**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 | Sub Q.N | Answer | marks |
|---|---|---|---|
| 1 | | **Answer any five** | **10** |
| 1 | a | **Thermal conductivity:** It is a measure of the ability of the substance to conduct heat. It is the amount of heat passing through a material of a unit thickness with a unit heat flow area in unit time when a unit temperature difference is maintained across the opposite faces of the material.<br>**Unit:** W/ (m.K) | 1<br><br>1 |
| 1 | b | **Film heat transfer coefficient**: Film heat transfer coefficient h is defined as the quantity of heat transferred in unit time through unit area at a temperature difference of $1^0$ between the surface and surrounding.<br>**Formula & Unit:**<br>$h=Q/A\Delta T$<br>Unit: $W/m^2K$ | 1<br><br>1 |
| 1 | c | **Reynold's Number :**<br>**Mathematical formula**:<br>Reynold's Number $N_{Re} = Du\rho/ \mu$<br>**Significance:**<br>Reynold's number is used to decide the nature of flow- whether the flow is laminar or turbulent<br>OR<br>Reynold's no. Inertia force/ viscous force | 1<br><br>1 |
| 1 | d | **Single pass and multi pass shell and tube heat exchanger: (Any 2 points)** | 1 mark each |

| **Single pass** | **Multi pass** |
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| | |
|---|---|
| Simple in construction | complex in construction |
| Flow may be parallel or counter current | Flow is parallel as well as counter current |
| Inexpensive | expensive |
| Heat transfer coefficients are low | Heat transfer coefficients are high |
| Frictional losses are low | Frictional losses are high |
| Heat transfer rates are low | Heat transfer rates are high |
| Floor space requirement is large | Floor space requirement is low |

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| 1 | e | **Classification of heat transfer equipment:**<br>**Heat transfer equipments:**<br>1. Cooler: To cool process fluid by means of water or atmospheric air.<br>2. Condenser: To condense a vapour or mixture of vapours.<br>3. Chiller: To cool a process fluid to a temperature below that can be obtained by using water as a cooling media<br>4. Heater: Which imparts sensible heat to process fluid.<br>5. Vaporiser: Which vaporizes part of liquid.<br>6. Reboiler: Employed to meet latent heat requirement at the bottom of distillation column.<br>7. Evaporator: To concentrate a solution by evaporating water. | ½ mark each for any 4 |
| 1 | f | The **capacity** of an evaporator is defined as the number of kilogram of water evaporated per hour.<br>The **economy** of an evaporator is defined as the number of kilogram of water evaporated per kilogram of steam fed to the evaporator. | 1<br>1 |
| 1 | g | **The Sider –Tate equation for laminar flow is**<br>$h D/k = 1.86[ (NRe) (Npr) (D/L)]^{1/3} (\mu/\mu w)^{0.14}$ | 2 |

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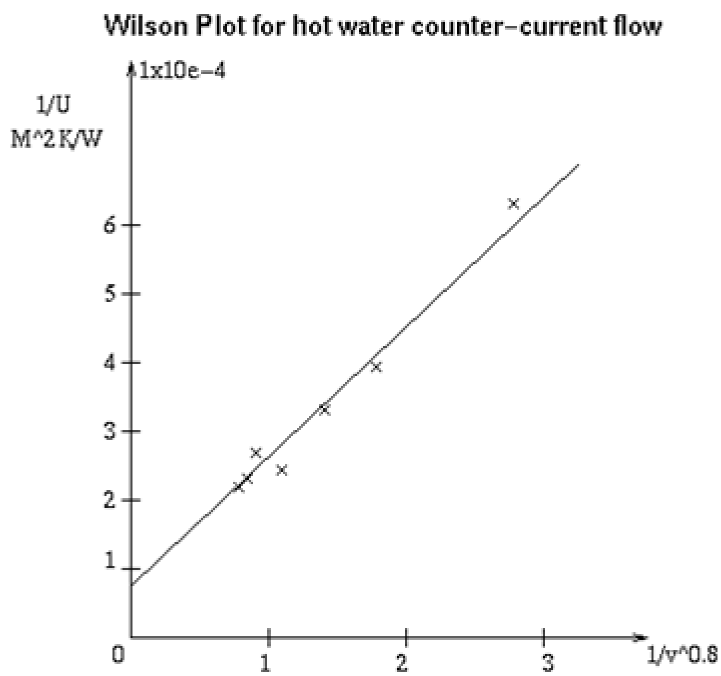
| **2** | | **Answer any three** | **12** |
| 2 | a | **Modes of heat transfer are:**<br>**1. Conduction**<br>**2. Convection**<br>**3. Radiation**<br>1) **Conduction :** If a temperature gradient exist in a continuous substance, heat can flow unaccompanied by any observable motion of mater. Heat flow of this kind is called conduction.<br>**Example:** Heat flow in the metal wall of tube<br>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.<br>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.<br>**Example**: heating of water by hot surface<br>**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<br>**Example:** heat flow to a fluid pumped through a heated pipe<br>3) **Radiation**: Radiation is transfer of energy through space by electromagnetic waves.<br>**Example**: Loss of heat from unlagged pipe. | 2 marks for explanation, 2 marks for examples |
| 2 | b | **Wilson Plot:**<br>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.




1

1

1/U = 1/hi + C (Where C is constant as C = 1/ho + Xw/k)

Where c is a constant.

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 1

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/$h_0$. The values of $h_0$ is obtained from the intercept and a represents the value of film coefficient hi for a unit velocity of cold fluid. 1

**Use:** 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

| | | | |
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| | | inside. | |
| 2 | c | **Multiple effect evaporator method to improve economy of evaporators:**<br>**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.<br>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.<br>**Methods of feeding multiple effect evaporation system:**<br>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.<br>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.<br>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. | 2<br><br>2 |
| 2 | d | **Stefan-Boltzmann Law** :<br>It states that the total energy emitted (emissive power) by a black body is proportional to fourth power of its absolute temperature. | 2 |

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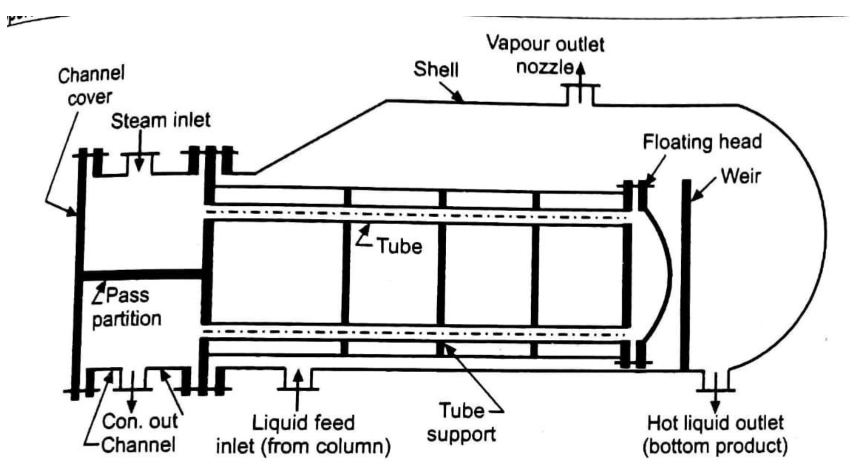
| | | $W_b$ ά $T^4$<br>**Mathematical expression:**<br>$W_b = \sigma T^4$ where σ is Stefan Boltzman constant=$5.67*10^{-8}$ $(W/m^2K^4)$ | 2 |
| 3 | | **Answer any three** | 12 |
| 3 | a | Rate of heat transfer by radiation<br>$e_1 = 0.85$ $e_2 = 0.75$ $\sigma = 5.67*10^{-8}$ $W/(m^2.K^4)$<br>$T_1 = 703$ K $T_2 = 513$ K<br>The net radiation rate per 1 $m^2$ is<br>$Q/A = \sigma (T_1^4 - T_2^4) / [(1/e_1)+(1/e_2)-1]$<br>$= \times 5.67 \times 10^{-8} (703^4 - 513^4) / [(1/0.85)+(1/0.75)-1]$<br>**$Q_r$ / A = 6571 W/m$^2$** | 1<br><br>1<br><br>1<br>1 |
| 3 | b | **Kettle/ Reboiler type Heat Exchanger:**<br>**Diagram**<br><br>**Construction and Working:**<br>It is either provided with an internal floating head arrangement or a U-tube bundle. To provide a vapour space above the tube bundle, a shell is made larger in diameter. | 2<br><br>2 |

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| | | It consists of a enlarged shell containing a relatively small tube bundle. At one end of the bundle, the tubes are expanded into a stationary tube sheet clamped between shell and channel flange.<br>In a channel, pass partition is incorporated so that inlet and outlet for the tube side 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 liquid inlet and outlet connections at the bottom as shown in figure. 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.<br>The heating medium, usually steam, flows through the tubes and the condensate is removed through a steam trap The liquid to be vaporised is introduced in the enlarged shell through a liquid inlet. The tube bundle is always submerged in a pool of boiling liquid and for this purpose an over-flow weir is incorporated in the shell, which is set aside of the tube bundle. Heat transfer to boiling liquid takes place from a submerged surface.<br>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 | c | **Plate type heat exchanger:** | |

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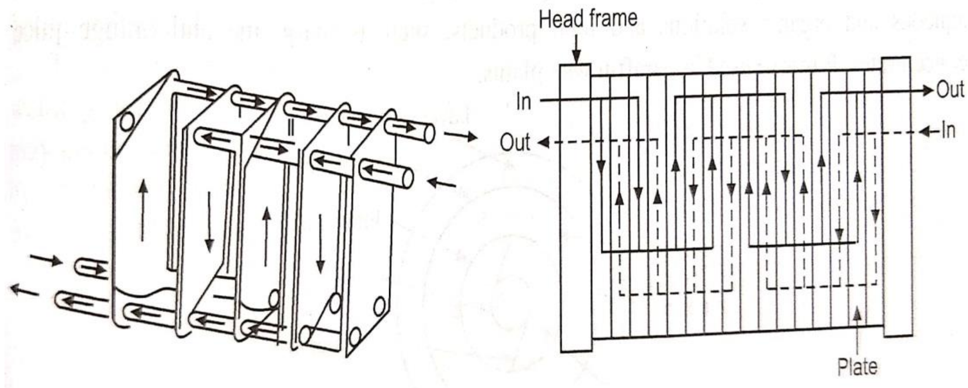
| | |  | 2 |
| | | **Construction:**<br>It consists of a series of rectangular, parallel plates held firmly together between head frames. The plates have corner ports and are sealed by gaskets around the ports and along the plate edges. The plates are having corrugated faces. These plates serve as heat transfer surfaces and are of stainless steel.. It is provided with inlet and outlet nozzles for fluids at ends. | 1 |
| | | **Working:**<br>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 | d | **Calendria type(Short tube) evaporator:** | |

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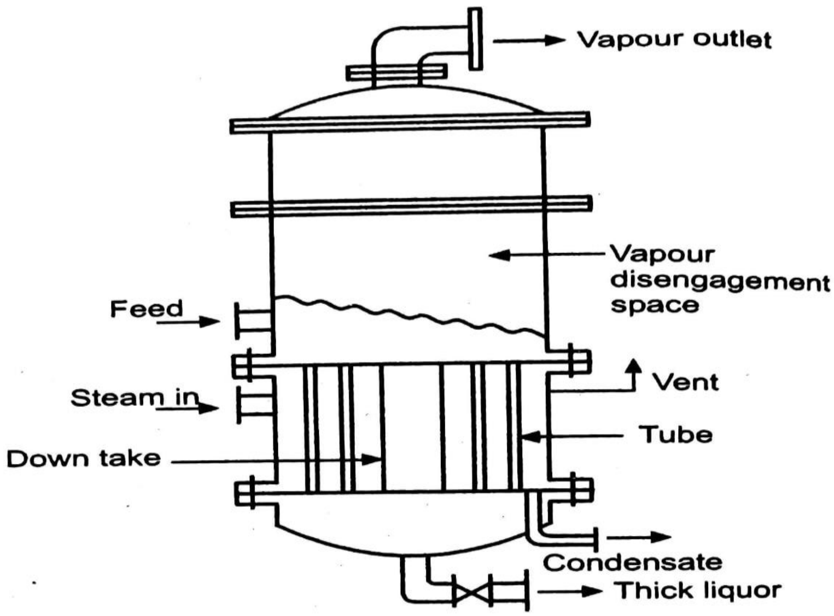
<tr><td></td><td></td><td>
</td><td>2</td></tr>
<tr><td></td><td></td><td>Working: Thin liquor is introduced to the tube side and steam into steam chest . The liquor covers top of tubes. Heat transfer to boiling liquid inside the tubes take place from condensing steam on outside of tubes. Vapours formed 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.</td><td>1</td></tr>
<tr><td></td><td></td><td>Application:<br>1. For non corrosive liquor<br>2. Clear liquor<br>3. Non crystallising liquor<br>4. widely used in sugar industry in evaporation of cane-sugar juice.</td><td>1/2 mark for any 2</td></tr>
<tr><td>4</td><td></td><td>Answer any three</td><td>12</td></tr>
<tr><td>4</td><td>a</td><td>Kirchoff’s law of radiation:<br>Kirchoff’s law: It states that at equilibrium temperature, the ratio of total emissive power of any body to absorptivity depends only upon the</td><td>1</td></tr>
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| | | | |
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| | | temperature of the body.<br>Thus when any body is at equilibrium temperature with its surrounding, its emissivity and absorptivity are equal.<br>Consider that the two bodies are kept into a furnace held at constant temperature of T K. Assume that, of the two bodies one is a black body& the other is a non-black body i.e. the body having 'a' value less than one. Both the bodies will eventually attain the temperature of T K & the bodies neither become hotter nor cooler than the furnace. At this condition of thermal equilibrium, each body absorbs and emits thermal radiation at the same rate. The rate of absorption & emission for the black body will be different from that of he non-black body.<br>Let the area of non-black body be $A_1$ and $A_2$ respectively. Let 'I' be the rate at which radiation falling on bodies per unit area and $E_1$ and $E_2$ be the emissive powers ( emissive power is the total quantity of radiant energy emitted by a body per unit area per unit time)of non-black & black body respectively.<br>At thermal equilibrium, absorption and emission rates are equal, thus,<br>$Ia_1 A_1 = A_1 E_1$ ………………..(1.1)<br>$\therefore Ia_1 = E_1$ …………….(1.2)<br>And $Ia_b A_2 = A_2 E_b$……………..(1.3)$Ia_b = E_b$………….(1.4)<br>From equation (1.1) and (1.4).we get<br>$\frac{E1}{a1} = \frac{Eb}{ab}$ ………….(1.5)<br>Where $a_{1,}a_b$= absorptivity of non-black & black bodies respectively.<br>If we introduce a second body (non-black) then for the second non-black body,we have : | 1<br><br>1 |

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| | | $I A_3 a_2 = E_2 A_3$ …………(1.6)<br>$\therefore Ia_2 = E_2$ …………..(1.7)<br>Where $a_1 = E_2$ are the absorptivity and emissive power of the second non-black body.<br>Combining equations (1.2),(1.4) and(1.7) we get,<br>$\frac{E1}{a1} = \frac{E2}{a2} = \frac{E3}{a3} = E_b$ ………..(1.8) | 1 |
| 4 | b | The equation to be used is:<br>$\frac{1}{U} = \frac{1}{h_o} + \frac{1}{h_i} + \frac{1}{k/x}$<br>Where U = overall heat transfer coefficient<br>ho = outside heat transfer coefficient<br>= 1750 W/(m$^2$.K)<br>hi = inside heat transfer coefficient<br>= 5800 W/(m$^2$.K)<br>k = thermal conductivity of metal wall<br>= 46.52 W/(m.K)<br>x = thickness of metal wall of tube<br>= (O.D. – I.D.) / 2<br>= $\frac{(30-20)}{2}$ = 5mm = 0.005m<br>$\frac{1}{U} = \frac{1}{1750} + \frac{1}{5800} + \frac{1}{\frac{46.52}{0.005}}$<br>U = **1175 W/(m$^2$.K)** | 1<br>1<br>1<br>1 |
| 4 | c | **Rate of heat transfer through sphere:**<br>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. | 1 |

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| | | Consider a spherical element at radius r and thickness dr. the rate of heat flow can be written as Q= -kA dT/dr<br>$= -k4\Pi r^2 \, dT/dr$<br>$dr/r^2 = -k4\Pi \, dT/Q$ | 1 |
| | | Integrate the eqn (ii) between the limits<br>When $r = r_1$, T = T1<br>When r = r2, T = T2<br>$\int_{r_1}^{r_2} \frac{dr}{r^2} = -\frac{k(4\pi)}{Q} \int_{T_1}^{T_2} dT$ …..(iii)<br>r2 [-1/r]<br>r1 = -k (4π)/Q ( T2 - T1)…..(iv) | 1 |
| | | [1/r1 – 1/r2] = k (4π)/Q ( T1 - T2) ……(v)<br>Rate of heat flow through sphere is :<br>... Q = k (4π) ( T1 - T2) / [1/r1 – 1/r2] vi)<br>It can be put into more convenient form by expressing the rate of heat flow as :<br>$Q = \frac{\mathbf{k\ 4}\pi(r_1 . r_2)(T_1 - T_2)}{(r_2 - r_1)}$ | 1 |
| | | Where $r_m$ is the geometric mean radius & is given by<br>$r_m = \sqrt{(r_1 . r_2)}$<br>$r_m^2 = r_1 . r_2$<br>$A_m = 4\pi r_m^2$….(ix)<br>Am is called as geometric mean area.<br>Equation (viii) becomes<br>$Q = \frac{\mathbf{k\ A_m}(T_1 - T_2)}{(r_2 - r_1)} = \frac{\Delta T}{R}$<br>$Q = \frac{(T_1 - T_2)}{[(r_2 - r_1)/k A_m]} = \frac{\Delta T}{R}$ | |

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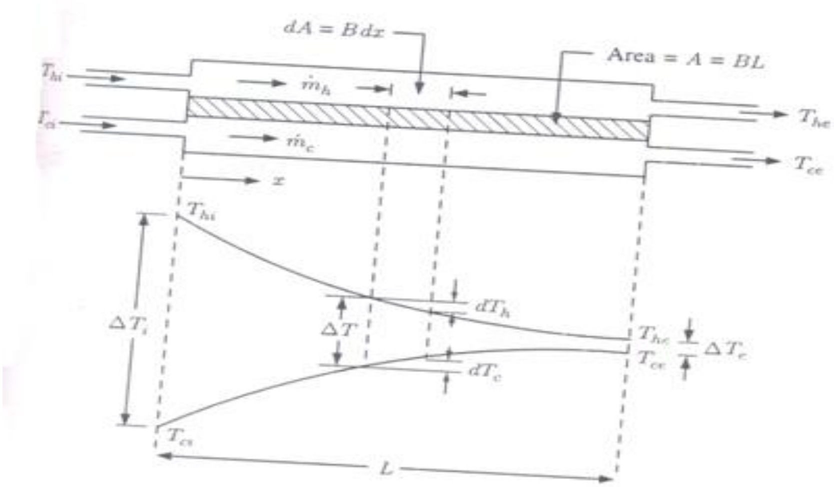
| | | Where $R = \frac{(r2 - r1)}{kAm}$ | |
| 4 | d | **To derive Q=UA $\Delta T_{lm}$**<br><br><br>Consider an elementary area dA( =B.dx). The rate of heat transfer across it is given by<br>dq= U (Th-Tc) B dx -------------(1)<br>Since there are no losses to the surroundings, the heat transfer rate is also equal to the rate of change of enthalpy on either side. Therefore,<br>dq= -mh Cph dTh-------------------(2)<br>= mc Cpc dTc ----------------------(3)<br>Now $\Delta T$ = Th- Tc -----------------(4)<br>On differentiating<br>d($\Delta T$) =dTh- dTc --------------------------------------(5)<br>substituting for dq, dTh and dTc from equations (1), (2) and (3) into equation (5) , we obtain | 1<br><br>1 |

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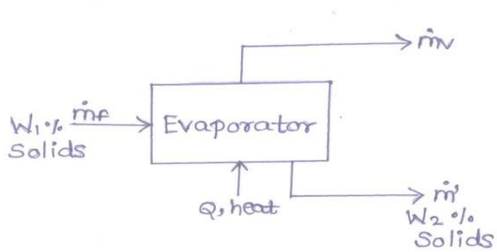
| | | $d(\Delta T)/\Delta T = -(1/(m_h C_{ph}) + 1/(m_c C_{pc}))\, U\, B\, dx$<br><br>$\int_{\Delta T_i}^{\Delta T_e} d(\Delta T)/\Delta T = -(1/(m_h C_{ph}) + 1/(m_c C_{pc}))\, U\, B \int_0^L dx$<br><br>$\ln(\Delta T_e/\Delta T_i) = -(1/(m_h C_{ph}) + 1/(m_c C_{pc}))\, U\, A$ ---------------------------(6)<br><br>where $\Delta T_e = T_{he} - T_{ce}$<br><br>$\Delta T_i = T_{hi} - T_{ci}$<br><br>Now if q is the total rate of heat transfer in the heat exchanger, then<br><br>$q = m_h Cp_h (T_{hi} - T_{he})$ -----------------------------(7)<br><br>$= m_c Cp_c (T_{ce} - T_{ci})$ --------------------------(8)<br><br>Substituting equations (7) and (8) into equation (6),<br><br>$\ln(\Delta T_e/\Delta T_i) = -1/q[(T_{hi} - T_{he}) + (T_{ce} - T_{ci})]U A$<br><br>$q = U A (\Delta T_i - \Delta T_e)/\ln(\Delta T_i/\Delta T_e)$ -----------------------------(9)<br><br>Equation (9) is the performance equation for a parallel-flow heat exchanger.<br><br>**$Q = U A \Delta T_{lm}$**<br><br>Where $\Delta T_{lm} = (\Delta T_i - \Delta T_e)/\ln(\Delta T_i/\Delta T_e)$ | 1<br><br>1 |
| 4 | e | **Material balance equation for single effect evaporator:**<br>Consider that the evaporator is fed with $m_f$ kg/h of weak solution containing $w_1$ % solute & thick liquor is withdrawn at m' kg/h containing $w_2$ % solids | |

by weight. Let $m_v$ be the kg/h of water evaporated. Then : 2




**Overall material balance :**

$$m_f = m_v + m \ldots.(i)$$

**Material balance of solute :**

Solute in feed = Solute in thick liquor

$$W_1 \text{ x } m_f /100 = w_2 \, m' / 100$$

$$W_1 \text{ x } m_f = w_2 \, m' \ldots\ldots(ii)$$

Knowing three out of five quantities ,we can find the values of other two with the help of above two equations.

**Energy balance equation for single effect evaporator:** 2

Let Tf , T and Ts be the temperatures of feed entering the evaporator , solutions in the evaporators and condensing steam respectively.

Let '$\lambda$s' be the latent heat of condensation of steam at saturation temperature and assume that only latent heat of condensation is used. Then, rate of heat transfer through heating surface from steam is :

$$Q_s = m_s \lambda_s \ldots.(iii)$$

Where $m_s$ is mass flowrate of steam to the evaporator in kg/h.

Heat transfer rate on steam side = Heat transfer rate on liquor side.

Enthalpy balance can be written in terms of specific heats & temperatures of

| | | | |
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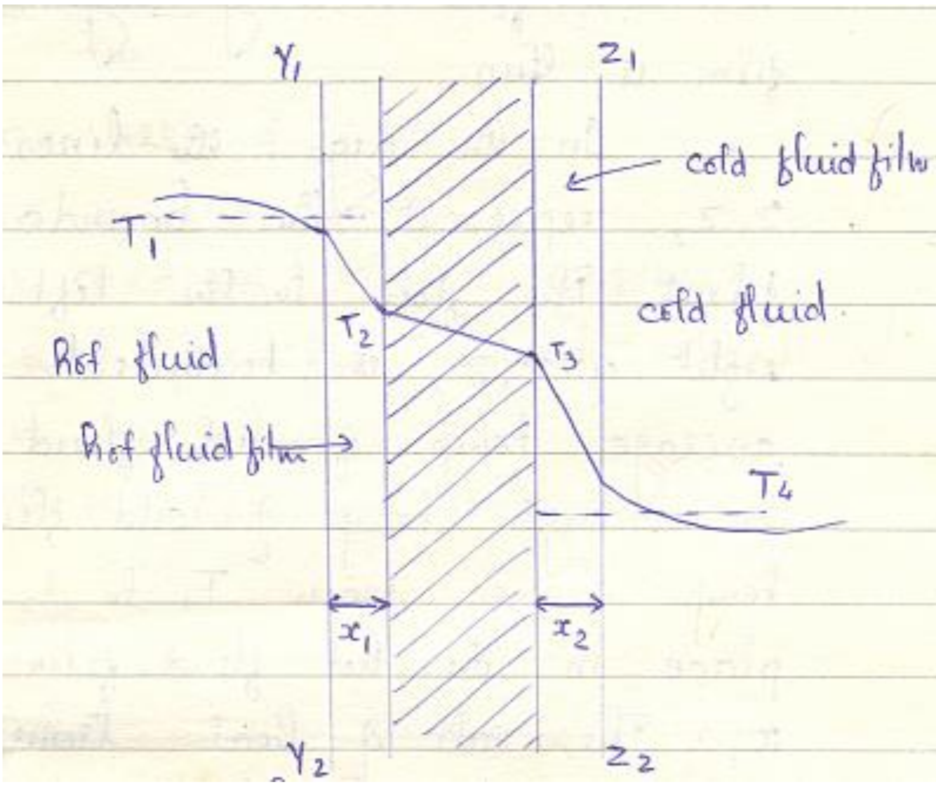
| | | solutions , in case of solutions having negligible heats of dilution.<br>Heat transfer to solution in evaporator by condensing steam (in absece of heat losses) is utilised to heat the feed solution from Tf to T and for vaporisation of water from solution.<br>$$Qs = Q$$<br>$$= m_f Cpf (T - T_f) + (m_f - m') \lambda_v .......(vii)$$<br>$$m_s .\lambda_s = mf\ Cpf (T - T_f) + (m_f - m') \lambda_v .....(viii)$$<br>where $Cp_f$ = specific heat of feed solution<br>$\lambda_v$ = latent heat of evaporation from thick liquor<br>For negligible boiling point rise $\lambda v = \lambda$<br>Where $\lambda$ =latent heat of vaporisation of water at pressure in the Vapour space& can be read from steam tables.<br>Above equation (viii) becomes :<br>$$m_s \lambda_s = m_f Cp_f (T - T_f) + (m_f - m') \lambda ......(ix)$$<br>$$m_s \lambda_s = m_f Cp_f (T - T_f) + m_v \lambda .....(x)$$ | |
| 5 | | **Answer any two** | **12** |
| 5 | a | **Derivation for relation between overall and individual heat transfer coefficients:** | |




1

Consider a hot fluid is flowing through a circular pipe and cold fluid is flowing on the outside of the pipe. The heat will flow from hot fluid to cold fluid through a series of resistances.

In the diagram the lines $Y_1 Y_2$ and $Z_1 Z_2$ represent the boundaries of think films. The flow to the left of $Y_1 Y_2$ and right of $Z_1 Z_2$ is turbulent. $T_1$ is the average temperature of hot fluid and $T_4$ is the average temperature of cold fluid. The temperature change from $T_1$ to $T_2$ is taking place in the hot fluid film of thickness $x_1$ . The rate of heat through this film is given by 1

$Q=hiAi(T_1-T_2)$ ………….(1)

The overall resistance to heat flow from hot fluid to cold fluid is made up of three resistances in series. They are

1) Resistance offered by film of hot fluid

| | | | |
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| | | 2) Resistance offered by metal wall.<br>3) Resistance offered by film of cold fluid<br>Heat transferred through metal wall<br>$Q=kAw(T_2-T_3) / xw$ …… (2)<br>The rate of heat transfer through cold fluid film<br>$Q=h_0A_0(T_3-T_4)$ ………….(3)<br>$T_1-T_2 = \frac{Q}{hi \quad Ai}$<br>$T_2-T_3 = \frac{Q}{kAw/xw}$<br>$T_3-T_4 = \frac{Q}{h0 \quad A0}$<br>$T_1-T_2+ T_2-T_3 + T_3-T_4 = Q[\frac{1}{hi \quad Ai} + \frac{xw}{k \quad Aw} + \frac{1}{h0 \quad A0}]$……(4)<br>But $Q = U_0A_0(T_1-T_4)$ ……(5)<br>Equating (4) and (5)<br>$\frac{1}{U0 \quad A0} = \frac{1}{hi \quad Ai} + \frac{xw}{k \quad Aw} + \frac{1}{h0 \quad A0}$<br>$\frac{1}{U0} = \frac{D0}{hi \quad Di} + \frac{xw\ D0}{k \quad Dw} + \frac{1}{h0}$ | 1<br><br>1<br><br>1<br><br>1 |
| 5 | b | **633K-------→ 573K**<br>**400K---→303K**<br>**LMTD for counter current flow,** | 1 |

| | | | |
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| | | $\Delta T_2 = T_{ho} - T_{ci} = 573 - 303 = 270$ K | 1 |
| | | $\Delta T_1 = T_{hi} - T_{co} = 633 - 400 = 233$ K | 1 |
| | | LMTD = (270-233) / ln (270/233) =251K | 1 |
| | | $Q = m\, Cp\, \Delta T = U\, A\, \Delta T_{LM}$ | 1 |
| | | 1.2*2083 (633-573) = A*500*251 | 1 |
| | | **A=1.196 m2** **for counter current flow** | |
| 5 | c | Basis : 10,000 Kg/h of weak liquor entering the evaporator.<br>Let m be the kg/h of thick liquor leaving the evaporator.<br>**Material balance of caustic soda:**<br>Caustic soda in feed = Caustic soda in thick liquor<br>$0.04 \times 10000 = 0.25 \times m$<br>m = 1600kg/h<br>**Overall material balance:**<br>kg/h of feed = kg/h evaporated + kg/h of thick liquor<br>1000 = kg/h water evaporated + 1600<br>water evaporated = 10000 – 1600<br>= 8400 kg/h<br>∴ capacity of evaporator = **8400kg/h** | 1<br><br>1<br><br>1<br><br><br>1<br><br>1<br><br>1 |
| 6 | | **Answer any two** | **12** |
| 6 | a | Basis: 1 m length<br>$r_1 = 0.0325$m $r_2 = 0.0825$m | |

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| | | $r_{L1} = (r_2 - r_1) / \ln(r_2/r_1) = 0.0537$m<br>$A_{L1} = 2\pi r_L L = 0.3371\ m^2$<br>$K_1 = 0.14$ W/mK<br>$R_1 = B_1 / K_1 A_{L1}$<br>= 0.05/0.14* 0.3371<br>= 1.059 K/W<br>$r_2 = 0.0825$m $r_3 = 0.1225$m<br>$r_L = (r_3 - r_2) / \ln(r_3/r_2) = 0.101$m<br>$A_{L2} = 2\pi r_L L = 0.6355\ m^2$<br>$K_2 = 0.035$ W/mK<br>$R_2 = B_2 / K_2 A_{L2}$<br>= 0.04/0.035* 0.6355<br>= 1.798 K/W<br>$R = R_1 + R_2$<br>= 2.857 K/W<br>Temp.drop $\Delta T = 115$ K<br>Heat loss $Q = \Delta T / R$<br>= 115 / 2.857<br>= **40.3 W** | 1<br>1<br>1<br>1<br>1<br>1 |
| 6 | b | **Dropwise and Filmwise condensation:**<br>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 | 1 |

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| | | vapour to the surface takes place and the vapour gets condensed on the surface.<br>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<br>**Dropwise condensation**: When a saturated vapour comes into contact with a cold surface, it condenses and if condensate does not wet the surface, the 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.<br>**Filmwise condensation**:<br>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.<br>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. | 2<br><br>3 |
| 6 | c | **Double pipe heat exchanger:**<br>It is the simplest type of heat exchanger. It is used when the heat transfer | |

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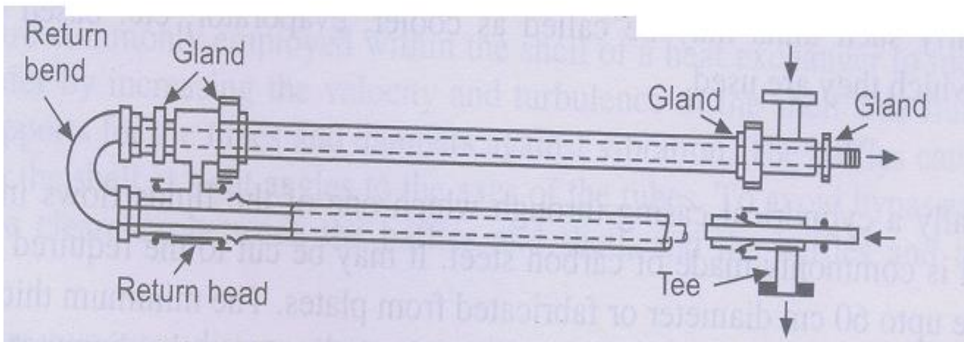
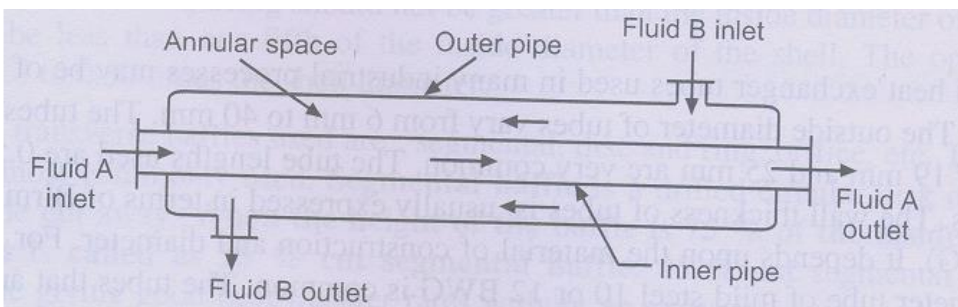
| | | area required is relatively small.<br>**Diagram:**<br><br><br>**OR**<br><br> | 2 |
| | | **Construction:-**It consist of concentric pipes, connecting trees, returns heads and return bends. The packing glands support the inner pipe within the outer pipe. A double pipe heat exchanger arranged in two legs. Tees are provided with nozzles or screwed connections for permitting the entry and exit of the annulus fluid which crosses from one leg to the other through the return head. The return bend connects two legs of the inner pipes to each other. These exchanger are usually assembled in effective legths of 3.65, 4.57, 6 m.<br>**Working:-** This exchanger can be very easily assembled in any pipe-fitting | 2 |

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| | | shop as it consists of standard parts and it provides inexpensive heat transfer surface. In this exchanger, one of the fluids flows through the inside pipe and the other fluid flows through the annular space created between two concentric pipes either in co-current or counter-current fashion. It is usually employed for decreasing the temperature of a hot fluid with the help of cold fluid when flow rates are low. | 2 |