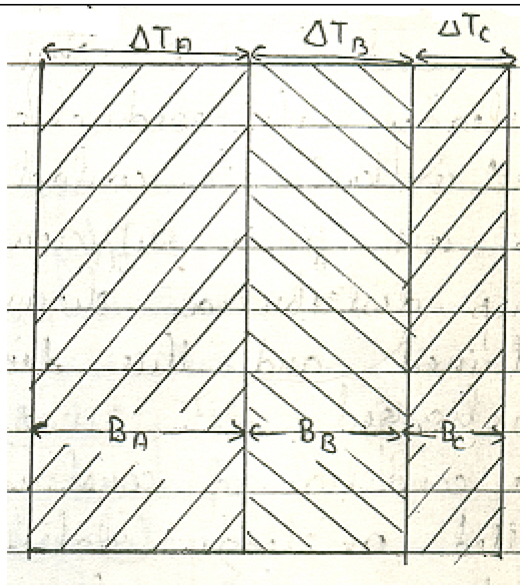
Important Instructions to examiners:

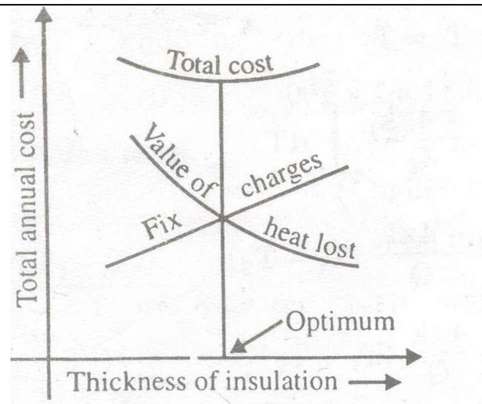
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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
1 A	Any three	12
1A-a	**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	2 2
1A-b	Nusselt Number N_{NU}= hD/K Where, h - heat transfer coefficient D- diameter of pipe K- thermal conductivity Grashoff Number $N_{GR} = D^3\rho^2 g\beta\Delta T/\mu^2$ Where, D- diameter of pipe ρ - density g – acceleration due to gravity β – coefficient of thermal expansion ΔT – temperature difference μ - viscosity	1 1 1 1
1A-c	**Kirchoff's law**: It states that at temperature equilibrium, the ratio of total emissive power of any body to absorptivity depends only upon the temperature	2

	of the body. Take to any two bodies in temperature equilibrium with surrounding. $W_1/\alpha_1 = W_2/\alpha_2$ If the first body is a black body then, $\alpha_1=1$ $W_1=W_b= W_2/\alpha_2$ But $W_2/\alpha_2=\varepsilon_2$ **OR** $\alpha_2=\varepsilon_2$ Thus when any body is at temperature equilibrium with its surrounding, its emissivity and absorptivity are equal.	2
1A-d	**Advantages of multi pass heat exchangers:** 1. Floor space requirement is low 2. Heat transfer rates are high 3. Heat transfer coefficients are high 4. Fluid flow number of times through exchanger 5. Flow is parallel as well as counter current **Disadvantages of multi pass heat exchangers:** 1. Complex in construction 2. Expensive 3. Frictional losses are high	1 mark each for any2 1 mark each for any2
1.B	**Any one**	6
1B-a	**Heat loss through a composite wall:**	

		2
	Consider a flat wall constructed of a series of layers of thickness x1, x2, x3 respectively. Let the thermal conductivities of layers be K_1, K_2, K_3 . Let ΔT1, ΔT2, ΔT3 be the temperature drop across the layers. Let ΔT be the total temperature drop across the entire wall. $\Delta T= \Delta T_A+ \Delta T_B+ \Delta T_C$ $\Delta T_A= q_1*B_A/ K_1*A$ $\Delta T_B= q_2*B_B/ K_2*A$ $\Delta T_C= q_3*B_C/ K_3*A$ Where A is the area of the wall at right angle to the plane Then $\Delta T= q_1*B_A/ K_1*A + q_2*B_B/ K_2*A + q_3*B_C/ K_3*A$ In steady state conduction, all the heat passes through the first resistance should pass through second and third. So $q_1= q_2= q_3$ $\Delta T= q[B_A/ K_1*A + B_B/ K_2*A + B_C/ K_3*A]$ $= q[R_1+R_2+R_3]$ OR $q= \Delta T/[R_1+R_2+R_3]$ But $q= \Delta T/R$ Therefore : $R= R_1+R_2+R_3$ In heat flow through a series of layers the overall resistance is equal to the sum	2 2

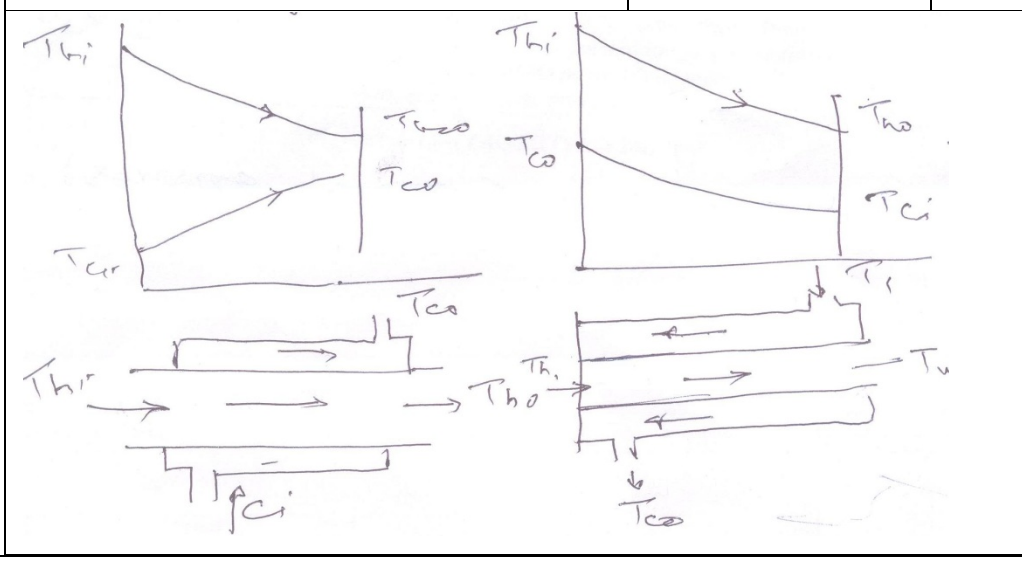
	of individual resistances.	
1B-b	**Thermal recompression:** To increase the economy of single effect evaporator, the principle of thermal recompression is used. Here the vapour from the evaporator is compressed to increase its temperature so that it will condense at a temperature higher enough to permit its use as heating media in the same evaporator. In this method, vapour is compressed by means of jet ejectors.. **Properties of evaporating liquid** 1. concentration 2. foaming 3. scale 4. temperature sensitivity 5. material of construction	3 3
2	Any four	16
2-a	**Optimum thickness of insulation:** The optimum thickness of an insulation is obtained by purely economic approach. The greater the thickness, the lower the heat loss & the greater the initial cost of insulation & the greater the annual fixed charges. It is obtained by purely economic approach. Increasing the thickness of an insulation reduces the loss of heat & thus gives saving in operating costs but at the same time cost of insulation will increase with thickness. The optimum thickness of an insulation is the one at which the total annual cost (the sum values of heat lost and annual fixed charges) of the insulation is minimum.	2

	 **Optimum Thickness Of Insulation**	2
2-b	**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. In metallic solids thermal conduction results from the motion of unbound electrons. In most liquid and solids which are poor conductors of electricity, thermal conduction results from the transport of momentum of individual molecules. In gases conduction occurs by the random motion of molecules. **Example:** Heat flow in the metal wall of tube 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. Since convection is a macroscopic phenomenon, it can occur only when forces act on the particle or stream	2 marks each for any two types

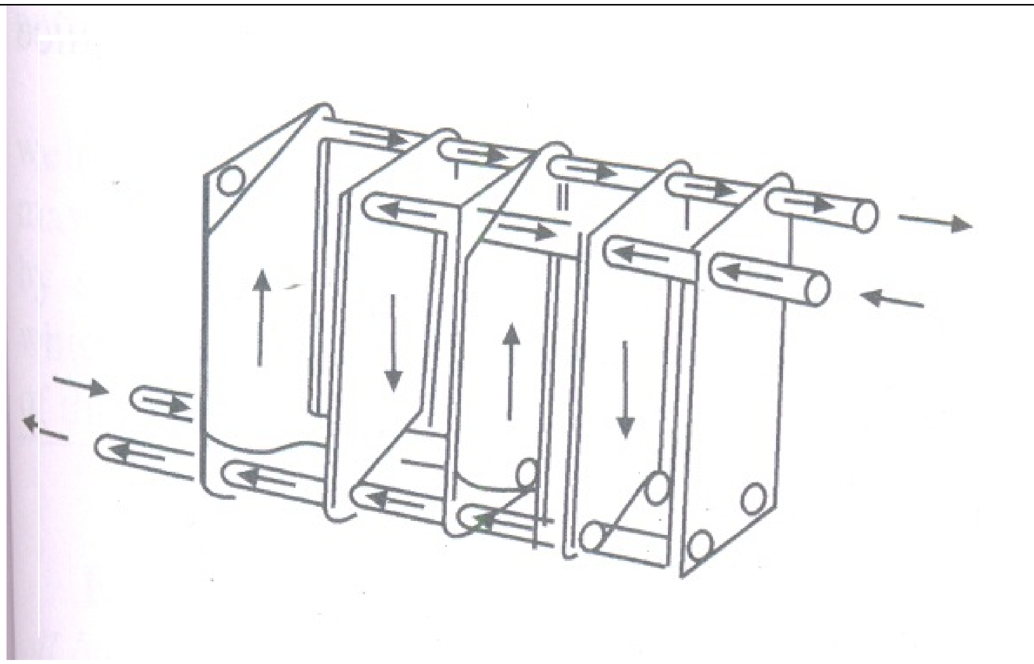
	of fluid and maintain its motion against the force of friction. There are two types of convection- natural and forced. If the currents are the result of buoyancy forces generated by differences in density and the differences in density are in turn caused by temperature gradient the action is called natural convection. **Example**: heating of water by hot surface **Forced convection** : If the currents are set in motion by the action of a mechanical device such as a pump or agitator, the flow is called forced convection **Example:** heat flow to a fluid pumped through a heated pipe 3) **Radiation**: Radiation is transfer of energy through space by electromagnetic waves. If radiation is passing through empty space, it is not transformed into other forms of energy, nor is it diverted from its path. If matter appears in its path, the radiation will be transmitted, absorbed or reflected. It is only the absorbed energy that appears as heat. Fused quartz transmits all radiation falling on it, a polished opaque surface will reflect all the radiation and a black surface will absorb most of the radiation receiving. **Example**: Loss of heat from unlagged pipe.	
2-c	**Stefan-Boltzmann Law** : It states that the total energy emitted (emissive power) by a black body is proportional to fourth power of its absolute temperature. $W_b \alpha T^4$ $W_b = \sigma T^4$ 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 2

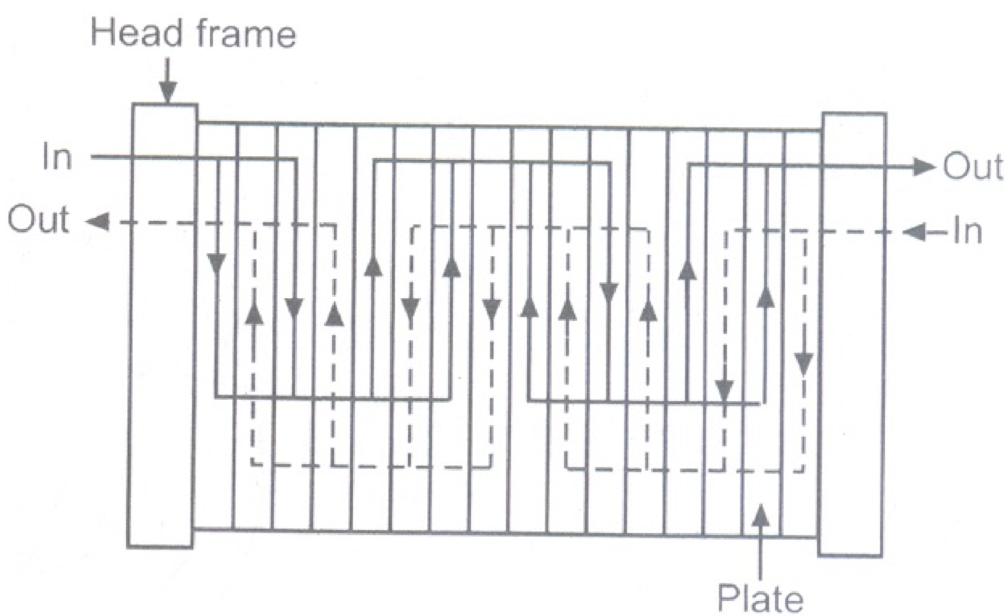
2-d **Co current and counter current flow:** (1 mark each for any 4)

Co current flow	Counter current flow
i) Both hot fluid & cold fluid enter at same end & come out from other end	i) Both hot fluid & cold fluid enter at different ends & come out from Different ends.
ii) Both fluid flow in the same direction.	ii) Both fluid flow in opposite direction.
iii) LMTD is low	iii)) LMTD is more.



2-e **Plate and frame heat exchanger:**





(2)

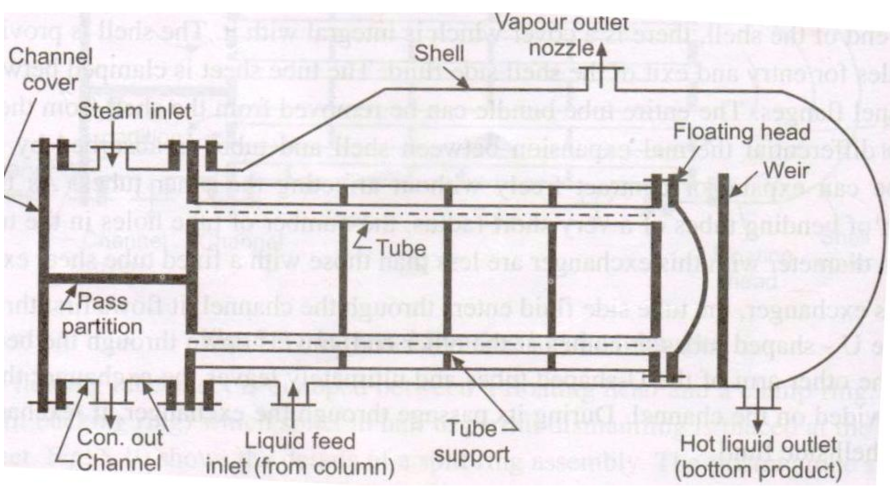
Construction:

It consists of a series of rectangular, parallel plates held firmly together between (1)

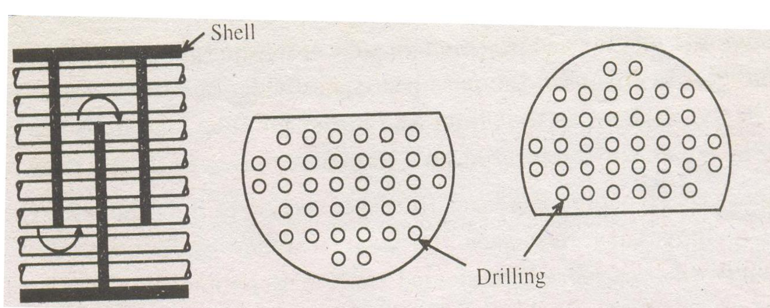
	head frames. The plates have corner ports and are sealed by gaskets around the ports and along the plate edges. The plates are having corrugated faces. These plates serve as heat transfer surfaces and are of stainless steel.. It is provided with inlet and outlet nozzles for fluids at ends. **Working:** 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.	1
3	**Any two**	16
3-a	**Film coefficient**:In the case of convective heat transfer taking place from a surface to a fluid, the circulating currents die out in the immediate vicinity of the surface and a film of the fluid, free of turbulence, covers the surface. Heat transfer through this film takes by thermal conduction. Since the thermal conductivity of most fluids is low, the main resistance to heat transfer lies in the film. Therefore, an increase in the velocity of the fluid over the surface results in improved heat transfer mainly because of reduction in the thickness of the film. If the resistance to heat transfer is considered as lying within the film covering the surface, the rate of heat transfer Q is given by $Q = kA\,\Delta T/x$ The effective thickness x is not generally known and therefore this equation is usually rewritten in the form: $Q = h\,A\,\Delta T$ This is the basic equation for the rate of heat transfer by convection under steady state conditions, where 'h' is called the film heat transfer coefficient or surface coefficient or simply film coefficient. The value of 'h' depends upon the properties of the fluid within the film region, hence it is called the film heat	1 1 1

	transfer coefficient. It depends upon the various properties of the fluid, linear dimension of surface and fluid velocity (i.e. the nature of flow). Numerically, heat transfer coefficient (h) is the quantity of heat transferred in a unit time through a unit area at a temperature difference of one degree between the surface and surrounding. h has the units o W/ (m2.K) in the SI system. When heat is flowing from hot liquid to cold liquid across a metal wall, there are three resistances in series. 1) Resistance of stagnant film on hot side 2) Resistance of metal wall 3) Resistance of stagnant film on cold resistance	1
	$R_i = \frac{1}{hiAi}$ $R_m = \frac{Lm}{KmAm}$ $Ro = \frac{1}{hoAo}$	1
	Rate of heat transfer = $\frac{T1-T2}{Ri+Rm+Ro}$ $Q = \frac{\Delta T}{\frac{1}{hiAi}+\frac{Lm}{KmAm}+\frac{1}{hoAo}}$	1
	$Q = \frac{\Delta T\ Ai}{\frac{1}{hi}+\frac{Lm\ Ai}{KmAm}+\frac{1\ Ai}{hoAo}}$ We define,	

	$\frac{1}{Ui} = \frac{1}{hi} + \frac{Lm}{Km}\frac{Ai}{Am} + \frac{1}{ho}\frac{Ai}{Ao}$ $Q = \frac{Ai\Delta T}{\frac{1}{Ui}}$ Or **$Q = UiAi\Delta T$** **Thus surface coefficients play important role is finding out rate of heat transfer in combined construction & convection.**	1 1
3-b	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** For counter current flow LMTD = 60-58.2/ln(60/58.2) = 59.1 Q=U.A.LMTD 1570125*1000/3600 = 3490*A*59.1 **A = 2.11 m^2**	1 1 1 1 1 1 1 1
3-c	**Kettle Reboiler Heat Exchanger:** In distillation operation, a reboiler is used to meet the latent heat requirements at the bottom of a column. It consists of an enlarged shell containing a relatively small tube bundle. At one end of the bundle, the tubes are expanded into a stationery tube sheet clamped between shell and channel flange. In the channel pass partition is incorporated so that inlet and outlet for the tube side	3

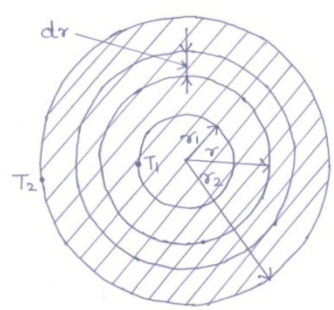
	fluid is provided on the same channel. At opposite end of the bundle, tubes are expanded into a freely riding floating tube sheet. The tubes are free to expand. The shell is provided with inlet and outlet connections at the bottom. A vapour outlet is provided at the top. A weir is incorporated in the shell to maintain a pool of liquid in the shell so that the tube bundle remains submerged in the liquid. The heating medium usually steam, flows through the tubes and the condensate is removed through a steam trap. The liquid to be vaporized is introduced in the enlarged shell through a liquid inlet. Heat transfer to boiling liquid takes place from the submerged surface. The shell is of a large diameter mainly for vapour- liquid separation. The vapours are generated, disengaged and removed from the top, and unvaporised liquid spills over the weir, and is withdrawn as the bottom product, through a liquid outlet provided at the bottom of the shell. 	3 2
4 A	Any three	12
4A-a	Basis: 1 m^2 area $B_1 = 0.23m$ $K_1 = 1.0$ W/mK $A = 1\ m^2$	

	$R_1 = B_1 / K_1A$	1
	$= 0.23/1.0 = 0.23$ K/W	
	$B_2 = 0.01$m	
	$K_2 = 0.4$W/mK	
	$A = 1\ m^2$	
	$R_2 = B_2 / K_2A$	1
	$= 0.01/0.4 = 0.025$ K/W	
	$R = R_1 + R_2 +$	1
	$= 0.23+0.025 = 0.255$ K/W	
	Temp.drop $\Delta T = 30$ K	
	Heat loss $Q = \Delta T / R$	1
	$= 30 / 0.255$	
	= **117.65W**	
4A-b	**(i)Evaporator for concentrating viscous solution is** forced circulation evaporator.	1
	Due to the high velocity obtained by the use of pump, viscous liquids can be treated in forced circulation evaporator.	1
	(ii)Evaporator for concentrating foaming solution is long tube vertical evaporator.	1
	The vapour deflector placed in the vapour space acts as a primary separator and foam breaker**.**	1
4A-c	**Absorptivity :**	2
	It is the fraction of radiation falling on a body which is absorbed.	
	Reflectivity :	
	It is the fraction of radiation falling on a body which is reflected.	
	Transmissivity :	
	It is the fraction of radiation falling on a body which is transmitted.	

	Kirchoff's law states that at temperature equilibrium, the ratio of total emissive power of any body to absorptivity depends only upon the temperature of the body. Take to any two bodies in temperature equilibrium with surrounding. $W_1/\dot{\alpha}_1 = W_2/\dot{\alpha}_2$ If the first body is a black body then, $\dot{\alpha}_1=1$ $W_1=W_b= W_2/\dot{\alpha}_2$ But $W_2/\dot{\alpha}_2=\varepsilon_2$ **OR** $\dot{\alpha}_2=\varepsilon_2$ Thus when any body is at temperature equilibrium with its surrounding, its emissivity and absorptivity are equal.	2
4A-d	Baffles are commonly used on shell side to increase rate of heat transfer by increasing the turbulence of shell side liquid. They also support the tubes against vibration. The baffles cause the fluid to flow through the shell at right angles to the axis of tube. Clearance between baffles & shell should be minimum to avoid by passing of fluid. Common types of baffles are segmental baffle. Segmental baffle is drilled circular disc of sheet metal with one side cut away when the height of baffle is 75% of inside dia of the shell it is called as 25% cut segmental baffle.  	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. 1



(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 of this cylindrical element is dr. 1

$$Q = -k\, 2\prod L\, (dT / dr) \ldots.(i)$$

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

$$dr / r = -k\, (2\prod L) /Q.dT \ldots..(ii)$$

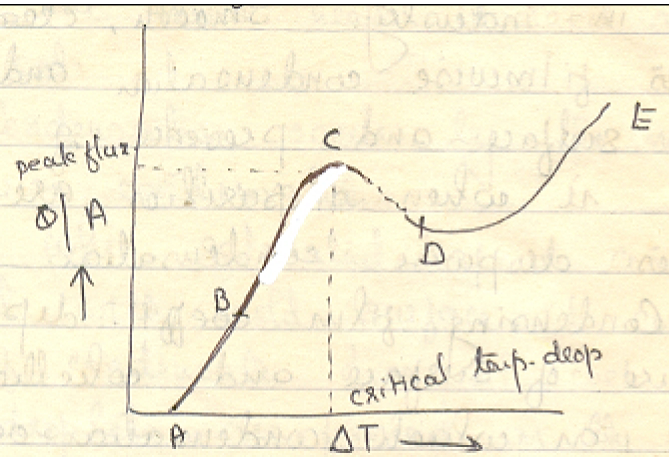
Only variables in eqn (ii) are r and T (assuming k to be constant).

Integrate the eqn (ii) between the limits

When $r = r_1$, $T = T_1$ 1

	When $r = r_2$, $T = T_2$	
	$$\int_{r2}^{r1} dr/r = -k (2\prod L) / Q \int_{T1}^{T2} dT \ldots(iii)$$	1
	$$\ln\ r_2 - r_1 = -k (2\prod L) (T_1 - T_2) \ldots(iv)$$	
	$$\ln (r_2 / r_1) = k (2\prod L) (T_1 - T_2) / Q \ldots(v)$$	
	Rate of heat flow through thick walled cylinder :	
	$$\therefore Q = k (2\prod L) (T_1 - T_2) / \ln (r_2 / r_1) \ldots(vi)$$	
	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 :	
	$$Q = k (2\prod r_m L) (T_1 - T_2) / (r_2 - r_1) \ldots(vii)$$	1
	Where r_m is the logarithmic mean radius & is given by	
	$$r_m = (r_2 - r_1) / \ln (r_2 / r_1)$$	
	$$= (r_2 - r_1) / 2.303 \log (r_2 / r_1) \ldots(viii)$$	
	$$A_m = 2\prod r_m L \ldots(ix)$$	
	A_m is called as logarithmic mean area.	
	Equation (viii) becomes	
	$$\mathbf{Q = k\ A_m (T_1 - T_2) / (r_2 - r_1) \ldots(x)}$$	1
	$$Q = (T_1 - T_2) / [(r_2 - r_1)/k\ A_m] = \Delta T /R$$	
	Where $R = (r_2 - r_1)/k\ A_m$	
4B-b	Basis: 20000 kg/hr feed is fed to the evaporator.	
	Material balance of solids:	
	Solids in feed= solids in the thick liquor	1
	0.05x20000=0.2xm’	

	m'=5000kg/h. overall Material balance: kg/h feed= kg/h water evaporated + kg/h thick liquor water evaporated= mv=20000-5000=15000kg/h enthalpy balance over evaporator(assuming no heat loss) $Q = m_s \lambda_s = m_f . C_{pf} . (T - T_f) + m_v \lambda$ Ms x 2185 = 20000 x 4 (380-298) + 15000 x 2257 ms=18496.57kg/h. steam consumption= 18496.57 kg/h steam economy= kg/h water evaporated/kg/h steam consumed = 15000/18496.57=**0.811** Heat load= Q= ms λs= 18496.57 x 2185=**40415000KJ/hr** **= 11226388.89 W**	1 1 1 1 1
5	Any two	16
5-a	**Heat transfer in boiling liquids :**	2



AB - natural convection $\frac{Q}{A} \propto \Delta T^{1.25}$ 2

BC - nucleate boiling

CD - transition boiling 1

DE - film boiling

D - Leidenfrost point

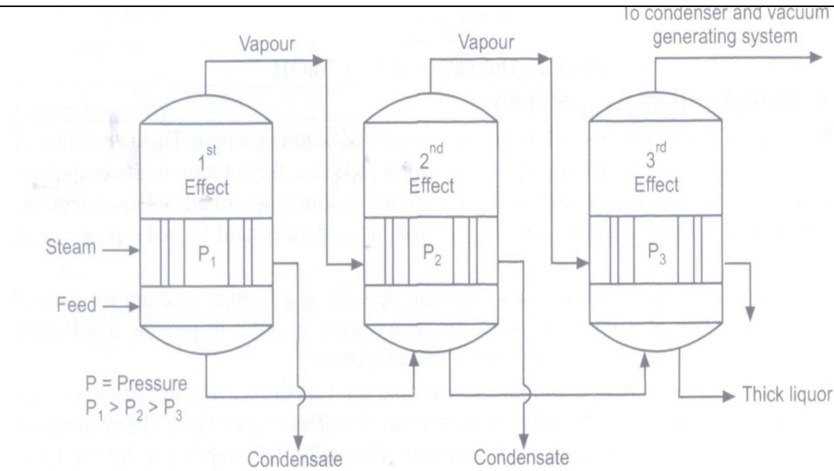
ΔT - temp. diff. between tube wall & boiling liquid.

Consider a horizontal tube immersed in a vessel containing boiling liquid. Assume that Q/A, the heat flux and ΔT, the difference between the temperature of the tube wall and that of the boiling liquid , are measure . A plot of Q/A vs ΔT on log coordinates is drawn . This curve can be divided into four segments. 1

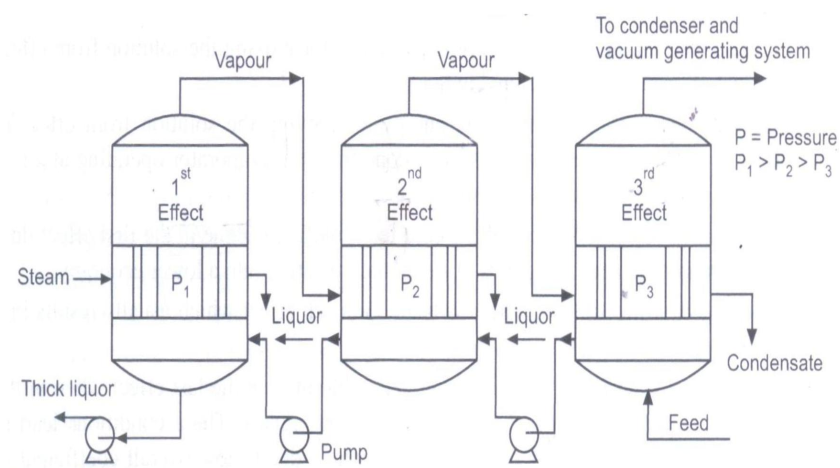
At low temperature drops, the line AB is straight and has slope of 1.25.Here heat transfer is by **natural convection**. Bubbles formed on the surface of the heater, are released from it , raise the surface and are disengaged in to the vapour space. 1

The segments BC is also straight but slope is greater than AB. The rate of bubble production is large enough for the stream of bubbles moving up through 1

	the liquid to increase the velocity of the circulation currents and coefficient of heat transfer becomes greater than that in undisturbed natural convection. This is called **nucleate boiling**. In the segments CD the flux decreases as the temperature drop raises and reaches a minimum at point D. As the temperature drop is raised , more and more bubbles are present that they tend to coalesce on the heating surface to formed and layer of insulating vapour. This type is called **transition boiling.** In DE the flux again increases with ΔT and at large temperature drop surpasses the previous maximum reached. The hot surface becomes covered with a film of vapour through with heat is transferred by conduction and by radiation .This is known as **film boiling**.	
5-b	**Methods of increasing the economy of an evaporator:** 1. Using multiple effect evaporator 2. Vapour recompression **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. 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 6 marks for explanation of any one



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.

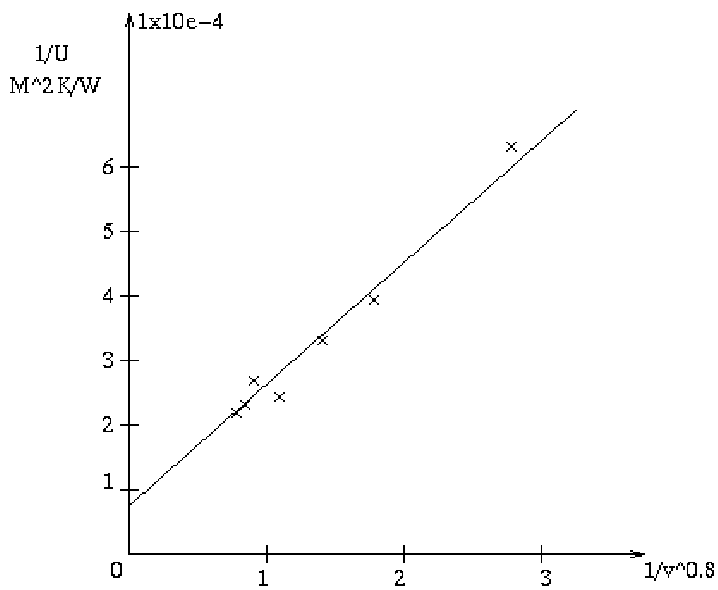


3. Mixed feed arrangement: In this feed arrangement, steam is admitted to the first effect. Feed solution is admitted to an intermediate effect and flows to the first effect from where it is fed to last effect for final concentration. This is adopted for best overall performance.

	B.Methods of increasing economy by vapour recompression methods are: **1.** Mechanical recompression **2.** Thermal recompression **Vapor-recompression evaporation** is the evaporation method by which a blower, compressor or jet ejector is used to compress, and thus, increase the pressure of the vapor produced. Since the pressure increase of the vapor also generates an increase in the condensation temperature, the same vapor can serve as the heating medium for its "mother" liquid or solution being concentrated, from which the vapor was generated to begin with. If no compression was provided, the vapor would be at the same temperature as the boiling liquid/solution, and no heat transfer could take place. If compression is performed by a mechanically driven compressor or blower, this evaporation process is usually referred to as **MVR** (**Mechanical Vapor Recompression**). In case of compression performed by high pressure motive steam ejectors, the process is usually called **Thermocompression** or **Steam Compression**.	
5-c	For parallel flow	
	Δ T1=423-311 =112K, ΔT2= 367-339 = 28 k	1
	Δ Tlm= (112-28)/ln(112/28) = **60.59 K**	2
	For counter current	
	Δ T1=423-339 =84K, ΔT2= 367-311 = 56 k	1
	Δ Tlm= (84-56)/ln(84/56) = **69.06 K**	2
	Since the value of Δ Tlm is higher for counter current flow, it is preferred.	2
6	Any two	16
6-a	**Wilson Plot:**	2

The Wilson plot method was developed by Wilson in 1915 to evaluate the convection coefficients in shell and tube condensers for the case of a vapour condensing outside by means of a cool liquid flow inside. It is based on the separation of the overall thermal resistance into the inside convective thermal resistance and the remaining thermal resistances participating in the heat transfer process.

Wilson Plot for hot water counter-current flow



Data points:

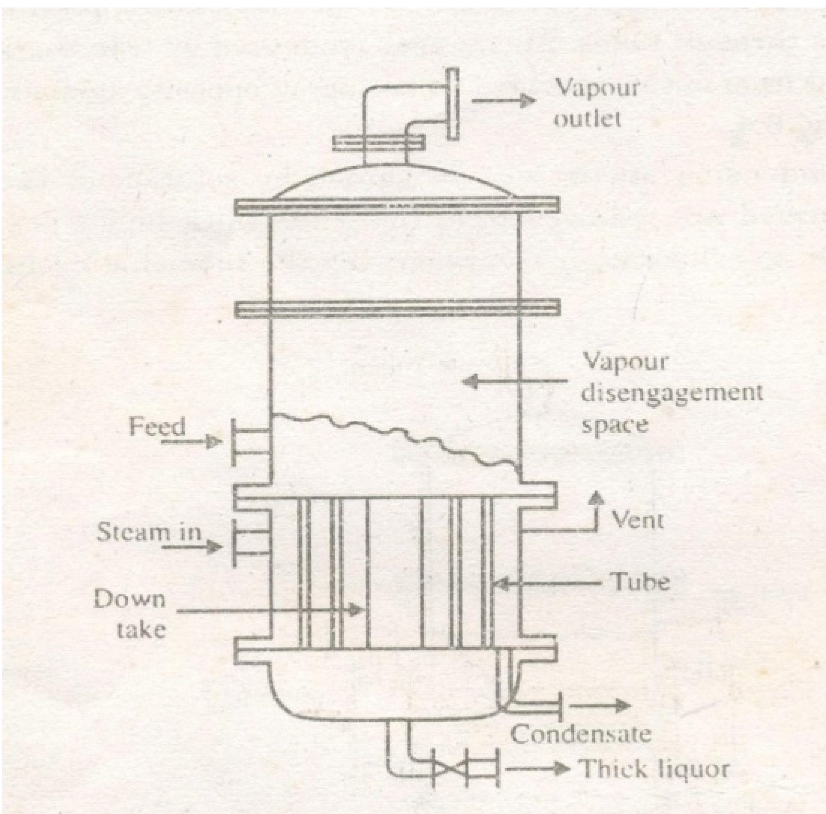
1/V^0.8	1/U (x10e−4)
0.84	2.15
0.86	2.22
0.99	2.78
1.38	3.37
1.14	2.44
1.77	3.94
2.85	6.37

1/U=1/h1+c

Where c is a constant.

2

	For turbulent flow we can write Nnu α $NRe^{0.8}$ hi α $v^{0.8}$ hi= a . $v^{0.8}$ therefore 1/U=1/ a . $v^{0.8}$ +C where u is the linear velocity of the cold fluid. A plot of 1/U vs 1/ $v^{0.8}$ results in a straight line with the slope equal to 1/a and intercept equal to Xw/K +1/h0. The values of h0 is obtained from the intercept and a represents the value of film coefficient hi for a unit velocity of cold fluid.	2 2
6-b	NRe =Duρ /μ Where D= 16mm= 0.016m, u=3m/s μ = $485x10^{-6}$ Pa.s or $N.s/m^2$ ρ= $984.1kg/m^3$ NRe = (0.016x3x984.1)/ $485x10^{-6}$ = 97395 NPr = Cp μ/k = ($4187x485x10^{-6}$)/0.657 = 3.09 (i) It is a cooling process as the temperature of water is reduced. The Dittus –Boelter equation for cooling is NNu = $0.023(NRe)^{0.8}(NPr)^{0.3}$ hD/k = $0.023(NRe)^{0.8}(NPr)^{0.3}$ h = $0.023(NRe)^{0.8}(NPr)^{0.3}$x (K/D) h= $0.023(97395)^{0.8}(3.09)^{0.3}$x(0.656/0.016) h= **12972.6 W/(m^2.k)** (ii) The Sieder –Tate equation is	 1 1 1 2

	$NNu = hD/k = 0.023(NRe)^{0.8}(NPr)^{1/3}(\mu/\ \mu w)^{0.14}$ $h = 0.023\ (97395)^{0.8}(3.09)^{1/3}\ ((485x10^{-6})/(920x10^{-6}))^{0.14}x(0.657/0.016)$ = **12267.7 W/(m²·k)**	1 2
6-c	**Standard vertical tube evaporator:**  **Construction:** It consists of vertical cylindrical shell incorporating short vertical tube bundle with horizontal tube sheet. Vapour inlet is provided at top cover while thick liquor discharge is provided at bottom. Downtake is provided	3 3

	at centre of tube bundle for circulating cooler liquid back to the bottom of the tubes. Solution to be evaporated is inside the tubes and steam flows outside the tubes in the steam chest. Baffles are incorporated in steam chest to promote uniform distribution of steam. The condensate is withdrawn at a point near lower tube sheet, while non condensable gas is vented to atmosphere from point near top tube sheet. **Working:** Thin liquor is introduced to the tube side and steam into steam chest . The liquor covers top of tubes. Heat transfer to boiling liquid inside the tubes take place from condensing steam on outside of tubes. Vapours formed will rise through the tubes, come to the liquid surface from which they are disengaged into the vapour space and removed from the vapour outlet. Thick liquor is removed from the bottom of the evaporator.	2