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10AU65

**Sixth Semester B.E. Degree Examination, Dec.2015/Jan.2016**  
**Heat and Mass Transfer**

Time: 3 hrs.

Max. Marks:100

**Note:** Answer any FIVE full questions, selecting atleast TWO questions from each part.

**PART - A**

- 1 a. Derive 3 – D heat conduction equation stating all the assumptions made in Cartesian co-ordinates. Reduce the general conduction equation to Fourier – Biot equation, Poisson equation, Diffusion equation and Laplace equation. (10 Marks)
- b. In an attempt to reduce the energy loss from a 2cm outer diameter pipe line with hot water, a plumber decides to insulate the line with 1cm thick insulation having  $K = 0.1 \text{ W/mK}$ . The entire metal tube can be considered to remain at a uniform temperature of  $70^\circ\text{C}$ . The line is surrounded by air at  $15^\circ\text{C}$  for which heat transfer coefficient is  $6.5 \text{ W/m}^2\text{K}$ . Find the critical thickness of insulation and also justify the plumber's decision. (10 Marks)
- 2 a. Find the temperature distribution and heat transfer for a rectangular cross section fin of infinite length. State all the assumptions. (10 Marks)
- b. One end of a long rod, 3cm in diameter is inserted into a furnace with outer end projecting into outside air. Once steady state is reached, the temperature of the rod are measured at two points 15cm apart and are found to be  $140^\circ\text{C}$  and  $100^\circ\text{C}$ . The atmospheric air temperature is  $30^\circ\text{C}$  and convective heat transfer coefficient is  $20 \text{ W/m}^2\text{K}$ . Calculate the thermal conductivity of the rod. State all assumptions made. (10 Marks)
- 3 a. For a lumped system, find the temperature distribution and heat transfer with usual notations. (10 Marks)
- b. It is proposed to quench steel balls of a bearing 1cm in diameter, initially at  $400^\circ\text{C}$ . These are placed in a cold chamber maintained at  $-20^\circ\text{C}$ . The steel balls pass through the chamber on a conveyor belt. Optimum bearing production requires that 75% of initial thermal energy content of the balls above  $-15^\circ\text{C}$  be removed. How long the balls should be placed on the conveyor belt? (10 Marks)
- 4 a. Define the following and mention their significances :  
 i) Reynold's number    ii) Prandtl number    iii) Grashof number  
 iv) Nusselt number    v) Stanton number. (10 Marks)
- b. A circular disc heater 0.2m in diameter is exposed to ambient air at  $25^\circ\text{C}$ . One surface of the disc is insulated and the other surface is maintained at  $130^\circ\text{C}$ . Calculate the amount of heat transferred from the disc when it is i) horizontal with hot surface facing up ii) horizontal with hot surface facing down. (10 Marks)

**PART - B**

- 5 a. Using Buckingham  $\pi$  – theorem, establish  $\pi_3 = f(\pi_1, \pi_2)$  with usual notations for forced convection. (10 Marks)
- b. Air at 1 atm,  $40^\circ\text{C}$  flows with a velocity 8m/s along a flat plate 3m long, which is maintained at a uniform temperature of  $100^\circ\text{C}$ , calculate the local heat transfer coefficient ( $h_x$ ) at the end of the plate and also average heat transfer coefficient over the entire length of the plate, given  $R_{e_{cv}} = 2 \times 10^5$ . (10 Marks)

- 6 a. For a co-axial parallel flow heat exchanger, establish  

$$\epsilon = \frac{1 - e^{-NTU(1+c)}}{1+c}$$
 with usual notation. (10 Marks)
- b. A shell and tube condenser is constructed with 2.5cm OD. Single pass horizontal tube with steam condensing at 54°C, the cooling water enters the tube at 18°C at a flow rate of 0.7kg/s for tube and leaves at 36°C. The overall heat transfer coefficient based on outer surface of the tube is 3509W/m<sup>2</sup> K. Calculate the tube length and heat transfer rate by NTD method. (10 Marks)
- 7 a. Draw the typical boiling curve for water and show all the boiling regimes, natural convection boiling, nucleate boiling, transition boiling and film boiling. Explain. (10 Marks)
- b. An electric wire of 1.5mm diameter and 20cm length is laid horizontally and submerged in water at 1 atm/pressure. The current flowing through the wire is 40 amps while the voltage drop is 16V. Calculate the heat flux, heat transfer coefficient and excess temperature. Use appropriate correlation.  

$$[h = 1.54 \left( \frac{Q}{A} \right)^{3/4} = 5.58 (\Delta J_e)^3].$$
 (10 Marks)
- 8 a. Define the following : i) Black body ii) Emissive power iii) Irradiation  
 iv) Gray body v) Diffuse and specular reflections. (10 Marks)
- b. Two large parallel planes with emissivity 0.6 are at 900K and 300K. A radiation shield with one side polished and having emissivity of 0.05 and the other side with emissivity 0.4 is proposed. Which side of the shield must face the hotter plane in order to keep the temperature of shield minimum? Justify your answer. (10 Marks)

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10AU65

Sixth Semester B.E. Degree Examination, Dec.2016/Jan.2017

**Heat & Mass Transfer**

Time: 3 hrs.

Max. Marks: 100

**Note: 1. Answer FIVE full questions, selecting at least TWO questions from each part.****2. Heat transfer data book and steam tables are permitted.****PART – A**

- 1 a. State assumptions and derive general 3 – dimensional heat conduction equation in Cartesian coordinates. (08 Marks)
- b. State the laws governing three basic modes of heat transfer. (06 Marks)
- c. A long hollow cylinder ( $k = 50 \text{ W/m.k}$ ) has an inner radius of 10cm and outer radius of 20cm. The inner surface is heated uniformly at constant rate of  $1.16 \times 10^5 \text{ W/m}^2$  and outer surface is maintained at  $30^\circ\text{C}$ . Calculate the temperature of inner surface. (06 Marks)
- 2 a. Derive an expression for temperature distribution and rate of heat transfer in plane wall with proper assumptions. (10 Marks)
- b. A very long rod, 25mm in diameter, has one end maintained at  $100^\circ\text{C}$ . The surface of rod is exposed to ambient air at  $25^\circ\text{C}$  with convective coefficient of  $10 \text{ W/m}^2.\text{k}$ .
  - i) What are heat losses from rods, constructed of pure copper ( $K = 398 \text{ W/m.k}$ ) and stainless steel ( $k = 14 \text{ W/m.k}$ )? Also write the remarks.
  - ii) Estimate how long the rods must be, to be, considered infinite. (10 Marks)
- 3 a. A titanium alloy blade of an axial compressor for which  $K = 25 \text{ W/m.k}$ ,  $\rho = 4500 \text{ kg/m}^3$  and  $C = 520 \text{ J/kg.k}$  is initially at  $60^\circ\text{C}$ . The effective thickness of the blade is 10mm and it is exposed to gas stream at  $600^\circ\text{C}$ , the blade experiences a heat transfer coefficient of  $500 \text{ W/m}^2.\text{k}$ . Use low Biot number approximation to estimate the temperature of blade after 1, 5, 20 and 100 seconds. (10 Marks)
- b. Define Biot number and Fourier number? Write their physical significances. (04 Marks)
- c. What are heisler charts? Explain their significances in solving transient conduction problem. (06 Marks)
- 4 a. Using Buckingham's  $\pi$  theorem, obtain relationship between Nu, Pr and Gr, for natural convection heat transfer. (12 Marks)
- b. The velocity distribution in the boundary layer is given by ;  $\frac{u}{U} = \frac{y}{\delta}$ , where 'u' is the velocity at a distance 'y' from the plate and  $u = U$  at  $y = \delta$ ,  $\delta$  being boundary layer thickness. Find : i) the displacement thickness ii) Momentum thickness  
iii) the energy thickness and iv) the value of  $\frac{\delta^*}{\theta}$  (08 Marks)

**PART – B**

- 5 a. Explain the following briefly with sketches :  
i) Boundary layer thickness ii) Thermal boundary layer thickness. (12 Marks)
- b. The efficiency ( $\eta$ ) of a fan depends on density ( $\rho$ ) the dynamic viscosity ( $\mu$ ) of the fluid, the angular velocity ( $\omega$ ), diameter (D) of the rotor and discharge (Q). Expresses ( $\eta$ ) in terms of dimensionless parameters. (08 Marks)

- 6 a. A heat exchanger is required to cool 55000kg/hr of alcohol from 66°C to 40°C using 40,000kg/hr of water entering at 5°C. Calculate :
- Exit temperature of water
  - Heat transfer rate
  - Surface area required for parallel flow type and counter flow type. (08 Marks)
- b. Derive an expression for effectiveness of parallel flow heat exchange by 'NTU' method with proper assumption. (12 Marks)
- 7 a. Distinguish between nucleate boiling and film boiling with neat sketch. (06 Marks)
- b. Determine the rate of heat loss by radiation from a steel tube of outside diameter 70mm and 3m long at a temperature of 227°C. If the tube is located with in a square brick conduit of 0.3m side and at 27°C. Take  $\epsilon$  (steel) = 0.79 and  $\epsilon$  (brick) = 0.93. (10 Marks)
- c. State and explain fick's law of diffusion. (04 Marks)
- 8 a. With reference to thermal radiation, explain the following terms :
- Black body and gray body
  - Specular and diffuse surface
  - Plank's law and weins displacement law
  - Radiosity and irradiation
  - View factor and Radiation shield. (10 Marks)
- b. A steam condenser consist of 16 tubes arranged in 4×4 array, water flows through the tube at 65°C while steam condenses at 75°C over the tube surface. Find the rate of condensation if,
- Tube are horizontal
  - Tubes are vertical.
- Take latent heat of steam as 2300kJ/kg and properties of water at 70°C.
- $\rho = 977.8 \text{ kg/m}^3$   
 $K_f = 0.668 \text{ W/m.k}$   
 $\beta = 5.7 \times 10^{-3}$   
 $C_p = 4.187 \text{ kJ/kg.k}$   
 $\nu = 0.415 \times 10^{-6} \text{ m}^2/\text{s}$   
 $L = 1.2\text{m}, D = 25\text{mm}.$  (10 Marks)

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10AU65

**Sixth Semester B.E. Degree Examination, June/July 2015**  
**Heat and Mass Transfer**

Time: 3 hrs.

Max. Marks:100

**Note: 1. Answer any FIVE full questions, selecting atleast TWO questions from each part.**  
**2. Use of heat transfer data hand book is permitted.**

**PART – A**

- 1
  - a. State the modes of heat transfer with governing laws and equations. (09 Marks)
  - b. Discuss with an example heat transfer in combined mode. (05 Marks)
  - c. With sketches, write the mathematical representation of boundary condition 2<sup>nd</sup> kind and 3<sup>rd</sup> kind for 1-D heat conduction in rectangular coordinates. (06 Marks)
  
- 2
  - a. Derive an expression for the critical radius for the insulation of a cylinder. (08 Marks)
  - b. Fins, 12 in number with tips insulated, having thermal conductivity 75 W/m-K and 0.75 mm thickness protrude 25 mm from a cylindrical surface of 50mm diameter and 1 m length placed in an atmosphere of 40°C. If the cylinder surface is maintained at 150°C and the heat transfer coefficient is 23 W/m<sup>2</sup>K, calculate:
    - i) The rate of heat transfer by fins.
    - ii) The percentage increase in heat transfer due to fins.
    - iii) The temperature at the centre of the fins and
    - iv) The fin efficiency
    - v) The fin effectiveness. (12 Marks)
  
- 3
  - a. What is lumped system analysis? When is it applicable? What is the physical significance of Biot number? (06 Marks)
  - b. A solid iron rod [ $K = 60$  W/m-K,  $\rho = 7280$  kg/m<sup>3</sup>,  $c_p = 410$  J/kg K and  $\alpha = 2 \times 10^{-5}$  m<sup>2</sup>/s] of 6cm diameter, initially at temperature 800°C is suddenly dropped into an oil bath at 50°C. The heat transfer coefficient between the fluid and the surface is 400 W/m<sup>2</sup>K. Using the transient temperature charts, determine:
    - i) The centerline temperature 10 min after immersion in the fluid.
    - ii) The temperature at a depth of 2cm from the surface 10 min after immersion in the fluid.
    - iii) The energy removed from the rod during this period. (14 Marks)
  
- 4
  - a. Define the following dimensionless members. Also give their physical significance.
    - i) Prandtl number
    - ii) Nusselt number. (08 Marks)
  - b. A horizontal pipe 0.3m in diameter is maintained at a temperature of 245°C in a room where the ambient air is at 15°C. Calculate the free convection heat loss per meter length of the pipe. Take the properties of air at the bulk mean temperature of 130°C as [ $K = 34.14 \times 10^{-3}$  W/m-K,  $\gamma = 26.63 \times 10^{-6}$  m<sup>2</sup>/s and  $Pr = 0.685$ ]. (12 Marks)

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.  
 2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

## PART – B

- 5 a. Distinguish between hydrodynamic and thermal boundary layers with sketches. (08 Marks)  
 b. Air at 20°C and at atmospheric pressure flows over a flat plate at a velocity of 3 m/s. The plate is 0.3m long and at 60°C. The properties of air at the bulk mean temperature of 40°C are [ $K = 0.02756 \text{ W/m-K}$ ,  $C_p = 1005 \text{ J/kg K}$ ,  $\rho = 1.128 \text{ kg/m}^3$ ,  $\gamma = 19.96 \times 10^{-6} \text{ m}^2/\text{s}$  and  $P_r = 0.699$ ]. Calculate:  
 i) Velocity and thermal boundary layer thickness at 0.2m from the heading edge.  
 ii) Local and average friction coefficient.  
 iii) Average heat transfer coefficient.  
 iv) Rate of heat transfer by convection.  
 v) Total drag force on the plate per unit width. (12 Marks)
- 6 a. Briefly explain the classification of heat exchanger by flow management. (08 Marks)  
 b. A two-shell pass, four-tube pass heat exchanger has water on the shell side and brine on the tube side. Water is cooled from 18°C to 6°C with brine entering at -1°C and leaving at 3°C. The overall heat transfer coefficient is 600 W/m<sup>2</sup> K. Calculate the heat transfer area required for a design heat load of 24 kW. (12 Marks)
- 7 a. Sketch and explain boiling curve. (08 Marks)  
 b. Air free saturated steam at 85°C [ $P = 57.83 \text{ kPa}$ ] condenses on the outer surface of 215 horizontal tubes of 1.27 cm diameter in a 15-by-15 array. Tube surfaces are maintained at a uniform temperature of 75°C. Calculate the total condensation rate per 1m length of the tube bundle. The physical properties of water at  $T_f = 80^\circ\text{C}$  are  $K = 0.688 \text{ W/m K}$ ,  $\rho_f = 974 \text{ kg/m}^3$ ,  $\mu_f = 0.355 \times 10^{-3} \text{ kg/m-s}$ ,  $h_{fg} = 2309 \text{ kJ/kg}$ . (12 Marks)
- 8 a. State: i) Wein's displacement law; ii) Kirchoff's law; iii) Planck's law, also state their significances. (09 Marks)  
 b. Consider two large parallel plates; one at 1000K with emissivity 0.8 and the other is at 300 K with emissivity 0.6. A radiation shield is placed between them. The shield has emissivity of 0.1 on the side facing hot plate and 0.3 on the side facing cold plate. Calculate the percentage reduction in radiation heat transfer as a result of radiation shield. (11 Marks)

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10AU65

## Sixth Semester B.E. Degree Examination, June/July 2016

### Heat & Mass Transfer

Time: 3 hrs.

Max. Marks: 100

- Note: 1. Answer FIVE full questions, selecting at least TWO questions from each part.**  
**2. Heat transfer data book and steam tables are permitted.**

#### PART – A

- 1
  - a. Explain the basic equations for conduction, convection and radiation. (06 Marks)
  - b. Derive an expression for the heat flow rate through a hollow cylinder provided with two layers of insulation by taking into account of convective effects. (06 Marks)
  - c. A hollow sphere made up of steel having thermal conductivity of  $45 \text{ W/m}^\circ\text{C}$ . It is heated by means of a coil of resistance  $100\Omega$  which carries a current of 5 amperes. The coil is located inside the hollow space at the centre. The outer surface area of the sphere is  $0.2 \text{ m}^2$  and its mass is 32 kg. Assuming the density of sphere material to be  $8 \text{ gm/cc}$ , find the temperature difference between inner and outer surfaces. (08 Marks)
  
- 2
  - a. Explain critical insulation thickness. (04 Marks)
  - b. A brick wall of 5 m length, 3 m height and 250 mm thick has temperatures of  $800^\circ\text{C}$  and  $20^\circ\text{C}$  maintained on its bounding surfaces. Assuming that the thermal conductivity of the brick material is related to its temperature by the relation.  
 $K = 1.00[1 + 0.001 T] \text{ W/m}^\circ\text{C}$   
 Calculate the average thermal conductivity, thermal resistance and heat loss from the wall. What will the temperature at 100 mm distance from the wall surface at  $800^\circ\text{C}$ ? (10 Marks)
  - c. An electronic unit during operation generates an energy equal to 50 mill watts and the temperature at the surface of the unit is found to be  $95^\circ\text{C}$ . To increase the rate of heat transfer, the device is provided with aluminum fins of square cross section  $0.5 \text{ mm} \times 0.5 \text{ mm}$  of length 1 cm. the temperature of the surrounding is  $30^\circ\text{C}$ . the heat transfer coefficient is  $12.5 \text{ W/m}^2^\circ\text{C}$  and the thermal conductivity of aluminum is  $175 \text{ W/m}^\circ\text{C}$ . Determine the number of fins required to dissipate the heat generated by the unit. Assume heat transfer from the end of fin is neglected. (06 Marks)
  
- 3
  - a. With neat sketch explain lumped system analysis show that  $\frac{T - T_\infty}{T_0 - T_\infty} = e^{-BiFo}$  and  
 $Q = \rho V c_p (T_0 - T_\infty) [e^{-BiFo} - 1]$  (10 Marks)
  - b. The average heat transfer coefficient for the flow of  $100^\circ\text{C}$  air over a flat plate is measured by observing the time history of a thick copper slab exposed to  $100^\circ\text{C}$  air. In one test run the initial temperature of the plate was  $210^\circ\text{C}$  and in 5 minutes the temperature becomes  $170^\circ\text{C}$ . Calculate the heat transfer coefficient in this case. (05 Marks)
  - c. An iron sphere  $K = 60 \text{ W/m}^\circ\text{C}$ ,  $C_p = 460 \text{ J/kg}^\circ\text{C}$ ,  $\rho = 7850 \text{ kg/m}^3$ ;  $\alpha = 1.6 \times 10^{-5} \text{ m}^2/\text{s}$  of diameter 5 cm is initially at a temperature of  $225^\circ\text{C}$ . Suddenly the surface of the sphere is exposed to an ambient air at  $25^\circ\text{C}$  with heat transfer coefficient  $500 \text{ W/m}^2^\circ\text{C}$ . Calculate :  
 i) Centre temperature at  $t = 2 \text{ min}$   
 ii) Temp at a depth of 1 cm from the surface at  $t = 2 \text{ min}$  (05 Marks)

- 4 a. With the help of dimensional analysis, correlate the free convection data. (10 Marks)  
 b. Hot fluid at  $300^{\circ}\text{C}$  flows through a horizontal pipe of 30cm outside diameter and 90cm long. The pipe is exposed to an atmosphere maintained at  $20^{\circ}\text{C}$ . Determine the natural convection heat transfer. (10 Marks)

### PART – B

- 5 a. Explain the significance of  
 i) Reynolds's number  
 ii) Prandtl number  
 iii) Nusselt Number  
 iv) Grashoff number  
 v) Stanton number. (10 Marks)  
 b. Determine the rate of heat loss per hour from a wall of a building when the wind is flowing parallel to its surface with a speed of 2km/hr. The wall is 5m long and 3m high. Temperature of the wall is  $25^{\circ}\text{C}$  and air temperature is  $5^{\circ}\text{C}$ . (10 Marks)
- 6 a. Derive an expression for LMTD of a parallel flow heat exchanger. (10 Marks)  
 b. Water enters a cross flow heat exchanger (both fluids unmixed) at  $15^{\circ}\text{C}$  and flows 7.5kg/s. It cools air ( $C_p = 1.005 \text{ kJ/kg}^{\circ}\text{C}$ ) flowing at the rate of 10 kg/s with inlet temperature of  $120^{\circ}\text{C}$ . The overall heat transfer coefficient is  $225 \text{ W/m}^2\text{C}$  and surface area of the heat exchanger is  $240\text{m}^2$ . Determine the total heat transfer rate and outlet temperatures using NTU method. (10 Marks)
- 7 a. With the help of boiling curve, explain various regimes of boiling. (08 Marks)  
 b. A vertical tube of 50 mm diameter and 2 m long is exposed to steam at atmospheric pressure. The outer surface of the tube is maintained at a temperature of  $80^{\circ}\text{C}$  by circulating water through the tubes. Determine the rate of heat transfer and condensate mass flow rate. (08 Marks)  
 c. Dry saturated steam at a pressure of 2.45 bar condenses on the surface of a vertical wall of tube of height 1 m. The tube surface temperature is  $117^{\circ}\text{C}$ . Estimate the thickness of the condensate film at a distance of 0.2 m from the upper end of the tube. (04 Marks)
- 8 a. With neat sketch explain the concept of black body. (06 Marks)  
 b. State and prove Kirchhoff's law of radiation. (06 Marks)  
 c. Two large parallel planes having emissivities 0.3 and 0.5 are maintained at temperature  $800^{\circ}\text{C}$  and  $300^{\circ}\text{C}$  respectively. A radiation shield having emissivity of 0.05 on both sides is placed between the two planes. Calculate ;  
 i) Heat transfer per unit area without shield  
 ii) Heat transfer per unit area with shield  
 iii) Temperature of the shield. (08 Marks)

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