SUMMER-22 EXAMINATION

Model Answer

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.
8) As per the policy decision of Maharashtra State Government, teaching in English/Marathi and Bilingual (English + Marathi) medium is introduced at first year of AICTE diploma Programme from academic year 2021-2022. Hence if the students in first year (first and second semesters) write answers in Marathi or bilingual language (English +Marathi), the Examiner shall consider the same and assess the answer based on matching of concepts with model answer.

Q No.	Answer	Marking scheme
1 a	**Attempt any 5**	**10**
1a	**Molecular Diffusion:** When diffusion results from the random movement of molecules, it is called molecular diffusion. **Eddy Diffusion:** When the movement of molecules occurs with the help of an external force, then it is called eddy or turbulent diffusion.	1 1
1b	**Types of gas absorption:** 1. **Physical absorption:** It is a purely physical phenomenon. Example: Absorption of ammonia from ammonia- air mixture by water 2. **Absorption accompanied by a chemical reaction.** Example: Absorption of NO_2 in water to produce nitric acid.	 ½ 1/2 ½ 1/2
1c	**Volatility:** It is the ratio of partial pressure of a component to its mole fraction in the liquid phase. Volatility of A = p_A / x_A	2
1d	**Different types of packings** (any 2): 1) Raschig rings. 2) Pall rings. 3) Hy-pak. 4) Berl saddles. 5) Intalox saddles. 6) Super intalox saddles 7) Lessing ring	1 mark each for any 2

1e	**Moisture content on wet basis:** It is the ratio of weight of moisture to the weight of wet feed material. **Moisture content on dry basis:** It is the ratio of weight of moisture to the weight of dry solids in wet feed material.	1 1
1f	**Selectivity**: The ratio of concentration ratio of solute to feed solvent in extract phase to that in raffinate phase. It is the measure of effectiveness of solvent for separating the constituents. When selectivity = 1, separation is not possible. Selectivity should be greater than 1.	2
1g	**Supersaturation:** It is the quantity of solute present in the solution in which crystals are growing compared with the quantity of the solute that is in equilibrium with the solution.	2
2	**Attempt any 3**	12
2-a	**Derivation of Equation of flux for steady state equimolar counter diffusion for gases:**	4

$$N_A = J_A + x_A (N_A + N_B)$$

$$= -D_{AB} \frac{dC_A}{dz} + \frac{C_A}{C} (N_A + N_B)$$

For ideal gas $P_A = C_A RT$

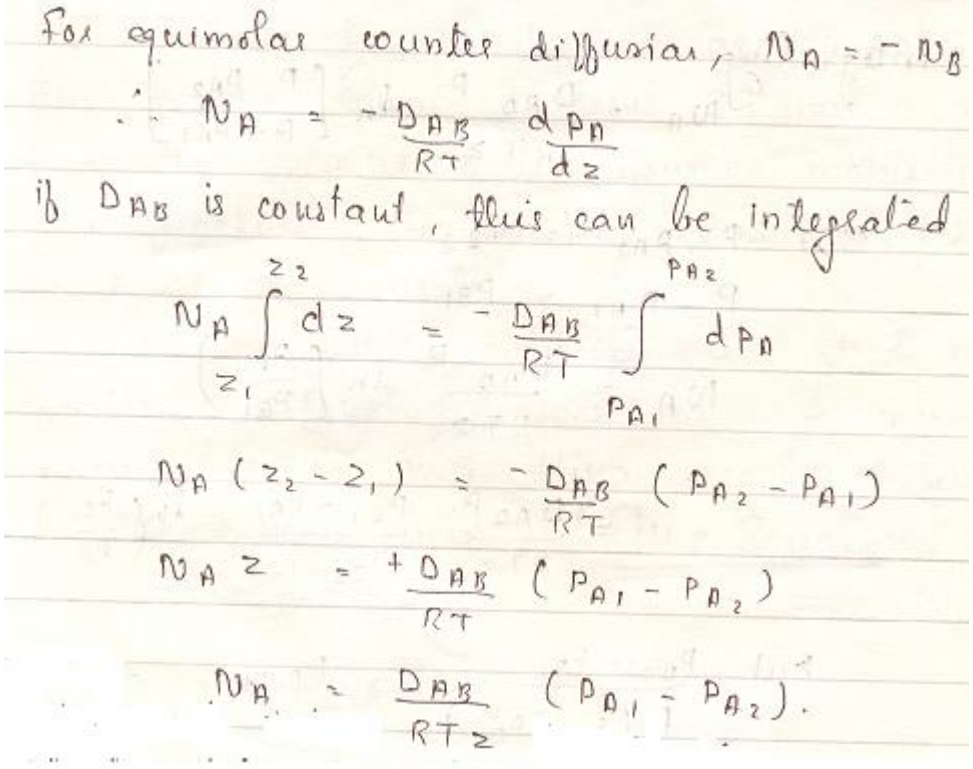
$$C_A = \frac{P_A}{RT}$$

$$dC_A = \frac{dP_A}{RT}$$

$$C = \frac{P}{RT}$$

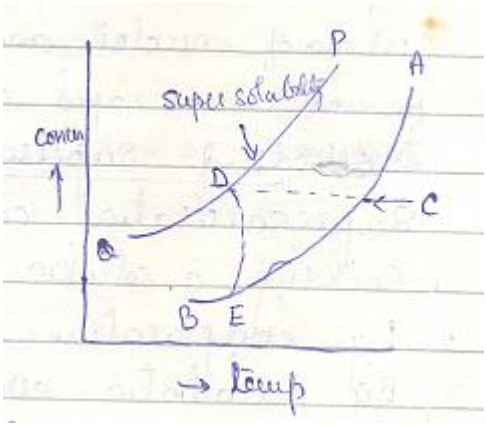
putting values of C_A, dC_A & C

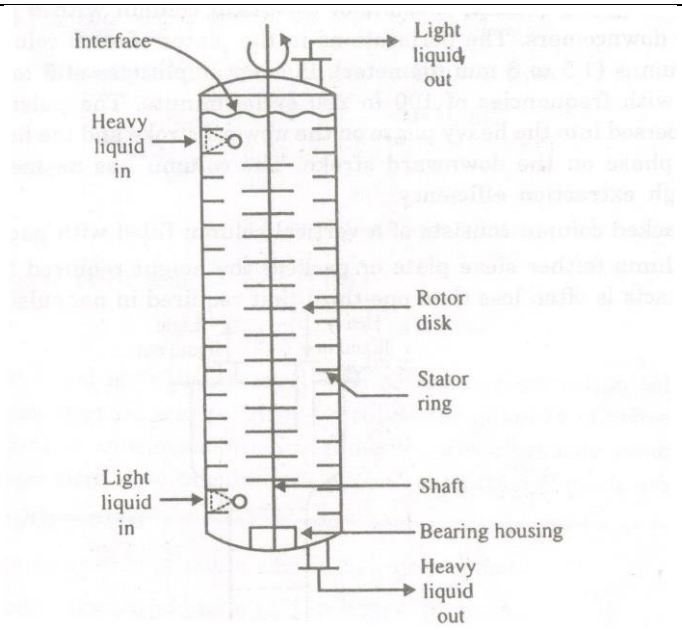
$$N_A = -D_{AB} \frac{dP_A}{RT} \frac{1}{dz} + \frac{P_A/RT}{P/RT} (N_A + N_B)$$

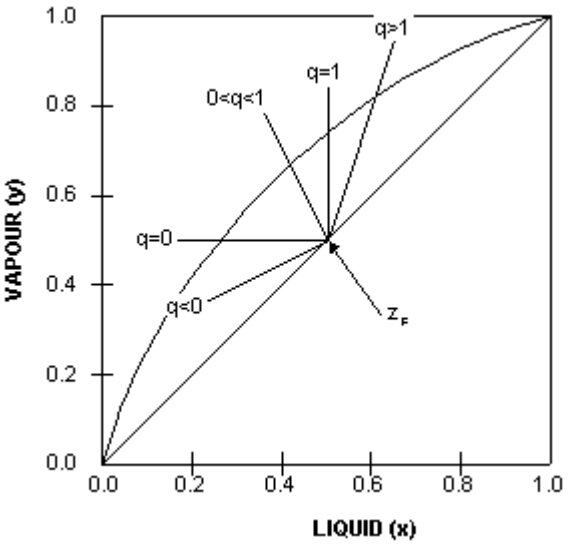
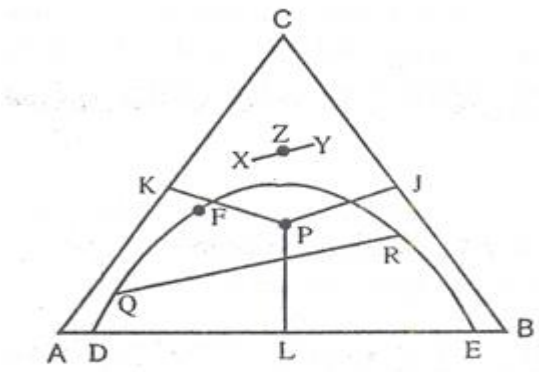
		
2-b	**Rayleigh equation:** Let F be moles of liquid mixture containing x_F mol fraction of A, D kmoles of distillate and W kmoles of residual liquid in still which are obtained at the end of operation. Let y_D and x_W be the mol fr of A in distillate and bottom residual liquid. Let L be kmoles of liquid in the still at any time during the course of distillation and let x be mol fr of A in liquid.Let very small amount dD kmol of distillate of composition y in equilibrium with the liquid is vaporized. Then composition and quantity of liquid decreases to (x-dx) and L to (L-dL) respectively. Overall material balance is L=L-dL+dD Or dL= dD Material balance for component A is Lx=(L-dL)(x-dx)+ydD	1 1

	$Lx = Lx - Ldx - xdL + dLdx + ydD$ $dLdx = 0$ $0 = -Ldx - xdL + ydL$ But $dD = dL$ i.e. $0 = -Ldx - xdL + ydL$ $Ldx = (y-x)dL$ $dL/L = dx/(y-x)$ Integrating the equation between the limits $L=F$, $x=x_F$, $L=W$ $x=x_W$ $\int_{F}^{W} dL/L = \int_{x_F}^{x_W} dx/(y-x)$ $Ln(F/W) = \int_{x_F}^{x_W} dx/(y-x)$ **This is Rayleigh's equation**	1 1
2-c	**Situations where liquid- liquid extraction is preferred** 1. Whenever very large amounts of latent heats are required 2. Whenever we are dealing with substances which are heat sensitive 3. Whenever we are dealing with liquid mixture forming azeotrope or close boiling mixture.	4
2-d	**Selection criteria for solvent in gas absorption** : (any 4) While selecting a particular solvent for absorption operation , the following properties of the solvent are considered. 1) Gas solubility : the solubility of solute gas in a solvent should be high . the solvent selected should have a high solubility for the solute to be absorbed 2) Volatility : As the gas leaving an absorption unit is generally saturated with	1 mark each for any 4

	the solvent, there will be a loss of the solvent with the gas leaving the unit operation, hence to minimize the solvent loss , the solvent should be less volatile. 3) Corrosive nature : the solvent should not be corrosive towards common materials of construction so that the construction material for an absorption equipment will not be too expensive. 4) Viscosity : the solvent should have a low viscosity for rapid absorption rates, low pumping cost and better heat transfer. The solvent should be non viscous. 5) Cost and availability : the solvent should be cheap and readily available 6) Miscellaneous : the solvent should be non-toxic, non-flammable, non-foaming, and chemically stable from a handling and storage point of view.	
3	**Attempt any 3**	12
3-a	**Purpose of drying operation in industry(Any 4)** 1. For reducing the transportation cost. 2. For purifying a crystalline product so that the solvent adhering to the crystal is removed. 3. To meet the market specification of solid product. 4. For making the material more suitable for handling, storage and shipping. 5. For providing definite properties to the materials. 6. To preserve the material over prolonged period. 7. As a part of the process 8. To prevent corrosion occurring due to the presence of moisture.	1 mark each
3-b	**Mier's supersaturation theory:**	

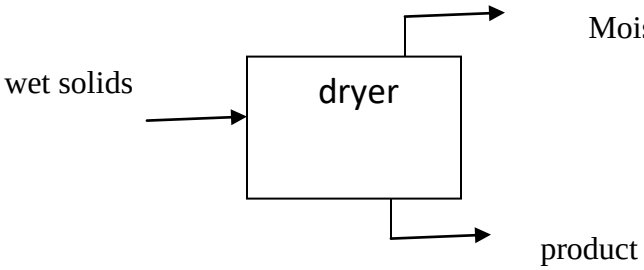
	According to Mier's theory there is a definite relationship between the conc and temp at which crystals will spontaneously formed in a pure solution. This relationship is represented by the super solubility curve which is approximately parallel tp the solubility curve. The curve AB is the solubility curve and curve PQ is the super solubility curve. The curve AB represents maximum conc of solution which can be achieved by bringing solid-solute into eqm with liquid solvent. If a solution having the composition and temp indicated by point C is cooled in the direction shown by the arrow it first crosses the solubility curve AB and it is expected to start of crystallization. Actually if the process started with initially unseeded solution crystal formation will not begin until the solution is super cooled considerably passed the curve AB. According to Mier's theory , crystallization will start in the neighbourhood of the point D and the concentration of the solution then follows roughly along the curve DE. For an initially unseeded solution , the curve PQ represents the limit at which spontaneous nuclei formation begin and consequently, crystallization can start.  	3 1
3-c	**Rotating disc contactor:**	

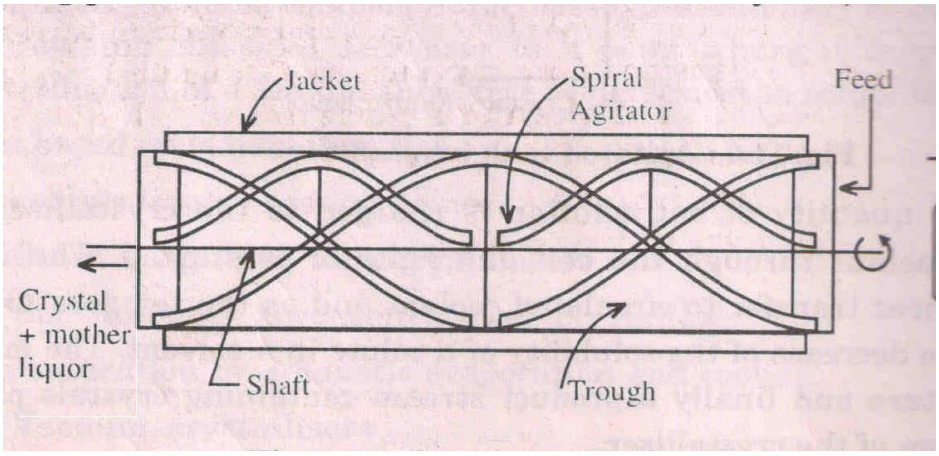
	 Fig,Shows rotating disk contactor for light phase dispersed. In these units,disks disperse the liquid & impel them outward towards the tower wall , where stator rings create quiet zones wherein the 2 phases can separate. Rotating disc contactor is a mechanically agitated counter current extractor agitation is brought with the help of rotating disc.	2 2
3 d	**Equation for q line** $y = \frac{-q}{1-q} x + \frac{XF}{(1-q)}$ **Values of q lines for various feed conditions:** q = 0 (saturated vapour) q = 1 (saturated liquid) 0 < q < 1 (mix of liquid and vapour) q > 1 (subcooled liquid) q < 0 (superheated vapour)	1 1

		2
4	**Attempt any three**	12
4a	**Triangular diagram:**  In liquid liquid extraction when the solvent is partially miscible with the original solvent , the solubility and equilibrium relations are often shown on a triangular diagram. The composition of ternary system can be shown by a point lying inside an equilateral triangle. Consider a system C (acetone).A (water),B (methyl isobutyl ketone) at 250C wherein acetone is solute , water is diluents	1 1

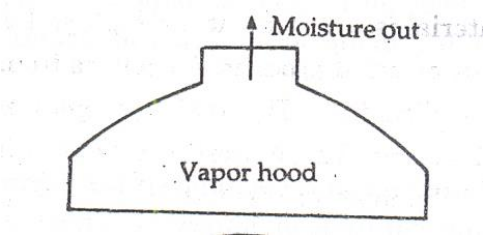
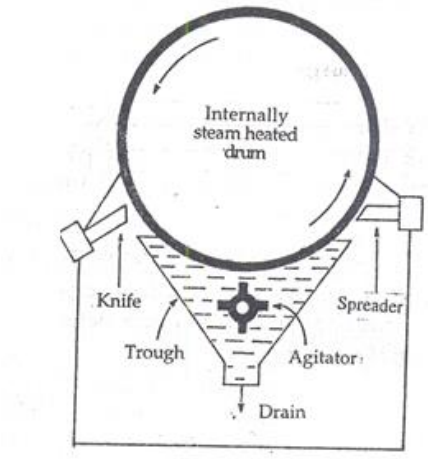
	and MIK is solvent for extracting the solute. Apex C in the triangle ABC represent 100% acetone and apex Aand B represent 100% water and 100% MIK respectively.Along line BC,concentration of Ais zero and the same is true for B and C along AC and AB. The ternary system represented by point P consist of three components C,A,B in the ratio of perpendiculars PL,PJ and PK respectively.The distances AD and BE represent the solubility of solvent B in A and A in B. The curve the line ERF indicates composition of saturated MIK layer and the curve line DQF represent the composition of saturated water layer. The area under binodal solubility curve represented by the curve line DQFRE represent a two phase region that will splitup into two layers in equilibrium with each other.The point F on the curve represents a single phase which does not split into two phases and corresponds to tie line of zero length and is known as plate point.	1 1
4 b	**Differentiate between plate and packed columns(Any 4)** .	1 mark each for any 4

Packed column	**Plate column**
They are differential contactors where mass transfer occurs throughout the length of the contactor and equilibrium is not reached at any point between the phases in contact.	They are stagewise contactors where mass transfer occurs stage wise and equilibrium is attained between the phases at a number of separate stages.
Packings are used as gas- liquid contacting devices	Plates are used as gas – liquid contacting devices.
Design mainly involves the calculation of height of transfer unit	Design involves the calculation of number of theoretical stages required

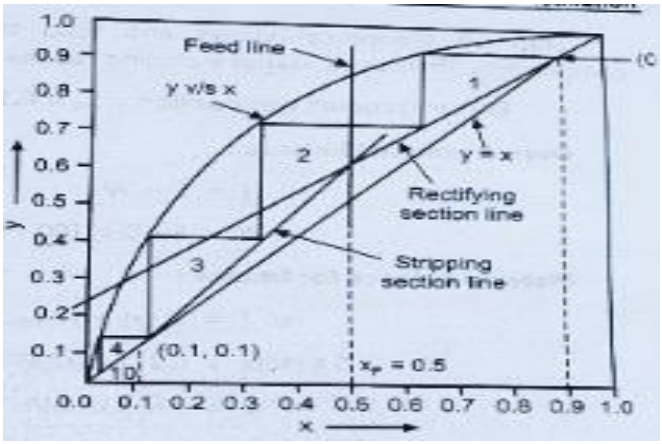
		and number of transfer units required to effect a desired separation.	to effect a desired separation.	
		Simple in construction.	Complex in construction	
		Raschig ring, pall ring, berl saddles, intalox saddles are types of packings.	Bubble cap plate, sieve plate , valve plate are the types of plates used in plate column.	
4 c		 Basis: 100 kg dried product Let X kg wet solids and Y kg moisture evaporated Overall balance is X = Y + 100 Solid balance is 0.2 X = 0.95* 100 Or X = 475 kg moisture evaporated 475-100 = **375 kg**		1 1 1 1
4 d		An **azeotrope** is a mixture of two or more liquids whose proportions cannot be altered by simple distillation. This happens because, when an azeotrope is boiled, the vapor has the same proportions of constituents as the unboiled mixture. An azeotrope is a liquid mixture with an equilibrium vapour of same composition as the liquid. The dew point and bubble point are identical at		**1**

	azeotropic composition and mixture vaporizes at single temperature, so azeotropes are called constant boiling mixture. Azeotrope cannot be separated by distillation because the dew point and bubble point are identical. Complete separation of constituents of binary azeotrope can be done by 1. Adding third component to the binary mixture and 2. Changing the system pressure. The third component added to a binary azeotrope usually forms a low boiling azeotrope with one of the feed constituents and withdrawn as distillate. The third component added is called as entrainer or azeotrope breaker. The process of distillation where the third component is added to the binary azetrope to effect the complete separation is called azeotropic distillation	**1** **1** **1**
4 e	**Swenson-walker Crystallizer:**  It is the cooling type continuous jacketed trough crystallizer. It is an example of scrapped surface crystallizer. **Construction:** It consists of a long open rectangular trough with a semi cylindrical bottom	2

	that is u shaped trough,of width 0.6m and length 3-6m. The trough is jacketed externally for circulating the coolant during operation.□ A spiral agitator rotating at about 7 rpm is incorporated in the trough in such a way that it is as close to the bottom of the trough as possible. It helps to transport crystals from one point to another point and doesn't allow crystals to settle at the bottom. At one end of the crystallizer an inlet foe hot solution isprovided.an at the other end, an over flow gate for the crystals and mother liquor discharge is provided, The function of spiral agitator include to scrap crystal, to lift and shower the crystal of uniform size, and to convey crystal from one end to the other end of equipment.	2
5	**Attempt any2**	**12**
5-a	**Flux Equation for the diffusion of A through non-diffusing B for gases:**	
	$N_A = [D_{AB} P/ RT z P_{B,M}] (P_{A1} - P_{A2})$	1
	Where N_A = molar flux of A=?, D_{AB} = Diffusivity of A in B =$2.3*10^{-5}$ m^2/s,	
	R = Universal gas constant=8314.51 m^3.Pa / (Kmol K), P=$1.103*10^5$ Pa	
	T=absolute temperature=298K, z=distance through which diffusion occurs=0.15m,	1
	P_{A1}= partial pressure of A at beginning of diffusion=$1.5*10^4$ Pa, P_{B1}=$8.63*10^4$ Pa	1
	P_{A2} = partial pressure of A at end of diffusion= $5*10^3$ Pa, P_{B2}=$9.63*10^4$ Pa	
	$P_{B,M} = (P_{B2} - P_{B1}) / \ln (P_{B2} / P_{B1}) = 9.121*10^4$ Pa	1
	N_A =7.484 * 10^{-7} kmol / (m^2.s)	
	Equation for steady state equimolar counter diffusion for gases:	
	$N_A = D_{AB} / RTz (P_{A1} - P_{A2})$ =	1
	6.19 * 10^{-7} kmol / (m^2.s)	1

5-b	**Rotary drum Dryer:** A rotary vacuum filter consists of a large rotating drum covered by a cloth. The drum is suspended on an axial over a trough containing liquid/solids slurry with approximately 50-80% of the screen area immersed in the slurry. **Working**: As the drum rotates into and out of the trough, the slurry is sucked on the surface of the cloth and rotated out of the liquid/solids suspension as a cake. When the cake is rotating out, it is dewatered in the dying zone. The cake is dry because the vacuum drum is continuously sucking the cake and taking the water out of it. At the final step of the separation, the cake is discharged as solids products and the drum rotates continuously to another separation cycle.  	3 3
5-c	Basis 100 kg feed solution at 353K	

	F=100 kg. x_F=64.2/164.2= 0.391	1
	Water in feed = 1000(1-0.391) = 609 kg	
	Water evaporated = 4 kg	1
	Mol wt of $MgSO_4$=120, Mol wt of $MgSO_4 7H_2O$ = 246	
	Solvent balance is	1
	$F(1- x_F) = V+C(126/246)+ L$	
	100 (1-0.391)=4+0.5122C+L	
	or L=60.9-4+0.5122C kg.	
	$MgSO_4$ balance	1
	$MgSO_4$in feed = $MgSO_4$ crystals + $MgSO_4$ in mother liquor.	
	0.391*100=C(120/246)+[60.9-4-0.5122C] * solubility of $NaNO_3$	
	39.1 = 0.488C+[60.9-4+0.5122C]*0.408	
	Or C=56.99 kg	1
	100 kg feed == 56.99 kg crystals	
	? == 1000 kg crystals	
	Feed = 1000*100/56.99	
	= **1754.56 kg**	1
6	**Attempt any 2**	**12**
6-a	Basis: 100 kmoles/hr feed	
	F = 100 x_F = 0.5 x_D = 0.9 x_W = 0.1	1
	F = D+W	
	$Fx_F = Dx_D + Wx_W$	
	Substituting the vales D = 50 kmol/hr	
	W = 50 kmoles/hr	1
	Construct equilibrium diagram with the given x-y data.	
	Reflux ratio = 3	
	Rectifying section:	

	Y intercept = $x_D/R+1$ = 0.9/(3+1) = 0.225 Draw operating line for rectifying section with (0.9,0.9) on diagonal and y intercept = 0.225 Draw feed line parallel to y axis through (0.5,0.5) on diagonal Draw operating line for stripping section with (0.1,0.1) on diagonal and meeting point of rectifying section line and feed line. Construct triangles starting from (0.9,0.9) on diagonal and ending with(01,0.1). Total plates 4 including reboiler. Therefore number of plates = **4-1=3.** Feed plate is 2nd from top. 	1 1 2
6-b	Basis: 1kmol of feed. X_F = mole fraction of hexane in the feed = 60/100=0.6 Feed is 50 mole% vaporized f= 50/100=0.5 The operating line for flash distillation is Y=-((1-f)/f)X+XF/f Slope= -(1-f)/f = -(1-0.5)/0.5 = -1	 1 1 1

	The point of intersection of the operating line with the diagonal is (0.6,0.6). Draw the equilibrium curve and draw the operating line with the slope to -1 passing through (0.6,0.6) on the diagonal. It intersects the equilibrium curve at P which gives us the equilibrium liquid and vapour compositions as **0.41** and **0.79** mole fraction hexane respectively. liquid compositions = **41% hexane** vapour compositions = **79% hexane**	1 1 1
6-c	Basis: Slabs of paper pulp 1m*1m*1.5 cm Initial moisture content X1 = 0.67/(1-0.67) = 2.03 Final moisture content X2 = 0.3/(1-0.3) = 0.428 Critical moisture content Xc = 006/(1-0.6) = 1.5 Equilibrium moisture content X* = 0.005/(1-0.005) = 0.005025 Rc = 1.5 kg/ m^2hr W = 2.5 kg Area A = 1*1*2 =2 m^2 Time for drying t = W'/(A.Rc)[(X1-Xc) +(Xc-X*) ln ((Xc-X*)/(X2-X*))] = 2.5/2*1.5[(2.03-1.5) +(1.5-0.005025) ln ((1.5-0.005025)/(0.428-0.005025))] **t = 2.01 hrs**	2 1 1 1 1