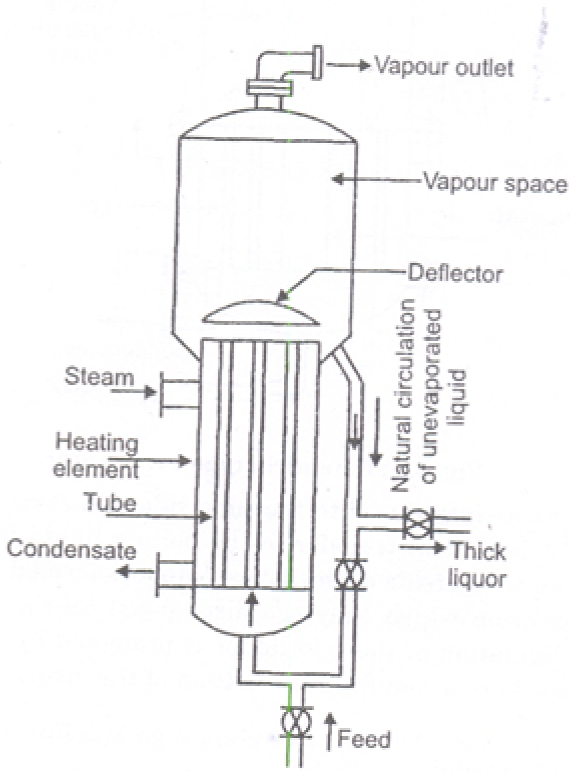
Important Instructions to examiners:

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.

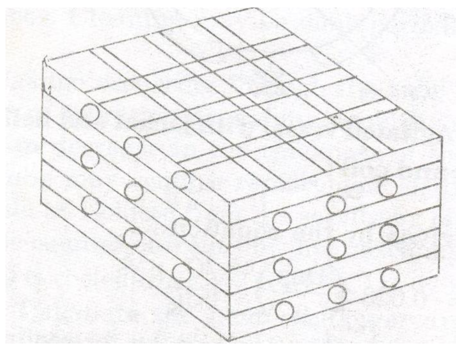
Q No.	Answer	marks	Total marks
1 A	Any three		12
1A-a	<table><tr><th></th><th>Evaporation</th><th>Drying</th></tr><tr><td>1</td><td>It is an operation in which a weak solution/liquor is concentrated by vaporising a portion of the solvent</td><td>It is an operation in which the moisture of a substance is removed by thermal means.</td></tr><tr><td>2</td><td>It is a heat transfer operation.</td><td>It is a mass and heat transfer operation.</td></tr><tr><td>3</td><td>Evaporation involves the removal of water as a vapour at its boiling point.</td><td>Drying involves the removal of water at a temperature below its boiling point.</td></tr><tr><td>4</td><td>In evaporation operation, the product obtained is a liquid.</td><td>In drying operation, the product obtained is a solid.</td></tr></table>	1 mark each	4
1A-b	**Fourier's law of conduction:** It states that the rate of heat flow across an isothermal surface is proportional to the temperature gradient at the surface. $\frac{dQ}{dA} = - k\frac{\partial T}{\partial n}$ Q- rate of heat transfer A- Area perpendicular to heat flow k- Thermal conductivity T- Temperature	4	4
1A-c	**Stefan-Boltzmann Law :**	2	4

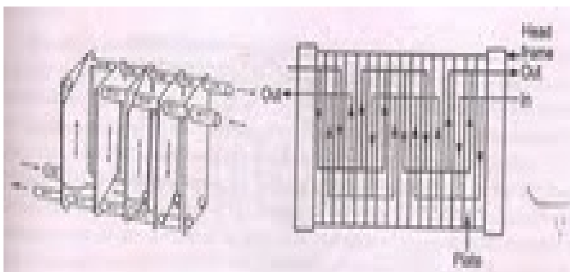
	It states that the total energy emitted (emissive power) by a black body is proportional to fourth power of its absolute temperature. $W_b \propto T^4$ $W_b = \sigma\ T^4$ Where W_b = total energy emitted (emissive power) by a black body σ = Stefan Boltzman constant= $5.67*10^{-8}$ W/m ^{2} K T = absolute temperature	2	
1A-d	**Effect of non condensable gases in condensation process:** If non condensable gas is present in condensing vapour, it hinders the process of heat transfer. The non condensable gas collects in the vicinity of condensing surface, and the condensing vapour has to diffuse through the gas film. The presence of this diffusion resistance in the process of condensation decreases the rate of condensation far below than that for a pure material. Presence of about 1% by volume air in the condensing vapour can reduce the heat transfer coefficient by 60% of its value for no air.	4	4
1.B	**Any one**		6
1B-a	**Rate of heat transfer through sphere:** Consider a hollow sphere of inner radius r1 and outer radius r2. Let T1 be the temp. at the inner surface and T2 be the temp. at the outer surface. Heat will flow from outside to inside. Consider a spherical element at radius r and thickness dr. the rate of heat flow can be written as Q= -kA dT/dr = $-k4\Pi r^2$ dT/dr dr/r^2 = -k4Π dT/Q Integrating and applying the limits between r1 to r2 and T1 to T2 1/r1-1/r2 = k4Π (T1-T2)/Q (r2-r1)/r1r2 = k4Π (T1-T2)/Q	2 2 2	6

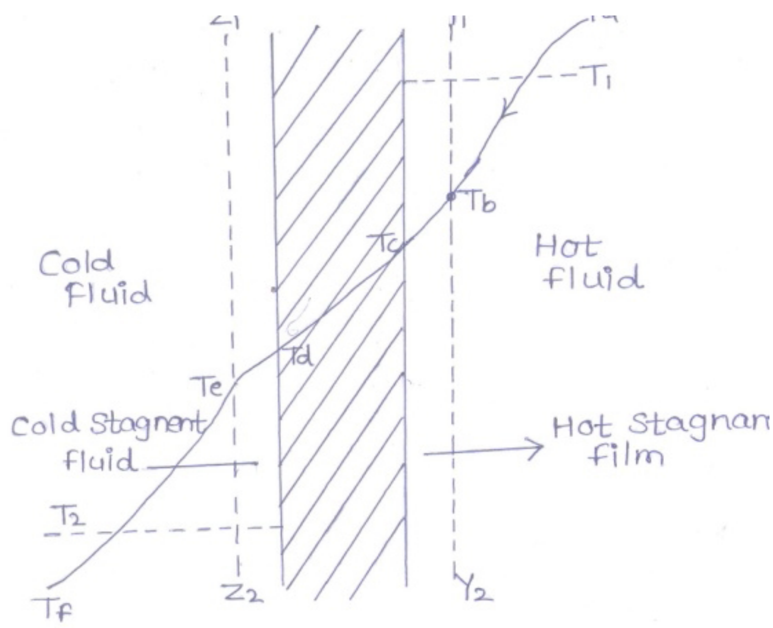
	Q= k4Πr1r2 (T1-T2)/ (r2-r1)		
1B-b	**Long tube vertical evaporator**  **Construction:** A long tube evaporator consist of a long tubular heating element incorporating tubes 25mm to 50mm in diameter and 4to 8 m in length. The tubular heating element projects into a vapour space for removing entrained liquid from the vapour. The upper tubesheet of tubular exchanger is free and a vapour deflector is incorporated in the vapour space just above it. A return pipe connecting the vapour space to the bottom of the exchanger is provided for natural circulation of a unvapourised liquid. It is provided with inlet connection for feed, steam and outlet connections for vapour, thick liquor ,condensate etc.	2 2	6

	Working: In this evaporator feed enters the bottom of the tubes,gates heated by the condensing steam, starts to boil part way up the tubes and the mixture of vap. and liquid comes out from the top of the tubes and finally impinges at high velocity on a deflector. The deflector acts both as a primary separator and foam breaker. The separated liquid enters the bottom of the exchanger and parts of this liquid is taken out as a product. This type of evaporator is widely used for handling of foamy, frothy liquids. It is typically used for the production of condensed milk and concentrating black liquor in the pulp and paper industry.	2	
2	Any four		16
2-a	**Modes of heat transfer are:** **1. Conduction** **2. Convection** **3. Radiation** 1) **Conduction :** If a temperature gradient exist in a continuous substance, heat can flow unaccompanied by any observable motion of mater. Heat flow of this kind is called conduction. 2) **Convection** : When a macroscopic particle of fluid crosses a specific surface, it carries with it a definite quantity of enthalpy. Such a flow of enthalpy is called convection. 3) **Radiation** : Radiation is transfer of energy through space by electromagnetic waves	2 2	4
2-b	Basis: 1 m^2 area B_1 = 0.225m		4

	K_1= 1.4 W/mK A=1 m^2 R_1= B_1 / K_1A = 0.225/1.4 = 0.160 K/W B_2 = 0.120m K_2= 0.2W/mK A=1 m^2 R_2= B_2 / K_2A = 0.120/0.2 = 0.60 K/W B_3= 0.225m K_3= 0.7 W/mK A=1 m^2 R_3= B_1 / K_1A = 0.225/0.7 = 0.321 K/W R= R_1+ R_2+ R_3 = 0.16+0.6+0.321 = 1.081 K/W Temp.drop ΔT= 1200-330 = 870 K Heat loss Q= ΔT / R = 870 / 1.081 = **804.81W**	2 1 1	
2-c	**Graphite block heat exchanger:** Graphite heat exchangers are well suited for handling corrosive fluids. Graphite is inert towards most corrosive fluids and has very high thermal conductivity. Graphite being soft, these exchangers are made in cubic or cylindrical blocks. In cubic exchangers, parallel holes are drilled in a solid cube such that parallel holes of a particular row are at right angles to the holes of the row above & below. Headers bolted to the opposite sides of the vertical faces of	1 2	4

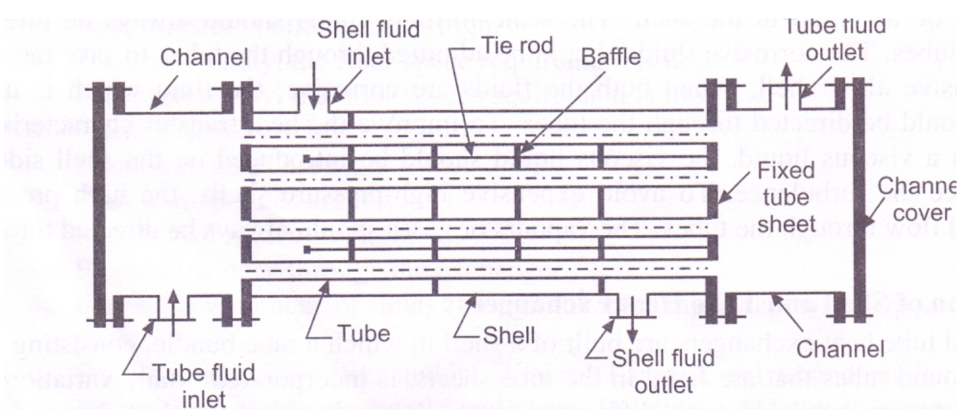
<table>
<tr><td></td><td>the cube provide the flow of process fluid through the block. The headers located on the remaining vertical faces direct the service fluid through the exchanger in a cross flow.

Applications of graphite block h.e.
i) It is used for very radioactive liquid.
ii) It can be used for Corrosive Fluid.</td><td>1</td><td></td></tr>
<tr><td>2-d</td><td>Single pass and multi pass shell and tube heat exchanger:
<table>
<tr><td>Single pass</td><td>Multi pass</td></tr>
<tr><td>Simple in construction</td><td>complex in construction</td></tr>
<tr><td>Flow may be parallel or counter current</td><td>Flow is parallel as well as counter current</td></tr>
<tr><td>Inexpensive</td><td>expensive</td></tr>
<tr><td>Heat transfer coefficients are low</td><td>Heat transfer coefficients are high</td></tr>
<tr><td>Frictional losses are low</td><td>Frictional losses are high</td></tr>
<tr><td>Heat transfer rates are low</td><td>Heat transfer rates are high</td></tr>
<tr><td>Floor space requirement is large</td><td>Floor space requirement is low</td></tr>
</table></td><td>1 mark each for any 4</td><td>4</td></tr>
<tr><td>2-e</td><td>Monochromatic Emissive power:
Monochromatic radiation emitted from unit area in unit time is called monochromatic emissive power.</td><td>2</td><td>4</td></tr>
</table>

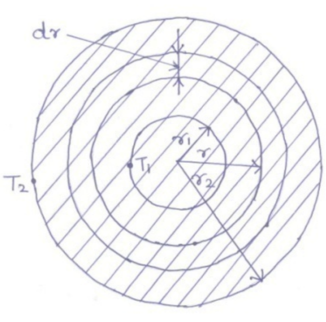
	Total Emissive power: It is the total quantity of radiant energy of all wave length emitted by a body per unit area per unit time.	2	
3	**Any two**		16
3-a	**Plate and frame heat exchanger:**  **Construction:** It consists of a series of rectangular, parallel plates held firmly together between head frames. The plates have corner ports and are sealed by gaskets around the ports and along the plate edges. The plates are having corrugated faces. These plates serve as heat transfer surfaces and are of stainless steel.. It is provided with inlet and outlet nozzles for fluids at ends. **Working:** The hot fluid passes between alternate pairs of plates, transferring heat to cold fluid in the adjacent spaces. The plates can be readily separated for cleaning and heat transfer area can be increased by simply adding more plates.	2 3 3	8
3-b	**Relationship between overall and individual heat transfer coefficients**: Consider a hot fluid flowing through a circular pipe & a cold fluid flowing on the outside of the pipe. Heat is flowing from the hot fluid to the bulk of cold fluid through a Series of resistances. (i) When heat is flowing from bulk of hot fluid to the metal wall , although heat		8

	transfer in bulk fluid takes by convection current ,there is a very small layer of fluid near the pipe in which heat transfer takes place by conduction. This is because flow in this layer is laminar & there is no mixing of molecules. This layer is known as viscous sublayer. This thin film of fluid flowing in Laminar flow is of great importance in determining the rate of heat transfer. The Thermal conductivity of fluid is very low so that resistance offered by this film is very large through the film is thin. (ii) When heat across metal wall resistance is comparatively low. (iii) When heat transfer takes place from metal to the bulk of fluid there exists a thin film of cold fluid which has a high resistance. (iv) Heat then flows from this thin film to bulk of cold fluid by convection.The process of heat transfer from bulk of hot fluid to bulk of cold fluid is represented by fig.	2	
	 Y1, y2 represents thin film on hot side in which liquid is flowing in Laminar	2	

	flow. Ta – Tb –Tc is temperature drop from bulk of hot fluid to metal wall on hot side. T_1 = is Avarage temperature on hot side Z_1 Z_2 represents thin film on cold side in which liquid is flowing in Laminar flow. Td –Te – Tf is temperature drop from metal wall to the bulk of cold fluid. T2 is average temperature on cold side. The rate of heat tranfer on hot side liquid is given by $Q = k_i A_i (Ta - Tc)/x_1$ ……..(i) The effective thickness x_1 depends on nature of flow , nature of surface and is generally not known. Therefore an indirect method of calculating heat transfer rate is by use of inside heat transfer coefficient represented by hi. Rate equation is usually written as Q =hi Ai (Ta – Tc) ……..(ii) Comparing equation (i) & (ii), $hi = k_1/x_1$ Resistance for heat tranfer is given as $R = x/k_A = 1/K/x(A) = 1/hiAi$ Resistance offered by film on hot side= 1/hiAo = Resistance of metal wall = L/KmAm = Resistance of thin film on cold fluid =1/hoAo So effectively heat transfer is across this there is Q1 +Q2 +Q3 films.	2	

	At Steady State, $Q1 = Q2 = Q3 = Q = Constant$ $\therefore Q = \Delta t / R1+R2+R3$ $Q = T1 - T2/[(1/hiAi)+(Lm/R\ Am)+(1/hoAo)]$ …….(i) We multiply N & D by Ai=area of heat transfer on hot side,we get $Q = (T1-T2)Ai / [(1/hiAi)+(Lm/Km.Am + (1/ho.Ao)]\ Ai$ $=(T1-T2)\ Ai\ [(1/hi)+(Lm/Km.Ai/Am)+(1/ho.Ai/Ao)]$ Since pipes are circular, $A = 2\pi rl$ $= (T1-T2)Ai[(1/hi)+(Lm/Km.2\pi ri\ L/2\pi rm\ L)+(1/ho.2\pi ri/2\pi ro)]$ $= (T1-T2)Ai[(1/hi)+(Lm/Km.\ ri/rm)+(1/ho.\ .\ ri/ro)]$ We assume a new parameter, Ui = Overall heat transfer coefficient on inside liquid. $\therefore 1/Ui = 1/hi + Lm/Km.ri/rm + 1/ho\ ri/ro$ ……(i)	2	
3-c	The rate of heat transfer in this case is given by Q = U.A.FT. (LMTD) for counter current flow Q = rate of heat transfer = 116 kw = $116*10^3$ w A = Area of heat transfer = 1.5 m^2 FT = correction factor for LMTD = 0.85 LMTD = log mean temperature difference for counter current flow =23k	2 2	8

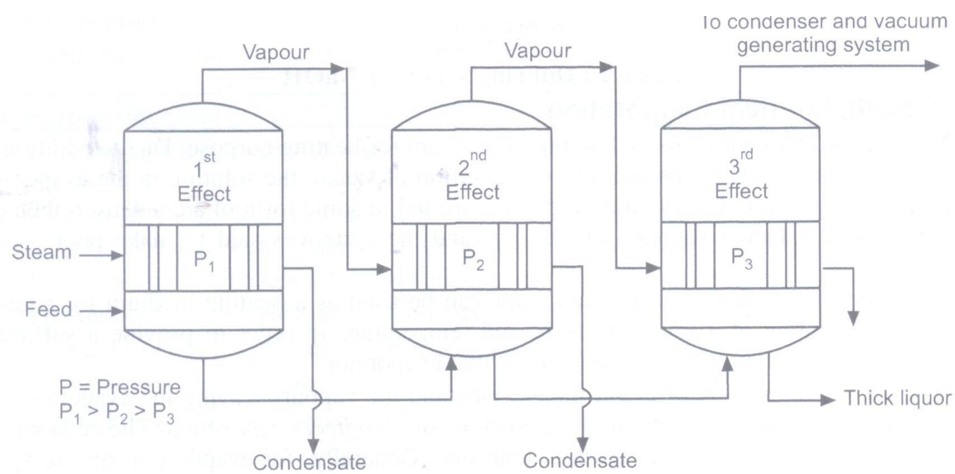
	U= Heat transfer coefficient in $W/(m^2.K)$ 116*103 = U *1.5*0.85*23 $U = \frac{116*103}{1.5*0.85*23}$ **= 3956 $w/(m^2.K)$**	2 2	
4 A	Any three		12
4A-a	**Solution :** Length of pipe = 1 m e= 0.8 σ = 5.67*10-8 $w/(m^2.k^4)$ T^1 = 423 k T^2 = 300k Do = 60mm = 0.06m Outside surface area per 1 meter length of pipe is A = π Do L = π*0.06*1 = 0.189 m^2 The net radiation rate per 1 m length of pipe is $Qr = e\sigma A (T1^4 - T2^4) = 0.8 *5.67 *10\text{-}8*0.\overline{18}9(4\overline{23}^4 - 300^4)$ **= 205 w/m**	1 1 1 1	4
4A-b	**Fixed tube sheet heat exchanger:** 	4	4
4A-c	**Capacity:** The capacity of an evaporator is defined as the number of kilograms of water vaporized/evaporated per hour. **Economy of evaporation**: The economy of an evaporator is defined as the	2 2	4

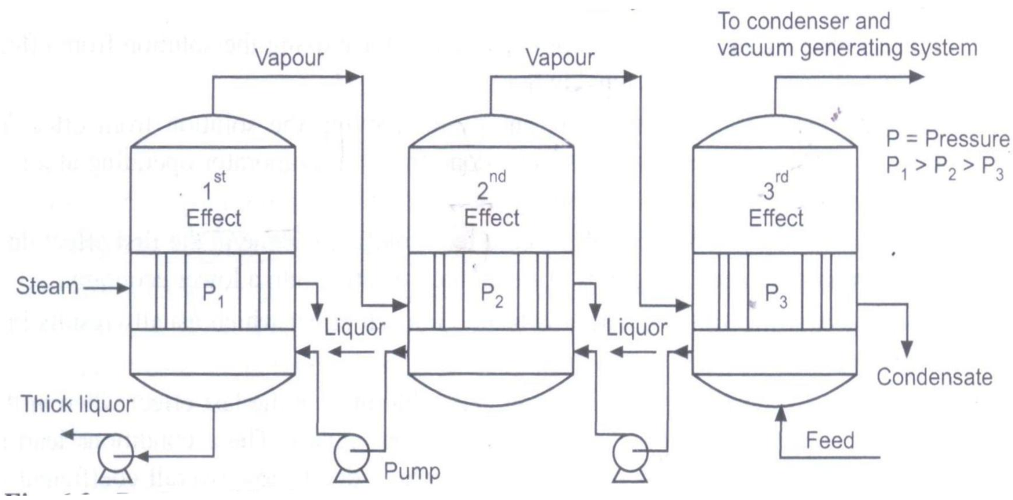
	number of kilograms of water evaporated per kilogram of stem fed to the evaporator.		
4A-d	Solution: Area= 1 m^2 Thickness x= 0.3 m T_1 = 593K, T_2= 311 K $Q/A = 1/x\ [0.003/2(T_2^2-T_1^3)-10^{-6}/3(T_2^2-T_1^2)]$ $Q/A = 1/x\ [0.003/2(593^2-311^3)-10^{-6}/3(593^2-311^2)]$ = 1/ 0.3[382.392-59.48] Q= **1076 W**	1 2 1	4
4 B	**Any one**		6
4B-a	Consider the thick walled hollow cylinder as shown in fig.(a).The inside radius of cylinder is r_1 and the outside radius is r_2 and length of cylinder is L. Assume that thermal conductivity of the material of which cylinder is made be k. Let the temperature of the inside surface be T_1 and that of the outside surface be T_2 . Assume that $T_1 < T_2$,therefore the heat flows from the inside of cylinder to outside . It is desired to calculate the rate of heat flow for this case.  **(a)Heat flow through thick walled cylinder** Consider a very thin cylinder (cylindrical element) , concentric with the main cylinder , of radius r , where r is between r_1 and r_2 . The thickness of wall	1	6

	of this cylindrical element is dr. $Q = -k\,2\prod L\,(dT/dr)$….(i) Equation (i) is similar to eqn (a) . Here area perpendicular to heat flow is $2\prod rL$ and dx of eqn (a) is equal to dr. Rearranging the eqn (i) ,we get $dr/r = -k\,(2\prod L)/Q.dT$…..(ii) Only variables in eqn (ii) are r and T (assuming k to be constant). Integrate the eqn (ii) between the limits When $r = r_1$,$T = T_1$ When $r = r_2$,$T = T_2$ $_{r2}\int^{r1} dr/r = -k\,(2\prod L)/Q\ _{T1}\int^{T2} dT$…..(iii) $\ln\ r_2 - r_1 = -k\,(2\prod L)\,(T_1 - T_2)$…..(iv) $\ln(r_2/r_1) = k\,(2\prod L)\,(T_1 - T_2)/Q$……(v) Rate of heat flow through thick walled cylinder : $\therefore Q = k\,(2\prod L)\,(T_1 - T_2)/\ln(r_2/r_1)$….(vi) Equation (a) can be used to calculate the flow of heat through a thick walled cylinder. It can be put into more convinient form by expressing the rate of heat flow as : $Q = k\,(2\prod r_m L)\,(T_1 - T_2)/(r_2 - r_1)$……(vii) Where r_m is the logarithmic mean radius & is given by $r_m = (r_2 - r_1)/\ln(r_2/r_1)$ $= (r_2 - r_1)/2.303\log(r_2/r_1)$……(viii) $A_m = 2\prod r_m L$….(ix)	1 1 1 1	

	A_m is called as logarithmic mean area. Equation (viii) becomes **$Q = k\ A_m\ (T_1 - T_2) / (r_2 - r_1)$….(x)** $Q = (T_1 - T_2) / [(r_2 - r_1)/k\ A_m] = \Delta T / R$ Where $R = (r_2 - r_1)/k\ A_m$	1	
4B-b	**Advantages of short tube evaporator :** i) Relatively inexpensive ii) As scaling occurs inside the tubes , it can be easily removed by mechanical or chemical means. iii) Provides moderately good heat transfer at a reasonable cost. iv) Can be put into more rigorous services than horizontal tube evaporator. **Disadvantages of short tube evaporator :** i) Floor space required is large ii) Amount of liquid hold up in the evaporator is large iii) Since there is no circulation, these units are not suitable for viscous liquid.	3 3	6
5	Any two		16
5-a	MFR of thermic fluid = 21*950 = 19950 kg/hr MFR of cold fluid = 15*1000 = 15000 kg/hr Heat gained by cold fluid = 15000*4.187(328-303) Heat given out by thermic fluid = 19950*2.93(388-T_2) Equating, T_2= **361.2 K**	2 2 1 1 2	8
5-b	For parallel flow Δ T1=423-308 =115K, ΔT2= 363-338 = 25 k Δ Tlm= (115-25)/ln(115/25) = **58.97 K**	 2 2	8

	For counter current Δ T1=423-338 =85K, ΔT2= 363-308 = 55 k Δ Tlm= (85-55)/ln(85/55) = **68.92 K** Since the value of Δ Tlm is higher for counter current flow, it is preferred.	 2 2	
5-c	Basis: 30000 kg/hr feed is fed to the evaporator. Material balance of solids: Solids in feed= solids in the thick liquor 0.10x30000=0.05xm' m'=6000kg/h. overall Material balance: kg/h feed= kg/h water evaporated + kg/h thick liquor water evaporated= mv=30000-6000=24000kg/h enthalpy balance over evapoprator(assuming no heat loss) Q=ms λs= mf.Cpf.(T-Tf)+ mv λ msx220=30000x3.98x(323-293)+24000x2383 ms=276245.45kg/h. steam consumption= 276245.45kg/h steam economy= kg/h water evaporated/kg/h steam consumed = 24000/276245.45 =**0.087** Heat load= Q= ms λs= 276245.45x220=16881666.39 w ΔT=Ts-T= 393-323=70K A =Q/U ΔT= 16881666.39 /2900x70= **83.16m^2**	1 1 1 1 1 1 1 1	8
6	Any two		16
6-a	**Multiple effect evaporation:** In this system, evaporators are arranged in series so that the vapour produced in first effect is fed to the steam chest of second effect as heating medium in which boiling takes place at low pressure and temperature and so on.	2	8

	Increasing the number of effects between steam supply and condenser increases the amount of evaporation per kg of steam fed to the first effect and also the operating cost will be less, but capital cost, maintenance and repair charges increases with increase in number of effects. **Methods of feeding multiple effect evaporation system:** 1. Forward feed arrangement: In this, the liquid feed flows in the same direction as the vapour flows. Fresh feed and steam are fed to the first effect. For effectively utilizing temperature potentials, this arrangement is preferable. 2. Backward feed arrangement: In this arrangement, the feed solution and vapour flow in opposite direction. Fresh feed is admitted to the first effect and steam to the last effect. If the liquid is very viscous, then we adopt backward feed arrangement. 3. Mixed feed arrangement: In this feed arrangement, steam is admitted to the first effect. Feed solution is admitted to an intermediate effect and flows to the first effect from where it is fed to last effect for final concentration. This is adopted for best overall performance.  **Forward feed arrangement**	2 mark each for any 2 1 mark each for any 2	

	 **Backward feed arrangement** ***Note: Mixed feed arrangement also should be given due consideration***		
6-b	The change from liquid to vapour state is known as vapourisation and that from vapour to liquid is known as condensation. In either case, the latent heats involved are identical. In the condensation of a pure vapour, it is necessary to remove the latent heat of vapourisation. Condensation is a convection process that involves a change of phase from vapour to liquid and it occurs whenever a saturated vapour comes into contact of a cold surface, for example In surface condenser, heat transfer from the vapour to the surface takes place and the vapour gets condensed on the surface. The process of condensation which is the reverse of boiling,occurs by two distinct mechanism and that too at very different rates of heat transfer, The two distinct mechanism are 1) Dropwise condensation 2) Filmwise condensation 估 **ropwise condensation**: When a saturated vapour comes into contact a cold surface, it condenses and if condensate does not wet the surface, the	4	8

	droplets are formed on the surface.. The droplets grow and ultimately fall from or fall down under the influence of gravity leaving behind the bare metal surface on which further condensation takes place.The condensation occurring by this mechanism is known as dropwise condensation. **Filmwise condensation**: When a saturated vapour comes into contact with the cold surface, it condenses and if condensate wets the surface it formes a continuous film of condensate through which heat mass be transferred. The additional vapour is then required to condense into the liquid film rather than directly on the surface. The condensate ultimately flows down the surface under the influence of gravity. In Filmwise condensation, the film covering the acts as a resistance to heat transfer while in dropwise condensation a large portion of a surface is directly exposed to the vapour. Because of this the rate of heat transfer and heat transfer coefficient in dropwise condensation is larger than filmwise condensation.	4	
6-c	The **logarithmic mean temperature difference** (also known as **log mean temperature difference** or simply by its initialism**LMTD**) is used to determine the temperature driving force for heat transfer in flow systems, most notably in heat exchangers. The LMTD is a logarithmic average of the temperature difference between the hot and cold feeds at each end of the double pipe exchanger. The larger the LMTD, the more heat is transferred. The use of the LMTD arises straightforwardly from the analysis of a heat exchanger with constant flow rate and fluid thermal properties. Understanding the concept of log mean temperature difference or LMTD is very important for heat exchanger design especially for the heat exchangers	2	8

	with no phase change. The LMTD is the driven force for the heat exchange between the two fluids. As the LMTD value increases, the amounts of heat transfer between the two fluids also increase. The LMTD value is used for calculating the heat duty of the heat exchanger. The formula is: **Q = U * A * LMTD** Where, Q – Heat duty of the heat exchanger (in *watts*) U – Heat transfer co-efficient (in *watts/Kelvin/Meter square*) A – Heat transfer area (in meter square)	2	
	Assume heat transfer is occurring in a heat exchanger along an axis *z*, from generic coordinate *A* to *B*, between two fluids, identified as *1* and *2,* whose temperatures along *z* are $T_1(z)$ and $T_2(z)$. The local exchanged heat flux at *z* is proportional to the temperature difference: $$q(z) = U(T_2(z) - T_1(z))/D = U(\Delta T(z))/D,$$ where *D* is the distance between the two fluids. The heat that leaves the fluids causes a temperature gradient according to Fourier's law: $$\frac{dT_1}{dz} = k_a(T_1(z) - T_2(z)) = -k_a \Delta T(z)$$ $$\frac{dT_2}{dz} = k_b(T_2(z) - T_1(z)) = k_b \Delta T(z)$$ Summed together, this becomes	2	

	$$\frac{\mathrm{d}\,\Delta T}{\mathrm{d}\,z} = \frac{\mathrm{d}\,(T_2 - T_1)}{\mathrm{d}\,z} = \frac{\mathrm{d}\,T_2}{\mathrm{d}\,z} - \frac{\mathrm{d}\,T_1}{\mathrm{d}\,z} = K \Delta T(z)$$ where $K=k_a+k_b$. The total exchanged energy is found by integrating the local heat transfer q from A to B: $$Q = \int_A^B q(z) dz = \frac{U}{D} \int_A^B \Delta T(z) dz = \frac{U}{D} \int_A^B \Delta T\, dz$$ Use the fact that the heat exchanger area Ar is the pipe length A-B multiplied by the interpipe distance D: $$Q = \frac{U Ar}{(B-A)} \int_A^B \Delta T\, dz = \frac{U Ar \int_A^B \Delta T\, dz}{\int_A^B dz}$$ In both integrals, make a change of variables from z to ΔT: $$Q = \frac{U Ar \int_{\Delta T(A)}^{\Delta T(B)} \Delta T \frac{\mathrm{d}z}{\mathrm{d}\,\Delta T}\, d(\Delta T)}{\int_{\Delta T(A)}^{\Delta T(B)} \frac{\mathrm{d}z}{\mathrm{d}\,\Delta T}\, d(\Delta T)}$$ With the relation for ΔT found above, this becomes $$Q = \frac{U Ar \int_{\Delta T(A)}^{\Delta T(B)} \frac{1}{K}\, d(\Delta T)}{\int_{\Delta T(A)}^{\Delta T(B)} \frac{1}{K \Delta T}\, d(\Delta T)}$$ Integration is at this point trivial, and finally gives: $$Q = U \times Ar \times \frac{\Delta T(B) - \Delta T(A)}{\ln[\Delta T(B)/\Delta T(A)]},$$ from which the definition of LMTD follows.	2	