}_2 \end{aligned}$$

$$\begin{aligned} \text{eq(2) moles of } \text{CO} &= 98 \text{ moles } \text{CH}_4 \times \frac{1 \text{ mole } \text{CO}}{1 \text{ mole } \text{CH}_4} \times \frac{15}{100} \\ &= 14.7 \text{ mole } \text{CO} \\ &= \text{H}_2\text{O} = \\ &= \text{O}_2 = \end{aligned}$$

$$\text{out let } \text{O}_2 = 588 - (\text{mole of } \text{O}_2 \text{ in eq(1)} + \text{mole of } \text{O}_2 \text{ in eq(2)})$$

$$\text{out let } \text{H}_2\text{O} =$$

$$= \text{N}_2 =$$

$$= \text{CH}_4 =$$

<u>stack gas</u>	<u>mole</u>	<u>%</u>
CO ₂	/	/
CO	/	/
H ₂ O	/	/
O ₂	/	/
N ₂	/	/
CH ₄	/	/

$$\phi = \frac{(F/A)_{\text{actual}}}{(F/A)_{\text{stoic}}}$$

$$H = \frac{h}{353 \left[\frac{1}{T_1} - \frac{\omega + 1}{\omega} * \frac{1}{T} \right]}$$

$$\omega = \frac{\text{air weight}}{\text{fuel weight}}$$

$$\text{air weight} = (N_{O_2} + N_{N_2}) * 29$$

$$\begin{aligned} \text{fuel weight} &= \text{CH}_4 \\ &= 1 * 0.98 \\ &= 1 \text{ kg} \end{aligned}$$

$$Q_{211} \quad CH = \frac{X_{N_2} - X_{O_2}}{3.76} = \frac{85}{3.76} = 21.2\%$$

The wet product analysis by volume is

$$O_2 = \frac{4}{1.17} = 3.42\%, \quad CO_2 = 8.55\%, \quad H_2O = 14.53\%, \quad N_2 = 73.05\%$$

$$\frac{N_c}{N_F} = 0.75 \times 2 + 3 \times 0.25 = 2.25$$

$$\frac{N_P}{N_F} = \frac{2.25}{0.855} = 2.63$$

$$H_{sp} = 0.0342 \times 1.882 + 0.0855 \times 2.525 + 0.1453 \times 2.142 + 0.7305 \times 1.838 = 1.94 \text{ KJtu/lbmole}$$

$$MF = 0.75 \times 30 + 0.25 \times 44 = 33.5 \text{ lb/lbmole}$$

$$HHV = 23.3 \times 33.5 = 780.55$$

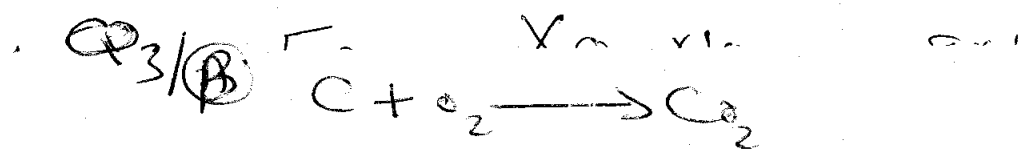
$$LHV = 780.55 - 0.1453 \times 1.03 \times 18 \times 14.5 = 741.55$$

$$\eta = \frac{741.55 - 145 \times 1.94}{741.55}$$

Q3// (A) سواء خلية الوقود قابلة للاستخدام عند تدرج
في الوقود في الخلية بين طين احوال ودرجات لدرجات الوقود واما عند
اتق واحد نسبة للوقود في خلية عند حرق الخلية فية نسبة للوقود خارج
الخلية طين بواسطة حرارة كهربائية فليكون الى حدوث تفاعل كيميائي
من خلية الهيدروجين وبنسبة ذلك هو انه ناتج الهيدروجين وبنسبة الخلية باخذ من
الحرارة المتولدة منه الى ان الكهرباء كذا نقل الحرارة الى الماء لتنتج بخار
ل: احد لدرجات و احوال لتقابل لدرجات
للخط الهيدروجين

$$L = \frac{100}{\frac{a_1}{b_1} + \frac{a_2}{b_2} + \frac{a_3}{b_3}}$$

اذا كانت النسبة المتفاوتة في الوقود



$$\text{No of mole of } (C) = \frac{W}{Mwt} = \frac{24 \times 10^{-3} \frac{gm}{s}}{12 \frac{gmole}{s}} = 0.002 \frac{gmole}{s}$$

C	CO ₂
1	1
0.002	X

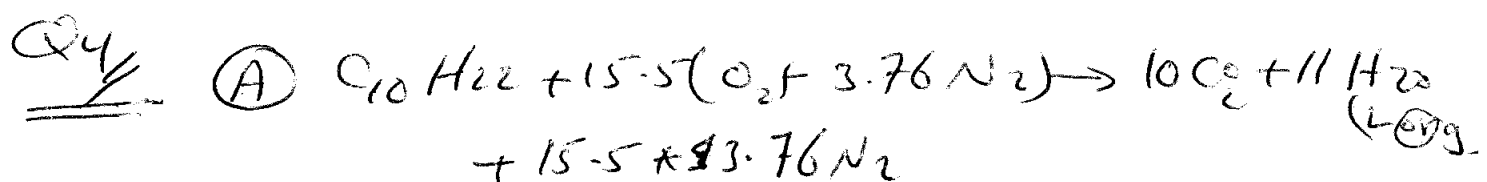
$$X = N_{CO_2} = 0.002 \frac{gmole}{s}$$

In = out

the energy balance $(Wh)_r = (Wh)_p + q$

$$0 = (N \Delta h)_{CO_2} + q$$

$$\Delta h_{CO_2} = \frac{-787 \text{ W}}{0.002 \frac{gmole}{s}} = -393.5 \frac{MJ}{kgmole}$$



$$\Delta H_c = -\Delta H_R = H_{\text{react}} - H_{\text{prod}}$$

$$H_{\text{react}} = \sum_{\text{react}} N_i h_i, \quad H_{\text{prod}} = \sum_{\text{prod}} N_i h_i$$

$$\Delta H_{c, H_2O(l)} = H_{H_2O} = 1 \text{ hf} - [10 \text{ hf}_{CO_2} + 11 \text{ hf}_{H_2O(l)}]$$

$$\text{hf}_{H_2O(l)} = -285857 \text{ KJ/Kmole}$$

$$\Delta H_{c, H_2O(l)} = 1(-244.659) - [10(-393.546) + 11(-285.8)]$$

$$= 6830096$$

$$\Delta h_c = \frac{\Delta H_c}{N_{C_{10}H_{22}}} = \frac{6830096}{1 \text{ Kmole}} = 6830096 \frac{KJ}{Kmole}$$

$$\Delta h_c = \frac{\Delta h_c^*}{\text{Mwt}_{\text{C}_{10}\text{H}_{22}}} = \frac{6830096}{142.284} = 48003$$

For the lower heating value we use $h_f \text{H}_2\text{O(g)} = -24184 \frac{\text{kJ}}{\text{kmole}}$

in place $h_f \text{H}_2\text{O(l)} = -285857 \text{ kJ/kmole}$

$$\Delta h_c^* = 6345986 \frac{\text{kJ}}{\text{kmole}}$$

$$\Delta h = 44601 \frac{\text{kJ}}{\text{kg}}$$

(B) For $\text{C}_{10}\text{H}_{22}$ in the liquid state

$$H_{\text{reac}} = 1(h_f \text{C}_{10}\text{H}_{22}(\text{g}) - h_f \text{g})$$

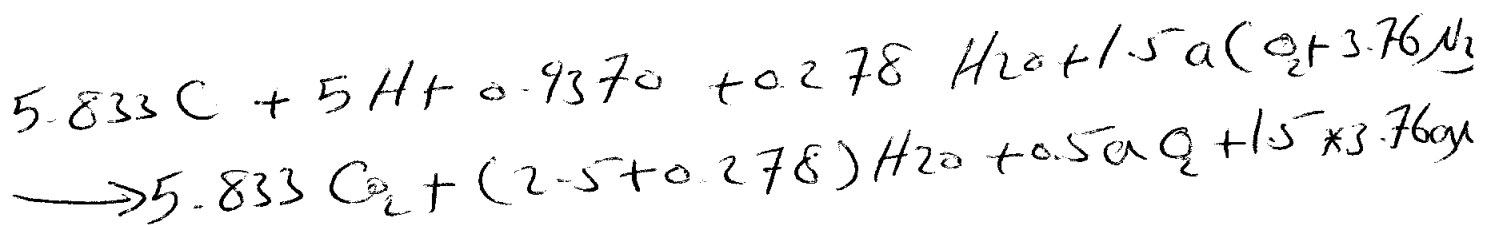
$$\Delta h_c(\text{liq}) = \Delta h_c(\text{fuel}) - h_f \text{g}$$

$$\Delta h_c(\text{higher}) = 48003 - 359 = 47644 \frac{\text{kJ}}{\text{kg}}$$

$$\Delta h_c(\text{lower}) = 44601 - 359 = 44242 \frac{\text{kJ}}{\text{kg}}$$

Q5// Basis for 100 kg of coal

Species	M(kg)	M(kg)/(kmole)	N(kmole)
C	70	12	5.833
H	5	1	5
O	15	16	0.937
H ₂ O	5	18	0.278



$$a = \frac{5.833}{4} - \frac{0.937}{2} = 6.614$$

$$P = \frac{100}{100 + 1.5 \times (1 + 3.76) \times 29} = 0.073$$

$$T_{\text{flame}} = T_0 + \frac{F}{1+F} \frac{LHV}{C_p}$$

$$= 298 + \frac{0.073}{1+0.073} \frac{10100}{1.17}$$

$$= 885.29 \text{ } ^\circ\text{C}$$

سرعت الحرق لأستيباتل بزيادة الضغط

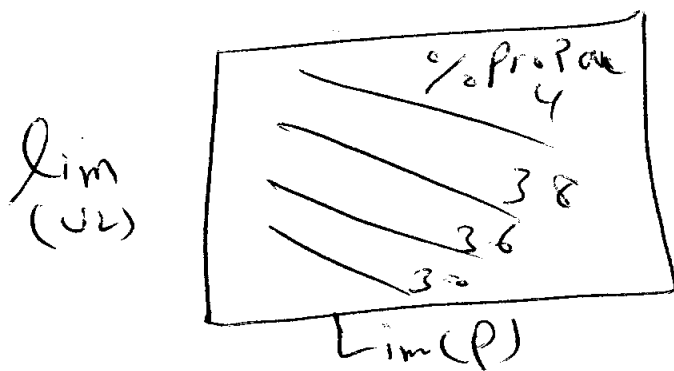
(13)

$$V_L = a \cdot P^\beta$$

$P = \text{Press in atm}$

$$\beta = 0 \rightarrow 0.5$$

الضغط يزداد وسرعة الحرق تزداد
الدفعات لذلك يتزايد عدم اليقين في سرعة الحرق

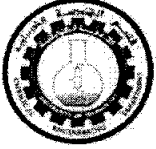


السرعة الحرق للهيدروجين عند أي ضغط حرق يتزايد بزيادة الضغط

$$\text{critical velocity} \left(\frac{\text{ft}}{\text{sec}} \right) = \frac{32.17 \times R \times 1544 \times \frac{C_p}{C_u}}{M_{wt}}$$

$R \rightarrow R^\circ$ درجة الحرارة

$\frac{C_p}{C_u} \rightarrow$ نسبة الجزيئات



University of Technology
Chemical Engineering Department
Final Examination



Subject: Democracies
Branch: Both Branch
Examiner: Dr. Bushra

2011/2012

Class: Third
Time: 3 hours
Date: /may

ملاحظة: الإجابة على ثلاثة أسئلة.

س1/ أ- ما هي جماعة الضغط وما هو الفرق بينها وبين الأحزاب السياسية ؟

ب- ما هي أركان الديمقراطية عددها فقط؟

(20 درجة)

س2/ أ- هناك تحديات تواجه عملية التحول الديمقراطي في الوطن العربي. وضح ذلك؟

ب- البرجوازية الحامل الطبيعي للديمقراطية. وضح ذلك.

(20 درجة)

س3/ أ- ما هي محاسن الديمقراطية وما هي مساوئها؟

ب- ما هي أهم المشاكل التي تواجه تطبيق الديمقراطية في الوطن العربي؟

(20 درجة)

س4/ أ- ما هي أسباب انهيار الديمقراطية؟

ب- يرى بعض المحللين عدم صلاحية النظام الديمقراطي للمجتمعات الإسلامية وضح ذلك؟

(20 درجة)

تمنياتي لكم بالنجاح

هو اجتهاد (ب)

احكامه اربعة الفها كالتفصيل

اولها: في السيرة والادب والمجتمعات والازمة لا يقتصر
عنه ما تقتضي بعض الادب من ازمة اقتضاه وقت في نظام
عريقه والادب المستقر والركود لا يقتصر فيه عين اذن
في ليل القابل لكل شيء الا انه لا يقتصر في السيرة
فقط كل الذي في الحياة الحاضرة من اوزم
فيها يستقل المعارضة فيها الفهم وسد الباب
المعارضة للديمقراطية لا يخافه من كل احد

ثانيها: في الوضوح والبيان في استقر بعض الادب
الثاني في تعدد الامور وتقلب الكمالات المتعددة
وسقوط المواقف في اكلوم الديمقراطية
فما حركه الفهم في صلب الوضوح

ثالثاً - السَّعْيُ فِي السَّعْيِ لِمَعْرِفَةِ الْحَقِّ وَالْعَمَلِ
بِمَنْ يَكُونُ نِعْمَةً دُونَ الْحَقِّ الْحَقِّ لِمَعْرِفَةِ الْحَقِّ
عَرَضِيَّةً لِنَفْسِهِ وَالتَّعَاقُتِ الْفَوَاحِشِ وَتَهْدِيهِ
الرُّؤْيَا الْأَمَّا الْعَارِضُ فِي عَيْنِ كَاهِلِ السَّعْيِ وَالْمَقَامِ
لِقُدْرَتِهِ فَوَيْلٌ لِمَنْ كَتَمَ ذَلِكَ تَوْبَةً

رابعاً - استغناء السَّعْيِ الْعَنَامِ وَالسَّعْيِ
الْمُتَعَرِّضِ لِلْوُجْهِ الْإِقْتِرَافِ الْمُسْتَأْزِمِ وَبِطْنِ وَعَالِيهِ
لِحُضْرَةِ الْمَرْحُومَةِ الْأَمَامِ الْعِيَادَةِ الْكَرِيمَةِ وَالْقَدَرِ
عَلَى الْكِبَرِيَّةِ أَمَّا لَمْ يَحْتَلَمْ حَيْثُ يَكُونُ بَارِعاً
مَعْدُوداً إِلَى السَّعْيِ وَالْعَمَلِ عَنِ الْمَرْحُومَةِ
الْإِقْتِرَافِ بِرَحْمَةِ وَاقِعَةِ السَّعْيِ الْإِلَهِيِّ الْإِسْرَافِ
وَيَقْضُونَ عَلَى الْقَوَاضِ الْمُتَعَلِّقِ بِالْعَمَلِ الْعَنِفِ الْإِسْرَافِ

مساوى الديمقراطية

منتقدو الديمقراطية كشكل من أشكال الحكم يدعون بأنها تتميز بمساوى متصلة بطبيعتها وكذلك في تطبيقها. وبعض هذه المساوى موجودة في بعض أو كل أشكال الحكم الأخرى بينما بعضها الآخر قد يكون خاصاً بالديمقراطية

١ - الصراعات الدينية والعرقية

الديمقراطية وخاصة الليبرالية تفترض بالضرورة وجود حس بالقيم المشتركة بين أفراد الشعب، لانه بخلاف ذلك ستسقط الشرعية السياسية. أو بمعنى آخر أنها تفترض بان الشعب وحدة واحدة. ولأسباب تاريخية تفتقر العديد من الدول إلى الوحدة الثقافية والعرقية للدولة القومية. فقد تكون هناك فوارق قومية ولغوية ودينية وثقافية عميقة. وفي الحقيقة فقد تكون بعض الجماعات معادية للأخرى بشكل فاعل. فالديمقراطية والتي كما يظهر من تعريفها تتيح المشاركة الجماهيرية في صنع القرارات، من تعريفها أيضاً تتيح استخدام العملية السياسية ضد العدو. أما النظام غير الديمقراطي السابق قد كبت هذا التنافس الداخلي ومنعه من البروز إلى السطح. ولكن مع ذلك تظهر هذه الخلافات في الديمقراطيات العريقة وذلك على شكل جماعات معاداة المهاجرين. إن انهيار الإتحاد السوفيتي ودمقرطة دول الكتلة السوفيتية السابقة أديا إلى حدوث حروب وحروب أهلية في يوغسلافيا السابقة وفي القوقاز ومولدوفا كما حدثت هناك حروب في أفريقيا وأماكن أخرى من العالم الثالث. ولكن مع ذلك تظهر النتائج الإحصائية بان سقوط الشيوعية والزيادة الحاصلة في عدد الدول الديمقراطية صاحبها تناقص مفاجئ وعنيف في عدد الحروب والحروب الأهلية والعرقية والثورية وفي أعداد اللاجئين والمشردين

٢ - البيروقراطية :

أحد الانتقادات الدائمة التي يوجهها المتحررون والملكيين إلى الديمقراطية هو الإدعاء بأنها تشجع النواب المنتخبين على تغيير القوانين من دون ضرورة تدعو إلى ذلك والإتيان بسيل من القوانين الجديدة. وهو ما يُرى على أنه أمر ضار من عدة نواح. فالقوانين الجديدة تحد من مدى ما كان في السابق حريات خاصة. كما أن التغيير المتسارع للقوانين يجعل من الصعب على الراغبين من غير المختصين البقاء ملتزمين بالقوانين.

والنقد الآخر الموجه إلى الديمقراطية هو بطؤها المزعوم والتعقيد الملازم لعملية صنع القرارات فيها

٣ - التركيز قصير المدى :

إن الديمقراطية الليبرالية المعاصرة من تعريفها تسمح بالتغييرات الدورية في الحكومات. وقد جعلها ذلك تتعرض إلى النقد المألوف بأنها أنظمة ذات تركيز قصير المدى. فبعد أربعة أو خمسة سنوات ستواجه الحكومة فيها انتخابات جيدة وعليها لذلك أن تفكر في كيفية الفوز في تلك الانتخابات. وهو ما سيشجع بدوره تفضيل السياسات التي ستعود بالفائدة على الناخبين (أو على السياسيين الإنتهازيين) على المدى القصير قبل موعد الانتخابات المقبلة، بدلاً من تفضيل السياسات غير المحبوبة التي ستعود بالفائدة على المدى الطويل

٤ - نظرية الاختيار الشعبي :

تعد نظرية الاختيار الشعبي جزءاً فرعاً من علم الاقتصاد يختص بدراسة سلوك إتخاذ القرارات لدى الناخبين والساسة والمسؤولين الحكوميين من منظور النظرية الاقتصادية. وأحد المشاكل موضع الدراسة هي أن كل ناخب لا يملك إلا القليل من التأثير فيظهر لديه نتيجة لذلك إهمال معقول للقضايا السياسية. وهذا قد يتيح لمجموعات المصالح الخاصة الحصول على إعانات مالية وأنظمة تكون مفيدة لهم ومضرة بالمجتمع.

٥ - حكومة الأثرياء :

إن كلفة الحملات السياسية في الديمقراطيات النيابية قد يعني بالنتيجة بأن هذا النظام السياسي يفضل الأثرياء،

ففي الديمقراطية الأثينية كانت بعض المناصب الحكومية تخصص بشكل عشوائي للمواطنين وذلك بهدف الحد من تأثيرات حكومة الأثرياء.

أما الديمقراطية المعاصرة فقد يعتبرها البعض مسرحية هزلية غير نزيهة تهدف إلى تهدئة الجماهير، أو يعتبرونها مؤامرة لإثارة الجماهير وفقاً لأجندة سياسية معينة. وقد يشجع النظام المرشحين على عقد الصفقات مع الأغنياء من مؤيديهم وأن يقدموا لهم قوانين يفضلونها في حال فوز المرشح في الانتخابات - أو ما يعرف بسياسات الاستمرار في الحفاظ على المناطق الرئيسية.

٦ - فلسفة حكم الأغلبية :

من أكثر الانتقادات شيوعاً والتي توجه إلى الديمقراطية هو خطر "طغيان الأغلبية".

ومن الانتقادات الكثيرة التي توجه إلى الديمقراطية :

• ان نسبة كبيرة من الناخبين "جهلة" لا يعرفون صالحهم ولا يجوز منحهم قرار تحديد سياسة الدولة وان التساوي في "القوة الانتخابية" بين الناخبين هو امر غير منصف ، فهل يمنح الشخص المتخلف الذي يعيش اليوم بعقلية القرون الغابرة والذي لا يعرف حتى القراءة والكتابة نفس الصوت والقدرة مثل الاستاذ الجامعي المتنور او القاضي الحكيم ؟

• في جميع المجتمعات وعلى مر العصور فان "النخبة" التي يجب ان تقود المجتمع هي "أقلية" انتخابية . والديمقراطية تؤدي الى سيادة مفاهيم الرعاع على المجتمع .
• ان اساس الديمقراطية هو عقلية القطيع التي تمنح الغلبة للكثرة وتؤدي الى اضطهاد الاقليات .

• وفي المجتمعات الحديثة نرى ان الاولويات في الانتخابات نادراً ما تكون صحيحة . ومن الامثلة على ذلك اندحار شخصيات مثل تشرشل وديغول ، والشؤون التي تعتبر مهمة في الانتخابات الأمريكية .

• ان القيادة غالباً ماتكون بيد فئة طبيعتها القدرة على تحريك البسطاء وبهجة الامور وكيل الوعود والادعاء بما لا يملكون من صفات حميدة (انظر استطلاعات رأي الناس في السياسيين في الدول الديمقراطية الحديثة) . ان الذين لهم القدرة على "تسويق" أنفسهم لا يكونون عادةً من النوع الرصين والوقور والعميق . اذا فان نوع القادة الذين تفرزهم العملية الانتخابية هم ليسوا من النوع المطلوب

وان الديمقراطية بطبيعتها تؤدي الى ساسة "مرنين" اكثر مما هو مطلوب وغير مبدئيين يحاولون ترضية القوى المختلفة المؤثرة في اعادة انتخابهم . أي ان الديمقراطية تمنح المتحذلقين وسيئي النية قدرة على السيطرة على جماهير من السذج

• كثرة التقلبات السياسية في البلاد والتي تشمل عادة جهاز الدولة

• ثبت في كثير من النظم الديمقراطية الحديثة وجود تأثيرات مهمة من الأعلام ومن جهات تعمل في الخفاء (ومثال ذلك تأثير المنظمات اليهودية والمؤسسة الصناعية – العسكرية في الولايات المتحدة)

• الصعوبة ، الصعوبة هي أن العقائديين يؤمنون أحيانا بصلاحيه مذهبهم الى الدرجة التي يضحون بأرواحهم في سبيلها وبطبيعة الحال لايمكن لهؤلاء ان يكونوا ديمقراطيين او ان يقتنعوا ان من حق فئة أخرى اكثر منهم عددا وتختلف معهم في المبدأ ان تمسك زمام الامور !

أحمد الزاهد
السنة الثامنة

2011-2-7

نهرى صندق
السنة ثمانية

موضوع الدرس

Date : / / الموافق

التاريخ /

☆ المثقف والسلامة ☆

هناك أسئلة ت طرح نفسها وهي هل المثقف
دائمًا وابدأ يؤيد السلامة ويطلق تبرير
لسياستها الفكرة تحت شعارات مختلفة

سؤال - ما هي السمات العامة لعلاقة المثقف
بالسلامة وهل تختلف من مجتمع إلى مجتمع
آخر ؟

الاشكالية المعروفة اليوم حول علاقة المثقف
بالسلامة وخاصة في المجتمعات التي سيطرت
عليها نظم استبدادية .

هنا نجد في موقف النخبة المثقفة من يؤيدها
ويحاول تبرير سياستها تحت شعارات
مختلفة .

فسمات العلاقة بين المثقف والسلامة تختلف
من بلد إلى آخر ومن مرحلة تاريخية إلى
مرحلة أخرى ويمكن أن نحدد فئتين
أساسيتين من رواد الحركة التنويرية العربية

موضوع الدرس _____ Subject _____

التاريخ / / الموافق / / Date :

١- فقه أولئك الذين كانوا في عصرهم دعاة
الاساسية من دعاة الحكم المطلق الاستبدادي

هل كانت لهذه الفقه المتفق لها دور في
اصلاح نظام السلطنة من خلال نشر افكارهم
الاصلاحية هنا ما سترأه فيما بعد

٢- فقه ثانيا كانت معارضة للسلطة الاستبدادية
حاولت الفقه الاول الاصلاح داخل السلطنة
السياسية عندها قدمت نموذجاً للسلطة في
الديار المتقدمة او الغربية
ومن جهة اخرى سعت الى تأسيس نظام
تعليمي عصري يعتمد على الحداثة
الهدف خلق جيل جديد من المتعلمين
الاصلاحيين

اما الفقه الثاني التي ايقنت لا اقل في الاصلاح
السياسي فكانت الهدف القضاء على
الحكم الاستبدادي المطلق وتأسيس نظم
دستورية جديدة وتحويل نظام الملك



موضوع الدرس _____
Subject _____

التاريخ / / الموافق / /
Date : / /

المستبد الى فلك حفيد بالقوانين لذلك ذهب
اليقظ الى ضرورة الثورة ضد هذه النظم
ان لنزاع الامر

السؤال المهم الذي يبرز في هذا المهدد
هل كان انهيار الفئه الثانيه قد ركن ان
لا يمكن تحقيق التقدم والاصلاح في تلك
الحكم الاستبدادي السلموي وان الك لا يريد
ان يبدأ بالتغيير حتى يقدم والمجتمع خموله
ثابته فوق الحداته الحقيقه الى

نعم ايمن درواز الفئه الثانيه انه لا بد من
مؤسسات دستوريه قائمه على العدل السياسي
والحرية

ولو كان انهيار هذه الفئه ان التغيرات
الدستوريه يجب ان لا تكون هوريه بل يجب
ان تكون عمليه تمثلا حقيقيا وان تكون
لها رقابته على السلطه
اي ان تكون الحكومه فسؤوليه اجام البرلمان
ولها الحق في سحب الثقة من اعضائه



موضوع الدرس _____
Subject 28 - 2 - 2011

التاريخ / / الموافق / /
Date :

خلاصة القول يمكننا ان نوكد بان المثقف ذو مرتبة رفيعة لانه يملك الوجدان البشري ويدافع عن مبادئه وقيمه وعما له ولكن اذا ما انقلب الدور واهج المثقف يملك وجدان السلمه او الحاكم فمن يكون وجدان المثقف عندما يهدر نفسه حاكما اي يعني وجود الحاكم والمثقف في شخص واحد ولهذا ما حدث في القرون الوسطى عندما كانت السلمه والمجتمع والمثقف في خدمه الكنيسه التي تقود المجتمع وتحكم باسم الكنيسه هكذا اهبج المثقف موظف فوكل لاهوت بل اهبج جلادا في خدمه السلمه التي كانت تجسد اندماج الدوله و الكنيسه.

٥. المثقف هنا هو ملح السلمه فاذا فسد الملح فماذا يملح السلمه اي يعني اخر ان المثقف هو الضابط للواقع ولانه الناطق باسم اوبلسان المثاليه والتي هي اعلى من الواقع فاذا اهبج المثقف واقعا فما هذا الضابط الذي يضبط الواقع وعليه ويجب عليه المثقف ذو مرتبة عاليه و رفيعة يرتقي اليها في كل الاوقات



١٠. وفيه المثقف هو انتاج اليوتوبيا وان
اليوتوبيا للمثقفين يجب ان تكون يوتوبيا
دائمة والذهبية الضمنية لليوتوبيا اذا ما تحولت
الى واقع.

فما لك على ذلك الماركسيه (السويعيه) كانت يوم
من الايام يوتوبيا ولكن عندما افترفت نفسها
واقعا للتطبيق العملي ازدرأت (استهزأت)
كل اليوتوبيات التي بقيت في المجتمع مثل
المدنية الفاضله للغرائبي وجمهورية افلاطون
وقدنيه السليب.

الذات هذه ان اليوتوبيا يجب ان تشق طريقها
للتفكير والتطبيق العملي ولا تبقى اليوتوبيا
مذاهبا مثل القنبلة الذرية التي وجدت لكي لا
تسحقك.

نقول ان اجمال ما في (اليوتوبيا) فطاليتها حادفت
يوتوبيا او فتي حادفت اليوتوبيا من فطاليتها
الخيالية النبيلة والمبالي التي منقير الحياة و
الواقع الا انها لا تستر شرا عند انتعاليها
الى حيز الوجود.



University of Technology
Chemical Engineering Department



Subject: Environmental Eng
Branch: Chem. Processing Eng.
Examiner: Dr. Jenan A. Al-Najar

Final Examination

2011/2012

Class: Third
Time: 3 hours
Date: 9 Sep.

Attempt four (4) questions only

Q1: Answer the following:

1. Define the global warming. What are the effects of global warming? How can control the global warming?
2. What are the types of water pollutants and their effects?

25 Mark

Q2: Answer the following:

1. Derive the terminal velocity equation and the terminal velocity in stocks region.
2. What are the factors that must be determined to choice the collection equipment for air pollution?

25 Mark

Q3: A gravity settling chamber in a small heating plat that uses a travelling grate stocks. You are requested to determine the overall collection efficiency of the settling chamber given the following operating conditions, chamber dimensions and particle size distribution data:

Chamber: width = 10.8 ft, height = 2.46 ft and length = 15 ft. The actual volumetric flow rate of contaminated air streams is 130 ft³/s. Particles specific gravity = 2.65. Particles size distribution data are given below:

Size range, dp, μm	0-20	20-30	30-40	40-50	50-60	60-70	70-80	80-94	+94
Weight percent, w%	2.7	6.9	9.4	10.5	10.5	9.5	7	9.5	34

Assuming the actual terminal velocity is one-half the stock law velocity. The air viscosity is 1.75x10⁻⁵ lb/ft.s.

25 Mark

Q4: Specific town discharges 0.4 m³/s of sewage into a nearby river. The river has flow rate of 0.7 m³/s with depth of 2 m and velocity of 6 km/h. Other information is:

	Temp. (°C)	DO (mg/l)	BOD5 (mg/l)
Stream	21	5.0	5.0
sewage	26	2.0	150

The deoxygenating constant (k_1) evaluated at 20 °C is 0.37 day⁻¹. The saturation concentration of dissolved oxygen at average temperature is 9 mg/l. Determine the critical oxygen deficit, Dc and its location, xc.

25 Mark

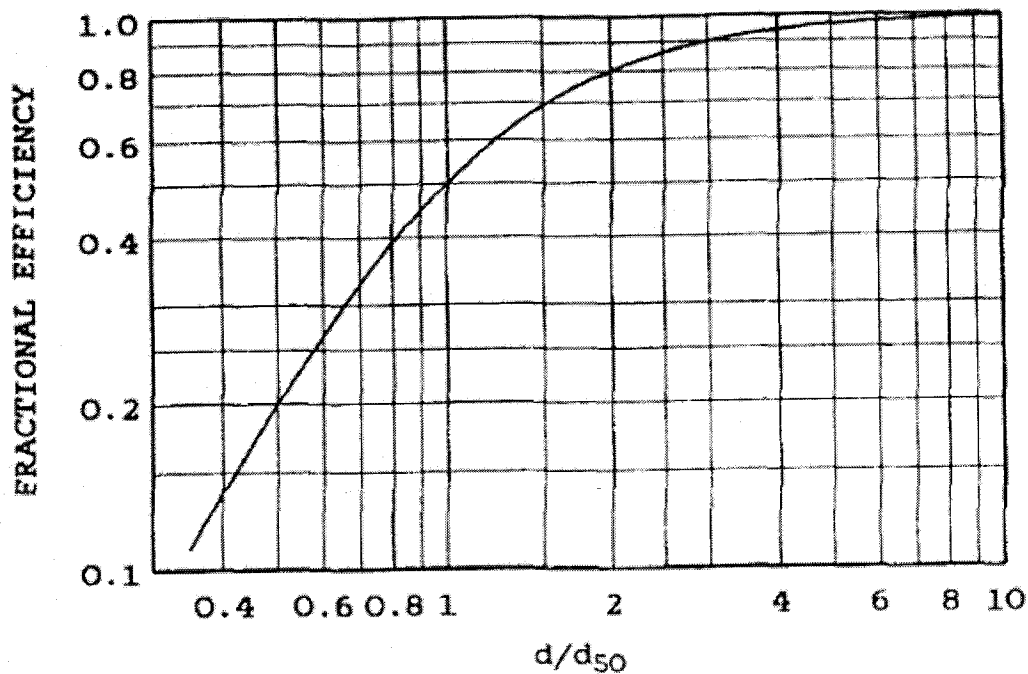
Q5- A particulate sample in an air stream has the following weight percent distribution:

Particle Size, $d_p, \mu\text{m}$	1	10	50	100	200
Weight percent, w%	10	20	40	20	10

A cyclone separator is employed in the basis of the following data inlet:

Cyclone width = 0.3 m, effective number = 5, inlet gas velocity = 6 m/s, particle density = 1.6 g/cm^3 , gas density = 1.2 kg/m^3 , gas viscosity = 0.018 mN.s/m^2 , using the figure below to estimate the percentage of the total weight, that would be removed in the cyclone.

25 Mark



Cyclone efficiency versus particle-size ratio

Good luck



University of Technology
Chemical Engineering Department



Subject: Environmental Eng
Branch: Chem. Processing Eng.
Examiner: Dr. Jenan A. Al-Najar

Final Examination

2011/2012

Class: Third
Time: 3 hours
Date : 7 June

Note: Answer only four questions.

Q1: Answer the following:

1. **Define the global warming. What are the effects of global warming? How can control the global warming?**

Global warming is increase in global average temperature near the Earth's surface as a result of increasing in concentration of greenhouse gases in the atmosphere from human sources. If more greenhouse gases are added to the atmosphere from human activities, they will absorb more of infrared radiation reflected by the Earth's surface. The surface and the lower atmosphere will warm further. This extra warming is called the enhanced greenhouse effect.

Effects of global warming

The following effects will results from the global warming (rising temperature):

- 1- Thermal expansion of the water and melting of polar ice caps would cause sea level to rise.
- 2- Could lead to changes in regional wind systems which would influence global rainfall distribution and lead to redistribution and frequently of flood, draught, and forest fires.
- 3- Climate change would create favorable conditions for growth in insect population, which this have bad effect on agriculture and human health.
- 4- Disrupts the Water supply and draughts would be more common.

Controlling global warming

- 1- Reduce deforestation and develop way to sustainable agriculture.
- 2- Use of technologies to absorb CO₂ from emission.
- 3- Increased absorption of CO₂ by planting more trees.
- 4- Sequester CO₂ in deep Ocean.
- 5- Increased dependence on renewable energy source.
- 6- Change and more environmentally complete life style.

2. What are the types of water pollutants and their effects?

The main pollutants in water are:

1. **Oxygen demanding wastes:**

a- **Dissolved oxygen, DO:**

Dissolved oxygen is the amount of oxygen dissolved in water to sustain the plant and animal life in any aquatic system.

b- **Biochemical oxygen demand, BOD:**

BOD is the measurement of the amount of oxygen utilized by microorganisms during oxidation of organic material. It is the most widely known measurement for assessing the water pollution by a given organic waste.

2. **pathogens:**

Pathogens are a disease causing agents. Water is a potential carrier of pathogenic microorganisms. These pathogens are carried into the water bodies by sewage and waste from farms and various industries.

3. **Refractory organic compounds:**

These include pesticides, herbicides, phenols, synthetic organic chemical and detergents. These compounds in contrast to the organic waste are not biodegradable and may persist for a long periods.

4. Nutrients:

Nutrients are the chemical material required to growth of aquatic life, Such as nitrogen and phosphorus. Nitrogen and phosphorus enter the water bodies directly from the manufacture and use of fertilizers and from the processing of biological material such as food and textiles. When large concentrations of nutrient are present in water, an excess growth of algae known as algae bloom appears. This produces an unsightly green slime layer over the surface of water body lead to eutrophication.

5. Inorganic chemical and minerals:

These include inorganic salts, mineral acids, and heavy metal compounds. Most of these are toxic and are capable of killing living organisms in the water bodies.

6. sediments:

These include soil, sand, and mineral particles or pulverized coal ash. Their effects increasing turbidity and consequently of reducing the amount of sunlight available to water plants.

7. Radioactive substances:

The refining of uranium is the most important source of radioactive waste producing radium, bismuth, etc. Radioactive substances can enter human with food and water and accumulated in blood, liver, muscular tissues (الانسجة العضلية) causing to serious of health problem to human kinds.

8. Thermal pollution

Power plant and industry use large quantities of water for cooling purpose. This could results in increase or decrease in the temperature of the water bodies and causing in the change in the percentage of dissolved oxygen in the aquatic media and decreases in the saturation percentage.

9. Oils:

Oils are important commodity and virtual for every human activity now. Oil wastes enter rivers and other water bodies from several sources like industrial effluents, oil refineries, storage tank, automobile waste oil, and petrochemical plants. Oil insoluble in water so it floats and spread rapidly into a thin layer. The lighter low molecular-weight elements, which are most toxic to organism, evaporate at slow rate effects on life in the water.

Q.2: Answer the following:

1. Derive the terminal velocity equation and the terminal velocity in stocks region. [3]

2. If the particle is settling in a fluid at its terminal velocity, three forces acting on it: drag, buoyancy, gravity force, as shown in Fig.8. The terminal settling velocity of the particles is found from forces balance as:

$$F_g = F_D + F_B$$

where

F_g = gravity force (secondary Newton law) = $m_p g$

$$F_D = \text{drag force} = F_D = \frac{\rho_g V_t^2 A C_D}{2}$$

$$F_B = \text{buoyancy force} = F_B = m_p \left(\frac{\rho_g}{\rho_p} \right) g$$

m_p = mass of particle = $\rho_p V_p$

g = gravitational acceleration, m^2/s

ρ_p = particle density, kg/m^3

ρ_g = gas density, kg/m^3

C_D = drag coefficient

V_t = terminal velocity, m/s

A = frontal cross sectional area, m^2

V_p = volume of particle, m^3

Substituting the overall balance then becomes

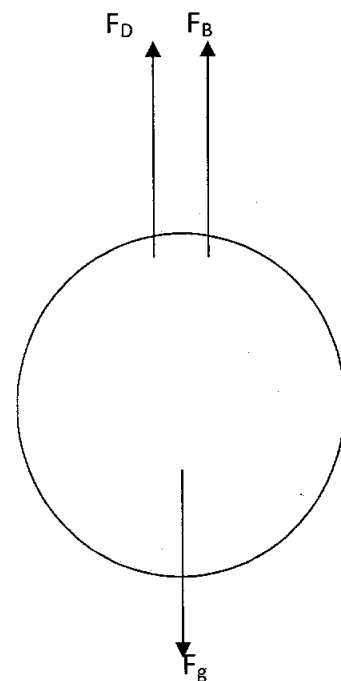


Fig.10. the forces acting on a particle in a fluid

$$m_p g = \frac{\rho_g V_t^2 A C_D}{2} + \left(\frac{\rho_g}{\rho_p} \right) g$$

The general solution to the equation, in term of V_t , is

$$V_t = \sqrt{\frac{2m_p g (\rho_p - \rho_g)}{\rho_p \rho_g A C_D}}$$

for spherical particle the **terminal velocity**:

$$V_t = \sqrt{\frac{4 g d_p (\rho_p - \rho_g)}{3 C_D \rho_g}} \quad (1)$$

where

$$V_p = \frac{\pi}{6} d_p^3, \quad A = \frac{\pi}{4} d_p^2, \quad m = \rho_p V_p$$

where

d_p = particle diameter, m

Eq.1 is the general equation for the terminal settling velocity

where C_D is the drag coefficient which is related to the particles Reynolds number,

$$Re_p = \frac{\rho_g V_t d_p}{\mu_g}$$

Where

The general drag coefficient for spherical particles may be represented by three relationships.

In Stocks law region, laminar flow around the particle

$$C_D = \frac{24}{Re_p}$$

Substituting Eq.(2) into Eq.(1), **we can calculate the terminal settling velocity in the Stokes region:**

$$V_t = \frac{g d_p^2 (\rho_p - \rho_g)}{18 \mu_g}$$

3. What are the factors that must be determined to choice the collection equipment for air pollution?

A number of factors must be determined before a proper choice of collection equipment can be made.

Among the most important data required are the following:

- 1- The physical and chemical properties of the particulates.
- 2- The range of volumetric flow rate of the gas stream.
- 3- The particulate size and concentration in gas stream.
- 4- The temperature and pressure of the flow stream.
- 5- The humidity.
- 6- The collection efficiency that required for outlet stream.

Q3: A gravity settling chamber in a small heating plant that uses a travelling grate stocks. You are requested to determine the overall collection efficiency of the settling chamber given the following operating conditions chamber dimensions and particle size distribution data:
 Chamber: width = 10.8 ft, height = 2.46 ft and length = 15 ft.
 Volumetric flow rate of contaminated air streams is $130 \text{ ft}^3/\text{s}$. Particles specific gravity = 2.65. Particles size distribution data are given below:

Size range,	0-20	20-30	30-40	40-50	50-60	60-70	70-80	80-94	+94
Weight	2.7	6.9	9.4	10.5	10.5	9.5	7	9.5	34

Assuming the actual terminal velocity is one-half the stock law velocity. The air viscosity $1.72 \times 10^{-4} \text{ lb/ft.s}$.

1.75×10^{-5}

25 Mark

Solution

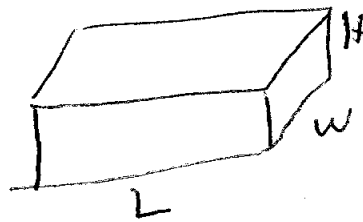
$$W = 10.8 \text{ ft}$$

$$H = 2.46 \text{ ft}$$

$$L = 15 \text{ ft}$$

$$Q = 130 \text{ ft}^3/\text{s}$$

$$\text{sp.gr of particle} = 2.65$$



$$V_{t \text{ actual}} = \frac{1}{2} V_t = \frac{1}{2} \frac{g d_p^2 (\rho_p - \rho_g)}{18 \mu g} \quad \text{--- (1)}$$

$$\eta = \frac{V_t L}{H u} \quad \text{--- (2)}$$

Sub eq. 1 into eq. 2

$$\therefore \eta = \frac{g d_p^2 (\rho_p - \rho_g) L}{36 \mu g H u} \quad \text{--- (3)}$$

$$\text{or } u = \frac{Q}{WH} \quad \text{--- (4)}$$

Sub eq. (4) into eq. 3 also neglecting ρ_g compare to ρ_p

$$\boxed{\therefore \eta = \frac{g d_p^2 \rho_p W L}{36 \mu g Q}} \quad \text{--- (5)}$$

$$P_p = 2.65 \times 62.4 = 165.4 \text{ lb/ft}^3$$

Using eq-5

$$\eta = \frac{(52.2) dp^2 (165.4) (10.8) (15)}{36 (1.75 \times 10^{-5}) (130) (304,800)}$$

عامل تحويل الوحدات

$$\eta = 1.14 \times 10^{-4} dp^2 \quad \text{--- (6)}$$

معامل dp

Rang dp	averag dp (mm)	W%	$\eta\%$	W% $\eta\%$ / 100
0-20	10	2.7	1.1	0.030
20-30	25	6.9	7.1	0.490
30-40	35	9.4	14	1.316
40-50	45	10.5	23	2.415
50-60	55	10.5	34	3.570
60-70	65	9.5	48	4.560
70-80	75	7	64	4.480
80-94	87	9.5	83	7.885
+94	+94	34	100	34.00
				<u>58.7</u>

\therefore The overall collection efficiency
for settling chamber is
58.7%

Q4: Specific town discharges $0.4 \text{ m}^3/\text{s}$ of sewage into a nearby river. The river has flow rate of $0.7 \text{ m}^3/\text{s}$ with depth of 2 m and velocity of 6 km/h. Other information is:

	Temp. ($^{\circ}\text{C}$)	DO (mg/l)	BOD ₅ (mg/l)
Stream	21	5.0	5.0
sewage	26	2.0	150

The deoxygenation constant (k_1) evaluated at 20°C is 0.37 day^{-1} . The saturation concentration of dissolved oxygen at average temperature is 9 mg/l. Determine the critical oxygen deficit, D_c and its location, x_c .

Solution

$$\text{sewage flow} = Q_{se} = 0.4 \text{ m}^3/\text{s}$$

$$\text{river flow} = Q_{ri} = 0.7 \text{ m}^3/\text{s}$$

$$H = 2 \text{ m}$$

$$V = 6 \frac{\text{km}}{\text{hr}} * \frac{\text{hr}}{3600} * \frac{1000}{\text{km}} = 1.67 \text{ m/s}$$

* Mixing Temp = T_m

$$T_m = \frac{Q_{se} T_{se} + Q_{ri} T_{ri}}{Q_{se} + Q_{ri}} = \frac{0.4(26) + 0.7(21)}{0.4 + 0.7} = 22.8^{\circ}\text{C}$$

* Mixing ~~DO~~ $\text{DO} = \text{DO}_m$

$$\text{DO}_m = \frac{Q_{se} \text{DO}_{se} + Q_{ri} \text{DO}_{ri}}{Q_{se} + Q_{ri}} = \frac{0.4(2) + 0.7(5)}{0.4 + 0.7} = 4 \text{ mg/l}$$

* Mixing BOD $\text{BOD}_{5,m} = Y_{5,m}$

$$Y_{5,m} = \frac{Q_{se} Y_{5,se} + Q_{ri} Y_{5,ri}}{Q_{se} + Q_{ri}} = \frac{0.4(150) + 0.7(5)}{0.4 + 0.7} = 57.7 \text{ mg/l}$$

* k_1 at $20^{\circ}\text{C} = 0.37 \text{ day}^{-1}$

$$k_1 \text{ at } T_m = k_{1,T_m} = k_{1,20} (1.056)^{T - 20}$$

$$= 0.37 (1.056)^{22.8 - 20}$$

$$= 0.37 (1.056)^{2.8} = 0.43 \text{ day}^{-1}$$

$$* L_{u,m} = \frac{Y_{5,m}}{1 - e^{-5k_{1,m}}} = \frac{57.7}{1 - e^{-5(0.43)}} = 65.3 \text{ mg/l}$$

D_o = oxygen deficit

$$* D_o = DO_s - DO_m = 9 - 4 = 5 \text{ mg/l}$$

$$* k_{2,20} = 3.9 \frac{V^{0.5}}{H^{1.5}} = 3.9 \frac{(1.67)^{0.5}}{(2)^{1.5}} = 1.79 \text{ day}^{-1}$$

$$* k_{2,22.8} = k_{2,20} \frac{T-20}{22.8-20} (1.047) = 1.79 (1.047) = 2.04 \text{ day}^{-1}$$

$$t_c = \frac{1}{k_2 - k_1} \ln \left[\frac{k_2}{k_1} \left(1 - D_o \frac{k_2 - k_1}{k_1 L_u} \right) \right]$$

$$= \frac{1}{2.04 - 0.43} \ln \left[\frac{2.04}{0.43} \left(1 - 5 \frac{2.04 - 0.43}{0.43 (65.3)} \right) \right] =$$

$$= 0.76 \text{ day}$$

$$* D_c = \frac{k_1}{k_2} L_u \exp(-k_1 t_c)$$

$$= \frac{0.43}{2.04} (65.3) \exp(-0.43 \times 0.76)$$

$$= 9.93 \text{ mg/l}$$

$$X_c = V \times t_c$$

$$= 6 \frac{\text{km}}{\text{hr}} \times \frac{24 \text{ hr}}{\text{day}} \times 0.76 \text{ day}$$

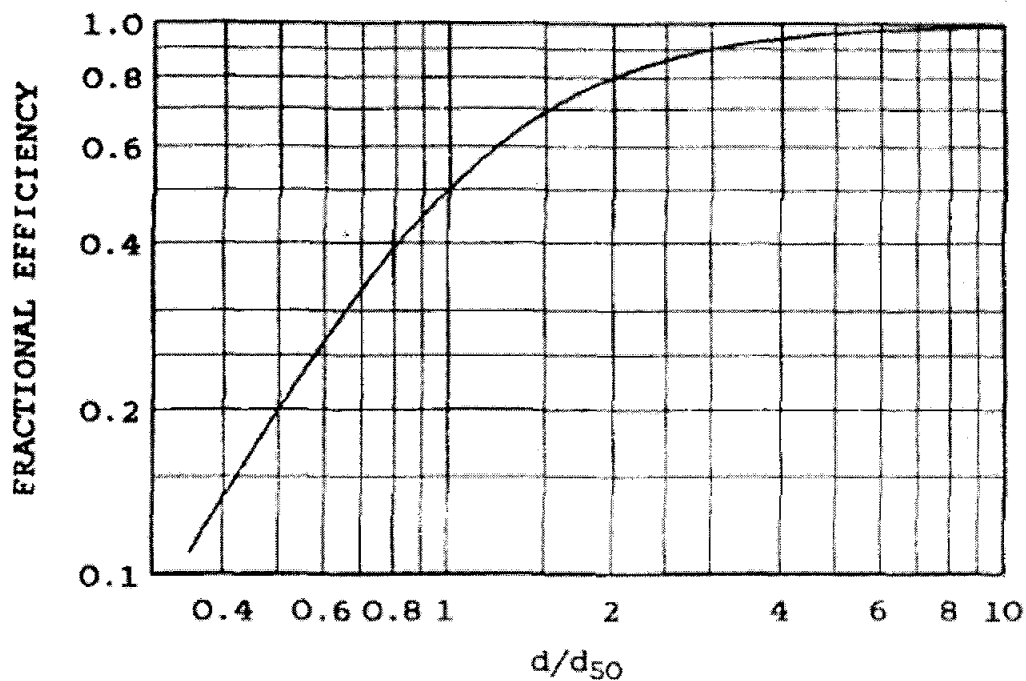
$$= 109.44 \text{ km}$$

Q5- A particulate sample in an air stream has the following weight percent distribution:

Particle Size, $d_p, \mu\text{m}$	1	10	50	100	200
Weight percent, w%	10	20	40	20	10

A cyclone separator is employed in the basis of the following data inlet:

Cyclone width = 0.3 m, effective number = 5, inlet gas velocity = 6 m/s, particle density = 1.6 g/cm^3 , gas density = 1.2 kg/m^3 , gas viscosity = 0.018 mN.s/m^2 , using the figure below to estimate the percentage of the total weight, that would be removed in the cyclone.



Cyclone efficiency versus particle-size ratio

Solution

$$b = 0.3 \text{ m}$$

$$N_e = 5$$

$$v_g = 6 \text{ m/s}$$

$$\rho_p = 1.6 \frac{\text{g}}{\text{cm}^3} = 1600 \text{ kg/m}^3$$

$$\rho_g = 1.2 \text{ kg/m}^3, \mu_g = 0.018 \times 10^{-3} \text{ N.s/m}^2$$

$$d_{p_{50}} = \left[\frac{9 \mu_g b}{2 \pi N_e V_g (P_p - P_g)} \right]^{1/2}$$

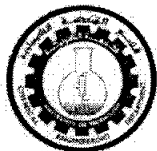
$$= \left[\frac{9 (0.018 \times 10^{-3}) (0.3)}{2 \pi (5) (6) (1600 - 1.2)} \right]^{1/2}$$

$$= 12.7 \times 10^{-6} \text{ m} = 12.7 \text{ } \mu\text{m}$$

$d_{p\mu\text{m}}$	$W/\%$	$d_p/d_{p_{50}}$	η_i	W/η_i
1	10	0.08	0	0
10	20	0.79	0.45	9
50	40	3.94	0.94	37.6
100	20	7.87	0.99	19.8
200	10	15.75	1	10
				<hr/>
				$\Sigma 76.4$

\therefore overall collection efficiency

is 76.4 %



University of Technology
Chemical Engineering Department



Subject: Equipment Design
Branch: Chemical processing
Examiner: Zainab Y.shnan

Final Examination

2011/2012

Class: Third
Time: 3 hours
Date : 6/9/2012

Attempt four questions only

Q1:- A/ Explain with details and sketch the mechanism of liquid-liquid separation equipment.

B/ Define of the following:-

- 1) Model 2) Man-hour 3) cost index 4) utility diagram

(25 mark)

Q2:- In a process plant cracked gas containing hydrocarbon gas and water is cooled to 43 °C and the liquid phases are to be recovered in a vertical drum. The vessel should have an extra surge time of (22 min) for the hydrocarbon phase. Given the following information:

Stream	Mass flow rate (kg/hr)	Density (kg/ m ³)	Viscosity (CP)
Cracked gas	W _v = 188636	P _v = 11.1	-
Hydrocarbon	W _L = 7500	ρ _L =858	μ _L =0.63
Water	W _h = 591	ρ _h =988	μ _h =0.76

Liquid-liquid separation constant (Stokes Constant) = 0.026

Vapour-liquid separation constant = 0.106

Design the vapour-two-liquid separator in this case ?

(25 mark)

Q3:- Explain with detail the term Data Sheet, and then make data sheet for the following:

- 1) Center fugal pump 2) Shell and tube heat exchanger 3) Spherical storage tank.

(25 mark)

Q4:- A/ Select site location for a chemical plant based on safety (layout).

B/ Explain the complete Design Procedure Steps with details for Liquid Surge Drum.

(25 mark)

Q5:- In a separation process by using a distillation column, it is required to design a bubble cap tray given the following information:-

materials	Mwt	pressure	Tempressure	Liquid density	Vapour density	Maximum liquid load	Maximum liquid load
Paraffin's	80	2 atm	90C ⁰	48 Ib/ft ³	0.3 Ib/ft ³	350 gpm(gal/min)	280 ft ³ /sec

Use trapezoidal slots C_s= 0.74

Use the formation in the table of the next page:

Table of Bubble Cap Tray Design

a) Standard bubble cap design for trapezoidal slots with $C_s=0.74$

Material	carbon steel		
Nominal size	3	4	5 inch
No. Of slots	10	26	39
Slot height	1	1.25	1.5
Slot area	5	8.12	14.64 inch ²
Cap area	7.5	13.15	29 inch ²
Slot to cap ratio	0.67	0.62	0.5

b) Bubble cap size and slot area

Nominal cap size inch	Ratio of a slot/ allocated cap area			
	=0.25	=0.3125	=0.375	=0.5
3	0.39	0.35	0.32	0.27
4	0.36	0.33	0.30	0.25
6	0.29	0.26	0.24	0.20

c) Tray type selection

Estimated tower dia	ft	range of liquid capacity gpm			
		reverse flow	cross flow	double pass	cascade double pass
3		0.30	30-200		
4		0.40	40-300		
6		0.50	50-400	400-700	
8		0.50	50-500	500-800	
10		0.50	50-500	500-900	900-1400
12		0.50	50-500	500-1000	1000-1600
15		0.50	50-500	500-1100	1100-1800
20		0.50	50-500	500-1100	1100-2000

d) Distribution of area as % of tower area

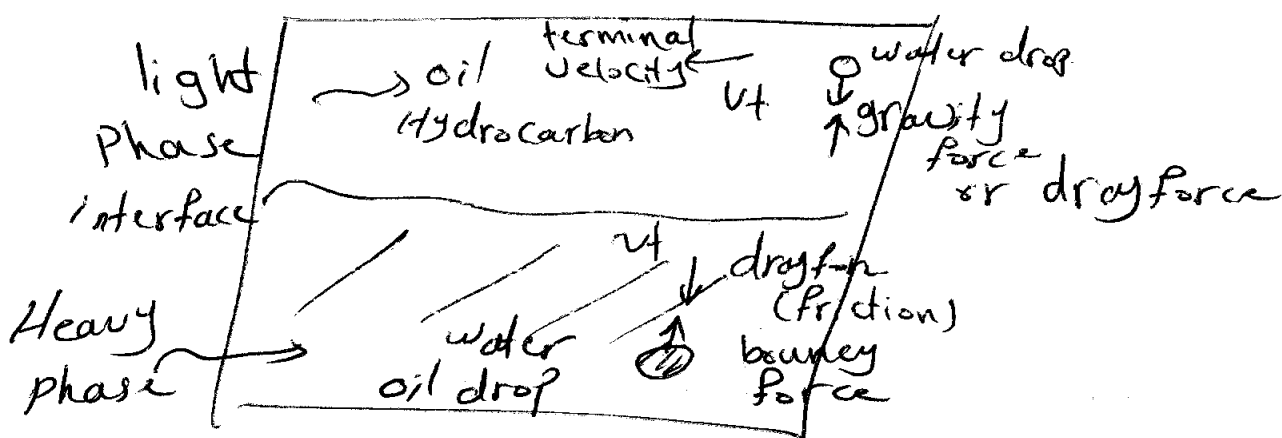
Tower dia ft	down flow area		liquid distribution area			end and wastage
	cross flow	double pass	cross flow	double pass	cascade double pass	
3	10-20		10-25			10-30
4	10-20		8-20			7-22
6	10-20	20-30	5-12	15-20		5-18
8	10-20	18-27	4-10	12-16		4-15
10	10-20	16-24	3-8	9-13	20-30	3-12
12	10-20	14-21	3-6	8-11	15-25	3-10
15	10-20	12-18	2-5	6-9	12-20	2-8
20		10-15		5-7	9-15	2-6

e) Tray design standard

Nominal size for		
2.5-5	ft tower	3 inch
4-15	ft tower	4 inch
10-20	ft tower	6 inch

Liquid-Liquid Separators. Q1A A ع/ د/ د/ د/ د/ د/ د/ د/ د/ د/ د/ د/ د/ د/ D

In separation of two liquids of marked densities difference, separation will occur by settling. The droplets of heavy phase (water droplet) will have a tendency to fall down out of light phase under the influence of gravitation. Frictional forces balance the gravitational force at this point the heavy droplet will continue to fall down (phase) of the light phase at a constant velocity which is the terminal velocity until it reach the interface. An analogous mechanism applies to separation of light phase droplets that maybe present in heavy phase (H₂O) except that in this case the motion is upwards and the drag frictional force opposed by buoyancy force.



Q1/13

MEMO

- model: -
- ① It is a small 3 dimensional sample of the original plant shows all units, piping and carrying pipes (Pipe rack)
 - ② it is used for design correction of instrument location of pipe (Position) location of units.
 - ③ useful in the training purposes as well as explaining the project to visitors after its down.

man-hours: - For a specific calculation vary with process equipment, process system, physical properties and familiarity of process engineer with design work

$$\text{Cost}:- P_b = P_a \left(\frac{C_b}{C_a} \right)^{0.6}$$

P_b : cost of plant or section of plant of new capacity "b"

P_a : = "a"

C_b : capacity of plant or section of new requirements

C_a : = "original"

Utility Diagram (UD): - Utilities are cooling water, steam, oil, N_2 , H_2 , flue gas, fire water.

② This diagram shows the quantities of required for each production step.

③ show the operating conditions of utilities that supply (specification, T, P, ...)

④ This diagram regarded as a complementary diagram for (PLD) & (PFI)

Q211

MEMO

Solution:- (1) Apply Sanneters-Brown to calculate vapour velocity

$$V_a = K \sqrt{\frac{\rho_L - \rho_v}{\rho_v}} = 0.106 \sqrt{\frac{858 - 11.1}{11.1}}$$

$$= 0.93 \text{ m/sec}$$

(2) Q_v = Volumetric Flowrate for Vapour

$$Q_v = \frac{W_v}{\rho_v} = \frac{188636}{60 \times 11.1} = 283 \text{ m}^3/\text{min}$$

$$Q_l = \frac{W_l}{\rho_l} = \frac{7500}{60 \times 858} = 0.145 \text{ m}^3/\text{min}$$

$$Q_h = \frac{W_h}{\rho_h} = \frac{591}{60 \times 988} = 0.01 \text{ m}^3/\text{min}$$

(3) Q_v = area \times Vapour velocity

$$Q_v = \frac{\pi}{4} D^2 \times (V_a \times 60)$$

$$\therefore D = 2.5 \text{ m} \Rightarrow A = \frac{\pi}{4} D^2 \approx 5 \text{ m}^2$$

(4) settling velocity

$$V_L = K_s \frac{\rho_h - \rho_L}{\mu_L} = 5.36 \text{ cm/min (o.k.)}$$

$$V_h = K_s \frac{\rho_h - \rho_L}{\mu_h} = 4.4 \text{ cm/min (o.k.)}$$

(5) assume $h_l = 30 \text{ cm}$

$$t_l = \frac{h_l}{V_L} = \frac{30}{5.36} = 5.6 \text{ min}$$

$$\text{assume } h_h = 30 \text{ cm, } t_h = \frac{h_h}{V_h} = \frac{30}{4.4} = 6.8 \text{ min}$$

$$\textcircled{6} Q_L = \frac{\text{Volume of light phase}}{Q_L} = \frac{5 \times 0.3}{0.146} = 10.3 \text{ m}$$

$$Q_h = \frac{V_h}{Q_h} = \frac{A \times h_l}{0.01} = 150 \text{ min}$$

$$\therefore Q_h > t_h \quad \underline{\text{ok.}}$$

$\textcircled{7}$ Since, an extra surge drum time of 25 min is required for H-C

$$h_s = \frac{Q_L t_s}{A} = \frac{0.145 \frac{\text{m}^3}{\text{min}} \times 25 \text{ min}}{5 \text{ m}^2} = 0.725 \text{ m}$$

$\textcircled{8}$ calculate L

$$L = h_{bn} + h_l + h_m + h_s + h_v$$

$$h_v = 0.5(1) + 0.5(0.9) = 1.7 \text{ m}$$

$$h_{bn} = 0.5(0.9) + 0.6 = 1.05 \text{ m}$$

$$h_s = 0.725 \text{ m}$$

$$h_l = 0.3$$

$$h_h = 0.3$$

$$h_b = 0.15 \text{ m}$$

$$\therefore L = 4.225 \text{ m}$$

Q311

① Center Fugal Pumps

- section Pressure
- Discharge Pressure
- BHP (Net Positive section)
- NPSH
- quality of flow
- type of fluid
- type of material of construction
- Physical Properties of fluid (ρ, μ, \dots)

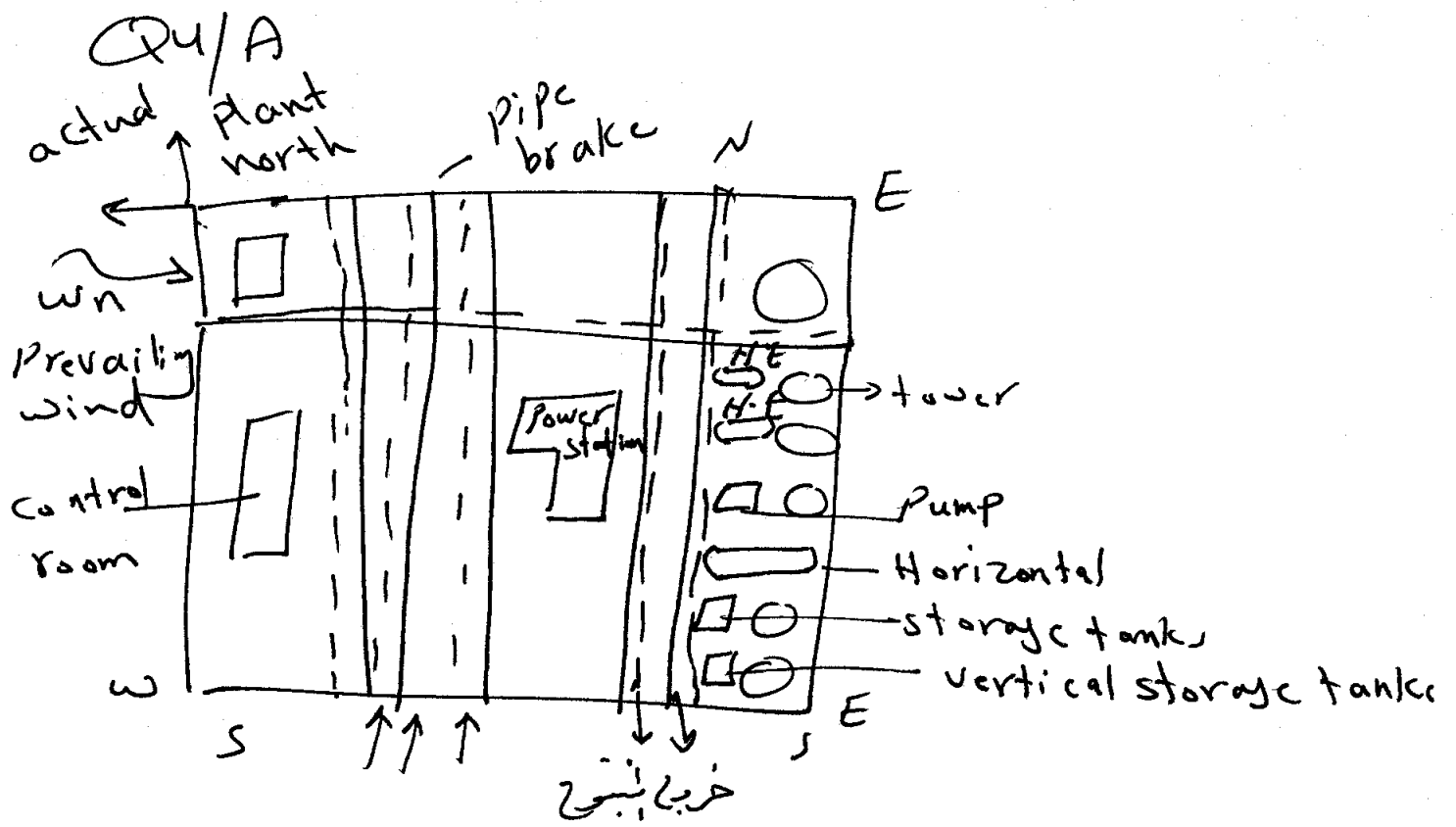
Item No	No of unite	Service	liquid	operation
1	2	3	4	5

② Shell & tube exchanger

- ① Physical Properties of fluid
- ② Temp & pressure
- ③ velocity ④ Fluid quantities
- ⑤ tube side diameter
- ⑥ Exchanger length
- ⑦ No. of tube Pass
- ⑧ DP
- ⑨ Thickness
- ⑩ μ, ρ

③ Vessel

- length
- Diameter
- operating Pressure
- Design Pressure
- Test Pressure
- internal (trans.) Thickness



Q4/3

Design surge drum

Length, Diameter, material of construction (Pun temp) thickness, nozzle (location and size), L/D relation between length to diameter; (L/D) depends on operating Pressure.

(L/D) = 1.5 for low Pressure (1.5-3 bar)

(L/D) = 3 for Pressure range (4-42 bar)

(L/D) = 5 " " " greater than 42 bar

material of construction it is depends on temp

* For operating temp -45 to 200°C we used Carbon steel where its tensile strength (P) = 950 kg/cm^2

* For operating temp -45 to -104°C we used $3\frac{1}{2}\text{Ni}$ where P = 7750 kg/cm^2

For operating temp -104 to -196°C we used stainless steel where its (P) = 1400 kg/cm^2

CP 65

① select cap size = we select 4" size for cap from table
② for slot height $H_s = 1.25$ inch

③ calculate minimum slot area

$$V_m = C_s \sqrt{H_s \left(\frac{\rho_L - \rho_V}{\rho_V} \right)} \quad A_s = 1.34 \times 10^{-5}$$
$$280 = 0.74 \sqrt{1.25 \left(\frac{48 - 0.3}{0.3} \right)} \quad A_s = 3.14 D^2 \times 10^{-5}$$
$$A_s = 26.8 \text{ ft}^2 \quad D^2 = \frac{3}{3.14 \times 10^{-5}} = \frac{3}{330}$$

④ select cap spacing we select 25% cap spacing utilize table (b)

\therefore ratio of slot to allocated cap area = 0.36

⑤ Determine required allocated cap area (by dividing slot area by ratio read from table)

$$\therefore \text{required allocated cap area} = \frac{26.8}{0.36} = 74.5 \text{ ft}^2$$

⑥ Estimate tower size (assuming allocated area = 60% of tower area).

$$\therefore A_t = \text{tower area estimated} = \frac{74.5}{0.6} = 124 \text{ ft}^2$$

$$\text{But } A_t = \frac{\pi}{4} D_t^2 \Rightarrow D_t = \text{tower diameter estimated} = 12.1 \text{ ft}$$

⑦ select tray type use table (c) for tower diameter of (12.1 ft) and liquid load of (350 gal/min) tray selected is cross flow

⑧ Reconsider cap selection utilizing table (e) we find that for tower diameter above 4" is adequate

Final Exam./Second Attempt

University of Technology
Chemical Eng. Dep.
Third Class/Refinery and Gas Engineering Branch
Combustion Engineering



Time: 3 hours
Date: 29/8/2010
Zainab Y. Shnean

Note: Answer Four Question

Q1/ A natural gas with the composition by volume $\text{CH}_4=97\%$ and $\text{N}_2=3\%$ burnt with 200 % by volume excess air. If 85% from methane change to CO_2 and 10% to CO and 5% not burned determine:-

1. Composition of flue gas.
2. The operating air fuel ratio.
3. The equivalence ratio.
4. The height of chimney if the draught is 12 mm water and the temperature of flue gases is 327°C and the temperature of air is 23°C .

(25-mark)

Q2/ A/ In a flow calorimeter 36 mgs of graphite particulate reacts completely with oxygen initially at 25°C to form carbon dioxide at 1 atm and 25°C , the rate of heat absorbed by the calorimeter water is 420 W. Find the heat of formation of CO_2 .

B/ Calculate the flame temperature produced from burnt methane with 10% excess air at 500°C . $\Delta H=191800 \text{ Cal}$, $C_p(\text{cal/l.}^\circ\text{C})$ for $\text{air}=0.324$, $\text{CO}_2=0.58$, $\text{H}_2\text{O}=0.46$, $\text{N}_2=0.36$

(20-mark)

Q3/ A/ What is the flammability limits (with details).
B/ The higher heats value of a dry ash. Free bituminous is 12500 Btu/lbm= 29.050 kJ/kg the cool containing 70%wt carbon and 5%wt hydrogen on a dry ash. Free basis find the enthalpy of formation of this cool. $\Delta H \text{ (kJ/kmole)}$ for $[\text{CO}_2 = -393520, \text{H}_2\text{O} = -285750]$

(20-mark)

Q4/ A/ Determine the upper and lower heating values at 298 K of gaseous n-decane $\text{C}_{10}\text{H}_{22}$ per kmole of fuel and per kg of fuel. The molecular weight of n-decane is 142.28.
B/ If the enthalpy of vaporization of n-decane is 359 kJ/kg fuel at 298K, what are the upper and lower heating values of liquid n-decane.
Enthalpy at 298 K (kJ/kmole) $[\text{CO}_2 = -393,596, \text{C}_{10}\text{H}_{22} = -249,659, \text{H}_2\text{O} = -241,847]$
 $H_{fg} \text{ of H}_2\text{O} = -285,857 \text{ kJ/kmole}$

(20-mark)

Q5/ Stack gas analysis of a natural gas-fired furnace gave the following analysis 8% O_2 , 18% CO_2 , 16% H_2O , 85% N_2 all a dry basis the fuel was 70% C_2H_6 , 30% C_3H_8 by volume and the higher heating value was 23700 Btu/lbm the fuel and air entered the furnace at 77°F and the stack gas temperature was 350°F . No blower was used and heat losses were negligible what the operating efficiency of this furnaces is and what is the excess air?

(15-mark)

Component	H (kJ/kmole)
O_2	1.882
CO_2	2.525
H_2O	2.142
N_2	1.838

GOOD LUCK

Q5/ 25/11

MEMO

⑧ Estimate distribution of tray selected to tower determined that

down flow = 15%
distribution = 8%
End to wastage = 7% } 30%

By difference = $100\% - 30\% = 70\%$

⑨ Estimate tower size $A_t = \frac{124}{0.7} = 177 \text{ ft}^2$

$\therefore D_t = 15.0 \text{ ft}$

⑩ Select tray spacing:- 2' spacing is selected from table for tower size spacing



Answer four Questions Only

Q1: A heat exchanger is to be designed to condense an organic vapour at a rate of 500 kg/ min which is available at its saturation temperature 355 K. Cooling water at 286 K is available at a flow rate of 60 kg/s. The overall heat transfer coefficient is 475 W/m².K. Latent heat of condensation of the organic vapour is 600kJ/kg.

Calculate:

- 1- The number of tubes required , if 25 mm outer diameter , 2 mm thick and 4.87 m long tubes are available , and
- 2- The number of tube passes, if the cooling water velocity (tube side) should not exceed 2 m/s. (Cp for water=4180 J/kg.K)

(25 Marks)

Q2:A) Calculate the heat loss per 10m pipe length which has an outside diameter of 0.15m and an inside diameter of 0.13m (k=1.2 W/m.k). This pipe has 0.06m thick lagging (k=0.3 W/m.k) and 0.04m asbestos insulation (k=0.2 W/m.k). The inside and out side surfaces temperatures are 500k and 350k respectively. Find also the temperatures at the interfaces surfaces?

(20 Marks)

B) What are the types of flow in heat exchanger?

(5 Marks)

Q3:A) Derive an expression for the critical thickness of insulation for a cylinder of radius r_i ?

(20 Marks)

B) Consider an insulated pipe exposed to the atmosphere. Will the critical radius of insulation be greater on calm days or on windy days? Why?

(5 Marks)

Q4: A thermocouple junction, which may be approximated as a sphere, is to be used for temperature measurement in a gas stream, $h=400$ W/m².k, $k=20$ W/m.k, $C_p=400$ J/kg.k, $\rho=8500$ kg/m³. Determine the junction diameter needed for the thermocouple to have a time constant (τ) of (1) sec. If the junction is at 25 c° and is placed in a gas stream that is at 200 c°, how long will it take for the junction to reach 199 c°?

(25 Marks)

Q5:A) Derive an expression for the thickness of the hydrodynamic boundary layer on a flat plate for a laminar flow of a Newtonian incompressible fluid starting from Van-Karman momentum equation?

(20 Marks)

B) Write the form of thermal resistance for Plane, Cylindrical and Spherical layer?

(5 Marks)

Q6: Water at atmospheric pressure is to be boiled in polished copper pan. The diameter of the pan is 350mm and is kept at 115 °C. Calculate the following:

- 1) Power of the burner.
- 2) Rate of evaporation in kg/h.
- 3) Critical heat flux for these conditions. The physical properties of water at 100 °C are: $C_{pl}=4220$ J/kg k , $\lambda = 2257$ kJ/kg , $\mu_l = 279 \times 10^{-6}$ kg/m.s , $k = 0.68$ W/m k , $\sigma = 58.9$ mN/m , $\rho_l = 957.9$ kg/m³ , $C_{sf}=0.013$, $\rho_v = 0.5955$ kg/m³ , $Pr = 1.76$.

(25 Marks)

Good Luck

Final Exam. / 2nd attempt

Third year

Heat Transfer

The Answers

Ans. of Q1

Heat lost by vapour = heat gained by water

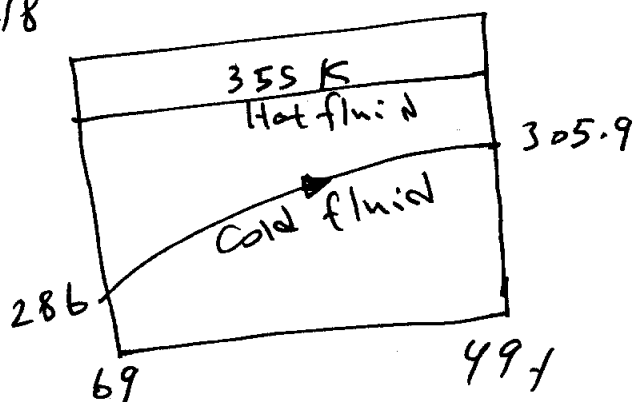
$$m \lambda = m c_p \Delta T$$

$$\frac{500}{60} \times 600 \text{ kJ/kg} = 60 \times 4.18 (T - 286)$$

$$T = \frac{8.33 \times 600}{60 \times 4.18} + 286 = 305.9 \text{ K}$$

$$\Delta T_{lm} = \frac{\Delta T_2 - \Delta T_1}{\ln \frac{\Delta T_2}{\Delta T_1}}$$

$$\Delta T_{lm} = \frac{69 - 49.1}{\ln \frac{69}{49.1}} = 58.5 \text{ K}$$



$$Q = U A \Delta T_{lm}$$

$$8.33 \times 600 \times 10^3 = 475 \times \pi (0.025 \times 4.87 \times N) \times 58.5$$

$$N = 470 \text{ tubes}$$

assume p No. of passes

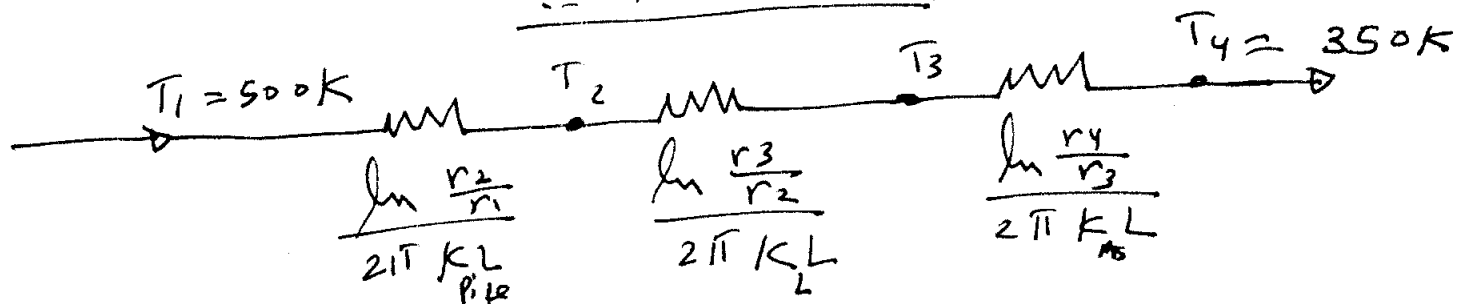
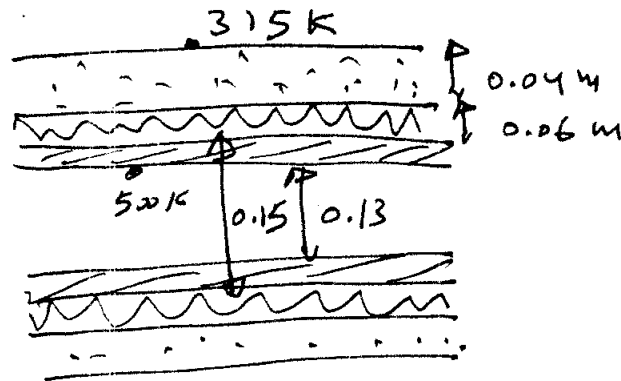
$$m_c = \left(\frac{\pi}{4} d_i^2 \times u \times p \right) N_p, \quad N_p = \text{Number of tubes in each pass}$$

$$60 = \frac{\pi}{4} \times (0.02)^2 \times 2 \times 1000 \times N_p$$

$$\therefore N_p = 95.5$$

$$\text{Number of passes } p = \frac{N}{N_p} = \frac{470}{95.5} = 4.91 = 5 \text{ passes}$$

Ans. Q2 A):



$$q = \frac{\Delta T}{R_{\text{overall}}} = \frac{2\pi L (T_1 - T_4)}{\frac{\ln \frac{r_2}{r_1}}{K_{\text{pipe}}} + \frac{\ln \frac{r_3}{r_2}}{K_L} + \frac{\ln \frac{r_4}{r_3}}{K_{\text{ins}}}}$$

$$r_1 = \frac{D_i}{2} = \frac{0.13}{2} = 0.065 \text{ m}, \quad r_2 = \frac{D_o}{2} = \frac{0.15}{2} = 0.075 \text{ m}$$

$$r_3 = 0.075 + 0.06 = 0.135, \quad r_4 = 0.135 + 0.04 = 0.175 \text{ m}$$

$$q = \frac{2 \times 3.14 \times 10 (500 - 350)}{\frac{\ln \frac{0.075}{0.065}}{1.2} + \frac{\ln \frac{0.135}{0.075}}{0.3} + \frac{\ln \frac{0.175}{0.135}}{0.2}} = \underline{\underline{2790.2 \text{ W}}}$$

$$q = \frac{T_1 - T_2}{\frac{\ln \frac{r_2}{r_1}}{2\pi K_{\text{pipe}} L}} \Rightarrow q = 2790.2 = \frac{500 - T_2}{\frac{\ln \frac{0.075}{0.065}}{2 \times 3.14 \times 1.2 \times 10}}$$

$$\therefore T_2 = \underline{\underline{494.7 \text{ K}}}$$

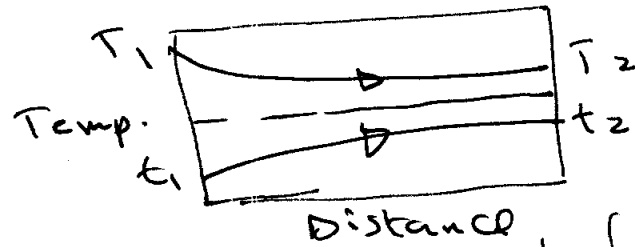
$$q = \frac{T_2 - T_3}{\frac{\ln \frac{r_3}{r_2}}{2\pi K_L L}} \Rightarrow q = 2790.2 = \frac{494.7 - T_3}{\frac{\ln 0.135/0.075}{2 \times 3.14 \times 0.3 \times 10}}$$

$$T_3 = \underline{\underline{407.6 \text{ K}}}$$

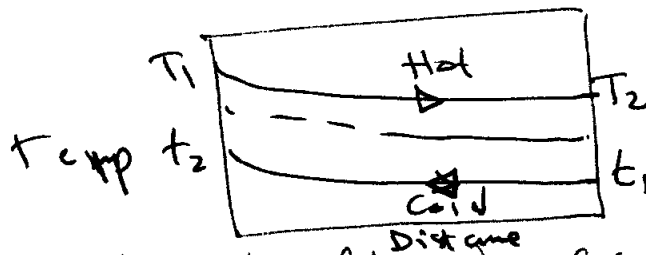
Ans. Q2 B

The Types of flow in heat exchanger:

1- Co-Current flow

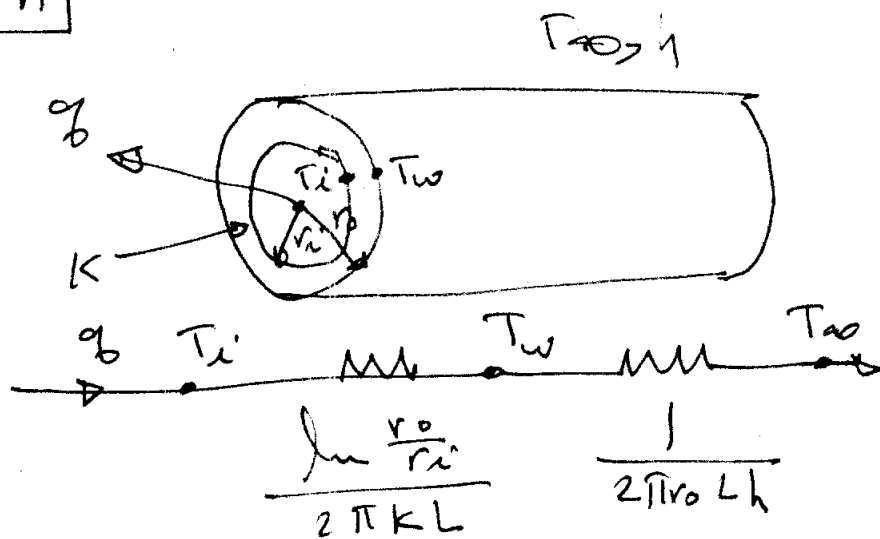


2- Counter Current flow



3- Mixed flow, cross-flow

Ann. Q3 A



$$q = \frac{\Delta T}{R_{\text{overall}}} = \frac{T_i - T_o}{\frac{\ln \frac{r_o}{r_i}}{2\pi K L} + \frac{1}{2\pi r_o L h}}$$

$$\therefore q = \frac{2\pi L (T_i - T_o)}{\left[\frac{\ln \frac{r_o}{r_i}}{K} + \frac{1}{r_o h} \right]} \quad \text{--- (1)}$$

for critical conditions:

$$\frac{dq}{dr_o} = \frac{-2\pi L (T_i - T_o) \left[\frac{1}{K r_o} - \frac{1}{h r_o^2} \right]}{\left[\frac{\ln \frac{r_o}{r_i}}{K} + \frac{1}{r_o h} \right]^2}$$

$$\text{Let } \frac{dq}{dr_o} = 0$$

$$\therefore \frac{1}{K r_o} - \frac{1}{h r_o^2} = 0$$

$$\therefore r_o = (r)_{\text{critical}} = \frac{K}{h}$$

Ans Q3 B $r_c = \frac{K}{h}$

$h_{\text{for windy days}} > h_{\text{for calm days}}$

$\therefore r_c \text{ for windy days} < r_c \text{ for calm days}$

Ans Q4]

$$\tau = \text{Time constant} = \frac{1}{hA} \rho V c_p$$

$$= \frac{1}{h \pi D^2} \cdot \rho \frac{\pi D^3}{6} c_p$$

$$= \frac{\rho c_p r_o}{3\pi h} = \frac{8500 \times 400 \times r_o}{3 \times 400 \times \pi} = 1 \text{ sec}$$

$$\therefore r_o = 3.53 \times 10^{-4} \text{ m}$$

$$B_L = \frac{hL}{k} = \frac{h \frac{r_o}{3}}{k} = \frac{400 \times 3.53 \times 10^{-4}}{20 \times 3} = 2.35 \times 10^{-4} < 0.1$$

$$\therefore \frac{\theta}{\theta_0} = e^{-\frac{hA}{\rho c_p V} t}$$

$$\therefore t = \frac{\rho c_p V}{hA} \ln \frac{\theta_0}{\theta}$$

$$= \frac{8500 \times 400 \times 7.06 \times 10^{-4}}{400 \times 6} \ln \frac{25 - 200}{199 - 200}$$

$$\therefore t = 5.25 \text{ sec.}$$

Ans Q 5 A)

The van-Karman momentum eqn. is

$$\frac{d}{dx} \left[\int_0^{\delta} u(u_{\infty} - u) dy \right] = \nu \left(\frac{du}{dy} \right)_{y=0}$$

assume the velocity profile

$$u = c_1 + c_2 y + c_3 y^2 + c_4 y^3$$

The boundary conditions:-

$$\begin{aligned} y=0 & \quad u=0 \\ y=\delta & \quad u=u_{\infty} \\ y=\delta & \quad \frac{du}{dy} = 0 \\ y=0 & \quad \frac{\delta^2 u}{\delta y^2} = 0 \end{aligned}$$

apply the B.C. in profile eqn. we get

$$u = \frac{u_{\infty}}{2} \left[3\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^3 \right] - \text{velocity profile}$$

inserting the expression of velocity profile into momentum eqn.

$$\frac{d}{dx} \left[\int_0^{\delta} \left[\frac{3}{2} \left(\frac{y}{\delta} \right) - \left(\frac{y}{\delta} \right)^3 \right] \left[u_{\infty} - \left(\frac{3}{2} \left(\frac{y}{\delta} \right) - \left(\frac{y}{\delta} \right)^3 \right) \right] dy \right] = \nu \left(\frac{du}{dy} \right)_{y=0}$$

$$\left(\frac{du}{dy} \right)_{y=0} = \frac{3}{2} \frac{u_{\infty}}{\delta}$$

$$\therefore \frac{d}{dx} \left\{ \rho u_{\infty}^2 \int_0^{\delta} \left[\frac{3}{2} \left(\frac{y}{\delta} \right) - \left(\frac{y}{\delta} \right)^3 \right] \left[1 - \frac{3}{2} \left(\frac{y}{\delta} \right) + \frac{1}{2} \left(\frac{y}{\delta} \right)^3 \right] dy \right\} = \frac{3}{2} \frac{\mu u_{\infty}}{\delta}$$

$$\therefore \frac{\delta^2}{2} = \frac{140}{13} \frac{\nu x}{u_{\infty}} + \text{const.}$$

$$x=0 \quad \delta=0$$

$$\therefore \delta = 4.64 \sqrt{\frac{\nu x}{u_{\infty}}}$$

$$\boxed{\therefore \frac{\delta}{x} = \frac{4.64}{Re^{1/2}}}$$

Ans Q5 B

$$Z = \frac{\Delta T}{R}$$

$$R_{\text{for plane}} = \frac{\Delta X}{KA}$$

$$R_{\text{for cylindrical}} = \frac{\ln \frac{r_2}{r_1}}{2\pi K L}$$

$$R_{\text{for spherical}} = \frac{\frac{1}{r_1} - \frac{1}{r_2}}{4\pi K}$$

Ans Q6

$$\Delta T_e = T_s - T_{\text{sat}} = 115 - 100 = 15^\circ$$

Nucleate pool boiling will occurs

$$\begin{aligned} q'_{\text{nucleate}} &= \mu_L \lambda \left[\frac{g(\rho_L - \rho_v)}{\sigma} \right]^{1/2} \left[\frac{c_{pL}(T_s - T_{\text{sat}})}{C_{sf} \lambda \rho_L h} \right]^3 \\ &= 279 \times 10^{-6} \times 2257 \times 10^3 \left[\frac{9.81(957.9 - 0.5955)}{58.9 \times 10^{-3}} \right]^{1/2} \\ &\quad \left[\frac{4220 \times 15}{0.013 \times 2257 \times 10^3 \times 1.76} \right]^3 \\ &= 629.703 [127.487] [1.84182] \\ &= 147859.7 = 147.86 \text{ kW/m}^2 \\ q &= q'' \cdot A = 147.86 \times \frac{\pi D^2}{4} = 147.86 \times 10^3 \times \frac{\pi \times 0.35^2}{4} \\ &= 14.226 \text{ kW power} \end{aligned}$$

$$q = m \lambda = \quad m = \frac{q}{\lambda} = \frac{14.226 \times 10^3}{2257 \times 10^3} = 0.0063 \text{ kg/s}$$

The critical heat flux for nucleate pool boiling

$$\begin{aligned} q_{\text{max}} &= 0.149 \lambda \left[\sigma g \rho_v^2 (\rho_L - \rho_v) \right]^{1/4} \\ &= 0.149 \times 2257 \times 10^3 \left[58.9 \times 10^{-3} \times 9.81 \times 0.5955^2 (957.9 - 0.5955) \right]^{1/4} \\ &= 65.945 \text{ kW/m}^2 \end{aligned}$$



University of Technology
Chemical Engineering Department



Subject: Mass

Branch: Both

Examiner: Dr. Orooba

Final Examination

2011/2012

Class: Third

Time: 3 hours

Date: 10/Sep.

Note: Attempt only five questions , 10 marks for each one

Q1 A small diameter tube closed at one end was filled with acetone to within 18 mm from the top, maintained at 298 K and 99.75 kN/m² with a gentle stream of air blowing across the top. After about 15ksec the liquid level had fallen to 27.5 mm. Calculate the diffusivity of acetone in air? Given that:-

$$\rho_{\text{Acetone}} = 790 \text{ kg/m}^3, \text{ Mwt} = 58 \text{ and } P_A^0 = 21.95 \text{ kN/m}^2.$$

Q2 In a mass exchange apparatus operating at a pressure of 3.1 atm, the individual mass transfer coefficients have the following values :-

$$k_x = 22.0 \text{ kmol/m}^2 \cdot \text{hr} \cdot \text{mol fraction} \quad k_y = 1.07 \text{ kmol/m}^2 \cdot \text{hr} \cdot \text{mol fraction}$$

The equilibrium relation $P = 0.08 \cdot 10^6 x$, determine:-

- 1- Overall mass transfer coefficient for both gas and liquid phases?
- 2- Mass flux, if the average gas mole fraction is (0.25) and (0.00295) for liquid?

Q3 A single stage batch still is used to separate a mixture of two components (A and B) at a rate of 1000 kg / hr, containing 60 % of (A). After distillation the remaining liquid contains 5 % mol of (A). Find the amount of the liquid remained and the distillate composition?

Where Mwt = (78 and 92) for both (A and B) respectively and $\alpha = 2.4$

Q4 A continuous distillation column designed to separate a mixture containing 14 % of A at 290 K into overhead product of 95 % (A) and a waste of 97 % (B). Assume plate efficiency 70 % and $R=3.16$ determine :-

- 1- All leaving streams flow rates.
- 2- R_{\min} , N_{\min} and N_{act} .
- 3- Condenser and reboiler duties.

Latent heat = 25900 kJ / kmol $C_{p \text{ feed}} = 1.7 \text{ kJ/kg} \cdot \text{K}$ liquid quality = 1.4
Mwt (A) = 76 , Mwt (B) = 142

Equilibrium data:-

x	0.03	0.06	0.11	0.14	0.26	0.33	0.53	0.55	0.86
y	0.09	0.16	0.27	0.33	0.5	0.63	0.75	0.82	0.93

Q5 An absorption process using a mixture of (NH_3 + Air) containing 5 mol % of NH_3 at a rate of 1000 kg/hr.m^2 to recover at least 95 % of NH_3 , using fresh water for absorption at a rate 50 % more than the minimum. Find the water flow rate and the height of the packing? given that :-

$$k_{G,a} = 22 \text{ kmol/hr.m}^2.\text{atm} \quad k_{L,a} = 102.22 \text{ kmol /hr.m}^2.\text{mol NH}_3/\text{mol H}_2\text{O}$$

$$P_{\text{NH}_3} = 0.95 x \text{ , } P \text{ (in atm) .}$$

Q6 A gaseous mixture of (CS_2 – N_2) at 24 C, has a partial pressure of

$\text{CS}_2 = 50 \text{ mmHg}$, is to be blown into packed absorber at 1 atm pressure at a rate of $0.4 \text{ m}^3/\text{s}$. pure hydrocarbon oil is used for absorption (Mwt = 180) to reduce the CS_2 concentration to 0.5% by volume. A height of 4.73 m of packing will be required. The vapor pressure of CS_2 is 346 mmHg and the system obeys Raoult's law. For column diameter = 0.725 m determine :-

- 1- The overall mass transfer coefficient?
- 2- If a tray column is used, how many trays must be provided?

$$\text{Mwt of CS}_2 = 76 \quad , \quad \text{Mwt of N}_2 = 28 \quad R = 0.082$$

Best Wishes To All

الحلول المتعددة للدور الثاني للعام الدراسي ٢٠١١ - ٢٠١٢

$$\underline{\underline{\Phi 1}} \quad \frac{-D_{AB}}{R \cdot T} \cdot \frac{P_T}{P_{BM}} (P_{A2} - P_{A1}) \cdot z = \frac{P_A}{M_A} \left(\frac{z_2^2 - z_1^2}{2} \right)$$

$$P_{A1} = P_A^0 = 21.95 \text{ kN/m}^2 \quad P_{A2} = 0$$

$$P_{B1} = P_T - P_{A1} = 99.75 - 21.95 = 77.8 \text{ kN/m}^2$$

$$P_{B2} = P_T - P_{A2} = 99.75 - 0 = 99.75 \text{ kN/m}^2$$

$$\therefore \frac{-D_{AB}}{8.314 \times 290} \cdot \frac{99.75}{88.33} (0 - 21.95) (15 \times 1000) = \frac{790}{58} \left(\frac{0.027^2 - 0.018^2}{2} \right)$$

$$\therefore D_{AB} = 1.9 \times 10^{-5} \text{ m}^2/\text{s} \quad P_{BM} = \frac{P_{B2} - P_{B1}}{\ln \frac{P_{B2}}{P_{B1}}}$$

$$\underline{\underline{\Phi 2}} \quad \textcircled{a} \quad \frac{1}{K_{oy}} = \frac{1}{K_y} + \frac{m}{K_x}$$

$$P_A = 0.08 \times 10^6 x \Rightarrow \frac{P_A}{P_T} = \frac{0.08 \times 10^6}{3.1 \times 760} \cdot x$$

$$\therefore \boxed{y_A = 33.96 x}$$

$$\therefore \frac{1}{K_{oy}} = \frac{1}{1.67} + \frac{33.96}{22} \Rightarrow \boxed{K_{oy} = 0.403 \text{ kmol/m}^2 \cdot \text{hr} \cdot \text{mol}}$$

$$\frac{1}{K_{ox}} = \frac{1}{m \cdot K_y} + \frac{1}{K_x}$$

$$= \frac{1}{33.96 \times 1.67} + \frac{1}{22} \Rightarrow \boxed{K_{ox} = 0.073 \text{ kmol/m}^2 \cdot \text{hr} \cdot \text{mol}}$$

$$(b) N_A = K_{oy} (y - y^*)$$

$$y^* = 33.96 x_B \Rightarrow y^* = 0.1$$

$$\therefore N_A = 0.0605 \text{ (0.25 - 0.1)}$$

$$N_A = 0.0605 \text{ kmol/m}^2 \cdot \text{hr}$$

$$\underline{\underline{\Phi 3}} \quad L_1 = 1000 \text{ kg/hr} \Rightarrow L_1 = \frac{1000}{0.6 \times 78 + 0.4 \times 92}$$

$$\therefore L_1 = 11.96 \text{ kmol/hr} \quad \begin{matrix} 1 \text{ initial} & 2 \text{ final} \end{matrix}$$

$$\ln \frac{L_1}{L_2} = \frac{1}{\alpha - 1} \left[\ln \frac{x_1}{x_2} + \alpha \ln \frac{1 - x_2}{1 - x_1} \right]$$

$$\ln \frac{11.96}{L_2} = \frac{1}{2.4 - 1} \left[\ln \frac{0.6}{0.05} + 2.4 \ln \frac{1 - 0.05}{1 - 0.6} \right]$$

$$\therefore \ln \frac{11.96}{L_2} = 3.26 \Rightarrow L_2 = 0.459 \text{ kmol/hr}$$

To find Composition :-

O.M.B on still :-

$$L_1 x_1 = L_2 x_2 + (L_1 - L_2) y_{\text{avg}}$$

$$11.96 \times 0.6 = 0.459 \times 0.05 + (11.96 - 0.459) y_{\text{avg}}$$

$$\therefore y_{\text{avg}} = 0.622$$

Q4 $q = 1.4 > 1$ then feed subcooled.

Basis = 100 kmol/hr feed

$$F = D + W \Rightarrow D = 100 - W$$

$$F \cdot x_f = D \cdot x_D + W \cdot x_W$$

$$100 \times 0.14 = D \times 0.95 + (100 - D) \times 0.03$$

$$\therefore D = 11.95 \text{ kmol/hr}$$

$$W = 88.043 \text{ kmol/hr}$$

$$\phi = \text{intercept} = \frac{x_D}{R+1} = \frac{0.95}{3.16+1} = 0.23$$

$$\text{From fig } \phi_{\min} = 0.34$$

$$\phi_{\min} = \frac{x_D}{R_{\min}+1} = \frac{0.95}{R_{\min}+1} = 0.34 \Rightarrow R_{\min} = 1.79$$

$$q_{\text{cond}} = \dot{L}_n \cdot V_n$$

$$V_n = D(R+1)$$

$$= 4.16 \times 11.95 = 49.74$$

$$\therefore q_c = 25900 \times 49.74 \Rightarrow q_c = 357.9 \text{ kW}$$

$$q_{\text{reb}} = \dot{L}_m V_m$$

$$\therefore V_m = V_n + F(1-q)$$

$$= 49.74 + 100(0.4)$$

$$V_m = 89.74 \text{ kmol/hr}$$

$$q_{\text{reb}} = 25900 \times 89.74$$

$$\therefore q_r = 645.6 \text{ kW}$$

$$3.5 = \frac{y_2 - 0.14}{x_2 - 0.14}$$

start from $x > 0.14$

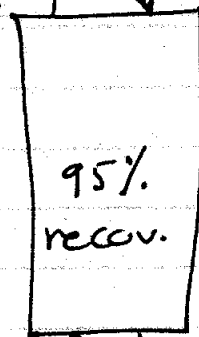


Q5

$$G_B = \frac{1000}{MWT} = \frac{1000}{0.05 \times 14 + 0.95 \times 29}$$

$$G_B = 35.2 \text{ kmol/hr.m}^2$$

100 - 95 = 5%
 $y_T = 0.05 \times 0.05$
 $y_T = 0.0025$
 $x_T = 0$



$$\left(\frac{L_m}{G_m} \right)_{\min} = \frac{y_B - y_T}{x_B^* - x_T}$$

$$= \frac{0.05 - 0.0025}{0.05 - 0}$$

$$= 0.95$$

$$\left(\frac{L_m}{G_m} \right)_{\text{op}} = 1.5 \times 0.95$$

$$= 1.425$$

$$G_B = 1000$$

$$y_B = 0.05$$

$$P_A = 0.95 \times$$

$$\frac{P_A}{P_T} = \frac{0.95}{1 \text{ atm}} x_B^*$$

$$y_B = 0.95 x_B^* = 0.05$$

$$\therefore x_B^* = 0.053$$

$$\therefore L_m = 1.425 \times G_m = 1.425 \times 35.2$$

$$L_m = 48.963 \text{ kmol/hr.m}^2$$

To find (x_B) make M.B

$$y_B - y_T = \frac{L_m}{G_m} (x_B - x_T) \Rightarrow x_B = 0.033$$

$$Z = \frac{G_m}{K_{OG} \cdot a \cdot S \cdot P} \cdot \frac{y_B - y_T}{(y - y^*) L_m}$$

$$\frac{1}{K_{OG} \cdot a} = \frac{1}{K_G \cdot a} + \frac{m}{K_L \cdot a}$$

$$= \frac{1}{22} + \frac{0.95}{102} \Rightarrow K_{OG} = 18.244 \frac{\text{kmol}}{\text{hr.m}^2 \cdot \text{atm}}$$

$$(y - y^*)_{Lm} = \frac{(y_B - y_B^*) - (y_T - y_T^*)}{\ln \frac{y_B - y_B^*}{y_T - y_T^*}}$$

$$y_B^* = 0.95 x_B$$

$$y_T^* = 0$$

$$= 0.032$$

$$\therefore (y - y^*)_{Lm} = 0.007$$

$$\therefore Z = \frac{35.2}{18.244} \times \frac{0.05 - 0.0025}{0.007}$$

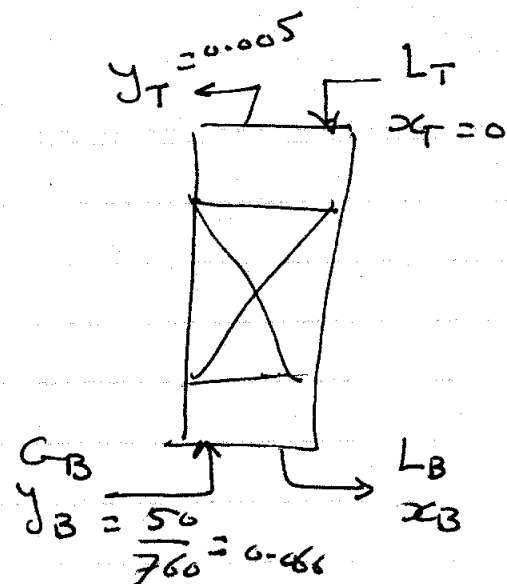
$$Z = 12.7 \text{ m}$$

Q6 Raoult's Law =

$$P_A = x_A \cdot P_A^0$$

$$\frac{P_A}{P_T} = x_A \cdot \frac{P_A^0}{P_T}$$

$$\therefore y_A = 0.455 x_A$$



To convert (G_m) from m^3/hr to $Kmol/hr$.

$$\rho = \frac{P \cdot Mwt}{R \cdot T} = \frac{1 \times 31.2}{0.082 \times 297} = 1.28 \text{ Kg/m}^3$$

$\leftarrow Mwt \times x$

$$G_B = 0.4 \frac{m^3}{s} \times 1.28 \frac{kg}{m^3} \times \frac{1}{0.066 \times 76 + 0.934 \times 28}$$

$$G_B = 0.016 \text{ Kmole/sec}$$

$$G' = G_B (1 - y_B) = 0.016 (1 - 0.066) = 0.0149 \frac{Kmol}{s}$$

$$G_{up} = \frac{0.0149}{1 - 0.005} = 0.015 \frac{Kmol}{s}$$

$$G_m = 0.0155 \frac{Kmol}{s}$$

$$\left(\frac{L_m}{G_m} \right)_{min} = \frac{y_B - y_T}{x_B^* - x_T} \quad x_B^* = \frac{y_B}{m} = \frac{0.066}{0.45} = 0.137$$

$$\therefore \left(\frac{L_m}{G_m} \right)_{min} = 0.443$$

$$\therefore \left(\frac{L_m}{G_m} \right)_{op} = 1.5 \times 0.443 = 0.664$$

$$\therefore L_m = G_m \times 0.664 \\ = 0.0155 \times 0.664 \Rightarrow L_m = 0.0103 \frac{\text{kmol}}{\text{sec}}$$

$$G_m (y_B - y_T) = L_m (x_B - x_T^0)$$

$$\therefore x_B = 0.0885$$

$$Z = HTU \times NTU$$

$$NTU = \frac{y_B - y_T}{\frac{(y_B - y_B^*) - (y_T - y_T^*)}{\ln \frac{y_B - y_B^*}{y_T - y_T^*}}} = 5.089$$

$$\therefore HTU = \frac{Z}{NTU} = \frac{4.73}{5.089} = 0.929$$

$$HTU = \frac{G_m}{K_{Oy} \cdot a \cdot S} = 0.929 = \frac{0.0155}{K_{Oy} \cdot a \times \frac{\pi}{4} (0.72)^2}$$

$$\therefore K_{Oy} \cdot a = 0.0404 \text{ kmol/m}^3 \cdot \text{s} \cdot \text{mol-fraction}$$

For a tray tower :-

$$N = \frac{\ln \left[\frac{y_B - m x_T}{y_T - m x_T} \left(1 - \frac{1}{A} \right) + \frac{1}{A} \right]}{1 - \frac{1}{A}}$$

$$\bar{A} = \frac{L_m}{m G_m} = \frac{0.01}{0.47 \times 0.015} = 1.455$$

$$\therefore N = 5.02$$



University of Technology
Chemical Engineering Department
Final Examination
2011/2012



Subject: Reactor Design

Class: Third
Time: 3 hours

Examiner: Dr. Mohammad Fadhil & Dr. Amer Aziz

Attempt (4) questions only

Q1) The homogenous gas phase reaction $A \rightarrow 3R$ follows a second order kinetics. For a feed rate of $4 \text{ m}^3/\text{h}$ of pure A at 5 atm and 350°C , an experimental reactor consisting of a 2.5 cm inside diameter pipe and 2m long gives 60% conversion of feed.

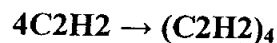
A commercial plant is to treat $320 \text{ m}^3/\text{h}$ of feed, consisting of 70% A, 30% inerts at 25 atm and 400°C . Assume plug flow in the pipe, negligible pressure drop and ideal gas behavior. Estimate the space velocity and the volume of PFR required to obtain 80% conversion, the activation energy 2 kcal/mol.
..... (15 marks)

Q2) An endothermic liquid-phase reaction $3A \rightarrow 2B + C$ is carried out in a batch reactor. The reaction mixture is heated up till 400°C and the reaction then proceeds adiabatically. During the heating up period, 8 mol % of A is converted. From this instant on, what is the time required to reach a conversion of 80 % of A. The specific heat and mass of the reaction mixture are 0.59 kcal/kg.K and 950 kg . The volume of the reaction mixture is constant (1.5 m^3) and the number of mols of A initially is 12.0 kmol. The heat of reaction being 25000 kcal/kmol . The variation of the rate constant with temperature is:

$$\ln k = (-10000/RT + 5) \quad [k \text{ in } (\text{m}^3/\text{mol})^2/\text{s}] \quad \text{..... (15 marks)}$$

Q3) An irreversible liquid phase reaction: $A + D \rightarrow P$, this reaction is carried out in a semi batch reactor. Reactant (A) at a concentration of 0.03 gmol/lit is to be fed at a rate of 0.48 lit/s to an aqueous solution of (D) contained in a reactor. The rate constant is $K = 0.02 \text{ s}^{-1}$. The initial volume of fluid in the reactor to be 6 lit. The initial moles of (A) in feed $N_{A0} = 0.08 \text{ moles}$. Determine the conversion of A as a function of time. Take $n = 0$ to 1 and time increment $(\Delta t) = 0.3 \text{ min}$.
..... (15 marks)

Q4) Two hundred m³/h of gaseous mixture containing 80% acetylene and 20% inerts measured at 550⁰ C and 20 atm , are to be fed to a tube furnace having any where up to 100 tubes in series , each tube is 3.5 m long and 5 cm inside diameter , all kept at 550⁰ C . At this temperature acetylene polymerizes as follows:



The rate constant (at 400⁰ C) = 0.6 m³/kmol.h

Neglecting pressure drop through the tubes, find how many tubes are needed for 60% conversion of acetylene to tetramer complex? The activation energy (E) =500 cal/gmole.

..... (15 marks)

Q5) It is desired to produce 10⁵ tonn/year of ethylene glycol (C) using a system of CSTR which is operated isothermally. A 1 kmol/m³ solution of ethylene oxide (A) in water is fed to the reactor together with an equal volumetric solution of water (B). The reaction is:



The reaction rate constant is 0.3 min⁻¹, and the molecular weights are: Mwt (A) =44; Mwt (B) =18; Mwt(C) =62

- Estimate the volume of a single CSTR to achieve 80% conversion of A.
- If two equally sized CSTRs (each 51 m³) are arranged in parallel and using the same volumetric flow rate in (a), what would be the conversion of A at the outlet?
- If the two reactors in (b) are arranged in series, determine the final conversion.

..... (15 marks)

$$R_g = 0.082 \text{ atm.lit/mol.K} = 1.987 \text{ cal/mol.K} = 8.314 \text{ J/mol.K}$$

GOOD LUCK

الحلول، النموذجية، لدراسة (شأن) نموذجية (3)
(2011 - 2012)

$$Q1 - C_{A0} = \frac{P_T y_{A0}}{R_T} = \frac{5 \times 1}{0.082 \times 623} = 0.098 \text{ kmol/m}^3$$

$$C_A = C_{A0} \left(\frac{1-x}{1+\epsilon x} \right) ; \epsilon = y_{A0} \delta = 1(3-1) = 2$$

$$\therefore C_A = C_{A0} \left(\frac{1-x}{1+2x} \right)$$

$$V = \frac{\pi}{4} d^2 L = \frac{3.14}{4} \times (0.025)^2 \times 2$$

$$\therefore V = 9.8 \times 10^{-4} \text{ m}^3$$

$$V = F_{A0} \int_0^x \frac{dx}{k C_{A0}^2 \left(\frac{1-x}{1+2x} \right)^2} \leftarrow F(x)$$

X	$\left(\frac{1-x}{1+2x} \right)^{-2}$	
0	1	$= f(x)_0$
0.3	5.22	$= f(x)_1$
0.6	30.25	$= f(x)_2$

$$F(x) = \frac{0.3}{3} (1 + 4(5.22) + 30.25)$$

$$F(x) = 5.213$$

$$V = \frac{V_0}{k C_{A0}} \times F(x) \Rightarrow 9.8 \times 10^{-4} = \frac{4 \times 5.213}{0.098 \times k}$$

$$\therefore k = 21.7 \times 10^4 \text{ m}^3/\text{kmol} \cdot \text{hr} \text{ at } 350^\circ \text{C}$$

For a commercial plant:-

$$k = 21.7 \times 10^4 \text{ m}^3 / \text{kmol} \cdot \text{hr} \text{ at } \underline{350^\circ\text{C}}$$

$$\ln \frac{k_1}{k_2} = \frac{E}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

$$\ln \frac{21.7 \times 10^4}{k_2} = \frac{2000}{1.987} \left(\frac{1}{673} - \frac{1}{623} \right)$$

$$\ln \frac{21.7 \times 10^4}{k_2} = 1006.5 (0.00148 - 0.0016)$$

$$\frac{21.7 \times 10^4}{k_2} = e^{-0.126} \Rightarrow \boxed{k_2 = 24.6 \times 10^4 \text{ m}^3 / \text{kmol} \cdot \text{hr} \text{ at } 400^\circ\text{C}}$$

$$C_{A_0} = \frac{y_{A_0} P_T}{R T} = \frac{0.7 \times 25}{0.082 \times 623} = \frac{17.5}{51.08}$$

$$C_{A_0} = 0.342 \frac{\text{kmol}}{\text{m}^3}$$

$$C_A = C_{A_0} \left(\frac{1-x}{1+\varepsilon x} \right) \quad ; \quad \varepsilon = y_{A_0} \delta = 0.7 (3-1) = 1.4$$

$$C_A = C_{A_0} \left(\frac{1-x}{1+1.4x} \right)$$

$$V = \frac{v_0}{k C_{A_0}} \int_0^{0.8} \frac{dx}{\left(\frac{1-x}{1+1.4x} \right)^2}$$

$$V = \frac{v_0}{24.6 \times 10^4 \times 0.342} \times F(x)$$

X	$\left(\frac{1-x}{1+1.4x}\right)^{-2}$
0	1 = $f(x)_0$
0.4	6.75 = $f(x)_1$
0.8	112.36 = $f(x)_2$

$$V = \frac{v_0}{84132} \times \frac{0.4}{3} \times [1 + 4(6.75) + 112.36]$$

$$\frac{V}{v_0} = \frac{0.4}{252346} \times (140.36)$$

$$\tau = \frac{56.144}{252346} \Rightarrow \tau = 0.000222 \text{ hr}$$

$$\text{Space velocity} = \frac{1}{\tau} = \frac{1}{0.000222}$$

$$\text{Space velocity} = 4504.5 \text{ hr}^{-1}$$

$$V = \frac{320 \times 56.144}{252346}$$

$$V = 0.0712 \text{ m}^3$$

Q2:-

Before heating, $C_{A0} = \frac{N_{A0}}{V_0} = \frac{12.0}{1.5} = 10 \text{ kmol/m}^3$

At $T = 400^\circ\text{C}$, the initial concentration is reduced to

$$C_A = C_{A0}(1-x) = 10(1-0.08) \Rightarrow C_A = 9.2 \text{ kmol/m}^3$$

$$(-r_A) = k C_A^3 = k C_{A0}^3 (1-x)^3$$

$$t = C_{A0} \int_0^{0.8} \frac{dx}{k C_{A0}^3 (1-x)^3} = \frac{1}{C_{A0}^2} \int_0^{0.8} \frac{dx}{k (1-x)^3} \quad \text{--- (1)}$$

Since $k = f(T)$, energy balance is required:

$$(-\Delta H_R) C_{A0} X = \rho_{\text{mix}} \cdot C_{p_{\text{mix}}} (T - T_0)$$

$$(-25000) 9.2 X = 950 \times 0.59 (T - 673)$$

$$-230000 X = 560.5 T - 377216.5$$

$$560.5 T = 377216.5 - 230000 X \quad \text{--- (2)}$$

$$T = 673 - 410.3 X$$

$$\ln k = (-10000 / RT + 5)$$

$$k = \exp \left(-\frac{10000}{RT} + 5 \right) \quad \text{--- (3)}$$

$$1.987 \frac{\text{cal}}{\text{mol} \cdot \text{K}}$$



X	T	K	$[K(1-x)^3]^{-1}$
0	673	0.084	12 = $f(x)_0$
0.4	498	0.0061	759 = $f(x)_1$
0.8	323	1.7×10^{-7}	$7.35 \times 10^5 = f(x)_2$

$$F(x) = \frac{0.4}{3} [12 + 4(759) + 7.35 \times 10^5]$$

$$F(x) = 98406.4$$

$$t = \frac{98406.4}{(9.2)^2} = \frac{98406.4}{84.64}$$

$$t = \underline{1162.64 \text{ s}} \text{ or } \underline{19.37 \text{ min.}} \text{ or } \underline{0.323 \text{ hr}}$$

$$Q38- C_A = \frac{F_{Ac}t - N_{A_0}X}{V_0 + v_0 t}$$

$$(-r_A) = k \frac{(F_{Ac}t - N_{A_0}X)}{(V_0 + v_0 t)} \quad \dots (1)$$

$$(-r_A)V = N_{A_0} \frac{dx}{dt} \Rightarrow (-r_A) = \frac{N_{A_0}}{V} \frac{dx}{dt}$$

$$(-r_A) = \frac{N_{A_0}}{V_0 + v_0 t} \frac{dx}{dt} \quad \dots (2)$$

$$\frac{N_{A_0}}{V_0 + v_0 t} \frac{dx}{dt} = k \frac{(F_{Ac}t - N_{A_0}X)}{V_0 + v_0 t} \quad (2) \& (1) \Rightarrow$$

$$\frac{dx}{dt} = \frac{k}{N_{A_0}} (F_{Ac}t - N_{A_0}X)$$

$$K_1 = \Delta t * F(x_n, t_n)$$

$$K_2 = \Delta t * F(x_n + \frac{K_1}{2}, t_n + \frac{\Delta t}{2})$$

$$K_3 = \Delta t * F(x_n + \frac{K_2}{2}, t_n + \frac{\Delta t}{2})$$

$$K_4 = \Delta t * F(x_n + K_3, t_n + \Delta t)$$

The known quantities are:

$$F_{Ac} = C_A \cdot v_0 = 0.0144 \text{ gmol/s.}$$

$$V_0 = 6 \text{ lit}, v_0 = 0.48 \text{ lit/s}, k = 0.02 \text{ s}^{-1}$$

$$\frac{dx}{dt} = \frac{0.02}{0.08} (0.0144 t - 0.08 X)$$

$$\frac{dx}{dt} = (3.6 \times 10^{-3} t - 0.02 x)$$

$$n=0 \Rightarrow t=0, x=0$$

$$n=1 \quad \therefore \Delta t = 0.3 \text{ min} \times 60 = 18 \text{ sec.}$$

$$\text{when } t=0, x_0 = 0$$

$$x_1 = x_0 + \frac{1}{6} (k_1 + 2k_2 + 2k_3 + k_4)$$

$$k_1 = \Delta t \times [F(x_0, t_0)]$$

$$= 18 (3.6 \times 10^{-3} \times 0 - 0.02 \times 0)$$

$$k_1 = 0$$

$$k_2 = \Delta t \times [F(x_0 + \frac{k_1}{2}, t_0 + \frac{\Delta t}{2})]$$

$$k_2 = 18 \times (3.6 \times 10^{-3} \times 9 - 0.02 \times 0)$$

$$k_2 = 0.583 \text{ s}^{-1}$$

$$k_3 = \Delta t \times [F(x_0 + \frac{k_2}{2}, t_0 + \frac{\Delta t}{2})]$$

$$= 18 \times (3.6 \times 10^{-3} \times 18 - 0.02 \times 0.29)$$

$$= 18 \times (0.0648 - 5.8 \times 10^{-5})$$

$$k_3 = 1.062 \text{ s}^{-1}$$

$$k_4 = \Delta t \left[f(x_0 + k_3, t_0 + \Delta t) \right]$$

$$k_4 = 18 \times (3.6 \times 10^{-3} \times 18 - 0.02 \times 1.062)$$

$$k_4 = 18 \times (0.0648 - 0.0212)$$

$$k_4 = 0.7848 \text{ s}^{-1}$$

$$x_1 = x_0 + \frac{1}{6} (k_1 + 2k_2 + 2k_3 + k_4)$$

$$x_1 = 0 + \frac{1}{6} (0 + 2(0.583) + 2(1.062) + 0.7848)$$

$$x_1 = \frac{1}{6} (1.166 + 2.124 + 0.7848)$$

$$x_1 = 0.68$$

n	t/sec	x
0	0	0
1	18	0.68

$$Q4:- \ln \frac{k_1}{k_2} = \frac{E}{R} \left[\frac{1}{T_2} - \frac{1}{T_1} \right]$$

$$\ln \frac{0.6}{k_2} = \frac{500}{1.987} \left[\frac{1}{823} - \frac{1}{673} \right]$$

$$\ln \frac{0.6}{k_2} = -0.07932$$

$$\Rightarrow \boxed{k_2 = 0.645 \text{ m}^3/\text{kmol} \cdot \text{h}} \text{ at } 550^\circ\text{C}$$

From the units of the rate constant, the reaction degree is 2nd order :-

$$\therefore (-r_A) = k C_A^2 \Rightarrow (-r_A) = k C_{A0}^2 \left(\frac{1-x}{1+\epsilon x} \right)^2$$

$$\therefore \epsilon = y_{A0} \delta \Rightarrow 0.8(1-4)$$

$$\therefore \epsilon = -2.4$$

$$\therefore \boxed{C_A = C_{A0} \left(\frac{1-x}{1-2.4x} \right)}$$

$$C_{A0} = \frac{y_{A0} P_T}{R T} = \frac{0.8 \times 20}{0.082 \times 823}$$

$$C_{A0} = 0.23 \text{ kmol/m}^3$$

$$\therefore V = F_{A0} \int_0^x \frac{dx}{(-r_A)} \Rightarrow V = \frac{C_{A0} v_0}{k C_{A0}^2} \int_0^{0.6} \frac{dx}{\left(\frac{1-x}{1-2.4x} \right)^2}$$

$$V = \frac{2}{0.64 \times 0.23} \times F(x)$$

X	$\left(\frac{1-x}{1-2.4x}\right)^2$	$\left(\frac{1-x}{1-2.4x}\right)^{-2}$
0	1	1
0.3	6.25	0.16
0.6	0.826	1.2

$$F(x) = \frac{0.3}{3} [1 + 4(0.16) + 1.2]$$

$$F(x) = 0.284$$

$$V = \frac{2}{0.147} \times 0.284$$

$$V = 3.86 \text{ m}^3$$

$$N = \frac{3.86}{\frac{\pi}{4} (0.05)^2 \times 3.5}$$

$$\underline{\underline{N = 570 \text{ tubes}}}$$

Q5:- (a) The production rate in kmol/min

$$F_c = 10^5 \frac{\text{ton}}{\text{year}} * \frac{1000 \text{ kg}}{1 \text{ ton}} * \frac{1 \text{ year}}{365 \text{ day}} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ hr}}{60 \text{ min}} * \frac{1 \text{ kmol}}{62 \text{ kg}} = 3.068 \frac{\text{kmol}}{\text{min}}$$

$$F_c = F_{A0} x \Rightarrow F_{A0} = \frac{F_c}{x} = \frac{3.068}{0.8} = 3.836 \frac{\text{kmol}}{\text{min}}$$

$$(-r_A) = k C_A$$

$$V = \frac{F_{A0} x}{(-r_A)} = \frac{v_0 C_{A0} x}{k C_{A0} (1-x)} = \frac{v_0 x}{k (1-x)}$$

$$v_0 = \frac{F_{A0}}{C_{A0}} = \frac{3.836}{1} = 3.836 \frac{\text{m}^3}{\text{min}}$$

$$V = \frac{v_0 x}{k (1-x)} = \frac{3.836 * 0.8}{0.3 (1-0.8)} = \underline{\underline{51.15 \text{ m}^3}}$$

(b) For two CSTRs in parallel.

$$\tau = \frac{V}{v/2} = \frac{51}{1.918} = 26.59 \text{ min}$$

$$x = \frac{\tau k}{1 + \tau k} = \frac{26.59 * 0.3}{1 + 26.59 * 0.3}$$

$$\underline{\underline{x = 0.888}}$$

③ For two CSTRs in series :-

The conversion in the 1st reactor :-

$$X_1 = \frac{\tau_1 k}{1 + \tau_1 k}$$

$$\text{when } \tau_1 = \frac{V_1}{v_0} = \frac{51}{3.836} = \underline{\underline{13.295 \text{ min.}}} = \tau_2$$

$$X_1 = \frac{13.295 * 0.3}{1 + 13.295 * 0.3}$$

$$X_1 = 0.799$$

To calculate the conversion in the 2nd reactor,

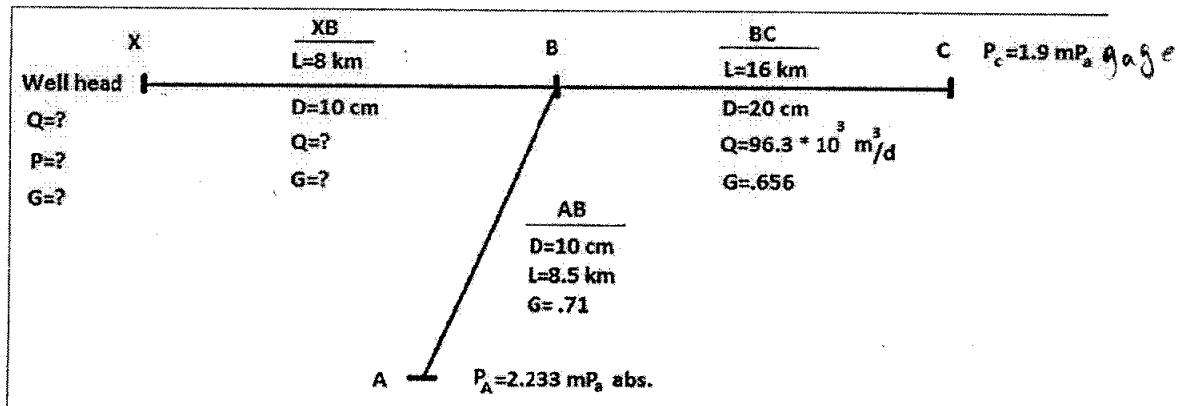
$$\tau_2 = \frac{X_2 - X_1}{k(1 - X_2)} \Rightarrow 13.295 = \frac{X_2 - 0.799}{0.3(1 - X_2)}$$

$$X_2 = 0.959$$



Answer 5 questions only, including question No.1

Q1:



The system shown above to be designed for gathering gas from well and X; then through B to be delivered to C. The average line temp. is 25°C.

- Find the flow rate of line XB. (14 marks)
- Find the well head press. of well X. (14 marks)

Q2:

If P_1 is initial press. of gas in pipeline and P_2 is the final press of it, at end of the pipeline.

- a) When P_A equivalent horizontal press. become less than P_2 , and why; show it mathematically and by words (explain concisely). (10 marks)
- b) When a valve is closed on a line a press. surge occurs. Why? And when become more series? (8 marks)
-

Q3:

Grid (net of lines) transporting natural gas (gas and liq. phases) to the consumers in the city.

- a) If 10% of the gas from main line enters the branch; how much liquid enters with it? (5 marks)
- b) Instead of 10% in (a) 36%; how much liquid continue to flow in main line. (8 marks)
- c) When gas flow rate shows bad transfer in the pipeline. What measure will be taken to improve it? (5 marks)
-

Q4:

- a) Increasing pipeline capacity during design can be accomplished. How? (8 marks)
- b) Draw piezometric press. **head** diagram of pipeline (Head vs. Distance) showing:
- (b1) Press. profile of liquid inside the pipe.
 - (b2) Elevation profile.
 - (b3) Actual line press.
 - (b4) Control point. (10 marks)

Q5:

- a) Write down rule-of-thumb estimating total storage losses. (6 marks)
- b) Under certain loading conditions failure of structure can take place not through gross yielding or plastic; by what? (6 marks)
- c) When this mode of failure will occur? (6 marks)
-

Q6:

Given that:

$$\varphi = -\frac{dw}{dx} = -\frac{1}{D} \frac{Px^3}{16} + C_1 \frac{x}{2} + \frac{C_2}{x}$$

- a) Find "w" as function of x. (8 marks)
- b) State the boundary conditions. Find C_1, C_2, \dots . (10 marks)

حل سوال 1
1

1

$$P_c = 1.9 + .1 = \underline{2 \text{ MPa abs.}}$$

To find P_B press. :

$$Q_{BC} = 1740 \left(\frac{273^\circ K}{100 \text{ KPa}} \right) \left[\frac{P_B^2 - 2^2}{.658 \cdot 298 \cdot 16} \right]^{\frac{1}{2}} \cdot (20)^{\frac{8}{3}} \cdot (E_p = 1)$$

$$96.3 \times 10^3 = \text{std m}^3/\text{d}$$

$$P_B = \underline{2.037 \text{ MPa abs.}}$$

To find the flow in branch A-B :

$$Q = 1740 \left(\frac{273^\circ K}{100 \text{ KPa}} \right) \left[\frac{2.933^2 - 2.037^2}{.71 \cdot (298^\circ K) \cdot (8.5)} \right]^{\frac{1}{2}} \cdot (10)^{\frac{8}{3}}$$

$$Q = 49.223 \times 10^3 \text{ std. m}^3/\text{d.}$$

(2)

To find flow rate ~~is~~ of X-B line:

$$96.3 \times 10^3 - 49.223 \times 10^3 = 47.077 \text{ m}^3/\text{d}_{\text{std}}$$

To find well head press.:

from the flow $47.077 = 1740 \left(\frac{273}{100 \text{ kPa}} \right) \left[\frac{P_x^2 - 2.037^2}{G \times 298.8} \right]^{\frac{1}{2}} \times 10^{\frac{8}{3}}$

hence G must be found firstly, which as follows:

$$96.3 \times 10^3 \times .656 = 47.077 \times 10^3 G + 49.223 \times 10^3 \times .71$$

$$\underline{G = .5995}$$

Back to the equation:

$$47.077 = 1740 \left(\frac{273}{100} \right) \left[\frac{P_x^2 - 2.037^2}{.5995 \times 298.8} \right]^{\frac{1}{2}} \times 10^{\frac{8}{3}}$$

or

$$P_x = \underline{\underline{2.191 \text{ MPa obs. check}}}$$

$$\frac{HG}{AT_a Z_a} = \ln \frac{P_A}{P_B} \quad \text{--- eq. 1}$$

H = head

m

G = gas relative density

T_a = average gas temp.

K

Z_a = average gas compressibility

P_A = Press. at bottom of static column

MPa

P_B = Press. at top of static column

MPa

A = constant

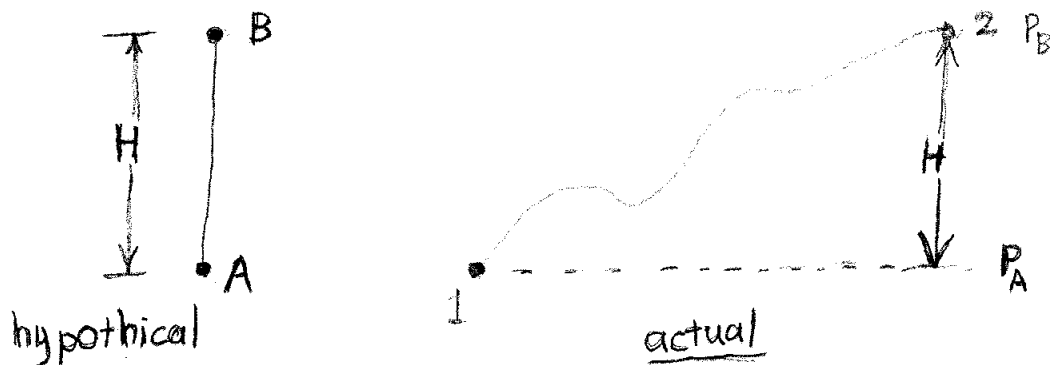
29.28

eq. 1 could be written in the form

$$P_A = P_B e^S$$

where $S = \frac{HG}{AT_a Z_a}$, $e = 2.718$

- Now, to do the correction to P₂, we convert the line from the actual profile shown before to that shown below:



- If press. 1 will be fixed P₁; then P_A will be calculated as equivalent horizontal press. to be used in the equations of flow in table 12.1, instead of P₂ which is specified.
- In case uphill the H will be positive and P_A

- will be higher than P_2
- In case downhill H will be negative and S will be negative and P_A equivalent horizontal will be less than actual P_2 . P_A to be used in the equations of table 12.1.
- Now for L to be used in equation of table 12-1 is the actual profile rather than geographical distance.
- The correction for P_2 and L has very small effect on final result.

Example: A gas line runs uphill. The following data apply:

4.0

$H = 100 \text{ m}$, $T_a = 300\text{K}$, $Z_a = 0.90$, $G = 0.70$, $P_2 = 4.0 \text{ MPa}$, $P_1 = 6.0 \text{ MPa}$

$$s = (100)(0.70) / (29.28)(300)(0.9) = 0.00885$$

$$\frac{HG}{A T_a Z_a} = Z$$

$$P_A = (4.0)e^{0.00885} = 4.04 \text{ MPa (which is equivalent } P_2 \text{ for horizontal flow)}$$

1
6.0
4.04

ملحوظة

1 عند ما يكون Uphill فالـ P_1 سوف يخسر ΔP للتغلب على الارتفاع وعلى الآخر كان. لذلك P_2 نقرأها بعد الخسارة ΔP الأكبر. وعند التصحيح P_A فهي الـ P_2 المصححة تكون أكبر من P_2 لأن $P_A = P_1 - \Delta P_A$ هي أصغر من ΔP الحقيقية. $\Delta x = 0$ لأن P_A تمثل الـ P_2 عند ما يكون الـ pipeline أفقياً.

2) عند ما يكون Downhill فالـ P_1 سوف يخسر ΔP صغيره بسبب مساعدة الـ gravity له. لذلك P_2 عند ما نقرأها تكون P_2 كبيرة. لذلك عند ما تصحيح P_2 الـ P_A تكون $P_2 = P_1 - \Delta P_A$ أكبر بسبب انعدام مساعدة الـ gravity لأن الـ pipeline يصبح أفقياً. لذلك $P_A = P_1 - \Delta P_A$ ويكون P_A أصغر من P_2 .

P_1/P_2 = Press. ratio on blowdown
and all other units are
the same.

5.3 — Press. Surges on Closing a Valve:

• When a valve is closed on a line a press. surge occurs. The kinetic energy of the fluid is converted to internal energy when flow stops. A wave (surge) travels back through the line countercurrent to the fluid still flowing forward, but slowing down.

• Each section of the line behaves in a different manner. Since flow does not stop upstream when stoppage occurs at some point downstream, the press. rise decreases as the wave front travels upstream.

• Some of the energy is absorbed by the expansibility of the fluid and

② the pipe. The more energy absorbed, the less press. rise. Thus, compressibility of the fluid is a primary factor. Since liquids are essentially incompressible, they represent the primary problem. By the same token, high press. gas will exhibit more press. rise than low press. gas.

straight = مستقيم / مباين

47

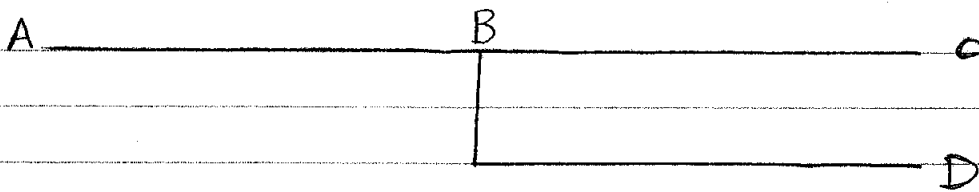
3.6 - Two-Phase Flow in Grid Systems:

- It is often transporting two-phase systems through a grid containing parallel lines. Logic would seem to indicate that the bulk of the liquid would continue to move straight ahead or would split evenly with the gas when two lines join. This is not true.
- Work has been performed which expresses what happens, on a semi-quantitative basis:
Fig. 3.6 shows the representative data from the study.

fig. 12.14

- The following conclusion could be made:

Fig 3.6



1. In case $< 20\%$ of the gas enters the branch BD, almost all of the liquid will flow straight ahead (BC).
2. If $> 35\%$ of the gas enters the branch, almost all of the liquid will enter the branch (BD).
3. Between 20-35%, the liquid will split as shown by the fig. 3.6.

line

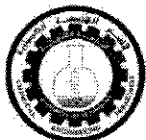
4

Pipelines

- Oil flows by pump or gravity or a combination of the two. Virtually all pumps are diesel-engine- or electric-motor-driven centrifugals. Early pipelines used steam-driven reciprocating pumps, and these are sometimes still used for very high viscosity oils. Pressures of about 1,200 psi are used for lines up to 12 in. For 24- to 30-in. pipe, pressures of 500 to 800 psi are more common. Among the largest pumps built for this service are those on the Trans-Arabian line, nominally 30 in., each driven by a 6,000-hp turbine and pumping up to 340,000 B/D at 800 psi. Long pipelines require frequent booster stations to restore pressure lost to line friction or gradient variations. A booster is usually installed wherever the line pressure drops to about 50 psi.
- Economics determines choice of pipe diameter and number of pumping stations. A given throughput can be attained with a small-diameter line and high head loss or with a large-diameter line and low head loss. Normally, capital cost will be lower

Underwater lines are starting to find increased use with the growth in offshore production and the rising use of large tankers which cannot tie up at shore berths. Such lines are coated and wrapped as is buried pipe and then covered with a few inches of concrete, which not only protects the pipe but also provides weight needed to anchor it against tidal currents.

• Head or press. head = The height of a column of fluid necessary to produce a specific pressure.



University of Technology
Chemical Engineering Department



Subject: Statistics

Branch: both branches

Examiner: Ebtisam H.

Final Examination

2011/2012

Time: 3hrs
Class: third
Date:

Attempt four questions only

Q.1) Given the following:

Class limit	0.0-					-4.1
frequency	9	12	24	23	15	7

Obtain the following:

(25 Marks)

A. Complete the frequency distribution. B. Calculate the arithmetic mean of standard score (Z).

Q.2) It is required to fit the following equation: $y = ax + bx^2$ to the data:

x: 1 2 3 4 5

y: 1.8 5.1 8.9 14.1 19.8

- A. Transform the equation to straight line form, and then determine the constants. (10 Marks)**
B. For a straight line relation, use a Least squares method to derive an expression for the centroidal point (\bar{x}, \bar{y}) . (15 Marks)

Q.3) If 3% of the plastic parts made by an injection molding machine are defective. If a sample of 30 parts is taken at random. Calculate:

- A. Probability that at most 3 parts will be defective. (10 Marks)**
B. Probability that at least 3 parts will be defective. (15 Marks)

Using: 1) Binomial distribution. 2) Normal approximation to Binomial.

Q.4) Each automobile leaving a certain motor company plant is equipped with 5 tires; the tires on each 100 automobiles were examined for defects with the following results:

No. of tires : 0 1 2 3 4 5

No. of automobiles : 75 18 4 2 0 1

(25 Marks)

Determine the goodness of fit of Poisson distribution at a significant level of 0.05. $(\chi^2_{0.95}) = 9.49$

Q.5) Explain the following:

- A. An instrument used to measure very low pressure. B. Types of an elastic medium in pressure measurement. C. Manometric thermometers. D. Flow measurement with a variable differential pressure. (25 Marks)**

With My Best Wishes for Success

(2) ~~is a data~~

Q1/ range = $4.1 - 0.01 = 4.1$, total width = $4.1 + 0.1 = 4.2$
 class width = $\frac{4.2}{6} = 0.7$
 interval = $0.7 - 0.01 = 0.6$

(A)

class limit	freq.	X	$\sum X$	$\sum (X - \mu)^2$	Z	$\sum Z$
0.0 - 0.6	9	0.03	0.27	0.27	-1.79	-16.14
0.7 - 1.3	12	0.1	1.2	0.129	-1.07	-12.87
0.14 - 0.20	24	0.17	4.08	0.027	-0.35	-8.41
0.21 - 0.27	23	0.24	5.52	0.079	0.37	8.54
0.28 - 0.34	15	0.31	4.65	0.168	1.093	16.4
0.35 - 0.41	7	0.38	2.66	0.217	1.814	12.7
	<u>90</u>		<u>18.38</u>	<u>0.84</u>		<u>0.22</u>

(B) $\mu = 0.204$ $\sigma = 0.097$ $Z = \frac{X - \mu}{\sigma}$

$Z' = \frac{\sum fZ}{\sum f} = 0.00244$

Q2

X	O_e	$X \cdot O_e$	$Pr(x)$	P_e	$(O - e)^2 / e$
0	75	0	0.69	69.07	0.509
1	18	18	0.255	25.55	2.23
2	4	8	0.047	4.73	0.13
3	2	6	0.00583	0.583	3.44
4	0	0	0.000539	0.0539	0.054
5	1	5	3.99×10^{-5}	3.99×10^{-3}	248.6
	<u>100</u>	<u>37</u>			<u>254.86</u>

$\chi^2 > \chi'_{0.95}$ reject the Poisson
not good.

Q.3 ① using Binomial

$$\Pr(\text{at most } 3) = \Pr(X \leq 3) = \Pr(3) + \Pr(2) + \Pr(1) + \Pr(0)$$

$$\Pr(3) = \frac{30!}{3!(30-3)!} (0.03)^3 (0.97)^{27} = 0.048$$

$$\Pr(2) = 0.1668, \Pr(1) = 0.372, \Pr(0) = 0.401$$

$$\Pr(X \leq 3) = 0.9878.$$

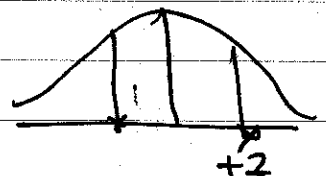
$$\begin{aligned}\Pr(\text{at least } 3) &= \Pr(X \geq 3) = \Pr(3) + \Pr(4) + \dots + \Pr(30) \\ &= 1 - \{ \Pr(0) + \Pr(1) + \Pr(2) \} \\ &= 1 - 0.9398 \\ &= 0.0602\end{aligned}$$

② using normal

$$\Pr(X \leq 3) \Rightarrow Z_1 = \frac{X - \mu}{\sigma} = \frac{3.5 - 0.9}{0.934} = 2.78$$

$$\mu = N \times p = 30 \times 0.03 = 0.9$$

$$\sigma = \sqrt{Npq} = 0.934$$



at z_1 , $A_1 = 0.4973$

$$\begin{aligned}\therefore \Pr(Z < 2.78) &= 0.5 + 0.4973 = 0.9973 \\ &= 0.9973\end{aligned}$$

$$\Pr(X \geq 3) \Rightarrow Z_2 = \frac{X - \mu}{\sigma} = \frac{2.5 - 0.9}{0.934} = 1.71$$

at z_2 $\rightarrow A_2 = 0.4564$

$$\Pr(Z > 1.71) = 0.5 - 0.4564 = 0.044$$

Q.4) (A) To min. $SSE = \sum e_i^2 = \sum [y_i - (a + bx_i)]^2$

$$\frac{\partial SSE}{\partial a, b} \Rightarrow$$

$$\sum y_i - na - b \sum x_i = 0$$

$$\sum x_i y_i - a \sum x_i - b \sum x_i^2 = 0$$

solve to get.

$$b = \frac{\sum xy}{\sum x^2} = \frac{\sum xy - \frac{1}{n} \sum x \sum y}{\sum x^2 - \frac{1}{n} (\sum x)^2}$$

$$a = \frac{\sum y - b \sum x}{n} = \bar{y} - b \bar{x}$$

Subst. $\hat{y} = a + bx_i$ in eqn. above to get:

$$(\hat{y} - \bar{y}) = b(x_i - \bar{x}) \text{ where } (\bar{x}, \bar{y}) \text{ is the centroidal pt.}$$

(13) $y = ax + bx^2$ $\frac{y}{x} = a + bx$

$$Y = y/x \quad X = x$$

$X = x$	y	$Y = y/x$	XY	X^2
1	1.8	1.8	1.8	1
2	5.1	2.55	5.1	4
3	8.9	2.966	8.9	9
4	14.1	3.525	14.1	16
5	19.8	3.96	19.8	25
15	48.8	14.8	49.7	55

$$b = \frac{49.7 - \frac{1}{5} \times 15 \times 14.8}{55 - \frac{1}{5} (15)^2} = \frac{5.297}{10} = 0.5297$$

$$a = \bar{y} - b \bar{x} = \frac{14.8 - 0.5297 \times 15}{5} = 1.37$$