Code No: R32033 **R10** **Set No: 1**

III B.Tech. II Semester Regular/Supplementary Examinations, May/June -2014

HEAT TRANSFER

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 75**

Answer any FIVE Questions

All Questions carry equal marks

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Heat and Mass Transfer data book is allowed

1. a) Explain the modes of heat transfer and Sate their basics laws of heat transfer.
   b) Identify the different modes of heat transfer in the following systems/operations.
   (i) Steam raising in a steam boiler
   (ii) Condensation of steam in a condenser
   (iii) Heat transfer from a vacuum flask
   (iv) Heating of water in a bucket with an immersion heater (9M+6M)

2. a) A plate having a thickness of 4 mm has an internal heat generation of 200 MW/m^3 and a thermal conductivity of 25 W/m ^{0}K. One side of the plate is insulated and the other side is maintained at 100^{o}C. Calculate the maximum temperature in the plate.
   b) A 3.3 cm OD steel pipe, outside surface of which is at 500 K, is surrounded by still air at 300 ^{0}K. The heat transfer coefficient by natural convection is 10 W/m^2 ^{0}K. It is proposed to reduce the heat loss to half by applying magnesia insulation (k= 0.07 W/m^{0}K) on the outside surface of the pipe. Determine the thickness of the insulation. Assume pipe surface temperature and convective heat transfer coefficient remains the same. (8M+7M)

3. a) What do you understand by 'lumped system analysis? Derive an expression for temperature distribution in a body during Newtonian heating or cooling.
   b) At a particular location, the soil is initially at a uniform temperature of 15^{o}C and the soil is subjected to a sub zero temperature of -20^{o}C continuously for 50 days. What is the minimum burial depth required to ensure that the water in the pipes does not freeze? i.e, pipe surface temperature should not fall below 0^{o}C. (8M+7M)

4. a) Write the pertinent dimensionless terms governing the phenomenon of forced convection and free convection.
   b) Caster oil at 36^{o}C flows over a 6 m long and 1 m wide heated plate at 0.06 m/s. For a surface temperature of 96^{o}C, determine i) the thermal boundary layer thickness at the end of the plate, ii) the local heat transfer coefficient at the end of the plate. (6M+9M)

5. a) Discuss the significance of following non dimensional numbers:
   i) Nusselt number ii) Prandtl number iii) Grashoff number iv) Reynolds number
   b) Liquid sulphur dioxide in a saturated state flows inside a 5 m long tube and 25 mm internal diameter with a mass flow rate of 0.15 kg/s. The tube is heated at a constant fluid temperature of -10^{o}C and the inlet fluid temperature is -40^{o}C. Determine the exit fluid temperature by making use of Sieder and Tate equation. (6M+9M)

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6. a) Why are the heat transfer coefficients in condensation and boiling very high compared to those in forced convection without phase change.
   b) A heated nickel plate at 110°C is submerged in water at one atmosphere pressure. Determine the rate of heat transfer per unit area. For nucleate boiling, assume $C_{s,f}$ = 0.006 and n=1. (6M+9M)

7. a) Derive the LMTD expression for counter flow heat exchanger.
   b) It is desired to cool 0.5 kg/s of oil from 105°C by using an equal flow rate of cooling water. The cooling water is available at 20°C. The specific heat of oil and water are 2.8 kJ/kgK and 4.2 kJ/kgK, respectively. The two double-pipe heat exchangers are available.
   Heat Exchanger 1: U=500 W/m^2K; A=4.5 m^2
   Heat Exchanger 2: U= 800 W/m^2K; A=2 m^2
   Which heat exchanger should be used for a parallel-flow arrangement? (7M+8M)

8. a) Sate and explain the 'Total radiation: Stefan-Boltzmann law', relating to thermal radiation and temperature of a radiating body.
   b) A square room 4m by 4 m has the floor heated to 320 ^{0}K, the ceiling to 300 ^{0}K and the walls are assumed to be perfectly insulated. The height of the room is 3 m. The emissivity of all surfaces is 0.8. Using the network method, find the net interchange between the floor and the ceiling and the wall temperature. (7M+8M)

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Heat and Mass Transfer data book is allowed

1. a) Derive the general heat conduction equation for cylindrical coordinate system.
   b) Explain the three modes of heat transfer with the help of examples.
   c) Write the assumptions of Fourier law. (8M+5M+2M)

2. a) A cylinder 5 cm diameter and 50 cm long, is provided with 14 longitudinal straight fins of 1 mm thick and 2.5 mm height. Calculate the heat loss from the cylinder per second if the surface temperature of the cylinder is 200°C. Take h=25 W/m^{2}K, k=80 W/m^{0}K and ambient temperature=45°C.
   b) Explain about critical thickness of insulation. Derive the condition for critical thickness of insulation for hallow cylinder. (9M+6M)

3. a) A ball of 6 cm diameter at 600°C is suddenly immersed in a controlled medium at 100°C. Calculate the time required for the ball to attain a temperature of 150°C. Assume k= 40 W/m^{0}K, C= 500 J/kg^{0}K, h= 20 W/m^2 ^{0}K and density= 800kg/m^3.
   b) Consider a thick wall, which is initially at a uniform temperature of 30°C. Suddenly one of its surfaces is raised to 150°C and maintained at that temperature. Calculate the temperature at 4.29 cm, 8.57 cm and 14.29 cm from the hot surface 30 minutes after raising of the surface temperature. Assume $\alpha = 7 x 10^{-7}$ m^2/s for the thick wall. (6M+9M)

4. a)Write short notes on hydraulic and thermal boundary layers. What is the importance of these boundary layers in heat transfer?
   b) Glycerin at 10°C flows over a flat plate 6 m long, maintained at 30°C with a velocity of 1.5 m/s. Determine the total drag force and the heat transfer rate over the entire plate per unit width. (8M+7M)

5. a) A hot wire probe is 5 mm in length, 10 µm diameter wire with an electrical resistance of 150 ohms/m. The wire is maintained at a constant temperature of 50°C. If the probe is kept in an air stream flowing at a velocity of 10 m/s and at 1 bar and 25°C, determine the current required to maintain the wire temperature at 50°C.
   b) A square plate 0.2 m x 0.2 m is suspended vertically in a quiescent atmospheric air at a temperature of 300 K. The temperature of the plate is maintained at 400 ^{0}K. Determine the average heat transfer coefficient over the entire length of the plate. (9M+6M)

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6. a) Discuss in detail the various regimes in boiling and explain the condition for the growth of bubbles. What is the effect of bubble size on boiling?
   b) Saturated steam at 2 bar condenses on a cylindrical vertical drum having an outside diameter of 25 cm and a temperature of 90.4°C. Calculate how long the drum must be to condense 50 kg of steam per hour. (8M+7M)

7. a) Derive the relationship between the effectiveness and the number of transfer units for a counter flow heat exchanger.
   b) A cross-flow heat exchanger with both fluids unmixed is used to heat water (C_p= 4.18 kJ/kgK) from 50°C to 90°C, flowing at the rate of 1.0 kg/s. Determine the overall heat transfer coefficient if the hot engine oil (C_p= 1.9 kJ/kgK) flowing at the rate of 3 kg/s enters at 100°C. The heat transfer area is 20 m^2. (9M+6M)

8. a) A 18 cm diameter heating pipe (emissivity=0.8) at surface temperature 475 K has been placed centrally in a brick duet (emissivity=0.9) of 25 cm side square section and at 300 ^{0}K temperature. Determine the radiation heat loss from each metre of the heating pipe.
   b) Define the following terms:
   i) Irradiation ii) Radiosity iii) Solid angle iv) Emissivity
   v) Radiation intensity vi) Gray body (9M+6M)

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Code No: R32033 **R10** **Set No: 3**

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Heat and Mass Transfer data book is allowed

1. a) Explain clearly the mechanism of conduction, convection and radiation. Write formulae to calculate the thermal resistance of conduction, convection and radiation.
   b) Derive the general heat conduction equation for cylindrical coordinate system and simplify to one-dimensional steady state with heat generation and constant thermal conductivity in radial direction. (7M+8M)

2. a) Heat is generated within a wire of 3 mm in diameter by passing a current of 350 A. The thermal conductivity and resistivity of the wire are 25 W/m ^{0}K and 80x10^{-8} Ω-m and the length of the wire is 2.2 m. This wire is immersed in a water bath maintained at 30^{o}C. The heat transfer coefficient at the outer surface of the wire is 4500 W/m^2 ^{0}K. Calculate the temperature at the centre of the wire and at the surface of the wire.
   b) Derive the equation for steady state, one dimensional conduction for the hallow sphere. (9M+6M)

3. a) Derive an expression for temperature required for cooling or heating for a body whose thermal resistance is zero.
   b) A large slab of wrought-iron is at a uniform temperature of 550^{o}C. The temperature of one surface is suddenly changed to 50^{o}C. Calculate the time required for the temperature to reach 225^{o}C at a depth of 80 mm (Take, for the slab, k= 60 W/m ^{0}K, α = 1.6 x 10^{-5} m^2/s). (6M+9M)

4. a) Explain the Buckingham's π- theorem for forced convection heat transfer analysis.
   b) Caster oil at 36^{o}C flows over a 6 m long and 1 m wide heated plate at 0.06 m/s. For a surface temperature of 96^{o}C, determine (i) the thermal boundary layer thickness at the end of the plate, (ii) the local heat transfer coefficient at the end of the plate, and (iii) the rate of heat transfer from the entire plate. (6M+9M)

5. a) Air at 1 bar and 20^{o}C flows through a 6mm inner diameter, 1 m long smooth pipe, whose surface is maintained at a constant heat flux, with velocity of 3 m/s. Determine the heat transfer coefficient if the exit bulk temperature of air is 80^{o}C. Also determine the exit wall temperature and the value of heat transfer coefficient at the exit.
   b) A hot square plate 50 cm x 50 cm, at 100^{o}C is exposed to atmosphere air at 20^{o}C. Find the heat loss from both the surfaces of the plate:
   (i) if the plate is kept vertical (ii) if the plate is kept at horizontal. (8M+7M)

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6. a) Draw the boiling curve for pool boiling of water and explain flow regimes.
   b) Saturated steam at a temperature of 65^{o}C condenses on a vertical surface at 55^{o}C. Determine the thickness of the condensate film at locations 0.2m and 1.0 m from the top. Also calculate condensate flow rate at these locations. (6M+9M)

7. a) Derive an expression for the effectiveness of parallel flow heat exchanger.
   b) In a shell and tube heat exchanger 50 kg/min of furnace of oil is heated from 10 to 90^{o}C. Steam at 120^{o}C flows through the shell and oil flows inside the tube. Tube size: 1.65 cm ID and 1.9 cm OD. Heat transfer coefficient on oil and steam sides is: 85 and 7420 W/m^{2}K respectively. Find the number od passes and number of tubes in each pass if the length of each tube is limited to 2.85 m. Velocity of oil is 5 cm/s. Density and specific heat of oil are 900 kg/m^3 and 1970 J/kgK, respectively.
   (7M+8M)

8. a) State Planck's law of monochromatic radiation. What is its significance?
   b) A hemispherical furnace of radius 1.0 m has a roof temperature of 800 ^{0}K and its emissivity is 0.8. The flat circular floor of the furnace has a temperature of 600 ^{0}K and its emissivity is 0.5. Calculate the net radiant heat exchange between the roof and floor.
   (6M+9M)

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1. a) In what way is the science of heat transfer different form thermodynamics?
   b) Derive the general heat conduction equation for cylindrical coordinates. There from write down governing equation for one dimensional, temperature dependent, unsteady state conduction with heat generation. (6M+9M)

2. a) Derive the expression for the temperature distribution for a Fin of finite length with specified temperature at its ends.
   b) Explain the boundary conditions of first, second and third kinds. (9M+6M)

3. a) A steel ball of 5 cm diameter initially at a uniform temperature of 450°C is suddenly placed in an environment at 100°C. Heat transfer coefficient h, between the steel ball and the fluid is 10 W/m^2K. For steel c_p=0.46 kJ/kgK, density = 7800 kg/m^3, k= 35 W/mK. Calculate the time required to reach a temperature of 150°C. Also find the rate of cooling after 1 hr.
   b) What do you mean by a semi-infinite medium? In what situations the assumption of semi-infinite medium appropriate? (9M+6M)

4. a) Derive an expression for temperature distribution under one-dimensional steady state heat conduction with heat generation of q_g(W/m^3) for the plate of thickness L and temperature being T_1 and T_2 at the two faces.
   b) Sodium-potassium alloy (25% +75%) at 300°C, flows with a velocity of 0.4 m/s over a flat plate (size: 0.3 m x 0.1 m) maintained at 500°C. Calculate (i) the the hydrodynamic and thermal boundary layer thicknesses (ii) local and average value of friction coefficient (iii) heat transfer coefficient and (iv) total heat transfer rate. (7M+8M)

5. a) Write short note on Reynolds analogy between momentum and heat transfer, with reference to a flat plate.
   b) A fine wire of 0.2 mm diameter is maintained at a constant temperature of 64°C by an electric current. The wire is exposed to air at 1 bar and 10°C. Calculate the electric power necessary to maintain the wire temperature if the length of the wire is 1 m. (7M+8M)

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6. a) Dry saturated steam at atmospheric pressure condenses on a vertical tube of diameter 5 cm and length 1.5 m, surface of the tube is maintained at 80°C. Determine the heat transfer rate.
   b) Differentiate between film condensation and drop-wise condensation. In which case is the heat transfer higher? Why?. (8M+7M)

7. a) Derive an expression for the LMTD of a parallel-flow heat exchanger. State clearly the assumption.
   b) Oil at 100°C (C_p= 3.6 kJ/kg ^{0}K) flows at a rate of 30,000 kg/hr and enters into a parallel flow heat exchanger. Cooling water (C_p=4.2 kJ/kg ^{0}K) enters the heat exchanger at 10°C at the rate of 50,000 kg/hr. The heat transfer area is 10 m^2 and overall heat transfer coefficient is 1000 W/m^2K. Calculate the outlet temperature of oil and water. (7M+8M)

8. a) Find the view factor F_{11} (with respect to itself) for the following.
   (i) a cylinder cavity of diameter 'd' and depth 'h'
   (ii) a conical cavity of diameter 'd' and depth 'h'
   (iii) a hemispherical bowl of diameter 'd'
   b) Two large parallel planes facing each other and having emissivities 0.3 and 0.5 are maintained at 827°C and 527°C respectively. Determine the rate at which heat is exchanged between the two surfaces by radiation. If a radiation shield of emissivity 0.05 on both sides is placed parallel between the two surfaces, determine the percentage reduction in the radiation heat transfer. (6M+9M)

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