PROCESS HEAT TRANSFER
(CHE2201)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) Thermal resistance of composite wall is maximum when slabs of different materials are arranged in
(a) parallel (b) series
(c) partly parallel & partly series (d) random

(ii) In a heat transfer process through an insulated cylindrical pipe, the critical insulation radius depends on
(a) convective heat transfer coefficient outside the insulation
(b) thermal conductivity of the insulating material,
(c) both (a) & (b)
(d) overall radius of the insulated pipe

(iii) Fins are provided on heat transferring surface in order to increase
(a) heat transfer area (b) heat transfer coefficient
(c) temperature gradient (d) turbulence of fluid flowing over it

(iv) A body cooling from $80^{O}C$ to $70^{O}C$ takes 10 minutes when left exposed to environmental condition. If the body is to cool further from $70^{O}C$ to $60^{O}C$ under the same external condition, it will take,
(a) Same time of 10 mint
(b) More than 10 mint
(c) Less Than 10 mint
(d) Time will depend upon the environmental conditions

(v) The dimensionless parameter $l^3\rho^2\beta g\Delta T/\mu^2$ is referred to as
(a) Stanton number (b) Schmidt number
(c) Grashof number (d) Peclet number

(vi) Dropwise condensation usually occurs on
(a) Glazed surface (b) Smooth surface
(c) Oily surface (d) Coated surface

(vii) The convective heat transfer co-efficient in laminar flow over a flat plate
(a) increases with distance
(b) increases if a higher viscosity fluid is used
(c) increases if a denser fluid is used
(d) decreases with increase in free stream velocity

(viii) For film wise condensation on a vertical plane, the film thickness δ and heat transfer co-efficient h vary with distance x from the leading edge as
(a) δ decreases, h increases (b) Both δ and h increases
(c) δ increases, h decreases (d) Both δ and h decreases

(ix) The normal automobile radiator is a heat exchanger of the type
(a) Direct contact (b) Parallel flow
(c) Counter flow (d) Cross flow

(x) LMTD correction factor is applicable for
(a) 1-2 heat exchanger (b) Finned tube heat exchanger
(c) 2-4 heat exchanger (d) 1-1 heat exchanger

Fill in the blanks with the correct word

(xi) In case of heat transfer by conduction in a hollow cylinder ________ area is used to calculate the heat transfer rate.

(xii) Grashof number has a role in ________convection similar to that played by Reynolds number in ________ convection.

(xiii) The ________ is the point of maximum heat flux on the boiling curve at which transition from nucleate to film boiling initiates.

(xiv) In evaporator the Nu number is a function of ________.

(xv) In heat exchanger design, the ratio of overall conductance to minimum capacity rate is called the ________.

Group - B

2\. (a) State and explain Fourier law of heat conduction. Discuss how thermal conductivity of solid, liquid and gas varies with the temperature.
[(CO2)(Analyse/LOCQ)]

(b) Establish a relation for the time taken to form a layer of ice on the surface of a pond when the temperature of the surrounding drops below the freezing point of water. *[(CO4)(Analyse/IOCQ)]*

(c) How much time it will take for a layer of ice of thickness 20 cm to increase by 1 mm on the surface of a pond when the temperature of surroundings is -20°C? Given, thermal conductivity of ice 7.5 kJ/m-hr-K, latent heat of ice 335 kJ/kg, density of ice 910 kg/m^3. *[(CO4)(Apply/IOCQ)]*

(2 + 2) + 5 + 3 = 12

3\. (a) Develop a governing equation for one dimensional radial heat conduction in a cylindrical co-ordinate system with homogeneous heat generation under steady state condition. Now solve the governing equation with suitable boundary condition to determine a radial temperature distribution equation for a long cylinder with radius R. *[(CO2)(Analyse/HOCQ)]*

(b) A furnace wall (5 m × 2 m) comprises three layers: 13 cm inside layer of fire brick (k_1 =1.2 W /m-K), 7.5 cm thick middle layer of insulating brick (k_2 =0.14 W /m-K) and 12 cm thick outside layer of red brick (k_3 =0.85 W /m-K). The furnace operates at 900°C and outside of the furnace wall is maintained at 40°C. Assuming close bonding of layers at their interfaces, find the rate of heat loss from the furnace and the wall interface temperatures. *[(CO5)(Apply/IOCQ)]*

(4 + 4) + 4 = 12

Group - C

4. (a) The expression hl/K gives the Biot number as well as the Nusselt number. What is the difference between the two? *[(CO2)(Remember/IOCQ)]*

(b) A 3.5 KW plate heater of 15cm × 30cm is held vertically with larger side vertical in a water bath at 40°C. Make calculation for the steady state temperature attained by the heater if heat transfer is only due to convection. Use the following correlation, $Nu = 0.13\ (Gr\ Pr)^{0.33}$ and take $\beta = 4.15 \times 10^{-4}$ per °C.
The thermo physical properties of water at 70°C are,
$\rho = 977.8\ Kg/m^3$, $Cp = 4.187\ KJ/Kg.K$, $\upsilon = 0.415 \times 10^{-6}\ m^2/s$ and $K = 0.667\ W/mK$. *[(CO2)(Analyse/IOCQ)]*

(c) Set up the relationship between local heat transfer co-efficient and average heat transfer co-efficient for flow past a stationary flat plate. *[(CO3)(Remember/LOCQ)]*

2 + 7 + 3 = 12

5. (a) Write the Prandlt analogy with the assumption. *[(CO2)(Remember/LOCQ)]*

(b) Explain the concept of Prandlt number. *[(CO2)(Understand/IOCQ)]*

(c) Engine oil at 60°C flows with a velocity of 12 m/s over a 10 m long flat plate whose temperature is 30°C. The flow is parallel to the length of the plate. Determine the rate of heat transfer per unit width of the entire plate. The properties of the engine oil at a film temperature of 45^0C are as follows:
$\rho = 870\ Kg/m^3$, $Pr = 2850$, $K = 0.145\ W/m^0C$, $\nu = 250 \times 10^{-6}\ m^2/s$ *[(CO5)(Analyse/HOCQ)]*

2 + 4 + 6 = 12

Group - D

6. (a) The rate of heat transfer in drop-wise condensation is many times larger than that in film condensation why? *[(CO3)(Understand/IOCQ)]*

(b) How does film wise condensation differ from drop wise condensation? *[(CO4)(Apply/IOCQ)]*

(c) Saturated steam at atmospheric pressure condenses on the outer surface of a vertical tube of length 1m and outer diameter 75mm. The tube wall is maintained at a uniform surface temperature of 40^0C by the flow of cooling water inside the tube. Estimate the steam condensation rate and the heat transfer rate to the tube. What water flow rate will result in a 5^0C temperature difference of water between the outlet and inlet of pipe? Also calculate the flow Reynold's number to check the assumption of laminar flow conditions. The relevant fluid properties are, ρ = 977.8 kg/m^3, K = 2.403 KJ/m-hr.deg, $\mu = 4.06 \times 10^{-4}$ Kg/ms. *[(CO2)(Apply/HOCQ)]*

2 + 2 + 8 = 12

7. (a) State Stefan Boltzman Law of total radiation from a black body. How this law can be modified to take into account radiation from a non-black body?

[(CO3)(Understand/IOCQ)]

(b) Liquid oxygen (boiling temperature = -182^{0}C) is to be stored in a spherical container of 30 cm diameter. The system is insulated by an evacuated space between inner space and surrounding 45 cm ID concentric sphere. For both sphere ε = 0.03 and temperature of the outer sphere is 30^{0}C. Estimate the rate of heat flow by radiation to the oxygen in the container. Determine the rate at which liquid oxygen would evaporate at - 182^{0}C. Latent heat of oxygen is 215 KJ/Kg.

[(CO4)(Analyse/HOCQ)]

4 + 8 = 12

Group - E

8. (a) A parallel flow heat exchanger has its tubes of 5 cm internal and 6 cm external diameter. The air flows inside the tubes and receives heat from hot gases circulated in the annular space of the tube at the rate of 100 kW. Inside and outside heat transfer coefficients are 250 W/m^{2}K and 400 W/m^{2}K respectively. Inlet temperature of hot gases is 500°C, outlet temperature of hot gases is 300°C, inlet temperature of air 50°C, exit temperature of air 140°C. Calculate,
   (i) Overall heat transfer coefficient based on outer surface area
   (ii) Length of the tube required to affect the heat transfer rates. Neglect the thermal resistance of the tube
   (iii) If each tube is 3 m length find the number of tubes required.

[(CO3,CO5)(Analyse/HOCQ)]

(b) Derive expression for effectiveness of parallel flow heat exchanger.

[(CO3)(Remember/LOCQ)]

8 + 4 = 12

9. (a) In a counter flow double pipe heat exchanger, water is heated from 25°C to 65°C by oil with specific heat of 1.45 kJ/kg K and mass flow rate of 0.9 kg/s. The oil is cooled from 230°C to 160°C. If overall Heat transfer coefficient is 420 W/m^2°C. Calculate following:
   (i) The rate of heat transfer
   (ii) The mass flow rate of water, and
   (iii) The surface area of heat exchanger. *[(CO3,CO6)(Analyse/HOCQ)]*

(b) Derive LMTD for parallel flow heat exchanger. *[(CO6)(Understand/IOCQ)]*

8 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	13.54	38.54	47.92