MAHARASHTRA STATE BORAD OF TECHNICAL EDUCATION

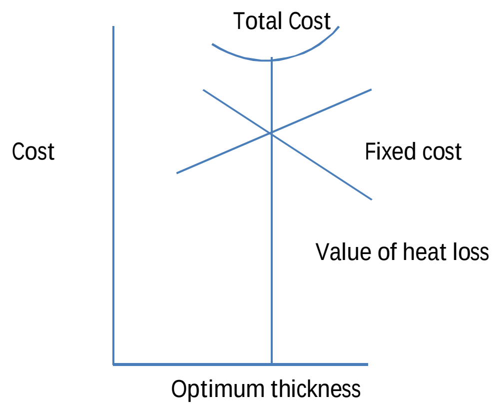
(Autonomous)

(ISO-27001-2005 Certified)

WINTER-12 EXAMINATION

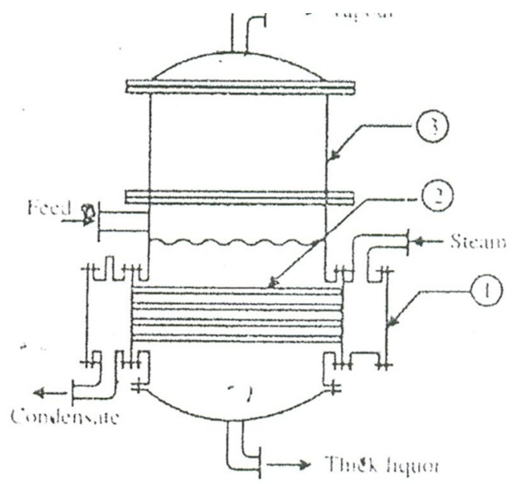
Subject Code-12204 Model Answer

Q. No.	Answer	Remark
1(A) a	Fourier's Law : If states that the rate of heat flow across an isothermal surface is proportional to the temperature gradient at the surface. OR It states that the rate of heat flow by conduction through a uniform (fixed) material is directly proportional to the area normal to the direction of the heat flow and the temperature gradient in the direction of the heat flow. $Q \propto A\,(-dT/dn)$ $Q = -kA(dT/dn)$ Where q - rate if heat transfer A – area perpendicular to heat flow K – thermal conductivity T – temperature n – distance measured normal to the surface.	1 Mark 1 Mark
	Convection: Convection is a mode of heat transfer when a macroscopic particle of hard crosses a specific surface, it carries with it a definite quantity of enthalpy such a flow of enthalpy is called convection. Convection occurs as a result of the movement of the fluid in the form of circulating currents. Eg. Heating of water by hot surface Flow of air across a heated radiator.	1 Mark 1 Mark Any one example may be given mark
A. b	Thermal conductivity: It is defined as the quantity of heat transferred in unit time through a uniform surface of unit area, of unit thickness at a temperature difference of $1^{o}C$ between the surfaces. It is denoted as k , unit is W/mK	2 marks
	Overall heat transfer coefficient: It is defined as the quantity of heat transferred in unit time through unit area, log mean temperature difference is unity.	2 marks

	It is denoted by U, unit is W/m^2K.	
A. c	**<u>Stefan Boltzman law:</u>** It states that the total energy emitted (emissive power) by a black body is proportional to the fourth power of its absolute temperature. **$W_b \propto T^4$ OR $W_b = \sigma T^4$** Where σ is Stefan Boltzman constant = $5.67 \times 10^{-8}\ W/m^2k^4$ But $\varepsilon = W/W_b$ OR $W = W_b\ \varepsilon$ i.e. $W = \sigma T^4 \varepsilon$	2 Marks 2 Marks
A. d	**<u>Classification of heat exchangers:</u>** 1. Bared on application : Eg. Graphite block heat exchanger for corrosive fluids Scrapped surface heat exchangers for viscous liquid 2. Based on quantity to be handled : Eg. Double pipe heat exchanges for small quantity to be handled Shell & tube heat exchanges for large quantity to be handled.	2 marks 2 Marks
1(B) a	**Concept log mean radius for thick water cylinders.** Log mean radius (r_L) is the radius which when applied to the integrated equation of a flat wall will give the correct rate of heat flow through a thick walled cylinder. $r_L = r_0 - r_i / \ln(r_0/r_i)$ where r_o is outer radius of cylinder and r_i is inner radius of cylinder **Optimum thickness of insulation.** The optimum thickness of insulation is arrived at by a purely economic approach. If a bare pipe were to carry a hot fluid, there would be a certain hourly loss of heat whose value can be determined from the cost of producing heat. Lower the heat loss greater the thickness, initial and annual fixed charges (maintenance and depreciation). By assuming a no. of thickness of insulation and adding the fixed charges to the value of heat loss, a minimum cost will be obtained and the thickness corresponding to it will be the optimum thickness.  Thickness of Insulation	3 Marks 3 Marks

(B) b	Heat gained by cold water Q_c=1000.4.2.(T_2-30) Heat lost by wall Q_h= 67.2.0.3454(600-30)/.005=324952.32W Qc =Q_h T_2=65.52^{0}C Rise in Temperature=65.52-30=35.52^{0}C	01 01 01 02 01
Q.2.a	Thickness of wall (B_1)= 300mm =0.3m Ti = 1000^0 C = 1273 K T_o = 150^0 C=423 K K_1 = 4.5 W/m K R_1 = B_1/ K_1 A = 0.3/4.5*1 = 0.0667 K/W Q = (T_i-T_0) / R_1 = (1273-423)/0.0667 = 12743.63 W B_2 = 200mm=0.2m K_2 =0.5 W mK T_i =150^0 C =423 K T_o = 50^0 C= 323 K R_2 = B_2/ K_2 A = 0.2/0.5*1 = 0.4 K/W R = R_1 + R_2 =0.4667 Q = (1273-323) /0.4667 = 2035.57 W Reduction in heat loss 12743.63 – 2035.57 = 10708.06 W	 3 Marks 2 Marks 2 Marks 1 Mark
2.b	Thickness B = 200 mm = 0.2 K= 1.45 W/m^2 K ΔT = 623– 313 = 310 K A = 2.5 m^2 Q = KA ΔT /B = 1.45 * 2.5 * 310/0.2 = 5,618.75 W Q=$h_i A_i$(350-T_w) Tw=327.95 ^{o}C Q=$h_o A_o$(T_{w1}-40) T_{w1}=149.8 ^{o}C	 02 04 01 01

2. c	$Tc_1 = 25^0$ C $Tc_2 = 65^0$ C $Th_1 = 230^0$ C $Th_2 = 160^0$ C m_h= 0.9 Kg/sec C_{ph}=1.45 KJ/Kg K $Q = m_h C_{ph} (Th_1 - Th_2)$ $= 0.9 * 1.45 (230 - 160)$ = 91.35 KJ/ Sec.	2 Marks
	$91.35 = m_c * 4.2 (40)$ $m_c = 91.35/4.2 * 40$ = 0.544 Kg/Sec	2 Marks
	Q. $= 91.35 * 10^3$ J/Sec For Counter current flow $\Delta T1 = 230-65 = 165$ $\Delta T2 = 160-25 = 135$ LMTD = (165-135)/ln (165/135) = 149.49	2 Marks
	Q = UA LMTD $91.35 * 10^3$ J/Sec = 420 *A* 149.49 $A = 1.45m^2$	2 Marks
3. a	Important parts of a shell & tube heat exchanges are 1) Shell 2) Shell side pass 3) Tube bundle i) Tube pitch a)Square b) Triangular 4) Channels &Channel covers 5) Tube sheet 6) Baffles 7) Tie rod 8) Spacers	½ Mark each
	OR Diagram with names of different parts	4 Marks
3. b	Evaporators are classified as 1) Natural circulating Evaporator 2) Forced circulation Evaporator Natural: 1) Short Tube 2) Basket Forced: 1) Long Tube 2) Forced circulation	2 Marks
	OR Diagram of Evaporator	2 Marks



1 – Steam chest 2 – Tube 3 – Evapora

3. c

Thermal recompression — 2 Marks

Thermal energy of vapours generated from a boiling solution in an evaporator can be utilized if at all there is temp difference between condensing vapours temp and boiling temp of solution . In a single evaporator this temperature difference is zero. To invrease economy of evaporation two methods are available.

1) Multiple effect evaporation
2) Thermal recompression

In thermal recompression vapours produced from an evaporator is compressed by means of a steam jet ejector. This increases the temperature of vapours to original temperature of steam & can be used as heating medium in evaporator.

Props of Solution which influences evaporation — ½ Marks each

1) Concentration
2) Foaming
3) Scale formation
4) Temp Sensitivity

3. d

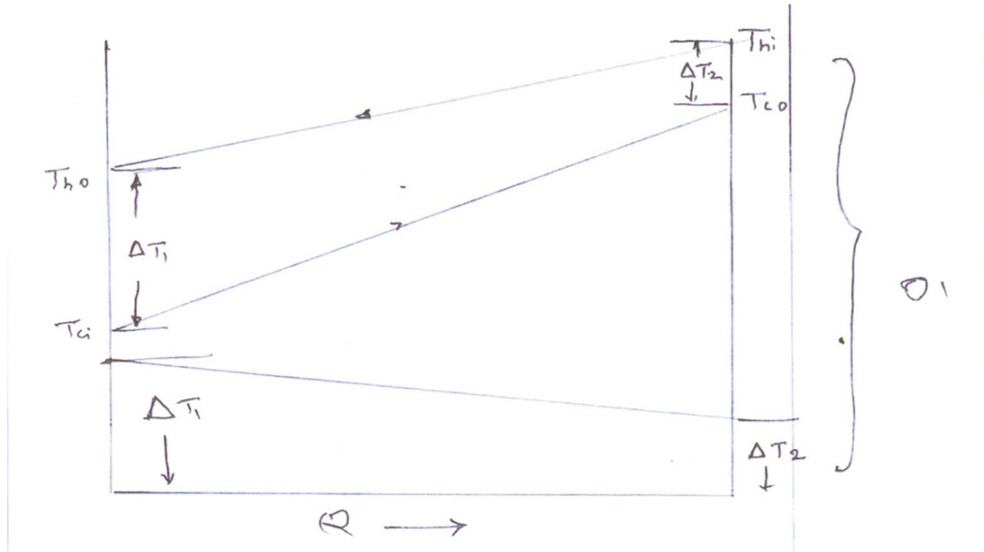
LMTD = Log mean temperature difference.

There are three flow arrangements for shell side liquid and tube side liquid flowing in a shell a tube type heat exchanges.

1) Para riel/ co current
2) Counter current
3) Cross Current

Temp gradient between hot third & cold third in both types of flows does not remain constant.

For accurately calculating temp gradient use of LMTD is essential.

		1mark
	The heat transfer flux is directly proportional to the driving force. Driving force for heat flow is taken as T_h-T_c where T_h T_c are temps of hot & cold fluids respectively. As $\Delta T = T_h - T_c$ varies along the length of heat exchanges flux also varies along the entire length. So we consider a differential element of area 'dA' over which temp does not change. Then we can write dq = U.dA. dt The above eq. is then integrated from L=0 to L= L of steady state of the heat exchanger to get value of LMTD. Assumptions here made are	1mark
	1) Overall heat trans coef. 'U' is const. 2) Sp.ht of hot & cold fluids are const. 3) Heat flow to & from atmos is negligible 4) Flow is steady in concurrent or counter current	½ mark each
3. e	i) Reynold's Number = Dus/μ ii) Prendti Number = Cp. μ/k NRe is used to know type of flow. Pr No gives prop of fluid For Laminar flow Nu = f $\{R_e G_r\}$ For Turbulent flow Nu = f $\{R_e\ P_r\}$	1 mark 1 mark
	Both Reynold's Number and Prandtl Number is used to find Nusselt which gives value of 'h', surface coefficient	2 marks
4. A (a)	We know that Q = UA LMTD Where	1 mark

U= Overall heat transfer coefficient
Value of ‘U’ in turn depends on surface coefficients of liquid on inside & outside so for

Ui = Overall heat transfer coefficient based on inside liquid is given as — 1 mark

$1/Ui = 1/hi + Ldi/kd_m + di/hodo$

Uo = Overall heat transfer coefficient based on outside liquid — 1 mark

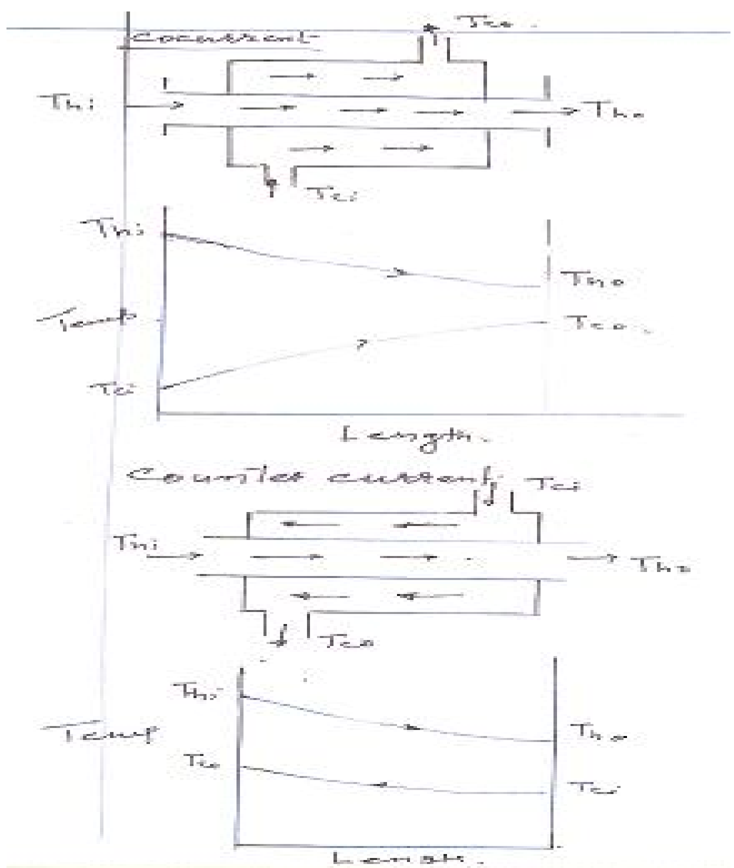
$1/ U0 = d0/hidi + Ld0/Kdm + 1/h0$ — 1 mark

So value of U will depend on value of hi & ho

4.A (b)

Dropwise condensation	Filmwise condensation	
		1 mark
1) Condensation takes in form of drops which fall down	Condensation takes place in form of a film which covers the surface	1 mark
2) Condensate does not wet the surface.	Condensate wets the surface.	1 mark
3) Rate of heat transfer is high as surface is available for more condensation	Rate of heat transfer is low due to resistance offered by film formed on surface	1 mark
4) This type is not common & takes place by chance	This type is very common.	

4. A (c)

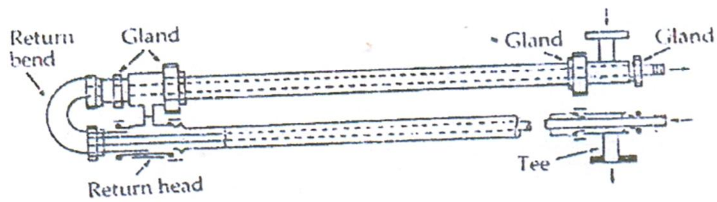


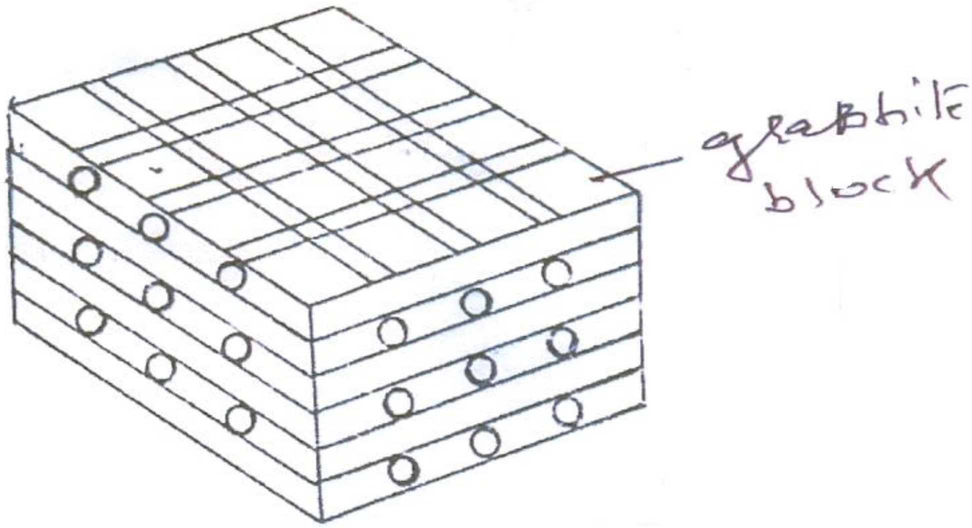
1 mark

1 mark

1 mark

1 mark

4. A (d)	Laminar flow. $$Nu = 2\left[\frac{mc_p}{KL}\right]^{1/3}\left[\frac{\mu}{\mu_w}\right]^{0.14}$$	2 Marks
	for Turbulent flow $$Nu = 0.023\left(\frac{DU\rho}{\mu}\right)^{0.8}\left(\frac{C_p\mu}{k}\right)^{1/3}\left(\frac{\mu}{\mu_w}\right)^{0}$$	2 Mark
4,B(a)	Doubble pipe heat exchanger. Diagram 	4 marks
	Advantages 1) Simple in construction 2) Assumbly is easy.	1 mark
	Disadvantages 1) Rate of heat trans is very low. 2) Area cannot be increased to a large extent	1 Mark

4. B (b)	Diagram of Graphite heat exchanger  	4 marks
	Graphite heat exchanger is ideally suited for processing corrosive liquids. Graphite is inert to most corrosive fluids and advantage is taken of very high thermal conductivity. It is very soft and is not ductile. Heat exchanger is made up of blocks. Circular channels are drilled across blocks to obtain cross current flow. These channels are drilled at alternate planes.	2 marks
5. a)	D=45 mm =45*10^{-3} m u= 0.78m/s l=3.2m k=0.66 w/mk	2 Marks
	μ= 0.478*10^{-6} Nm/s Npr=2.98 ρ =1000kg/m^3 Nre= Du ρ/μ= 45*10^{-3}*.78*1000/478*10^{-6}= 73430	1 Mark
	The flow is turbulent Then we have to use Dittus boelter equation	1 Mark
	The process is heating Thus the equation is	2 Marks
	NNU=0.023(NRE)0.8 (NPR)0.4 hd/k =0.023(73430)0.8(2.98)0.4 h =278.45*K/D=278.45*0.66/45*10^{-3}=4083.93w/m^2k T_1=(70+273)K=343K T_2=(50+273)K=323K THUS THE RATE OF HEAT TRANFER Q=ha(T1-T2)=4083.93*πDl*(343-323) =4083.93*3.14*45*10^{-3}*3.2*20=36931w	2 Marks

Q5B	heat content in hot fluid $Q_H=m_H cp_H(T_1-T_2)$ Heat content in cold fluid $Q_C=m_c\ cp_c\ (T_4-T_3)$ (where cpH=specific heat of hot fluid,cpc=specific heat of cold fluid) cpH=cpc(as both are water) According to energy balance $Q_H=Q_C$ $m_H cp_h(T_1-T_2)=m_c\ cp_c(T_4-T_3)$ $0.2*cp_H(75-45)=0.5*cp_H(T4-20)$ o.2*30=0.5(T4-20) 6=0.5(T4-20) T4-20=6/0.5=12 $T4=12+20=32^0c$ Q=UA LMTD 1/U=1/ho+1/hi 1/u=1/650+1/650=1+1/650=2/650 $U=650/2=325w/m^2\ {}^oC$ $Q_H=m\ cp_H(T_1-T_2)$ =0.2*4.187*(75-45) =25.122 kj/s $25.122*10^3$ j/s LMTD=ΔTI-ΔT2/ln(ΔTI-ΔT2) $=55-13/ln(55/13)=42/ln(4.23)=42/1.44=29.16\ {}^oC$ Q=UALMTD $A=Q/ULMTD=25*103/325*29.16=2.63m^2$ Since the value of x_w and k are not given, due consideration should be given.	 2 marks 2 marks 2 marks 2 marks
Q5C (i).	Mf=12000 kg/hr Solute in feed=solute in thick liquor 5/100*12000=20/100*m 600=20/100*m M=600*100/20=3000kg/hr Mf=m+mv Mv=mf-m =12000-3000 =9000kg/hr (ii) ms=9000kg/hr Economy=mv/ms=9000/9000=1	 4 Marks 4 Marks
Q6 a)	write the formula for the following. (i) nusselts number (ii) grashoff number in calculating film coefficient.state meaning of each term. ANS nusselt number (N_{NU}=hD/k)=wall heat transfer rate/heat transfer by conduction Where h=film heat transfer coefficient, D=dia of pipe;k=thyermal conductivity Grashoffs number(N_{Gr}= $\beta\ g\Delta TD^3\rho^2/\mu^2$=buoyancy forces*inertia forces/(viscous forces) ^{2} where β=thermal expansion coefficient, g=acceleration due to gravity, ΔT=difference in temperature ,D=dia of pipeline, ρ=density of liquid, μ=viscosity of liquid.	 2 Marks 2 Marks

6. b)	Explain the significance of heat transfer coefficient in boiling liquid and condensing vapors. The change from liquid to vapor state is known as vaporization and that from vapor to liquid is known as condensation, in either case, the latent heats involved are identical. In the condensation of a pure vapor, it is necessary to remove latent heat of vapourazation.condensation is a convection process that involves a change of phase from vapor to liquid and it occurs whenever a saturated vapor comes into contact of a cold surface,for e.g,in surface condensers, heat transfer from the vapor to the surface takes place and the vapor gets condensed on the surface. The phenomena of boiling, opposite of condensation, is commonly encountered in the unit operations such as distillation and evaporation and steam generation, in all cases where condensation is carried out , boiling apparatus associates it. in chemical industry usually the boiling takes place on a hot submerged surface,e.g,kettle reboiler or inside vertical tube,e.g,vertical tube evaporator. In boiling surface, initially the vapor is formed in the form of bubbles and afterwards as a distinct vapor phase above the liquid interface. As film of liquid is involved in both the cases hilm heat transfer coefficient is important over here.	2 Marks 2 Marks 2 Marks
6. c)	Explain the concept of black body and gray body. A black body for which a=1,r=ζ=0 , which absorbs all the incident radiant energy , is called a black body.It neither reflects nor transmit but absorbs all the radiation incidents on it. So it is treated as an ideal radiation receiver. It is not necessary that the surface of the body be black in colour. The black body radiates maximum possible amount of energy at a given temperature and though perfectly black bodies do not exist in nature, some materials approach it. E.g. lamp black is the nearest to ablack body.It absorbs 96% of visible light. Gray body= A body having the same value of monochromatic emissivity at all wave lengths is called a gray body.	2 Marks 2 Marks
6. d)	Define Kirchoff's law. Write the equation of Plank's law. It states that, at thermal equilibrium the ratio of total emissive power to its absorptivity is the same for all bodies. The emissivity "e" of any body is defined as the ratio of total emissive power E of the body to that of a black body E_b at the same temperature. The emissivity depends on the temp of body only. $e=E/E_b$ According to kirchoff's law $E_1/a_1=E_2/a_2=E_b/a_b=E_b$ Plank's law equation This law gives the relationship between the monochromatic emissive power of a black body, absolute temperature and the corresponding wavelength.	2 Marks

	$E_{b,,\lambda}$= 2 πhc^2 λ^{-5}/e^{hc}/k λT-1 Where $E_{b,,\lambda}$ is the monochromatic emissive power of the black body, W/(m^2. μm), h = plank's constant .k=boltzman constant, c= speed of light T=absolute temperature, λ=wave length of radiation.	
6. e)	How economy of an evaporator can be increased? Name method and explain any one of them. Ans: Economy of an evaporator is defined as the no of kg of water evaporated per kg of steam fed to the evaporator. It is also called the steam economy. Thus economy e= mv/ms. Where mv= kg of vapor evaporated & ms= kg of steam fed By increasing this ratio we can increase the economy of an evaporator. This is done by using two methods. They are i) Use of multiple effect evaporator ii) Vapor recompression. Explanation of multiple effect evaporation In multiple effect evaporation system, the vapor produced in first effect is fed to the steam chest of second effect as a heating medium in which boiling takes place at a low pressure and temperature and so on. Thus in a triple effect evaporator, 1kg of steam fed to 1st effect evaporates approximately 2.5 kg of steam.	2 Marks 2 Marks