



**Note: Answer 4 questions only.**

**Q.1-** Define five of the following:

Montreal protocol, Biochemical oxygen demand BOD, Environment and pollution, Activated sludge system with sketch, Acid rain, Nutrient.

( 25 Mark )

**Q.2-** Answer two of the following:

1. What are the wet scrubbers and what are the advantages and disadvantages of the wet scrubbers? Numerate the major types of the wet scrubbers. Explain one of the types in detail with sketch.
2. Define the solid waste and what are the classifications of solid wastes?
3. 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  $D_c$ .

( 25 Mark )

**Q3- a.** Derive the terminal velocity equation in Stock's region. (10 Mark)

**b.** A gravity settling chamber is used to remove limestone particles having a specific gravity of 2.31 from air stream. The unit is 2m wide and 1.5m height and 5m long. The volumetric flow rate of the air is  $5\text{ m}^3/\text{s}$ . The inlet size distribution of the limestone is given below:

Size range, $d_p, \mu\text{m}$	0-20	20-40	40-60	60-80	80-100	100-150
Weight percent, w%	3	7	15	15	25	35

Calculate the overall collection efficiency over each size range. The air density is  $1.2\text{ kg/m}^3$  and viscosity  $2.2 \times 10^{-5} \text{ kg/m s}$ .

(15 Mark)

**Q4-** A cyclone with an inlet width of 15cm is to be used to separate particulates matter of density  $2400\text{ kg/m}^3$  from gas stream. The inlet gas velocity is  $7.5\text{ m/s}$ . If the gas is air and its density is  $1.19\text{ kg/m}^3$  and viscosity is  $1.86 \times 10^{-5} \text{ kg/m s}$ . Using effective number,  $N_e=5$ , estimate:

1. What will the particle size in micrometer be collected with 80% efficiency, from air stream.
2. What will the particle size be if the inlet gas velocity is doubled and the collection efficiency is 80%.

( 25 Mark )

**Q5- 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  $4\text{ km/h}$  and has flow of  $0.5\text{ m}^3/\text{s}$ . Other information are:

	Temp. ( $^{\circ}\text{C}$ )	DO (mg/l)	BOD <sub>5</sub> (mg/l)
Stream	21	9	11
sewage	26	1.5	200

The deoxygenation constant ( $k_1$ ) evaluated at 20 °C is 0.4 day<sup>-1</sup>. The saturation concentration of dissolved oxygen at average temperature is given by:

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

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

(15 Mark)

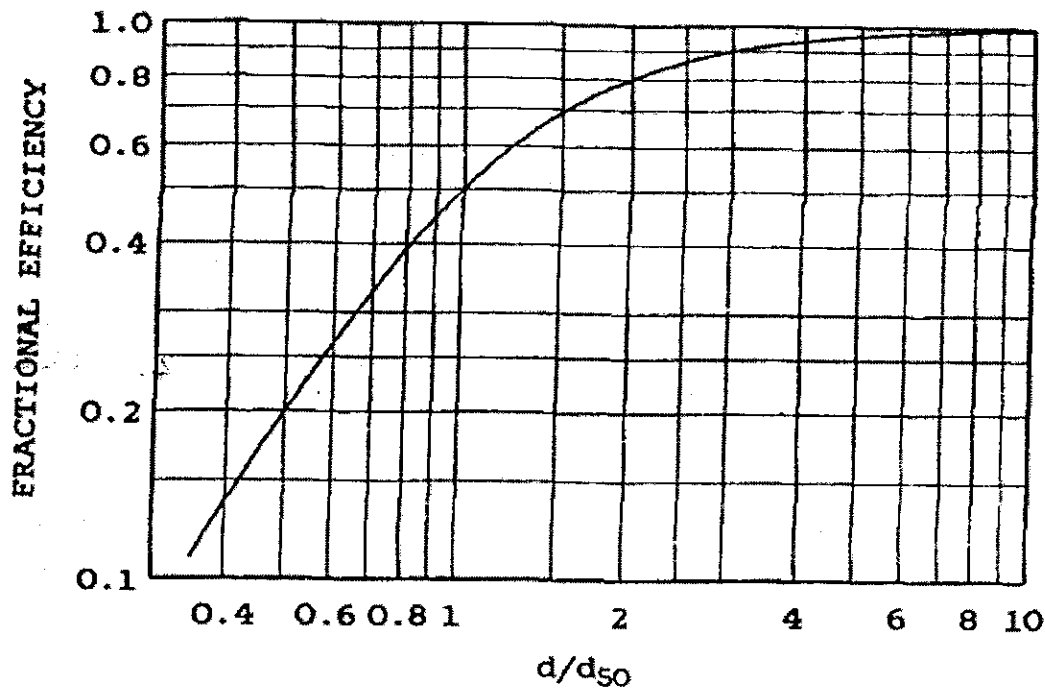
b. The following BOD results are observed for a sample of raw sewage at 20°C

t (days)	0	1	2	3	4	5
Y (BOD, mg/l)	0	65	109	138	158	172

1. Plot BOD curve.

2. Calculate the reaction-rate constant  $k_1'$  and the ultimate BOD,  $L_u$

(10 Mark)



Cyclone efficiency versus particle-size ratio

**GOOD LUCK**



Note: Answer only 4 questions

Q.1

- A. Find the series solution for the following differential equation:
- $$3x \frac{d^2 y}{dx^2} - (1-x) \frac{dy}{dx} - y = 0$$
- B. Show that if  $y(0) = 0$

$$y = Ax^{4/3} \left( 1 - \frac{x}{21} + \frac{x^2}{315} - \dots \right)$$

A is an arbitrary constant

(15 Marks)

Q.2 Find the Laplace transformation for the following:

(15 Marks)

1.  $\frac{1}{\sqrt{\pi t}}$
2.  $f(t) = \begin{cases} \sin t & 0 < t < \pi \\ 0 & t > \pi \end{cases}$
3.  $H(t-1) \cos(t-1)$
4.  $e^{-t} \sin^2 t$

Q.3

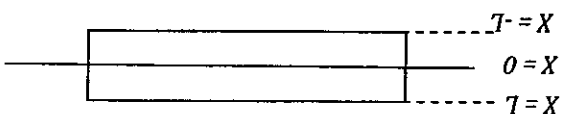
A. Invert the following:

1.  $\frac{e^{-s}}{s^2(s-1)}$
2.  $\frac{s^2(s+a)^2}{1}$

B. Solve the differential equation by Laplace Transformation:

$$\frac{dy}{dx} - y = \begin{cases} e^t & 0 < t < 1 \\ 0 & t > 1 \end{cases}, y(0) = 0$$

Q4. Slab of porous solid of thickness  $2L$  is soaked in pure ethanol. The pores are fine so that only molecular diffusion may take place through the liquid in the passages of the slab. The slab is transferred and placed in a large well-agitated reservoir of pure water. Assume there is no resistance to mass transfer in the water phase and the concentration of ethanol in water and at the slab's surface is kept constant at zero. Show the concentration profile inside the slab is:



$$\frac{C}{C_0} = \frac{L}{2} \sum_{n=1}^{\infty} (-1)^n \cos\left(\frac{2n-1}{2} \frac{\pi x}{L}\right) \cdot e^{-\frac{4L^2}{(2n-1)^2 \pi^2} D_{AB} t}$$

Q5. Suppose fluid of semi-infinite depth, initially was at a constant concentration of  $C_{A0}$ . Let the free surface concentration be suddenly changed to  $C_{Ai}$  and maintained at that value. Show the concentration profile in the fluid is:

$$\frac{C_A - C_{A0}}{C_{Ai} - C_{A0}} = \operatorname{erfc}\left(\frac{\sqrt{4D_{AB}t}}{x}\right)$$

(15 Marks)

Good Luck

Prof. Assist. N. W. Kasser



**Note: Answer Four questions only.**

Q1:- A/ Draw sketches symbology of (7) of the following:

- 1) Check valve 2) Pressure controller 3) Cross flow bubble cap tray 4) Spray column
- 5) Rotary kiln 6) Reciprocating pump 7) cooler-condenser 8) Rotary compressor
- 9) Rotometer 10) Orifice-flow meter

B/ Define the main three types of pressure, and what are the mathematical relations between them.

Q2:- Explain with details and sketch the mechanism of liquid-liquid separation equipment

(25 mark)

Q3:- A mixture of three components with the following specification:

Stream	Mass flow rate kg/hr	Density kg/m <sup>3</sup>	Viscosity, centipoises
Gas	$W_v = 1800$	$\rho_v = 10$	-
Hexane	$W_L = 7000$	$\rho_L = 780$	$\mu_L = 0.62$
Water	$W_h = 2000$	$\rho_h = 9800$	$\mu_h = 0.95$

The mixture was fed into a vapour-liquid separator. The operating pressure was 50 bar and operating temperature of 47°C. The vessel should have an extra surge time of (20 min) for the hexane.

Take: Liquid-liquid separation constant = 0.05

Vapour-liquid separation constant = 0.2

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

(25 mark)

Q4:-A/Define (4) of the following:-

- 1) 0.6 Factor 2) Instrumentation diagram 3) Man-hour 4) Surge drum

5) Model 6) Data sheet

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.

Q5: in a separation process by using a distillation column, it is required to design a bubble cap tray given the following information:-

Material	M.wt	Pressure	temp	Liquid Density	Vapour Density	Maximum Liquid load	Maximum Vapour load
Paraffin's	80	2 atm	90°C	48 lb/ft <sup>3</sup>	0.31b/ft <sup>3</sup>	350 gpm(gal/min)	280 ft <sup>3</sup> /sec

Use trapezoidal slots  $C_s = 0.74$

Use the formation in the table of the next page:

Follow 17

(25 mark)

**GOOD LUCK**

# Table of Bubble Cap Tray Design

a) Standard bubble cap design for trapezoidal slots with  $C_s=0.74$

Material	3	4	5	inch
carbon steel	10	26	39	
No. of slots	1	1.25	1.5	
Slot height	5	8.12	14.64	inch <sup>2</sup>
Slot area	7.5	13.15	29	inch <sup>2</sup>
Cap area	0.67	0.62	0.5	
Slot to cap ratio				

b) Bubble cap size and slot area

Ratio of a slot/ allocated cap area	0.25	=0.3125	=0.375	=0.5
Normal cap size inch	3	3	3	3
Tray type selection	6	4	0.20	0.25

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				
8	0.50	50-500				
10	0.50	50-500				
12	0.50	50-500				
15	0.50	50-500				
20	0.50	50-500				

d) Distribution of area as % of tower area

Tower dia	down flow area	liquid distribution area	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double pass	double 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e) Tray design standard

Normal size for	ft tower	inch
2.5-5	ft tower	3 inch
4-15	ft tower	4 inch
10-20	ft tower	6 inch

بسم الله الرحمن الرحيم

Answer one of the following:-

Q1

A- In a mass exchange apparatus operating at pressure of (3.1 atm), the individual mass transfer coefficient has the following values:-

$$k_y = 1.07 \text{ kmol/m}^2 \cdot \text{hr} \cdot \text{mol-fraction}$$

the equilibrium relationship  $P = 0.08 * 10^5 x$  (P in mmHg). Determine:-

- 1- Overall M.T.C in the liquid and gas phases.
- 2- How many times the diffusion resistance of the liquid phase differs from that of the gas phase.
- 3- Mass flux, if the average gas mole fraction is (0.25) and (0.00295) in liquid.

B- In an absorption tower,  $\text{NH}_3$  is being absorbed from air at atmospheric pressure by acetic acid. The flow rate of (2 kg /  $\text{m}^2 \cdot \text{s}$ ) in an experiment corresponds to (Re) of (5100) and a friction factor of ( $f_r = 0.0199$ ). The viscosity of the gas stream is (0.018 mNs /  $\text{m}^2$ ), the density is (1.154 kg /  $\text{m}^3$ ) and the diffusivity of  $\text{NH}_3$  in air is (0.196  $\text{cm}^2 / \text{s}$ ). Determine the M.T.C through gas film in three different forms. Given that:-

$$P_T = 105 \text{ N/m}^2 \quad R = 8.314 \text{ m}^3 \cdot \text{Kpas} / \text{Kmol.K} \quad T = 300\text{K}$$

Q2

In a tower (0.254 m) in diameter absorbing acetone from air at (293 K) and (1 atm) using pure water. The following experimental data were obtained:-

Height of (25 mm Rashing ring) packing = 4.88 m

Inert gas flow rate = 3.3 Kmol air / hr.

Mole fraction of inlet gas = 0.015 of acetone.

Pure water flow rate = 9.03 Kmol / hr

Equilibrium relation

$$y = 1.75 x$$

Calculate:-

- 1- Overall M.T.C in gas phase.
- 2-  $\text{HTU}_{\text{OG}}$  and  $\text{NTU}_{\text{OG}}$  using  $\frac{dy}{(y-y^*)}$ , then calculate (Z) and compared it with the given one?
- 3-  $\text{Min}^{\text{m}}$  liquid flow rate and the percentage of excess liquid used in the operation?
- 4- Relation between ( $\text{HTU}_G$  and ( $\text{HTU}_L$ )?
- 5- If a plate tower used, find the number of stages analytically?

Q3

Sulfur dioxide is to be recovered from air by contacting the gas with pure water in a packed column. The column will operate at 30°C and 1 atm. The entering gas flow rate (100 Kmol /  $\text{hr} \cdot \text{m}^2$ ) contains 20 mol%  $\text{SO}_2$  and the exiting gas is to contain 2 mol%. If the O.M.T.C is assumed to be (Koy a = 60 Kmol/ $\text{hr} \cdot \text{m}^2 \cdot \text{mol} \cdot \text{fract}$ ). Determine:-

- a- The  $\text{min}^{\text{m}}$  liquid flow rate in Kmol/ $\text{hr} \cdot \text{m}^2$ .
- b- The composition of the exit liquid, if the liquid flow rate is 20% excess of the minimum?
- c- The height of the packing in (m)?

Equilibrium data are:-

x	0	0.00042	0.0014	0.0028	0.007
y	0	0.01070	0.0473	0.1040	0.284

Q4

Starting from Rayleigh equation for simple differential distillation, show that

$$\ln(S_1/S_2) = (1/\alpha - 1) \{ \ln(x_1/x_2) + \alpha \ln(1-x_2/1-x_1) \}$$

A single stage batch still used to separate benzene - toluene mixture containing 60 mol% benzene. After distillation, the remained liquid contains (5mol%) benzene. Find the amount of the remained liquid and the average composition of the distillate ? where  $\alpha = 2.4$

Q5

200 Kmol/hr of a mixture contains (40mol%) benzene and (60mol%) toluene is introduced to a continuous fractional column with partial condenser. It is desired to operate at a reflux ratio of 2.5 times the minimum. The feed is cold and for each mole feed, (one mole) of vapor is condensed. Two side streams are drawn off the column, the first is saturated liquid 70mol% benzene and the second is saturated vapor 20 mol% benzene. The top product is 50 kmol/hr with purity of 96 mol%. The bottom product contains not more than 3 mol% benzene with flow rate of 60 kmol/hr. Calculate :-

- 1- The flow rates of the side streams.
- 2-  $R_{min}$ ,  $R_{act}$  and  $N_{min}$ .
- 3- Number of theoretical and actual plates if the efficiency is 70%, state the location of each stream.
- 4- The composition of liquid returned from the condenser to the column as a reflux.

Equilibrium data :-

x	0	0.02	0.13	0.26	0.41	0.58	0.78	1.0
y	0	0.04	0.26	0.455	0.63	0.78	0.90	1.0

Best Wishes to all





Note: Answer (4) questions only.

Q1) The reversible liquid phase reaction  $A \rightleftharpoons B$  is carried out in a PFR with recycle ( $R=2$ ), the initial concentration of A is 6 mol/lit. The inlet flow rate of liquid is 4 lit/s. the rate constant of the forward reaction is 6 mol/lit.s, and the equilibrium constant is 3:-

- Determine the volume of the recycle reactor to achieve 40% conversion of A.
- Estimate the space velocity of the recycle reactor.
- If the recycle stream is closed, find the volume of the reactor needed to obtain the same conversion of A (i.e. 40%).

.....(15 marks)

Q2) The production of methylbromide (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 semibatch reactor. Methylamine (A) at a concentration of 0.025 gmol/dm<sup>3</sup> is to be fed at a rate of 0.5 dm<sup>3</sup>/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<sup>3</sup>. The initial moles of A in feed  $N_{A0} = 0.1$  moles. Determine the conversion of A after (1) min., assume time increment ( $\Delta t$ ) = 0.5

.....(15 marks)

Q3) Ethyl acetate is to be produced from ethanol and acetic acid in a 0.5 m<sup>3</sup> batch reactor at 100 °C:



The reaction is elementary and has an equilibrium constant of 2.92, and the rate constant for the forward reaction ( $K_f$ ) is  $4 \times 10^{-4} \text{ L mol}^{-1} \text{ s}^{-1}$ . The feed contains 50% weight percent (wt %) of ethanol, 30% acetic acid, and the balance is water. The density of the fluid is essentially constant at  $1.0 \text{ g cm}^{-3}$ :

- What is the maximum conversion of acid that can be obtained?
- Determine the time required to achieve 25% of the acetic acid.

.....(15 marks)

Follow 17

GOOD LUCK

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

\*\*\*\*\*

.....(15 marks)

- a) Two 2.5 liter reactors were used as CSTRs in series.  
b) One 2.5 liter PFR was followed by a 2.5 liter CSTR.

be expected if:

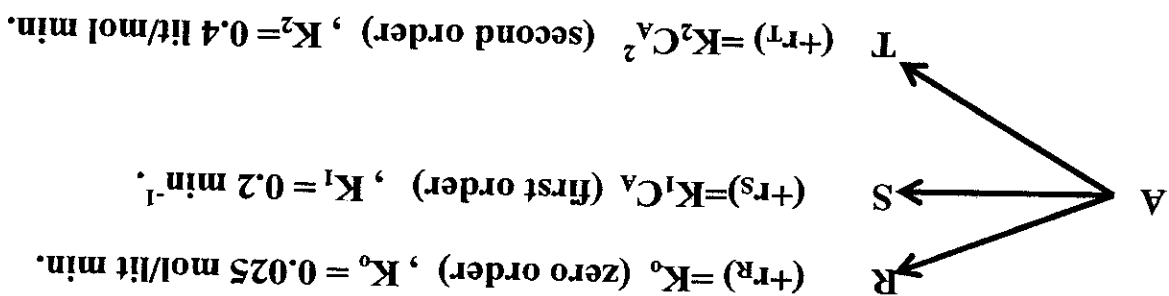
Q5) A dilute aqueous solution of acetic anhydride is to be hydrolyzed continually at 25 °C. At this temperature the rate constant of the reaction of anhydride is 0.158 min<sup>-1</sup>. The feed rate to be treated is 500 cm<sup>3</sup>/min of solution, with anhydride concentration of 1.5 × 10<sup>-4</sup> gmol/cm<sup>3</sup>. There are two 2.5 liter as reaction vessels or as tubular flow reactor. What final fractional conversion can

.....(7.5 marks)

- a) The optimum concentration of S.  
b) The arrangement of the system and the volume of each CSTR.

(S/A), find:

Are to be run in four equal – size CSTR, the initial concentration is (1) mol/lit, the feed flow rate is 100 lit/min. for maximizing the fractional yield of S or φ



B) The elementary reactions:

.....(7.5 marks)

- Q4) A) The rate of a gaseous irreversible reaction A → B at 450 K is 33 times its rate at 400 K. if the frequency factor in Arrhenius equation is  $5 \times 10^{10} \text{ sec}^{-1}$ . At what temperature will the reaction have a half life of (1) min?



**Answer four questions only**

Q.1) The diameter of sample of 50 washers can be measured to the 0.01 mm. If the class mark and frequency are given below:

Class mark: 3.21 3.24 3.27 3.30 3.33 3.36  
Frequency: 3 6 15 17 6 3

A. Complete the frequency distribution table.  
B. Obtain the following: 1. percent relative frequency curve plot. 2. Geometric mean.

Q.2)A. Construct the normal probability plot for the following data:  
3.01 , 3.35 , 4.79 , 5.96 , 7.89.

B. 10% of concrete samples have compressive strength less than 30 MN/m<sup>2</sup> and 20% have compressive strength greater than 36 MN/m<sup>2</sup>. If the minimum acceptable strength is 28 MN/m<sup>2</sup>, what is the probability that a sample will have a strength less than the minimum. (one unit in L.S.D.=1).

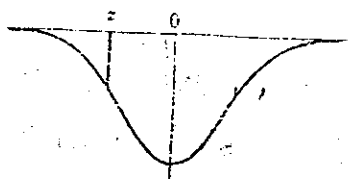
Q.3)A. The steel pins are subjected to a length and a diameter specification as shown below. Test the null hypothesis at 0.05 significance level. ( $\chi^2_{0.95} = 0.711$ ) (10 marks)

Diameter		Length	
Too thin	OK	Too short	OK
13	117	62	664
5	68	Too long	8
			80

B. The proportion of males in a particular area is 0.52. A sample of 20 people is taken at random.  
1. What probability distribution fits this case without any approximation? Why?  
2. Find the probability that a sample of 20 people will contain at least 15 but no more than 18 males. (Use prob. dist. in 1).

Q.4)A. For the least-square line:  $y = a + bx$ . Prove that:  $b = r \frac{s_y}{s_x}$ , where  $r$  is the correlation coefficient,  $s_y$ ,  $s_x$  are the standard deviation of  $y$  and  $x$ .  
B. It is required to fit the following equation:  $\ln y = A x e^x + B$  to the data:  
x: 0.21 0.27 0.35 0.38 0.43  
y: 10 22 70 100 24  
Calculate the variance.

Q.5)A. A cylindrical wire of radius  $R$  elongates when subjected to a tensile force  $F$ . Let  $L_0$ ,  $L_1$  represent the initial and the final length, Young's modulus is given by:  
$$Y = \frac{F L_0}{\pi R^2 (L_1 - L_0)}$$
  
Assume  $F = 800 \pm 1$ ,  $R = 0.75 \pm 0.1$ ,  $L_0 = 25 \pm 0.1$ ,  $L_1 = 30 \pm 0.1$   
Determine the maximum % error in  $Y$ .  
B. Explain only two of the following:  
1. Rate of flowmeters. 2. Solid expansion thermometers. 3. Draft gauge. (10 marks)



AREAS  
under the  
STANDARD  
NORMAL CURVE  
from 0 to 2

	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	0.2550
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	0.4685	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	0.4853	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	0.4978	0.4979	0.4979	0.4980	0.4981	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	0.4993	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995	0.4995	0.4997	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997	0.4997
3.4	0.4997	0.4997	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	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	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998
3.7	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998
3.8	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998
3.9	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998

# Answer four Questions Only

Subject : Heat Transfer  
Time : 3 hour  
Lecturer: Dr. Jamal Manace



Final Exam / I<sup>st</sup> attempt  
13/6/2011



University of Technology  
Chemical Eng. Dept.  
Third Class

Q1:

- A) What are the reasons for using insulating in heat transfer process? (5Marks)
- B) Hot water at  $T_1 = 120^\circ\text{C}$  flows in a stainless steel pipe ( $k = 15 \text{ W/m}\cdot^\circ\text{C}$ ) whose inner diameter is 1.6 cm and thickness is 0.2 cm. The pipe is to be covered with adequate insulation so that the temperature of the outer surface of the insulation does not exceed  $40^\circ\text{C}$  when the ambient temperature is  $T_o = 25^\circ\text{C}$ . Taking the heat transfer coefficient inside and outside the pipe to be  $h_i = 70 \text{ W/m}^2\cdot^\circ\text{C}$  respectively. Determine the thickness of fiberglass insulation ( $k = 0.038 \text{ W/m}\cdot^\circ\text{C}$ ) that needs to be installed on the pipe. (20 Marks)

Q2:

- A) List the types of heat exchanger? Draw the diagram of the famous type in chemical and petrochemical industries? (10 Marks)
- B) It is desired to heat  $230 \text{ kg/h}$  of water from  $35$  to  $93^\circ\text{C}$  with oil having an initial temperature of  $175^\circ\text{C}$ . The mass flow of oil is also  $230 \text{ kg/h}$ ,  $C_p$  of water =  $4180 \text{ J/kg}\cdot^\circ\text{C}$ ,  $C_p$  of oil =  $2100 \text{ J/kg}\cdot^\circ\text{C}$
- Two double-pipe heat exchanger are available:
- 1)  $U = 570 \text{ W/m}^2\cdot^\circ\text{C}$ ,  $A = 0.47 \text{ m}^2$
- 2)  $U = 370 \text{ W/m}^2\cdot^\circ\text{C}$ ,  $A = 0.94 \text{ m}^2$
- Which exchanger should be used? (15 Marks)

Q3:

- A) What are the types of reflection phenomena may be observed when a thermal radiation strikes a surface? (7 Marks)
- B) Derive an expression of the average heat transfer coefficient in a vapor condensation on a vertical surface, stating your assumptions? (18 Marks)

Q4:

- A) Define the Fin efficiency, Fin effectiveness, Biot No., and Fourier No.? (10 Marks)
- B) Longitudinal fin on the outside of a circular pipe is (75mm) high and (3mm) thick. If the pipe surface is at ( $400 \text{ K}$ ), Calculate the heat dissipated per meter length from the fin to the atmosphere at ( $290 \text{ K}$ )? The coefficient of heat transfer from its surface may be assumed constant at ( $h = 5 \text{ W/m}^2\cdot^\circ\text{K}$ ),  $k$  for the fin material is ( $50 \text{ W/m}\cdot^\circ\text{K}$ ) and the heat loss from the extreme edge of the fin may be neglected. (15 Marks)

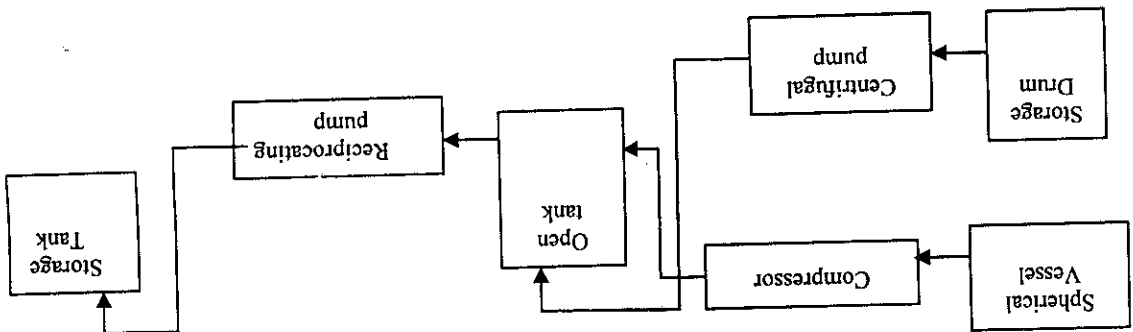
Q5:

- A) What are the types of convection heat transfer? Give examples of the values of heat transfer coefficient in these types? (5 Marks)
- B) Forced air at  $T_\infty = 25^\circ\text{C}$  and  $u_\infty = 10 \text{ m/s}$  is used to cool a flat plate  $4 \text{ cm}$  by  $4 \text{ cm}$ . The plate is releasing heat at the rate of (3)  $\text{W}$ . Estimate the temperature of the plate? For air  $\rho = 1.2 \text{ kg/m}^3$ ,  $C_p = 1 \text{ kJ/kg}\cdot^\circ\text{C}$ ,  $k = 0.026 \text{ W/m}\cdot^\circ\text{C}$ ,  $\mu = 185 \times 10^{-7} \text{ Ns/m}^2$
- Given:  $Nu_x = 0.04 (Re_x)^{0.85} (Pr)^{1/3}$  (20 Marks)

Good Luck

- Q1:- Complete the following
1. The main types of heat exchanger are 1-----, 2-----, 3-----, 4-----.
  2. The principle factors to consider when comparing the performance of different types of trays are 1-----, 2-----, 3-----, 4-----.
  3. The tubes in heat exchanger are usually arranged in 1-----, 2-----, 3-----.
  4. Vessel in chemical engineering is in two kinds 1-----, 2-----.
  5. Write the bundle diameter equation used in heat exchanger design -----.
  6. Total reflux is the condition when -----.
  7. The fluid physical properties required for condenser design are 1-----, 2-----, 3-----.
  8. The term baffle cut is used to specify the dimensions of -----.
  9. The liquid flow arrangement at the plate of distillation column are 1-----, 2-----.
  10. Write the equation used to estimate the minimum thickness of cylinders shell of vessel -----.

Q2:- A. Change the block diagram to PFD, symbology



- B. Draw the anatomy of chemical process
- Q3 A. Explain the different between continuous and batch process.
- B. Numerate the material of construction of pressure vessels.

- Q4 A. Draw the typical cross flow of sieve plate.
- B. Numerate the items of fixed capital cost.
- Q5 Numerate the main items included in PDI diagram.

Q6:- Water droplets are to be separate from air in a simple separation drum, the flow rate of air is  $1000 \text{ m}^3/\text{hr}$  at STP and it contains  $200 \text{ kg}$  of water. The drum will operate at  $1.1 \text{ atm}$  pressure and  $20^\circ \text{C}$ , size a suitable liquid-vapour separate (without demister).  
Water density  $990 \text{ kg/m}^3$

GOOD LUCK





Note: Answer Four questions only.

Q1/ Coke (C=82%, H<sub>2</sub>=4%, O<sub>2</sub>=4%, Ash=5%, and water=5%) burned with 20% excess of air, the temperature of flue gas is 300 °C and the temperature of air is 30 °C. Calculate the height of chimney if the draught is 10mm water.

Q2/ A fuel with composition of CH<sub>1.8</sub> has a higher heating value of 44,000kJ/kg. Find the lower heating value and the heat of formation of this fuel.

Enthalpy at 298 K (kJ/kmole) CO<sub>2</sub> = -393,596, H<sub>2</sub>O = -241,847, Enthalpy of vaporization (kJ/kmole) of H<sub>2</sub>O = 44,010

Calculate the flame temperature produced from burner methane with 20% excess air at 500°C. ΔH = 191800 cal. C<sub>p</sub> (cal/it.°C) for air = 0.324, CO<sub>2</sub> = 0.58, H<sub>2</sub>O = 0.46, N<sub>2</sub> = 0.36

(25 mark)

Q3/ A/ Explain the effect of stoichiometry on laminar burning velocity and how can calculate the critical velocity for any gas at any temperature.

B/ 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<sub>2</sub>.

(25 mark)

Q4/ 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.

LHV=10100 kJ/kg Cp=1.17 kJ/kg.K

B/ What is the draught in the furnaces? Explain all the types of draught with the aid of a sketch.

(25 mark)

Q5/ A natural gas-fired industrial operates with oxygen concentration of 5% in the flue gases the fuel and air at 77°F. If 5% of heat lost through the walls of the furnace and the combustion products exit the furnace to the stack at 340 °F. Assuming that the properties of natural gas as the same as propane.

A- Determine the equivalence ratio for the system.

B- Determine the useful heat output of the furnace per pounds of propane and operating efficiency. HHV (KBTU/lbmole) = 953,480

Enthalpy at 340 °F (KBTU/lbmole) CO<sub>2</sub> = 2,528, H<sub>2</sub>O = 2,142, N<sub>2</sub> = 1,838, O<sub>2</sub> = 1,882

H<sub>g</sub> of water = 1050 KBTU/lb

(25 mark)

Good Luck







**Note: Answer 3 questions only.**

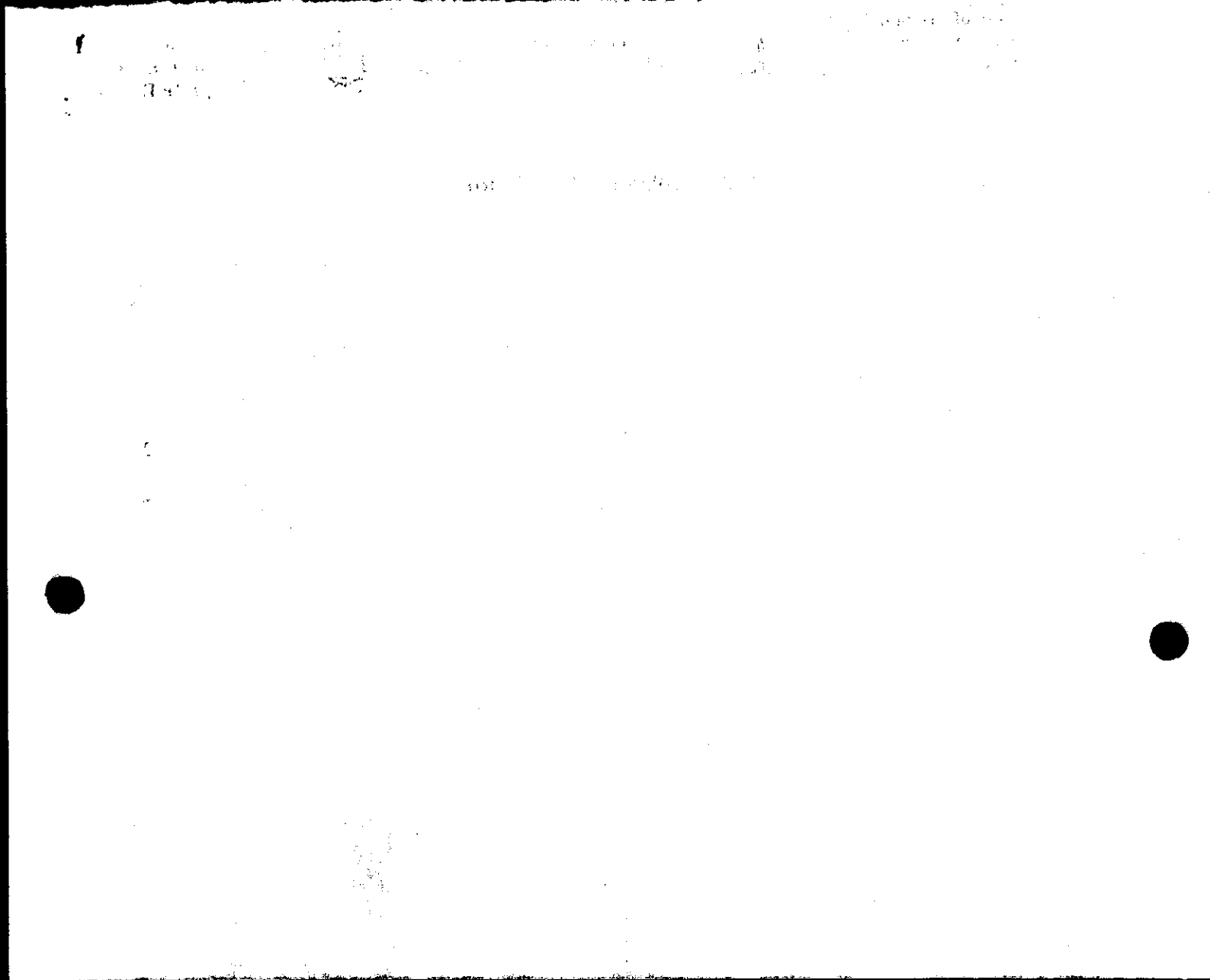
س1 أ / تكلم عن علاقة البناء النفسي بالحريات؟  
ب/ماهي علاقة العولمة بالديمقراطية ؟

س2/ ما هي المواطنه وما هي علاقتها بالتربية والتنشئه الاجتماعيه ؟

س3 أ / تكلم عن الديمقراطية بين التغير الاجتماعي والضغط الخارجي ؟  
ب/وضح ما يلي (البرجوازيه الحامل الطبيعي للديمقراطية وبانعدامها تنعدم ) ؟

س4 أ / ما هو دور الطبقة الوسطى في الحياة السياسي والثقافيه والاجتماعيه ؟  
ب/ هل الديمقراطية هي المفتاح السحري الذي يفتح به جميع الأبواب ام هي نفسها بحاجه الى مفتاح؟

تمنياتي



*Answer four questions only*

**Q.1)** Given the following data:

Class limit : 0.0-0.6   0.7-1.3   1.4-2.0   2.1-2.7   2.8-3.4   3.5-4.1

Frequency :   9            12            24            23            15            7

A. Complete the Frequency distribution table.

B. Omitting the highest 10% and the lowest 10% of the values, What is the remaining range. (Use the normal distribution).

**Q.2)**A. State the principle of least-square method, and derive the variance for a linear straight line.

B. It is required to fit the following equation:  $y = \frac{x}{a+bx}$  to the data:

x: 100   200   300   400   500

y: 3.5   7.2   12.6   16.4   20.2

Transform the equation to straight line form, and then determine the constants.

**Q.3)**The strength of individual bars with mean 28.4 and standard deviation 2.95 .To ensure safety a customer requires at least 95% of the bars to be stronger than 24 .

A. Do the bars meet the specification?

B.The manufacturer make the bars more uniform by decrease the standard deviation ,what value of standard deviation will just meet the specification?

**Q.4)**A survey of 320 families with five children given the distribution below. Is the result consistent with the hypothesis that the male and female births are equally probable?

Number of boys and girls	5 boys 0 girls	4 1	3 2	2 3	1 4	0 5	Total
Number of families	18	56	110	88	40	8	320

**Q.5)** Explain the following:

A. The instruments of temperature measurement which depend on liquid expansion.

B. The instruments of pressure measurement by balancing the force produced on a known area against the stress in an elastic medium.

*Best wishes of success*

## Appendix II

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



**Answer 5 questions only including question number 1.**

Q1/

There are 2 pipelines with 25 cm and 19 cm diameters respectively, also there is one million cubic meter of crude oil to be transferred for 27400 m distance.

If the physical properties of the c.o are as follows:

Viscosity = 0.0095 kg/m.s

Density = 840 kg/m<sup>3</sup>

While Pressure drop for 25 cm diameter is  $8.24 \times 10^6$  Pascal, and for 19 cm diameter is  $8.67 \times 10^6$  Pascal. Pipe length for both is the same = 27400 m. The cost of transferring of c.o per day will be for 25 cm 50% more than the cost of 19 cm per day.

Which pipeline do you choose?

(28 marks)

Q2/

Based on the following equation:

$$\frac{HG}{AT_a Z_a} = \ln \frac{P_A}{P_B}$$

(a) Define each term.

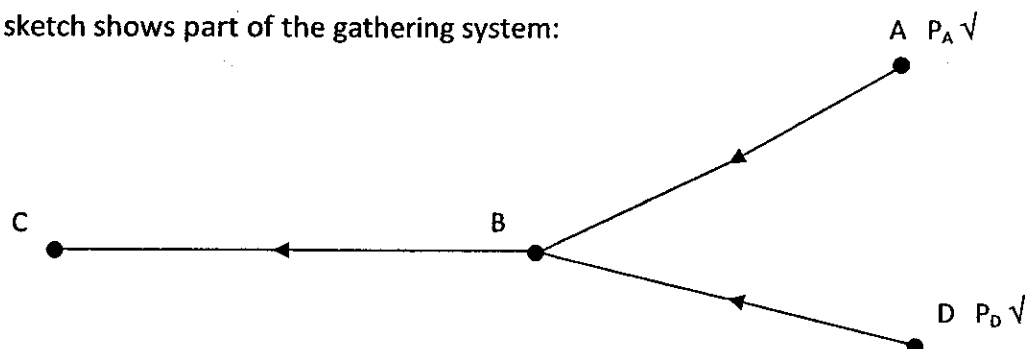
(b) Write it down in another form.

(c) Explain when we use this equation? Write two different applications with drawings.

(18 marks)

Q3/

The following sketch shows part of the gathering system:



(a) If the flow rates,  $P_A$ , and  $P_B$  are known for lines A B and D B.

What are the parameters to be established to optimize the initial cost and pressure losses.

(b) Based on sketch above and (a); write down proper approach to find a grid that is satisfactory.

(18 marks)

Q4/

Start with the following equation:

$$\phi = -\frac{dW}{dx} = -\frac{1}{D} \frac{Px^3}{16} + \frac{C_1 x}{2} + \frac{C_2}{x}$$

- Find the deflection as function of  $x$  in terms of  $C_1, C_2, C_3$ .
- Find all constants  $C_1, C_2$ , and  $C_3$ , for fixed edge of plate rigidly clamped, with radius  $a$ .
- Drive  $\phi$  and  $W$  of rigidly clamped circular plate with radius  $a$ .

(18 marks)

Q5/

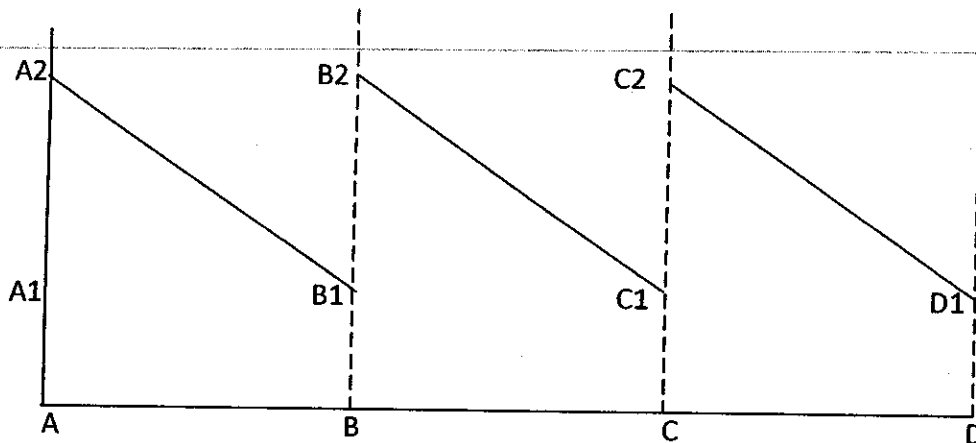
- Explain each type of the storage losses concisely.
- Evaporation of hydrocarbon from tank has many unwelcome consequences. What are these?

(18 marks)

Q6/

- The following drawing shows the performance of 3 pumping stations for pipeline transporting liquid hydrocarbon in steady state.

Show by dotted line performance of the station if station B is shut down.



- Derive (with drawing) the meridional stress in terms of  $P, r_2$  and  $t$  only.

(18 marks)



**Note: Answer 4 questions only.**

**Q1-** Define five of the following:

Environment, Chlorofluorocarbons CFCs, Kyoto protocol, Acid rain and its effect, Spray scrubber, Nutrients.

( 25 Mark )

**Q2-** Answer ~~two~~ of the following:

1. What is the activated sludge system in secondary wastewater treatment? Explain the system with sketch.

2. What are the classifications of solid wastes?

3. Derive the terminal velocity equation in Stock's region.

( 25 Mark )

**Q.3-** 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 7m long and 1.5m height, when the gas velocity in the collector is 1m/s. The CaO particle density is 3310kg/m<sup>3</sup> and the air density 1.2kg/m<sup>3</sup> and viscosity 2.17x10<sup>-5</sup>kg/m s.

**Q.4-** A cyclone with an inlet width of 0.25m is to be used to separate particulate matter of density 1600kg/m<sup>3</sup> from air. The inlet air velocity is 16m/s. An analysis of the particles yielded the following size distribution:

Particle size, $\mu\text{m}$	0-10	10-20	20-40	40-80	80-140	140-200
wt %	15	18	27	25	11	4

The air density is 1.18kg/m<sup>3</sup> and viscosity 1.81x10<sup>-5</sup>kg/m s. Using  $Ne = 5$ , estimate the overall separation efficiency.

( 25 Mark )

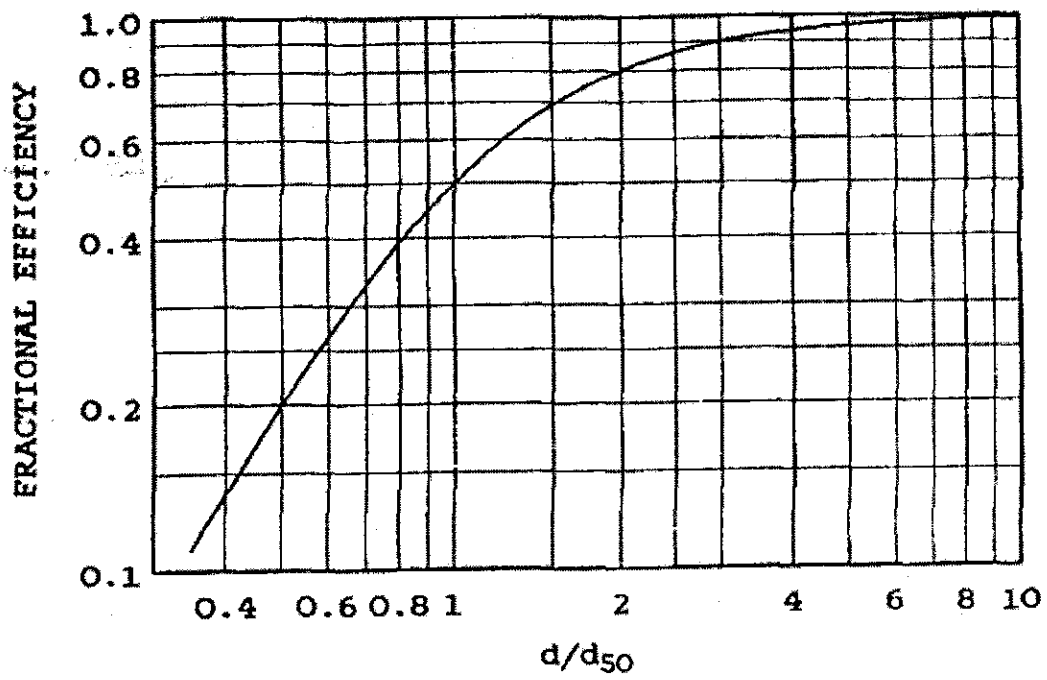
**Q5-** A town discharges 13000 m<sup>3</sup>/day of sewage into a nearby stream. The stream is with depth of 2m and a velocity of 6km/h and has flow of 0.3m<sup>3</sup>/s. Other information are:

	Temp. (°C)	DO (mg/l)	BOD <sub>5</sub> (mg/l)
Stream	19	8.3	10
sewage	25	1.5	180

The deoxygenation constant ( $k_1$ ) evaluated at 20 °C is 0.23 day<sup>-1</sup>. The saturation concentration of dissolved oxygen at average temperature is 9 mg/l. Determine the critical oxygen deficit,  $D_c$  and its location,  $x_c$ .

( 2.5 Marks )





Cyclone efficiency versus particle-size ratio

**GOOD LUCK**

*Handwritten signature*



Note: Answer (4) questions only.

Q1/ The irreversible gas phase reaction  $2A + B \longrightarrow C + D$  is an elementary reaction. The constant volume reaction is carried out isothermally at 727 °C and at a pressure of 20 atm in a batch reactor. The feed consists of 41% A and 41% B and 18% D. The reaction rate constant is 0.01 (liters/gmol)<sup>2</sup>/s. Calculate the time necessary to achieve 75% conversion of the limiting reactant. (15 Marks)

Q2) An endothermic liquid-phase reaction  $3A \longrightarrow 2B + C$  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, 10 mol % of A is converted. From this instant on, what is the time required to reach a conversion of 70 % 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 m<sup>3</sup>) and the number of mols of A initially is 10.9 kmol. The heat of reaction being 25000 kcal / kmol. The variation of the rate constant with temperature is  
 $\ln k = (-10000/RT + 5)$  [k in (m<sup>3</sup>/mol)<sup>2</sup> /s] (15 Marks)

Q3) The gas-phase reaction  $A \longrightarrow B$  is conducted at 500 °C and 3 atm in a tubular flow reactor. The feed contains 30 mole% A and the balance inert material. Total feed rate is 50 gmol/h. The rate constant is 0.2 min<sup>-1</sup>. What volume of reactor is needed for 95% conversion? (15 Marks)

Q4) A liquid-phase reaction  $A \longrightarrow B$  is to be conducted in a CSTR at steady-state at 163 °C. The temperature of the feed is at 20 °C, and 90% conversion of A is required. Determine the volume of a CSTR to produce 130 kg B h<sup>-1</sup>, and calculate the heat load (Q) for the process.

Data

$$C_p = 2.0 \text{ J g}^{-1} \text{ K}^{-1}$$

$$\rho = 0.95 \text{ g cm}^{-3}$$

$$k_A = 0.8 \text{ h}^{-1} \text{ at } 163 \text{ °C}$$

$$M_A = M_B = 200 \text{ g mol}^{-1}$$

$$\Delta H_R = -87 \text{ kJ mol}^{-1}$$

(15 Marks)

Q5) The liquid-phase irreversible reaction  $A \rightleftharpoons 2B$  is to be carried out into a two equal-sized CSTRs connected in series. The two reactors will be necessary to operate at different temperatures. The reaction rates in each reactor will be the same. The volumetric feed rates and the initial concentrations of A are 28 liter/ sec and 1 gmol/liter respectively. The second reactor operates at 120 °C where the reaction rate constant is  $1.5 \times 10^{-3}$  lit/mol.s. The equilibrium constant of the reaction is 1. Find the volume of the reactors to achieve a final conversion of 50%. The activation energy for the reaction is 70 kJ/mol. Find also the temperature of the first reactor.

(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***



Note: Answer only 4 questions

Q.1 Find the series solution for the following differential equation:

$$x(1-x)\frac{d^2y}{dx^2} + (3-7x)\frac{dy}{dx} - 9y = 0$$

(15 Marks)

Q.2

(15 Marks)

A. Find the Laplace transformation for the following periodic function: (7 Marks)

$$f(t) = \begin{cases} \sin t & 0 \leq t < \pi \\ 0 & \pi \leq t \leq 2\pi \end{cases}$$

B. Invert the following: (8 Marks)

1.  $\frac{1}{(s^2+a^2)(s^2)}$

2.  $\frac{se^{-s}}{(s^2+1)}$

Q3. Solve the differential equation by Laplace Transformation: (15 Marks)

$$\frac{d^2y}{dt^2} + 3\frac{dy}{dt} + 2y = e^t \dots, \text{ where } y(0) = 1 \text{ and } \dot{y}(0) = 0$$

Q4. The function  $u(x, y)$  satisfies the equation:

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$$

In the region  $0 \leq x \leq l$ ,  $0 \leq y < \infty$  and is zero on the other boundaries except for  $y = 0, 0 < x < l$  where it takes a constant value  $u_0$ .

Show that:

$$u(x, y) = \frac{4u_0}{\pi} \sum_{(odd\ n)}^{\infty} \frac{1}{n} e^{-n\pi y/l} \left( \sin \frac{n\pi x}{l} \right) \quad (15\ Marks)$$

Q5. Suppose fluid of semi-infinite depth initially with a constant concentration of  $C_{A0}$  through the whole depth. Let the free surface concentration is suddenly changed to  $C_{Ai}$  and maintained at that value. Show the concentration profile in the fluid as function of time and distance from the free surface?

---

(15 Marks)

Good Luck

Prof. Assist. N. W. Kasser



**Q1** Answer one of the following :-

A- Starting from the following equation :-  $N_A = - C_T (D_{AB} + E_d) dx_A/dZ + x_A(N_A + N_B)$

Find the following :-

$k_c$  and convert it to  $k_y$ ,  $k_c'$ ,  $k_y'$

$k_x'$  and convert it to  $k_x$  and  $k_L$ .

B- Solute A is being diffused from a gas mixture in a wetted wall column, with liquid flowing as a film down ward along the wall. At a certain point in the column the bulk gas concentration was 0.38 (mol.fraction), and the bulk liquid concentration was 0.1 (mol.fraction). The column is operating at 25°C and 1 atm. Equilibrium data as follows :-

$x_A$	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35
$y_A$	0	0.022	0.052	0.087	0.131	0.187	0.265	0.38

The solute (A) is diffusing through stagnant (B) and then through a non diffusing liquid. Given that  $k_y' = 1.46 \times 10^{-3} \text{ kmol/m}^2 \cdot \text{s}$   $k_x' = 1.96 \times 10^{-3} \text{ kmol/m}^2 \cdot \text{s}$ , calculate :-

1-Interface compositions.

2-Molar flux.

**Q2** Solute (A) being is absorbed from a mixture with an insoluble gas in a falling film of water at 30° C and 1.45 bar. The gas phase mass transfer coefficient is to be  $k_c' = 90.3 \text{ kmol/h.m}^2 \cdot \text{kmol/m}^3$ . It is known that 13.65 of the total mass transfer resistance lies in the gas-phase.

The mole fraction conc<sup>n</sup>. of the bulk gas is 0.065 and the interfacial conc<sup>n</sup>. of the solute in the liquid is to be 0.00201. The equilibrium solubility of the gas in water is

$$P = 3.318 \times 10^4 x^*$$

P=partial pressure in mmHg.

Calculate :-

- 1- Absorption flux of the gas in term of  $\Delta y$ .
- 2- Bulk liquid concentration.
- 3- Overall liquid phase mass transfer coefficient.
- 4- Overall and individual gas phase driving force.

**Q3** A soluble gas is to be absorbed from air in water in a packed tower, the equilibrium relationship may be represented by  $y = m \cdot x$ , where  $y$  &  $x$  are the mole fraction of the soluble component in the gas and liquid respectively. The molal flow rates of the streams G & L, and the entering solvent contains non of the soluble components. Show that :-

$$NTU_{OG} = (A/1-A) \ln \{ (1-(1/A) \cdot f)/(1-f) \}$$

Where A is the absorption factor  $f = (y_B - y_T)/y_B$

**Q4** A continuous distillation column is designed to separate a mixture containing 14% of (A) and 86% of (B) at 290K into over head product of 95% (A) and a waste of 97% of (B). Assume plate eff. of 70 % and liquid returned to column 3.16 per kmol of distillate.

Determine amounts of D, W,  $R_{min}$ ,  $N_{min}$  and  $N_{act}$ . given that Boiling point of feed = 336 K.  $\lambda$  for both A and B = 25900 kJ/ kmol.

Cp feed = 1.7 kJ /kg .K Liquid in feed = 1.0

M.wt (A) = 76 Mwt (B) = 142

x	0	0.03	0.06	0.11	0.14	0.26	0.33	0.53	0.55	0.86	1.0
y	0	0.09	0.16	0.27	0.33	0.50	0.63	0.75	0.83	0.93	1.0

**Q5** Derive, sketch and explain the effect of feed conditions on the amount of vapour and liquid in both distillation sections ( rectifying and stripping) .

**GOOD LUCK**





**Answer four Questions Only**

**Q1:A) What are the main variables affecting the process of pool boiling?**  
(5 Marks)

B) Starting from general conduction equation, Derive an expression for temperature distribution in a cylindrical of radius R with uniform heat generating  $q''$  and constant surface temperature  $T_0$  ?.

(20 Marks)

**Q2:A) A double-pipe (shell-and-tube) heat exchanger is constructed of a stainless steel ( $k = 15.1 \text{ W/m.k}$ ) inner tube of inner diameter 1.5 cm and outer diameter 1.9 cm and an outer shell of inner diameter 3.2 cm. The convection heat transfer coefficient is given to be  $h_i = 800 \text{ W/m}^2\text{.k}$  on the inner surface of the tube and  $h_o = 1200 \text{ W/m}^2\text{.k}$  on the outer surface. For a fouling factor of  $R = 0.0004 \text{ m}^2\text{.k/W}$  on the tube side and  $R = 0.0001 \text{ m}^2\text{.k/W}$  on the shell side, determine (a) the thermal resistance of the heat exchanger per unit length and (b) the overall heat transfer coefficients,  $U_i$ ,  $U_o$  based on the inner and outer surface areas of the tube, respectively.**

(18 Marks)

B) The arrangement of the tubes in the heat exchanger is very important, list these arrangement and the difference between them?

*Time* (7 Marks)

**Q3:A) Discuss the meaning of thermal constant  $\tau$ ?**

(7 Marks)

B) A sphere of diameter (D), which is at a uniform temperature of ( $T_i$ ), is suddenly removed from a furnace and suspended in a large room of air at uniform temperature of ( $T_\infty$ ). Neglecting heat transfer by radiation, determine the time taken by the sphere to cool to some temperature (T)?

$k=200 \text{ W/m.k}$ ,  $C_p = 0.9 \text{ kJ/kg.k}$ ,  $D= 50\text{mm}$ ,  $T_i = 800 \text{ k}$ ,  $T_\infty = 300 \text{ k}$ ,  $T = 400 \text{ k}$ ,  $h = 10 \text{ W/m}^2\text{.k}$ ,  $\rho = 3000 \text{ kg/m}^3$ .

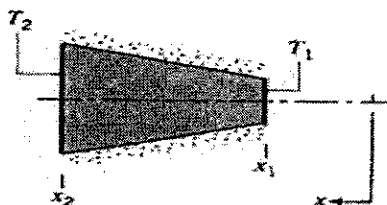
(18 Marks)

**Q4: The diagram shows a conical section fabricated from pyroceram. It is of circular cross section with the diameter  $D=ax$ . Where ( $a=0.25$ ), the small end is at ( $x_1=50\text{mm}$ ) and large end at ( $x_2=250 \text{ mm}$ ) the end temperatures are  $T_1=400 \text{ k}$  and  $T_2=600 \text{ k}$  while the lateral surface is well insulated. Take the thermal conductivity of pyroceram at  $500 \text{ k} = 3.46 \text{ W/m.k}$ .**

a) Derive an expression for the temperature distribution  $T(x)$  in symbolic form, assuming one – dimensional conditions.

b) Calculate the heat

*rate*  $\frac{\text{rate } q_x \text{ through the cone.}}{\text{rate}}$



(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.

(18 Marks)

B) What are the types of reflection phenomena may be observed when a thermal radiation strikes a surface?

(7 Marks)

Good Luck







Note: Answer four questions only.

Q1:-

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

\*The 1<sup>st</sup> drum diameter is (1 m) with operating pressure (2 bar), located as a reflex drum in distillation column.

\*The 2<sup>nd</sup> drum diameter is (2 m) and the operating pressure is (15 bar) located between two distillation column.

\*The 3<sup>rd</sup> drum diameter is (2.5 m) and the operating pressure is (60 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.

(25 mark)

Q2:-

A- Define with details the utility diagram, and what it is importance for the plant design.

B - Calculate the cost of polyethylene plant of new capacity of 20000 ton/year if you know that the previous capacity was 9500 ton/year with 10 million \$ cost.

(25 mark)

Q3:-

Design a horizontal liquid-liquid separator for a (Hydrocarbon / Water) mixture having a flow rate of (24000 kg/hr) containing 83% by weight Toluene and balance is water at  $45^\circ\text{C}$  and (5 bar) and having the following properties:

Hydrocarbon density =  $841 \text{ kg/m}^3$  and Viscosity  $\mu_L = 0.56$  centipoise

Water density =  $987 \text{ kg/m}^3$  and Viscosity  $\mu_h = 0.69$  centipoise

Take liquid-liquid separation constant  $k_s = 0.052$  and take  $(A_h/A) = 0.2$

(25 mark)

Q4:-

A- Explain with detail the term Data Sheet, and then make data sheet for the following:

- 1) Shell and tube heat exchanger.
- 2) Spherical storage tank.
- 3) Centrifugal Pump.

B- Explain with details the operation mechanism of vapour-liquid-separation.

(25 mark)

Q5:-

A- What are the main principle requirements that determine the selection of site for a chemical plant?

B- Explain the general steps in designing of bubble cap trays.

(25 mark)

**GOOD LUCK**



**Note: Answer 3 questions only.**

- 1 أ / ما هي محاسن ومساوئ الديمقراطية .  
ب/ ما هي السمات العامة لعلاقة المثقف بالسلطة.
- 2 أ / ما هو الفساد الإداري والمالي وما هي أهم انعكاساته .  
ب/ هل الحرية حكراً على الديمقراطية أم لا .
- 3 أ / ما هي فلسفة هوبهاوس في الحقوق والحريات .  
ب/ لماذا يعتقد ماركس بأن النظام الديمقراطي غير قابل للتطبيق .
- 4 أ / تكلم عن الديمقراطية بين الواقع والطموح.  
ب/ هناك من يعتقد بأن تحقيق الديمقراطية مرهون بتحقيق النمو الاقتصادي وضح ذلك مبيناً علاقة الديمقراطية بالتنمية

مدرس المادة

د. بشرى عبدالله

تمنياتي



**Note :Answer four questions only**

- Q.1** A series of batch runs with a constant enzyme concentration the following initial rate data were obtained as a function of initial substrate concentration .

Substrate concentration (mmole/L):	1	2	3	5	7
Initial reaction rate (mmol/min) :	0.2	0.22	0.3	0.45	0.41

Evaluate the Michaelis-Menten kinetic parameters by employing the langmuir polt And Lineweaver-Burk plot. Start from Michaelis-Menten equation. (15marks)

- Q.2** A) A carbohydrate (S) decomposes in the presence of an enzyme (E). The Michaelis-Menten kinetic parameters were found to be as follows :( $K_m = 200 \text{ mol/m}^3$ ) & ( $V_{max} = 100 \text{ mol/m}^3 \cdot \text{min}$ )  
The reaction was carried in a CSTR with various flow rates .If the inlet substrate concentration is ( $300 \text{ mol/m}^3$ ) and the flow rate is ( $100 \text{ cm}^3/\text{min}$ ). What is the steady \_state substrate concentration of the outlet? The reactor volume is ( $300 \text{ cm}^3$ ) . (10marks)

- B) What are the modes of bioreactors ? list and explain in details. (5marks)

- Q.3** A) Define the following terms:-

1- Biochemical engineering	2- Cultivation
3- Inoculation	4- Enzyme

(5marks)

- B) Derive the relationship show how the concentration changes with respect to time in Ideal Batch Fermenter. (10marks)

- Q.4** A) Derive the rate equation by Briggs\_Haldane assumption for a single substrate reaction. (10marks)

- B) Classify fermenters depending upon the nature of the microorganism growth. list and explain (5marks)

- Q.5** Explain with details Penicillin Production . (15marks)





**Note: Answer only 4 questions. Each question (15 marks)** ممنوع الإجابة بقلم الرصاص

**Q1) A manufacturer makes a range of three types of cars A, B and C in two factories; an engine plant E and a body factory F. The net profit on car A is \$1100, on car B is \$1200 and on car C is \$1450. There are 10120 labor units ( a labor unit is one/ man hour) available in E and 11000 labor unit in F each month. The number of labor units needed for each car is given below. Formulate and solve this optimization problem to maximize the profit using simplex method with constraints.**

Car Type	Labor Unit	
	Engine Plant E	Body Factory F
A	8	8
B	8	9
C	9	11

**Q2) You are the manufacturer of  $PCl_3$  which you sell in barrels at a rate of P barrels/day. The cost per barrel produced is**

$$C = 50 + 0.1P + 9000/P \quad \text{Dollars}$$

The selling price per barrel is \$300, determine:

- 1- The production level giving minimum cost per barrel.
- 2- The production level which maximize the profit per day.
- 3- The production level at Break-even point.
- 4- Why are the answers in 1 and 2 different?

**Q3) A: Find the optimum of the following function using DSC method;**

$$y = (x - 100)^2 \quad \text{starting at } x_0 = 0 \quad \text{and} \quad S = 3$$

**B: Solve the following functions analytically;**

$$1- y = 10(2x^2 - 1) - 2(2x^2 - 1)^2 - 3$$

$$2- y = 2x_1^2 + 2x_2^2 + 3x_3^3 + 2x_1x_2 + 2x_2x_3 + x_1 - 3x_2 - 5x_3$$

**Q4) Solve the following function using Fibonacci method (n=8).**

$$Y = X^2 - 6X + 3 \quad \text{for } -1 \leq X \leq 5$$

**Q5) Using graphical method, maximize the profit function**

$$P = x + y$$

Subjected to  $2x + y \leq 14$  ,  $-x + 2y \leq 8$  ,  $2x - y \leq 10$  ,  $x + y \geq 2$

If  $2x + y \leq 14$  is changed to  $x \leq 7$  dose P increase?

**GOOD LUCK**

