Code No: R1632034 **R16** SET - 1

III B. Tech II Semester Regular Examinations, April/May - 2019

HEAT TRANSFER

(Mechanical Engineering)

Time: 3 hours Max. Marks: 70

Note: 1. Question Paper consists of two parts (**Part-A** and **Part-B)**
2. Answer **ALL** the question in **Part-A**
3. Answer any **FOUR** Questions from **Part-B**
4. Heat transfer data book allowed

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PART –A

1. a) Write the Fourier rate equation for heat transfer by conduction. Give the physical significance of each term. [2M]
   b) Define effectiveness and efficiency of a fin. [2M]
   c) Write the expression for Biot number and explain it physical significance. [2M]
   d) What is meant by a hydrodynamic boundary layer? Explain the formation of Hydrodynamic boundary layer over a flat plate [3M]
   e) Distinguish between film wise and drop wise condensation. Which of the two gives a higher heat transfer coefficient? Why? [3M]
   f) Define irradiation and radiosity. [2M]

PART -B

2. a) Derive a three dimensional generalized heat conduction equation in cylindrical co-ordinates. [7M]
   b) A furnace wall is made of 25 cm fire brick, 20 cm common brick, 6 cm of magnesia and 4mm of steel plate on the outside. The inside and the outside surface temperatures are 1200 ºC and 100 ºC respectively. Calculate the temperature between layers and rate of heat transfer. Assume the thermal conductivities of fire brick, common brick, Magnesia and steel are 1.2 W/m-K, 0.75 W/m-K, 0.07 W/m-K and 71 W/m-K respectively. [7M]

3. a) A longitudinal copper fin (k=3.5 W/m-K), 6 cm long and 5 mm in diameter is exposed to air stream at 20 ºC. The connective heat transfer coefficient is 20 w/m^2-K. If the fin has the base temperature of 150 ºC, calculate the heat transfer by the fin and fin efficiency. [7M]
   b) In quenching process a copper plate of 3 mm thickness is heated up to 350 ºC and is suddenly dipped into water bath and cooled to 25 ºC Calculate the time required for the plate to reach the temperature of 50 ºC. The heat transfer coefficient on the surface of the plate is 28 W/m^2-K. The length and width of the plates are 40 cm and 30 cm respectively. The properties of copper are as follows: specific heat=380.9 J/Kg-K, density 8800 kg/m^3 and thermal conductivity 385 W/m-K. [7M]

4. a) State and explain Buckingham π theorem. [7M]
   b) Water flows in a duct having a cross section 5 X 10 mm with a mean bulk temperature of 20 ºC. If the duct wall temperature is constant at 60 ºC and fully developed laminar flow is experienced, calculate the heat transfer per unit length. [7M]
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5\. a) Air at 15 ºC and at a pressure of 1 atm is flowing along a flat plate at a velocity of 4.75 km/sec. If the plate is one meter wide and at 70 ºC, find the quantities given below at x=1m. [7M]
(i) Hydrodynamic Boundary layer thickness.
(ii) Local friction factor
(iii) Average friction
(iv) Local heat transfer co-efficient
(v) Rate of heat transfer.

b) A flat plate having dimensions 50 cm X 20 cm and at a uniform temperature of 100 ºC is kept in air stream at temperature 20 ºC. The velocity of air is 3 m/sec. Find out the rate of heat loss from the plate when the flow is (i) parallel to 50 cm (ii) parallel to 20 cm side. The Nusselt number for laminar and turbulent flows are given as $N_u=0.664\, P_r^{1/3}\, R_e^{1/2}$ and $N_u=0.037\, R_e 0.8 P_r^{1/3}$. [7M]

6\. a) Explain the regimes of pool boiling. [7M]

b) A liquid chemical flows through a thin walled copper tube of 12 mm diameter at the rate of 0.5 kg/sec water flows in opposite direction at the rate 0.37 kg/sec through the annular space formed by this tube and a tube diameter of 20 mm. The liquid chemical enters and leaves at 100 ºC and 60 ºC, while water enters at 10 ºC. Find the length of tube required. Also find the length of tube required if the water flows in the same direction as liquid chemical. The properties of water and liquid chemical are: [7M]

Properties	**Liquid Chemical At 80 ºc**	**Water At 27 ºc**
p, Kg/m^3	1078	995
µ .Kg/m - Sec^2	3200 X 10^{-6}	853 X 10^{-6}
Cp, J/Kg-K	2050	4180
K, W/mK	0.261	0.614

7\. a) Two large parallel plates having emissivity of 0.5 and 0.6 are maintained at 1000 K and 500 K respectively. A radiation shield having an emissivity of 0.03 on both sides is placed between the plates. Calculate: [7M]
(i) Heat transfer per unit area without shield.
(ii) Find out the temperature of the shield and heat transfer per unit area with shield.

b) Assuming the sun to be a black body having a surface temperature of 5800 K. Calculate: [7M]
(i) the total emissive power
(ii) the wave length at which the maximum spectral intensity occurs,
(iii) the maximum value of E_b and
(iv) the total amount of radiant energy emitted by the sun per unit time if its diameter can be assumed to be 1.391x10^9 m.

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PART –A

1. a) Define thermal resistance and thermal conductance. [2M]
   b) Describe various types of fins. [2M]
   c) Define Reynolds number. Why is it important? [2M]
   d) What is meant by a thermal boundary layer? How is Prandtl Number related to its thickness? [3M]
   e) Differentiate between pool boiling and flow boiling. [3M]
   f) Define Black body, White body and Grey Body. [2M]

PART -B

2. a) Derive the three dimensional heat conduction equations in Cartesian coordinates for a homogeneous and isotropic material with uniform heat generation under unsteady state. [7M]
   b) A 1.0 mm diameter wire is maintained at a temperature of 400 ^{0}C and exposed to a convective environment at 40 ^{0}C with h=50W/m^{2}K. Calculate thermal conductivity which just causes an insulation thickness of 0.2 mm produce a critical radius. How much of this insulation must be added to reduce the heat transfer by 75% from that which would be experienced by ban wire? [7M]

3. a) Derive an expression for temperature distribution and heat loss from a cylindrical rod extending out of a heat source. Assume the end of the rod is perfectly insulated. [7M]
   b) A long steel cylinder 12 cm in diameter and initially at 20 ºC is placed into a furnace at 820 ºC where the heat transfer coefficient, h=140 W/m^2.K. Calculate the time required for the axis temperature to reach 800 ºC. Calculate also, [7M]
   (i) The corresponding temperature at a radius of 4.8 cm at that time.
   (ii) The heat energy absorbed by the cylinder during this period, given that the thermal diffusivity, α = 6.11 X 10^{-6} m^2/s and the thermal conductivity, k=21 W/m.K.

4. a) Show by dimensional analysis that data for forced convection may be correlated by an equation of the form $N_u=f(R_e, P_r)$. [7M]
   b) For heating water from 20 ºC to 60 ºC an electrically heated tube resulting in a constant heat flux of 10 k/W/m^2 is proposed. The mass flow rate is to be such that Re_D=2000, and consequently the flow must remain laminar. The tube inside diameter is 25 mm. The flow is fully developed (velocity profile). Determine the length of tube required. [7M]
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5. a) Explain the phenomena of natural convection over a vertical hot plate. Sketch the boundary layer, temperature and velocity profiles. [7M]

b) Water at 38 ºC flows over a wide, 6 m long, heated plate at 0.06 m/s. For a surface temperature of 93 ºC, determine: (a) the hydrodynamic boundary layer thickness δ at the end of the plate (b) the total drag on the surface per unit width (c) The thermal boundary layer thickness δ_t at the end of the plate (d) the local heat transfer coefficient h_x at the end of the plate and (e) the total heat flux from the surface per unit width. [7M]

6. a) Deduce average heat transfer co-efficient equation in film condensation on a vertical flat plate using Nusselt's theory. [7M]

b) In an industry 0.6 kg/Sec of oil (Cp=2.5 kJ/kg-K) is to be cooled in a counter flow heat exchanger from 110 ºC to 35 ºC by the use of water entering at 20 ºC. The overall heat transfer coefficient is 1500 W/m^2-K. Presuming the exit water temperature should not exceeds 80 ºC, using NTU method, Calculate: [7M]
(i) Water flow rate
(ii) surface area required
(iii) The effectiveness of heat exchanger.

7. a) State and prove Kirchhoff's law of radiation. [7M]

b) Two parallel square plates each 4 m^2 area are large compared to a gap of 5 mm separating them. One plate has a temperature of 800 K and surface emissivity of 0.6, while the other has temperature of 300 K and surface emissivity of 0.9; Find the net exchange by radiation between the plates. If a thin polished metal sheet of surface emissivity 0.1 on both sides is now located centrally between the two plates, what will be its steady state temperature? [7M]

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PART –A

1. a) Explain the mechanism of thermal conduction in gases, liquids and solids. [2M]
   b) Briefly explain the applications of extended surfaces. [2M]
   c) Describe the physical mechanism of convection. How is the convection heat-transfer coefficient related to the mechanism? [2M]
   d) Sketch the temperature and velocity profiles in free convection on an isothermal vertical wall, for the cases of heating and cooling of a fluid. [3M]
   e) Differentiate between film condensation and drop wise condensation. [3M]
   f) Establish the relation between emissive power and intensity of radiation of a black body. [2M]

PART -B

2. a) Derive the general heat conduction equation in spherical coordinates. Obtain the reduced form for one-dimensional unsteady conduction with variable thermal conductivity and no heat generation. [7M]
   b) A hot gas at 573 K flows through a long metal pipe of 0.1 m Outer Diameter and 0.003 m thick. From the stand point of safety and of reducing heat loss from the pipe, mineral wool insulation (k=0.052 W/m K) is wrapped around so that the exposed surface of the insulation is at a temperature of 323 K. Calculate the thickness of insulation required to achieve this temperature if hi=29 W/m^2K, ho=11.6 W/m^2K and the surrounding air temperature in 298 K. Also calculate the corresponding heat transfer rate per unit length. [7M]

3. a) A 0.5 cm thick and 4 cm long fin has its base on a plane plate which is maintained at 1100c. The ambient air temperature is 20 ^{0}C. The conductivity of the fin material is 60 W/m-K and the heat transfer coefficient h= 150 W/m^2 –K. Assume that the tip of the fin is insulated. Determine: [7M]
   (i) Temperature at the end of the fin (ii) Temperature at the middle of the fin
   (iii) Total heat dissipated by the fin.
   b) Derive An expression for instantaneous heat transfer in a lumped body. [7M]

4. a) Show by dimensional analysis that data for free convection may be correlated by an equation of the form N_u=f(G_r, P_r). [7M]
   b) How the local and average convection coefficients for flow past a flat plate are related? Derive the relationship. [7M]
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5. a) Explain the concept of boundary layer for flow over flat plate showing different regimes of fluid flow. [7M]

   b) Oil at 25 ^{0}C is heated in a horizontal tube 15 m long having a surface temperature of 50 ^{0}C. The pipe has an inner diameter of 0.05 m. The oil flow rate is 1 kg/s at inlet temperature. What will be the oil temperature as it leaves the tubes? What is the average heat transfer coefficient? The flow rate is in the laminar region. The properties of the oil are: [7M]
   Specific gravity 0.8: Thermal conductivity 0.125 W/m.K: Specific heat 3.14 kJ/kg.K. Viscosity at 50 ^{0}C is 0.025 kg/m-s; Viscosity at 25 ^{0}C is 0.015 kg/m-s.

6. a) The outer surface of a vertical tube of 1.5 m length and outer diameter of 10 cm is exposed to saturated steam at atmospheric Pressure and is maintained at 50 ºC by the flow of cool water through the tube. Calculate the rate of heat transfer to the coolant and the rate of condensation of steam. The properties of saturated vapour at atmospheric pressure are as follow. Density = 0.596 Kg/m^3, latent heat of condensation is 2257 KJ/Kg. The properties of water are p=975 Kg/m^3, μ = 375 X 10^{-6} W.Sec/m^2, K=0.668 W/m-K. [7M]

   b) Derive an expression for effectiveness of a counter flow heat exchanger using NTU method. [7M]

7. a) Define radiation Intensity. Prove that for a diffusive surface, the emissive power is equal to π times the intensity of radiation. [7M]

   b) A black body of total area 0.045 m^2 is completely enclosed in a sphere bounded by 5 cm thick walls. The walls have a surface area 0.5 m^2 and the thermal conductivity is 1.1 W/m.^{o}C if the inner surface of the enveloping wall is to be maintained at 215 ^{o}C and the outer wall surface is at 30 ^{o}C calculate the temperature of the black body. [7M]

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PART –A

1. a) State the Newton's law of cooling. Discuss whether convective heat transfer coefficient is a material property. [2M]
   b) Define the term overall heat transfer coefficient? And explain its significance. [2M]
   c) List and explain various non dimensional numbers using in heat transfer. [2M]
   d) Explain the physical significance of Rayliegh Number. [3M]
   e) Drop wise condensation is faster than film condensation. State the reason. [3M]
   f) Distinguish between a black body and grey body. [2M]

PART -B

2. a) What are the various boundary conditions needed in general for the analysis of heat conduction problems. Explain with appropriate illustrations. [7M]
   b) A composite wall is made of fire clay brick of (K=1.5W/m.K) and magnesia insulation (K=0.04 W/m.K). The temperature of exposed surface of the fire clay brick is 3800 ºC and that of the external surface of the insulation is 45 ºC. Determine the insulation thickness required to provide a temperature of the interface not to exceed 300 ºC. Determine also the interface temperature if the insulation thickness is doubled. [7M]

3. a) Define fin efficiency. What are the assumptions made in deriving an expression for finding temperature distribution along a circular fin? [7M]
   b) A large aluminium plate of thickness 200 mm originally at a temperature of 530 ^{0}C is suddenly exposed to an environment at 30 ^{0}C. The convective heat transfer coefficient between the plate and the environment if 500 W/(m^2 K). Determine with the help of Heisler charts, the temperature at a depth of 20 mm from one of the faces 225 seconds after the plate is exposed to the environment. Also calculate how much energy has been lost per unit area of the plate during this time? Take for aluminium, $\alpha = 8 \times 10^{-5}$ m^2/s and k = 200 W/(m K). [7M]

4. a) Explain the physical significance of Reynolds Number, Prandtl Number and Nusselt Number [7M]
   b) Using Buckingham Π-Theorem obtain relation for natural convection in terms of dimensionless numbers. [7M]
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5. a) What is the criterion for transition from laminar to turbulent boundary layer in free convection on a vertical flat plate? Explain. [7M]

b) Explain velocity and temperature profile for a flat plate and vertical plate in forced convention. [7M]

6. a) The condenser of a steam power plant operates at a pressure of 7.38 kPa. Steam at this pressure condenses on the outer surfaces of horizontal pipes through which cooling water circulates. The outer diameter of the pipes is 2 cm, and the outer surfaces of the pipes are maintained at 30 ºC. [7M]
Determine
(i) the rate of heat transfer to the cooling water circulating in the pipes
(ii) the rate of heat transfer to the cooling water circulating in the pipes and
(iii) The rate of condensation of steam per unit length of a horizontal pipe.

b) Refrigeration is designed to cool 250 kg/h of hot liquids of heat 3350 J/kg k at 120 ºC using a parallel flow arrangement. 1000 kg/h of cooling water is available for cooling purpose at a temperature of 10 ºC. If the overall heat transfer co-efficient is 1160 W/m^{2}K and the surface area of the heat exchanger is 0.25 m^2. Calculate the outlet temperature of the cooled liquid and water and also effectiveness of the heat exchanger. [7M]

7. a) Derive an expression for radiation shape factor and hence deduce reciprocity relation. [7M]

b) Two large parallel planes having emissivities of 0.25 and 0.5 are maintained at temperatures of 1000 K and 500 K, respectively. A radiation shield having an emissivity of 0.1 on both sides is placed between the two planes. Calculate (i) the heat-transfer rate per unit area if the shield were not present, (ii) the heat-transfer rate per unit area with the presence of the shield and (iii) the temperature of the shield. [7M]

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