Heat and Mass Transfer VTU CBCS Question Paper Set 2018

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10ME63

Sixth Semester B.E. Degree Examination, Dec.2017/Jan.2018
Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

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

PART – A

1 a. Define Thermal Diffusivity. **(04 Marks)**

b. The inside temperature of a furnace wall with k = 1.35 N/m.K, 200 mm thick is 1400°C. The heat transfer coefficient at the outside surface is a function of temperature difference and is given by $(h = 7.85 + 0.08\Delta T)$ $W/m^2.K$. where ΔT is the temperature difference between outside wall surface and surroundings. Determine the rate of heat transfer per unit area, if the surrounding temperature is 40°C. **(08 Marks)**

c. The temperature distribution across a wall, 1 m thick at a certain instant of time is given as $T(x) = 900 - 300x - 50x^2$, where T is in degree Celsius and x in metre. The uniform heat generation of 1000 W/m^3 is present in wall of area 10 m^2 having the properties $\rho = 1600$ kg/m^3, k = 40 W/m.K and C = 4 kJ/kg.K. Determine

(i) The rate of heat transfer entering the wall at x = 0 and leaving the wall at x = 1 m.
(ii) The rate of change of internal energy of the wall
(iii) The time rate of temperature change at x = 0, 0.5 m. **(08 Marks)**

2 a. Define fin effectiveness. When the use of fins is not justified? **(03 Marks)**

b. A plane wall k = 45 W/m.K 10 cm thick, generated at a uniform rate of 8×10^6 W/m^3. The two sides of the wall are maintained at 180°C and 120°C. Neglect end effects, calculate

(i) Temperature distribution across the plate.
(ii) Position and magnitude of maximum temperature.
(iii) The heat flow rate from each surface of the plate. **(09 Marks)**

c. A very long rod, 25 mm in diameter, has one end maintained at 100°C. The surface of the rod is exposed to ambient air at 25°C with convection coefficient of 10 W/m^2.K. What are the heat losses from the rods, constructed of pure copper with K = 398 W/mK and stainless steel with K = 14 W/m.K ? Also, estimate how long the rods must be to be considered infinite. **(08 Marks)**

3 a. Define Biot number and Fourier number. **(03 Marks)**

b. An aluminium wire, 1 mm in diameter at 200°C is suddenly exposed to an environment at 30°C with h = 85.5 W/m^2K. Estimate the time required to cool the wire to 90°C. If the same wire to place in air stream (h = 11.65 W/m^2K), what would be time required to reach it to 90°C. Assume thermophysical properties C = 900 J/kg.K, ρ = 2700 kg/m^3, k = 204 W/m.K. **(09 Marks)**

c. A long cylindrical shaft 20 cm in diameter is made of steel k = 14.9 W/m.k, ρ = 7900 kg/m^3, C = 477 J/kg.K and $\alpha = 3.95\times10^{-6}$ m^2/s. It comes out an oven at a uniform temperature of 600°C. The shaft is then allowed to cool slowly in an environment at 200°C with an average heat transfer coefficient of 80 W/m^2 K. Calculate the temperature at the centre of the shaft, 45 min after the start of cooling process. Also calculate the heat transferred per unit length of the shaft during this period. **(08 Marks)**

4 a. Explain velocity and thermal boundary layer. **(04 Marks)**

b. A fan provides air speed upto 50 m/s is used in low speed wind tunnel with atmospheric air at 27°C. If this wind tunnel is used to study the boundary layer behavior over a flat plate upto $R_e = 10^8$. What should be the minimum plate length? At what distance from the leading edge would transition occur, if critical Reynolds number $R_{e_{cr}} = 5\times10^5$? **(08 Marks)**

c. Calculate the approximate Reynolds numbers and state if the flow is laminar or turbulent for the following:

(i) A 10 m long yatch sailing at 13 km/h in sea water, $\rho = 1000\ kg/m^3$ and $\mu = 1.3\times10^{-3}$ kg/m.S.

(ii) A compressor disc of radius 0.3 m rotating at 15000 rpm in air at 5 bar and 400°C and $\mu = \dfrac{1.46\times10^{-6}T^{\frac{3}{2}}}{(110+T)}\ kg/m.S$ **(08 Marks)**

PART – B

5 a. Define Grashof number and Stanton number. **(04 Marks)**

b. Air at 27°C and 1 atmosphere pressure flows over a heated plate with a velocity of 2 m/s. The plate is at uniform temperature of 60°C. Calculate the heat transfer rate from first 0.2 m of the plate. **(08 Marks)**

c. Air at velocity of 3 m/s and at 20°C flows over a flat plate along its length. The length, width and thickness of the plate are 100 cm, 50 cm and 2 cm respectively. The top surface of the plate is maintained at 100°C. Calculate the heat lost by the plate and temperature of bottom surface of the plate for the steady state conditions. The thermal conductivity of the plate may taken as 23 W/mK. **(08 Marks)**

6 a. Classify heat exchange in three broad classes. **(04 Marks)**

b. Hot engine oil is to be cooled in a double pipe counter flow heat exchanger. The copper tube has a diameter of 2 cm with negligible thickness. The inner diameter of outer tube is 3 cm. The water flow through the inner tube at a rate of 0.5 kg/s and oil flows through the annular space at a rate of 0.8 kg/s. Taking the average temperature of water and oil as 47°C and 80°C respectively. Assume fully developed flow, calculate overall heat transfer coefficient of flow conditions of the heat exchanger. **(12 Marks)**

c. Calculate the overall heat transfer coefficient based on outer surface of a steel pipe K = 54 W/mK with inner and outer diameters as 25 mm and 35 mm respectively. The inside and outside heat transfer coefficients are 1200 W/m^2K and 2000 W/m^2K respectively. **(04 Marks)**

7 a. Discuss modes of condensation. **(04 Marks)**

b. Saturated steam at 90°C and 70 kPa is condensed on outer surface of a 1.5 m long, 2.5 m diameter vertical tube maintained at uniform temperature of 70°C. Assuming film wise condensation, calculate the heat transfer rate on the tube surface. **(08 Marks)**

c. A tube 13 mm in outer diameter and 1.5 m long is used to condense the steam at 40 kPa $(T_{sat} = 76^0C)$. Calculate the heat transfer coefficient for this tube in : (a) horizontal position (b) vertical position. Take average tube wall temperature as 52°C. **(08 Marks)**

8 a. State and explain Kirchoff's law of radiation. **(02 Marks)**

b. A pipe carrying steam runs in a large room and exposed to air at 30°C. The pipe surface temperature is 200°C. Diameter of the pipe is 20 cm. If the total heat loss per metre length of the pipe is 1.9193 kW/m, determine the emissivity to the pipe surface. **(08 Marks)**

c. In an isothermal enclosure at uniform temperature two small surfaces A and B are placed . The irradiation to the surface by the enclosure is 6200 W/m^2. The absorption rates by the surfaces A and B are 5500 W/m^2 and 620 W/m^2. When steady state is established, calculate the following:

(i) What are the heat fluxes to each surface? What are their temperatures?
(ii) Absorptivity of both surfaces.
(iii) Emissive power of each surface
(iv) Emissivity of each surface. **(10 Marks)**

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10ME63

Sixth Semester B.E. Degree Examination, June / July 2013
Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

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

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 - A

1 a. Write down 3 – dimensional conduction equation in Cartesian coordinates. Explain the meaning of each term. **(06 Marks)**

b. What do you mean by initial conditions and boundary conditions of I, II & III kind? **(06 Marks)**

c. A composite wall consists of 10cm layer of building brick (0.7W/m^{0}C) and 3cm plaster (0.5W/m^{0}C). An insulating material of K = 0.08 W/m^{0}C is to be added to reduce the heat transfer through the wall by 70%. Determine the thickness of insulating layer. **(08 Marks)**

2 a. Obtain an expression for heat transfer through a plane wall in which thermal conductivity is given by $K = K_0(1+\alpha T)$, where α is constant, K_0 thermal conductivity at reference temperature T is the temperature. **(06 Marks)**

b. Derive an expression for critical thickness of insulation for a cylinder. **(06 Marks)**

c. A wire of 8mm diameter at a temperature of 60^{0}C is to be insulated by a material having K = 0.174W/m ^{0}C. Heat transfer coefficient h_a = 8W/m^{2}K and ambient temperature T_a = 25^{0}C. For max heat loss find the minimum thickness of insulation. Find increase in heat dissipation due to insulation. **(08 Marks)**

3 a. Obtain an expression for instantaneous heat transfer and total heat transfer for lumped heat analysis treatment heat conduction problems. **(08 Marks)**

b. Explain physical significance of Biot and Fourier numbers. **(06 Marks)**

c. A household electric Iron (ρ = 2700 kg/m^3, C_p = 0.896 kJ/kg K and K = 200W/m^{0}C) and weighs 1.5 kg. The total area of iron is 0.06m^2 and it is heated with 500W heating element. Initially the iron is at 25^{0}C (ambient Tempr). How long it takes for the iron to reach 110^{0}C. Take h_a = 15W/m^{2}K. **(06 Marks)**

4 a. Define Hydrodynamic and thermal Boundary layer incase of flow over a flat plate. **(06 Marks)**

b. An appropriate expression for temperature profile in thermal boundary layer is given by :

$$\frac{T_{(x,y)}-T_w}{T_\infty-T_w}=\frac{3}{2}\frac{y}{\delta_t(x)}-\frac{1}{2}\left(\frac{y}{\delta_t(x)}\right)^3,\ \text{where}\ \delta_{t(x)}=4.53\frac{x}{R_{ex}^{1/2}\,P_{\gamma}^{1/3}}.$$

Develop an expression for local heat transfer coefficient $h_{(x)}$. **(06 Marks)**

c. A vertical pipe 15cm OD, 1m long has a surface temperature of 90^{0}C. If the surrounding air is at 30^{0}C. What is the rate of heat loss by free convection? **(08 Marks)**

PART - B

5 a. Using dimensional analysis, obtain a relation between N_u, R_e and P_r for forced convection heat transfer. **(10 Marks)**

b. Air flows over a flat plate at 30^{0}C, 0.4m, 0.75m long with a velocity of 20m/s. Determine the heat transfer from the surface of plate assuming plate is maintained at 90^{0}C. Use

$Nu_L = 0.664\, R_e^{0.5}\, Pr^{0.33}$ for laminar

$= [0.036\, R_e^{0.8} - 836]P_r^{0.333}$. **(10 Marks)**

6 a. Derive an expression for effectiveness of parallel flow heat exchanger. **(08 Marks)**
b. Under what conditions LMTD and effectiveness methods are used in the design of heat exchanger. **(02 Marks)**
c. Oil at 100^0C (C_P = 3.6kJ/kg K) flows at a rate of 30,000 kg/hr and enters a parallel flow heat exchanger. Cooling water (C_P = 4.2kJ/kg K) enters heat exchanger at 10^0C at the rate of 50,000kg /hr. The heat transfer area is $10m^2$ and u = $1000W/m^2K$. Calculate outlet temperature of oil and water. **(10 Marks)**

7 a. With neat sketch, explain the regions of pool boilding. **(08 Marks)**
b. State and explain Fick's law of diffusion. **(04 Marks)**
c. Dry saturated steam at atmospheric pressure condenses on a vertical tube of diameter 5cm and length 1.5m. If the surface is maintained at 80^0C, determine the heat transfer rate and the mass of steam condensed per hr. **(08 Marks)**

8 a. Define : **(08 Marks)**
i) Black body ii) Plank's law iii) Wein displacement law iv) Lambert's law.
b. Prove that emissive power of a black body in a hemispherical enclosure is π times the intensity of radiation. **(08 Marks)**
c. Calculate net heat radiated (exchange) per m^2 for two large parallel plates maintained at 800^0C and 300^0C. The emissivites of two plates are 0.3 and 0.6 respectively. **(04 Marks)**

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10ME63

Sixth Semester B.E. Degree Examination, June/July 2014
Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

Note: 1. *Answer FIVE full questions, selecting at least TWO questions from each part.*
2. *Use of heat and mass transfer data handbook is permitted.*

PART – A

1 a. What is thermal diffusivity? Explain its importance in heat conduction problems. **(04 Marks)**

b. Describe different types of boundary conditions applied to heat conduction problems. **(04 Marks)**

c. Consider a one dimensional steady state heat conduction in a plate with constant thermal conductivity in a region $0 \le x \le L$. A plate is exposed to uniform heat flux q W/m^2 at $x = 0$ and dissipates heat by convection at $x = L$ with heat transfer coefficient h in the surrounding air at T_∞. Write the mathematical formulation of this problem for the determination of one dimensional steady state temperature distribution within the wall. **(04 Marks)**

d. An industrial freezer is designed to operate with an internal air temperature of -20°C when the external air temperature is 25°C and the internal and external heat transfer coefficients are 12 $W/m^2{}^\circ C$ and 8 $W/m^2{}^\circ C$, respectively. The wall of the freezer are composite construction, comprising of an inner layer of plastic 3 mm thick with thermal conductivity of 1 W/m°C. An outer layer of stainless steel of thickness 1 mm and thermal conductivity of 16W/m°C. Sandwiched between these layers is a layer of insulation material with thermal conductivity of 0.07 W/m°C. Find the width of the insulation required to reduce the convective heat loss to 15 W/m^2. **(08 Marks)**

2 a. What is critical thickness of insulation on a small diameter wire or pipe? Explain its physical significance and derive an expression for the same. **(10 Marks)**

b. A set of aluminium fins (K = 180 W/mK) that are to be fitted to a small air compressor. The device dissipates 1 KW by convecting to the surrounding air which is at 20°C. Each fin is 100 mm long, 30 mm high and 5 mm thick. The tip of each fin may be assumed to be adiabatic and a heat transfer coefficient of 15 W/m^2K acts over the remaining surfaces. Estimate the number of fins required to ensure the base temperature does not exceed 120°C. **(10 Marks)**

3 a. What are Biot and Fourier numbers? Explain their physical significance. **(06 Marks)**

b. What are Heisler charts? Explain their significance in solving transient convection problems. **(06 Marks)**

c. The temperature of a gas stream is measured with a thermocouple. The junction may be approximated as a sphere of diameter 1 mm, K = 25 W/m°C, $\rho = 8400$ kg/m^3 and C = 0.4 kJ/kg°C. The heat transfer coefficient between the junction and the gas stream is h = 560 $W/m^2{}^\circ C$. How long will it take for the thermocouple to record 99% of the applied temperature difference? **(08 Marks)**

4 a. Establish a relation between Nusselt, Prandtl and Grashof numbers using dimensional analysis. **(08 Marks)**

b. Explain velocity and thermal boundary layers. **(06 Marks)**

c. A 30 cm long glass plate is hung vertically in the air at 27°C while its temperature is maintained at 77°C. Calculate the boundary layer thickness at the trailing edge of the plate. Take properties of air at mean temperature $K = 28.15 \times 10^{-3}$ W/mK, $\gamma = 18.41 \times 10^{-6}$ m^2/s, $P_r = 0.7$, $\beta = 3.07 \times 10^{-3}$ K^{-1}. **(06 Marks)**

PART – B

5 a. Explain the significance of: i) Reynolds number, ii) Prandtl number, iii) Nusselt number, iv) Stanton number. **(08 Marks)**

b. Atmospheric air at 275 K and free stream velocity 20 m/s flows over a flat plate of length 1.5 m long maintained at 325 K. Calculate:

i) The average heat transfer coefficient over the region where the boundary layer is laminar.

ii) Find the average heat transfer over the entire length 1.5 m of the plate.

iii) Calculate the total heat transfer rate from the plate to the air over the length of 1.5 m and width 1 m. assume transition occurs at a Reynolds number 2×10^5. Take air Properties at mean temperature of 300 K.

$K = 0.026$ W/m°C, $P_r = 0.708$, $\gamma = 16.8 \times 10^{-6}$ m^2/s, $\mu = 1.98 \times 10^{-5}$ kg/m-s. **(12 Marks)**

6 a. Derive an expression for the effectiveness of a parallel flow heat exchanger. **(10 Marks)**

b. Engine oil is to be cooled from 80°C to 50°C by using a single pass counter flow, concentric-tube heat exchanger with cooling water available at 20°C. Water flows inside a tube with an internal dia of 2.5 cm with a flow rate of 0.08 kg/s and oil flows through the annulus at a rate of 0.16 kg/s. The heat transfer coefficient for the water side and oil side are respectively 1000 W/m^2°C and 80 W/m^2°C. The fouling factors are 0.00018 m^2°C/W and 0.00018 m^2°C/W, the tube wall resistance is negligible. Calculate the tube length required. Take specific heat of water as 4180 J/kg°C and for oil, 2090 J/kg°C. **(10 Marks)**

7 a. Explain film wise and drop wise condensation. **(04 Marks)**

b. Draw the boiling curve and discuss the different regimes of boiling. **(08 Marks)**

c. Derive an expression for the total mass of water vapour diffused from a water column to the air passing over the water container. **(08 Marks)**

8 a. Explain briefly the concept of a black body. **(04 Marks)**

b. State: (i) Kirchoff's law, ii) Plank's law, iii) Wien's displacement law. **(06 Marks)**

c. Calculate the net radiant heat exchange per m^2 area for two large parallel plates at temperature of 427°C and 27°C respectively $\in$ for hot plates is 0.9 and for cold plate it is 0.6. If polished aluminum shield is placed between them, find percentage reduction in the heat transfer. Assume $\in$ for shield = 0.4. **(10 Marks)**

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10ME63

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 permitted.

PART – A

1 a. State the laws governing three basic modes of heat transfer. **(06 Marks)**

b. A furnace has a composite wall constructed of a refractory material for the inside layer and an insulating material on the outside. The total wall thickness is limited to 60 cms. The mean temperature of the gases within the furnace is 850°C, the external air temperature is 30°C and the temperature of the interface of the two materials of the furnace wall is 500°C. The thermal conductivities of refractory and insulating materials are 2 and 0.2 W/m–K respectively. The coefficients of heat transfer between the gases and refractory surface is 200 W/m^2-k and between outside surface and atmosphere is 40 W/m^2-k. Find :

i) The required thickness of each material

ii) The rate of heat loss. **(08 Marks)**

c. A small electric heating application uses 1.82 mm diameter wire with 0.71 mm think insulation. K (insulation) = 0.118 W/m-K, and h_0 = 34.1 W/m^2-k. Determine the critical thickness of insulation for this case and change in heat transfer rate if critical thickness was used. Assume the temperature difference between surface of wire and surrounding air remain unchanged. **(06 Marks)**

2 a. Derive an expression for the temperature distribution for a short fin of uniform cross section without insulated tip starting from fundamental energy balance equation. **(10 Marks)**

b. Determine the amount of heat transferred through an iron fin of thickness 5mm, height 50 mm and width 100 cms. Also determine the temperature of the centre of the fin end of the tip of fin. Assuming atmospheric temperature of 28°C. Take K = 50 W/m – K, h = 10 W/m^2 – K, Base fin temperature = 108°C. **(10 Marks)**

3 a. Explain physical significance of :

i) Biot number

ii) Fourier numbers. **(04 Marks)**

b. A steel ball of 5 cm diameter at 450°C is suddenly placed in a controlled environment of 100°C. Considering the following data, find the time required for the ball to attain a temperature of 150°C.

c_p = 450 J/kg-K, k = 35 W/m-K, h = 10 W/m^2 – K, ρ = 8000 kg/m^3. **(06 Marks)**

c. A long 15 cm diameter cylindrical shaft made of SS 314 (k = 14.9 W/m-k, ρ = 7900 kg/m^3) allowed to cool slowly in a chamber of 150°C with an average heat transfer coefficient of 85 W/m^2 – K. Determine :

i) Temperature of the centre of the shaft 25 minutes after the start of cooling process.

ii) Surface temperature at that time

iii) Heat transfer/unit length of shaft during this time period. **(10 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.

4 a. Explain the significance of following non dimensional numbers :
   i) Prandtl number
   ii) Grashoff number
   iii) Nusselt number. **(06 Marks)**

b. A steam pipe 5 cm in diameter is lagged with insulating material of 2.5 cm thick. The surface temperature is 80°C and emissivity of the insulating material surface is 0.93. Find the total heat loss from 10 m length of pipe considering the heat loss by natural convection and radiation. The temperature of the air surrounding the pipe is 20°C. Also find the overall heat transfer co-efficient. **(08 Marks)**

c. A hot plate 1 m × 0.5 m at 130°C is kept vertically in still air at 20°C. Find :
   i) heat transfer co-efficient   ii) heat lost to surroundings. **(06 Marks)**

PART – B

5 a. For flow over flat plate, discuss concepts of velocity and thermal boundary layer with sketches. **(04 Marks)**

b. Air at a free stream temperature T_∞ and velocity U_∞ flows over a flat plate maintained at a constant temperature T_w. Dimensions of the flat plate is 50 cm × 25 cm. Compare the heat transfer co-efficient when the flow direction is along 50 cm side and 25 cm side. Assume laminar flow over entire plate. **(06 Marks)**

c. Hot air at atmospheric pressure and 80°C enters an 8 m long uninsulated square duct of cross section 0.2m × 0.2 m that passes through the attic of a house at a rate at 0.15 m^3/s. The duct is observed to be nearly isothermal at 60°C. Determine the exit temperature of the air and the rate of heat loss from the duct to the attic space. **(10 Marks)**

6 a. Derive an expression for LMTD for counter flow heat exchanger. State the assumptions made. **(10 Marks)**

b. 8000 kg/hr of air at 105°C is cooled by passing it through a counter flow heat exchanger. Find the exit temperature of air if water enters at 15°C and flows at a rate of 7500 kg/hr. The heat exchanger has heat transfer area equal to 20 m^2 and the overall heat transfer co-efficient corresponding to this area is 145 W/m^2- k. Take C_p of air = 1 kJ/kg – K and that of water (C_{pw}) = 4.18 kJ/kg – K. **(10 Marks)**

7 a. With a neat diagram, explain the typical boiling curve for water at 1 atm pressure. **(08 Marks)**

b. State and explain Fick's law of diffusion. **(04 Marks)**

c. A tube of 15 mm outside diameter and 1.5 m long is used for condensing steam at 40 KPa. Calculate the average heat transfer coefficient when the tube is : i) horizontal ii) vertical and its surface temperature is mentioned at 50°C. **(08 Marks)**

8 a. Explain briefly concept of black body with an example. **(02 Marks)**

b. State and explain :
   i) Planck's law
   ii) Kirchoff's law
   iii) Wiens displacement law
   iv) Lambert's cosine law. **(08 Marks)**

c. Two parallel plates, each of 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 a temperature of 300 K and a surface emissivity of 0.9. Find the net energy exchange by radiation between them. If a 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? How the heat transfer would be altered? Neglect the convection and edge effects if any. Comment upon the significance of this exercise. **(10 Marks)**

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10ME63

Sixth Semester B.E. Degree Examination, June/July 2016
Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

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

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 – A

1 a. What do you mean by boundary condition of I^{st}, 2^{nd} and 3^{rd} kind? **(06 Marks)**

b. Derive the general three dimensional heat conduction equation in cartesian co-ordinates and state the assumptions made. **(08 Marks)**

c. A pipe with outside diameter 20 mm is covered with two insulating materials. The thickness of each insulating layer is 10 mm. The conductivity of I^{st} insulating layer is 6 times that of the 2^{nd} insulating layer. Initially insulating layer is placed in the order of 1^{st} and 2^{nd} layer. Then it is placed in the order of 2^{nd} layer and 1^{st} layer. Calculate percentage change in heat transfer and increase or decrease. Assume a length of 1 m. In both the arrangement, there is no change in temperature. **(06 Marks)**

2 a. What is physical significance of critical thickness of insulation? Derive an expression for critical thickness of insulation for a cylinder. **(06 Marks)**

b. Derive an expression for the temperature distribution for a pinfin, when the tip of the fin is insulated. **(08 Marks)**

c. Find the amount of heat transferred through an iron fin of thickness of 5 mm, height 50 mm and width 100 cm. Also determine the temperature difference at the tip of the fin assuming atmospheric temperature of 28°C and base temperature of fin = 108°C. Assume the following K = 50 W/mK, h = 10 W/m^{2}K. **(06 Marks)**

3 a. Write a note on Biot number and Fourier number. **(04 Marks)**

b. Obtain an expression for instantaneous heat transfer and total heat transfer for lumped heat analysis treatment of heat conduction problem. **(08 Marks)**

c. A hot mild steel sphere (K = 43 W/mK) having 10 mm diameter is planned to be cooled by an air flow at 25°. The convection heat transfer coefficient is 115 W/m^{2}K. Calculate the following (i) time required to cool the sphere from 600°C to 100°C (ii) Instantaneous heat transfer rate 1.5 min after the start of cooling (iii) total energy transferred from the sphere during the first 1.5 min. **(08 Marks)**

4 a. Explain the following: (i) Velocity boundary layer (ii) Thermal boundary layer. **(06 Marks)**

b. Using dimensional analysis derive an expression relating Nusselt number, Prandtl and Grashoff numbers for natural convection. **(08 Marks)**

c. Air at 20°C flows over thin plate with a velocity of 3 m/sec. The plate is 2 m long and 1 m wide. Estimate the boundary layer thickness at the trailing edge of the plate and the total drag force experienced by the plate. **(06 Marks)**

PART – B

5 a. Explain the physical significance of the following dimensionless numbers:
(i) Reynolds number (ii) Prandtl number (iii) Nusselt number
(iv) Stanton number. **(08 Marks)**

b. Air at 20°C flows past a 800 mm long plate at velocity of 45 m/sec. If the surface of the plate is maintained at 300°C. Determine (i) The heat transferred from the entire plate length to air taking into consideration both laminar and turbulent portion of the boundary layer. (ii) The percentage error if the boundary layer is assumed to be of turbulent nature from the very leading edge of the plate. Assume unit width of the plate and critical Reynolds number to be 5×10^5. **(12 Marks)**

6 a. Derive an expression for LMTD for counter flow heat exchanger and state the assumptions made. **(10 Marks)**

b. A counter flow, concentric tube heat exchanger used to cool the lubricating oil for a large industrial gas turbine engine. The flow rate of cooling water through the inner tube. (d_i = 20 mm) is 0.18 kg/sec. While the flow rate of engine oil through the outer annulus (d_0 = 40 mm) is 0.12 kg/sec. The inlet and outlet temperature of oil are 95°C and 65°C respectively. The water enters at 30°C to the exchanger. Neglecting tube wall thermal resistance, fouling factors and heat loss to the surroundings, calculate the length of the tube. **(10 Marks)**

7 a. Clearly explain the regions of pool boiling with neat sketch. **(06 Marks)**

b. State and explain Ficks law of diffusion. **(06 Marks)**

c. Air free saturated steam at 85°C and pressure of 57.8 KPa condenses on the outer surface of 225 horizontal tubes of 1.27 cm outside diameter arranged in 15×15 array. Tube surfaces are maintained at a uniform temperature of 75°C. Calculate the total condensation rate/m length of the tube bundle. **(08 Marks)**

8 a. Explain : (i) Stefan Boltzmann law. (ii) Kirchoff's law (iii) Plank's law
(iv) Wein's displacement law. (v) Radiation shield. **(10 Marks)**

b. Calculate the net radient heat exchange per m^2 area for two large parallel plates at temperatures of 427°C and 27°C respectively. Take emissivity of the hot plate and cold plates are 0.9 and 0.16 respectively. If the polished aluminium shield is placed between them, find the percentage reduction in the heat transfer. Take emissivity of shield as 0.4. **(10 Marks)**

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10ME63

Sixth Semester B.E. Degree Examination, June/July 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. *Use of Heat transfer data hand book is permitted.*

PART – A

1 a. Explain the three types of boundary conditions used in conduction heat transfer. **(06 Marks)**

b. Derive general three dimensional conduction equation in Cartesian co-ordinate. **(08 Marks)**

c. A furnace wall is made up of three layers of thickness 250 mm, 100 mm and 150 mm with thermal conductivities of 1.65 K and 9.2 W/m°C respectively. The inside is exposed to gases at 1250°C with a convection co-efficient of 25 W/m^2°C and the inside surface is at 1100°C, the outside surface is exposed to air at 25°C with convection co-efficient of 12 W/m^2°C. Determine

(i) The unknown thermal conductivity K

(ii) The overall heat transfer co-efficient. **(06 Marks)**

2 a. Define critical thickness of insulation and explain its significance. **(04 Marks)**

b. Obtain an expression for temperature distribution and heat flow through a rectangular fin, when the end of the fin is insulated. **(08 Marks)**

c. A steel rod (K = 30 W/mK) 1 cms diameter and 5 cms long with insulation end is to be used as a spine. It is exposed to the surrounding temperature of 65°C and heat transfer co-efficient of 50 W/m^2K. The temperature of the base is 98°C. Determine (i) Fin efficiency (ii) Temperature at the end of spine (iii) Heat dissipation from spine. **(08 Marks)**

3 a. Explain the physical significance of Biot number and Fourier number. **(04 Marks)**

b. Derive an expression for temperature distribution in a lumped system. **(08 Marks)**

c. A steel ball 5 cms diameter and initially at 900°C is placed in still air at 30°C. Find

(i) Temperature of the ball after 30 seconds.

(ii) The rate of cooling in (°C/min) after 30 seconds.

Assume h = 20 W/m^2°C

K(steel) = 40 W/m°C

ρ(steel) = 7800 kg/m^3

C_p(steel) = 460 J/kg°C **(08 Marks)**

4 a. Explain briefly with sketches:

(i) Boundary layer thickness (ii) Thermal boundary layer thickness **(08 Marks)**

b. Explain the significance of Grashoff number. **(02 Marks)**

c. The water in a tank at 20°C is heated by passing the steam through a pipe of 50 cms long and 5 cms dia. If the pipe surface temperature is maintained at 80°C (i) find the heat loss from the pipe per hour if the pipe is kept horizontal (ii) If the pipe is kept vertical, then also find out the heat loss from the pipe per hour. **(10 Marks)**

PART – B

5 a. Obtain an empirical expression in terms of dimensionless numbers for heat transfer co-efficient in the case of forced convection heat transfer. (08 Marks)

b. Explain the significance of Nusselt number. (02 Marks)

c. A tube 5 m long is maintained at 100°C by steam jacketing. A fluid flows through the tube at the rate of 175 kg/hr at 30°C. The dia of the tube is 2 cms. Find out the average heat transfer co-efficient.

Take the following properties of the fluid :

$\rho = 850\ kg/m^3$

$C_p = 2000\ J/kg°C$

$\gamma = 5.1\times10^{-6}\ m^2/S$

$K = 0.2\ W/m°C$ (10 Marks)

6 a. Obtain an expression for the effectiveness of parallel flow heat exchanger by NTu method. (10 Marks)

b. The velocity of water flowing through a tube of 2.2 cms dia is 2 m/s. Steam condensity at 150°C on the outside surface of the tube heats the water from 15°C to 60°C over the length of the tube. Find the heat transfer co-efficient and the length of the tube neglecting the tube and steam side film resistance. Take the following properties of water at mean temperature $\rho = 990\ kg/m^3$; $K = 0.5418\ W/m°C$; $C_p = 4.2\ kJ/kg°C$; $\mu = 700\times10^{-6}\ kg/m.S$ (10 Marks)

7 a. State and explain the Fick's law of diffusion. (04 Marks)

b. Distinguish between the nucleate boiling and film boiling. (06 Marks)

c. Steam at 0.065 bar condenses on a vertical plate of 0.6 m square. If the surface temperature of the plate is maintained at 15°C. estimate the rate of condensation, $T_S = 37.7°C$.

hfg (at 0.065 bar) $= 2412\times10^3$ J/kg

The properties of water at mean temperature 26.4°C are listed below.

$\rho = 1000\ kg/m^3$;

$K = 0.913\ W/mK$;

$\mu = 864\times10^{-6}\ kg/m.S$ (10 Marks)

8 a. State and prove the Kirchoff's law of radiation. (06 Marks)

b. Explain the following terms:

(i) Black body and gray body.

(ii) Radiosity and irradiation (04 Marks)

c. The concentric spheres 20 cms and 30 cms in diameter are used to store liquid O_2 (-153°C) in a room at 300 K. The space between the spheres is evacuated. The surfaces of the spheres are highly polished as $\epsilon = 0.04$. Find the rate of evaporation of liquid air per hour. (10 Marks)

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10ME63

Sixth Semester B.E. Degree Examination, Dec.2013/Jan.2014
Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

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

PART – A

1 a. Explain briefly the mechanism of conduction, convection and radiation heat transfer. **(06 Marks)**

b. With sketches, write down the mathematical representation of three commonly used different types of boundary conditions for one dimensional heat equation in rectangular coordinates. **(08 Marks)**

c. A plate of thickness 'L' whose one side is insulated and the other side is maintained at a temperature T_1 is exchanging heat by convection to the surrounding area at a temperature T_2, with atmospheric air being the outside medium. Write mathematical formulation for one dimensional, steady state heat transfer, without heat generation. **(06 Marks)**

2 a. An electric cable of 10mm diameter is to be laid in atmosphere at 20°C. The estimated surface temperature of the cable due to heat generation is 65°C. Find the maximum percentage increase in heat dissipation, when the wire is insulated with rubber having K = 0.155 W/mK. Take h = 8.5 W/m²K. **(06 Marks)**

b. Differentiate between the effectiveness and efficiency of fins. **(04 Marks)**

c. In order to reduce the thermal resistance at the surface of a vertical plane wall (50 × 50cm), 100 pin fins (1 cm diameter, 10cm long) are attached. If the pin fins are made of copper having a thermal conductivity of 300 W/mK and the value of the surface heat transfer coefficient is 15 W/m²K. Calculate the decrease in the thermal resistance. Also calculate the consequent increase in heat transfer rate from the wall if it is maintained at a temperature of 200°C and the surroundings are at 30°C. **(10 Marks)**

3 a. Show that the temperature distribution in a body during Newtonian heating or cooling is given by $\frac{T - T_a}{T_i - T_a} = \frac{\theta}{\theta_i} = \text{Exp}\left(\frac{-hA_s t}{\rho C V}\right)$. **(06 Marks)**

b. The steel ball bearings (K = 50 W/mK, α = 1.3 × 10⁻⁵ m²/sec), 40mm in diameter are heated to a temperature of 650°C. It is then quenched in a oil bath at 50°C, where the heat transfer coefficient is estimated to be 300 W/m²K. Calculate:

i) The time required for bearings to reach 200°C.
ii) The total amount of heat removed from a bearing during this time and
iii) The instantaneous heat transfer rate from the bearings, when they are first immersed in oil bath and when they reach 200°C. **(14 Marks)**

4 a. With reference to fluid flow over a flat plate, discuss the concept of velocity boundary and thermal boundary layer, with necessary sketches. **(05 Marks)**

b. The exact expression for local Nusselt number for the laminar flow along a surface is given by $Nu_x = \frac{h_x x}{k} = 0.332\ R_{ex}^{1/2}\ P_r^{1/3}$. Show that the average heat transfer coefficient from x = 0 to x = L over the length 'L' of the surface is given by $2h_L$ where h_L is the local heat transfer coefficient at x = L. **(05 Marks)**

c. A vertical plate 15cm high and 10cm wide is maintained at 140°C. Calculate the maximum heat dissipation rate from both the sides of the plates to air at 20°C. The radiation heat transfer coefficient is 9.0 W/m^{2}K. For air at 80°C, take r = 21.09 × 10^{-6} m^2/sec, P_r = 0.692, k_f = 0.03 W/mK. **(10 Marks)**

PART – B

5 a. Explain the physical significance of i) Nusselt number; ii) Groshoff number. **(04 Marks)**

b. Air at 2 atm and 200°C is heated as it flows at a velocity of 12 m/sec through a tube with a diameter of 3cm. A constant heat flux condition is maintained at the wall and the wall temperature is 20°C above the air temperature all along the length of the tube. Calculate:

i) The heat transfer per unit length of tube.

ii) The increase in bulk temperature of air over a 4m length of the tube.

Take the following properties for air Pr = 0.681, μ = 2.57 × 10^{-5} kg/ms, K = 0.0386 W/mK and C_p = 1.025 kJ/kg K. **(10 Marks)**

c. Obtain a relationship between drag coefficient, c_m and heat transfer coefficient, h_m for the flow over a flat plate. **(06 Marks)**

6 a. Derive an expression for LMTD of a counter flow heat exchanger. State the assumptions made. **(08 Marks)**

b. What is meant by the term fouling factor? How do you determine it? **(04 Marks)**

c. Engine oil is to be coded from 80°C to 50°C by using a single pass counter flow, concentric tube heat exchanger with cooling water available at 20°C. Water flows inside a tube with inner diameter of 2.5cm and at a rate of 0.08 kg/sec and oil flows through the annulus at the rate of 0.16 kg/sec. The heat transfer coefficient for the water side and oil side are respectively h_w = 1000 W/m^2°C and h_{oil} = 80 W/m^2°C. The fouling factors is F_w = 0.00018m^2°C/W on both the sides and the tube wall resistance is negligible. Calculate the tube length required. **(08 Marks)**

7 a. Sketch a pool boiling curve for water and explain briefly the various regimes in boiling heat transfer. **(06 Marks)**

b. Define mass transfer coefficient. **(02 Marks)**

c. A 12cm outside diameter and 2m long tube is used in a big condenser to condense the steam at 0.4 bar. Estimate the unit surface conductance i) in vertical position; ii) in horizontal position. Also find the amount of condensate formed per hour in both the cases.

The saturation temperature of the steam = 74.5°C.

Average wall temperature = 50°C.

The properties of water film at average temperature of $\frac{75.4+50}{2} = 62.7°C$ are given below

ρ = 982.2 kg/m^3, h_{f_g} = 2480 kJ/kg, K = 0.65 W/mK, μ = 0.47 × 10^{-3} kg/ms. **(12 Marks)**

8 a. State and prove Wiens displacement law of radiation. **(06 Marks)**

b. The temperature of a black surface 0.2m^2 in area is 540°C. Calculate:

i) The total rate of energy emission.

ii) The intensity of normal radiation.

iii) The wavelength of maximum monochromatic emissive power. **(06 Marks)**

c. Derive an expression for a radiation shape factor and show that it is a function of geometry only. **(08 Marks)**

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10ME63

Sixth Semester B.E. Degree Examination, Dec.2014/Jan.2015
Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

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

PART – A

1 a. State the laws governing three basic modes of heat transfer. (06 Marks)

b. Write the 3-D heat conduction equation in Cartesian co-ordinate system. Explain the terms involved. (04 Marks)

c. A furnace has a composite wall constructed of a refractory material for the inside layer and an insulating material on the outside. The total wall thickness is limited to 60 cm. The mean temperature of the gases within the furnace is 850°C, the external ambient temperature is 30°C and the interface temperature is 500°C. The thermal conductivities of refractory and insulating materials are 2 W/m – K and 0.2 W/m – K. The combined co-efficient of heat transfer by convection and radiation between gases and the refractory surface is 200 W/m^2–K and between outside surface and atmosphere is 40 W/m^2–K. Find :
i) The required thickness of each material,
ii) The rate of heat loss to atmosphere is kW/m^2.
iii) The temperatures of the external and internal surfaces. (10 Marks)

2 a. Derive an expression for critical thickness of insulation for a cylinder. Discuss the design aspects for providing insulation scheme for cable wires and steam pipes. (10 Marks)

b. Find the amount of heat transferred through an iron fin of thickness of 5 mm, height 50 mm and width 100 cm. Also determine the temperature difference 'θ' at the tip of fin assuming atmospheric temperature of 28°C and base temperature of fin to be 108°C. Take $K_{fin} = 50$ W/m-K, h = 10 W/m^2-K. (10 Marks)

3 a. Define Biot number and explain its significance. (02 Marks)

b. Derive an expression for the instantaneous and total heat flow in terms of the product of Biot number and Fourier number is one dimensional transient heat conduction. (08 Marks)

c. Aluminium rod of 5 cm diameter and 1 metre long at 200°C is suddenly exposed to a convective environment at 70°C. Calculate the temperature of a radius of 1 cm and heat lost per metre length of the rod 1 minute after the cylinder is exposed to the environment – properties of Al $\rho = 2700$ kg/m³, $C_P = 900$ J/KG-K, K = 215 W/m-K, h = 500 W/m^2-K, $\alpha = 8.5\times10^{-5}$ m^2/S. (10 Marks)

4 a. Using dimensional analysis, derive an expression relating Nusselt number, Prandtl and Grashoff numbers for natural convection. (10 Marks)

b. A plate of length 750 mm and width 250 mm has been placed longitudinally in a stream of crude oil which flows with a velocity of 5 m/s. If the oil has a specific gravity of 0.8 and kinematic visocosity of 10^{-4} m^2/s, calculate:
i) Boundary layer thickness at the middle of plate.
ii) Shear stress at the middle of plate and
iii) Friction drag on one side of the plate. (06 Marks)

4 c. Two horizontal steam pipes having 100 mm and 300 mm are so laid in a boiler house that the mutual heat transfer may be neglected. The surface temperature of each of the steam pipes is 475°C. If the temperature of the ambient air is 35°C, calculate the ratio of heat transfer co-efficients and heat losses per metre length of the pipes. **(04 Marks)**

PART – B

5 a. Define stanton number and explain its physical significance. **(04 Marks)**

b. Prove that $\frac{N_{u_x}}{R_{e_x}.Pr} = \frac{C_{fx}}{2}$ with usual notations. **(08 Marks)**

c. Air at a temperature of 20°, flows over a flat plate at 3 m/s. The plate is $50cm \times 25cm$. Find the heat lost per hour if air flow is parallel to 50 cm side of the plate. If 25 cm side is kept parallel to the air flow, what will be the effect on heat transfer? Temperature of the plate is 100°C. **(08 Marks)**

6 a. Derive an expression for LMTD of parallel flow heat exchanger. State the assumptions made. **(10 Marks)**

b. A heat exchanger is used for cooling oil at 180°C using water available at 25°C. The mass flow rates of oil and water are 2.5 kg/s and 1.2 kg/s respectively. If the heat exchanger has 16 m^2 area available for heat transfer. Calculate the outlet temperatures of oil and water for,
i) Parallel flow and
ii) Counter flow arrangement.
Take $C_{P(oil)} = 1900 J/KG - K$, $C_{P(water)} = 4184$ J/KG – K, U = 285 W/m^2-K. **(10 Marks)**

7 a. Explain the influence of the non condensable gases in condensation process. **(04 Marks)**

b. Differentiate between the mechanism of filmwise and dropwise condensation. Explain why dropwise condensation is preferred over filmwise condensation. **(06 Marks)**

c. A metal-clad heating element of 10 mm diameter and of emissivity 0.92 is submerged in a water bath horizontally. If the surface temperature of the metal is 260°C under study boiling conditions, csalculate the power dissipation per unit length of the heater. Assume that the water is exposed to atmospheric pressure and is at uniform temperature. **(10 Marks)**

8 a. Explain briefly the concept of black body. **(04 Marks)**

b. State and explain the following laws:
i) Stefan-Boltzman law.
ii) Kirchoff's law.
iii) Planck's law.
iv) Wiens displacement law. **(08 Marks)**

c. Calculate the net radiant heat exchange per m^2 area for two large parallel planes at temperatures of 427°C and 27°C respectively. Take ∈ for hot and cold planes to be 0.9 and 0.6 respectively. If a polished aluminium shield is placed between them, find the percentage reduction in the heat transfer, given ∈ for shield = 0.04. **(08 Marks)**

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

Time: 3 hrs. Max. Marks:100

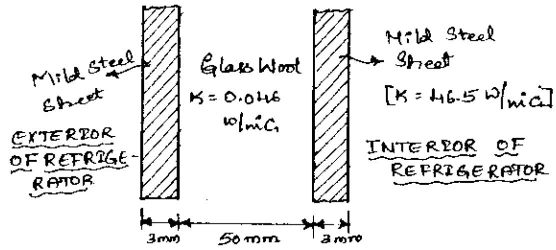
Note: 1. ***Answer any FIVE full questions, selecting atleast TWO questions from each part.***
2. ***Use of heat transfer data hand book and steam tables are permitted.***

PART - A

1 a. Derive the general 3 – D Heat conduction equation in Cartesian coordinate system and hence obtain Laplace and Poisson equations. **(10 Marks)**

b. The Interior of a Refrigerator having inside dimensions of 0.5 × 0.5m base area and 01 mtr height is to be maintained at 6^0C. The walls of the Refrigerator are constructed of 2 mild steel sheets, three (3mm) thick. [K = 46.5 W/m ^{0}C] with a 50mm of glass wool insulation [K = 0.046W/m ^{0}C] between them. If the Average Heat transfer coefficients at the inner and outer surfaces are 11.6W/m^2 ^{0}C and 14.5W/m^2 ^{0}C respectively.
Calculate : i) The rate at which the heat must be removed from the Interior to maintain the specified temperature in the kitchen at 25^0C and ii) The temperature on the outer surface of the metal sheet. **(10 Marks)**

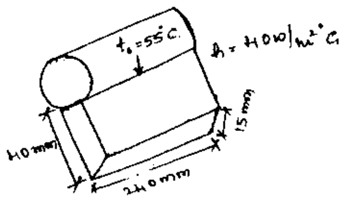
Fig.Q1(b)



2 a. Derive an expression for critical thickness of insulation for a sphere. **(08 Marks)**

b. A motor body is 360mm in diameter (OD) and 240mm long. It's surface temperature should not exceed 55^0C when dissipating 340 watts. Longitudinal fins of 15mm thickness and 40mm height are produced. The convection coefficient is 40W/m^2 ^{0}C. Determine the number of fins required. Assume, the atmospheric temperature is 30^0C for a finite fin. [Fig.Q2(a)]. **(12 Marks)**

Fig.Q2(b)



3 a. Show that the temperature distribution under Lumped analysis is given by,

$\frac{T - T_a}{T_i - T_a} = e^{-B_i F_o}$, where T_i = Initial temperature , T_a = Ambient temperature. **(10 Marks)**

b. A 15mm diameter Mild Steel Sphere (K = 42W/m ^{0}C) is exposed to cooling air flow at 20^0C resulting in the convective coefficient 'h' = 120 W/m^2 ^{0}C. Determine the following :
i) Time required to cool the sphere from 550^0C to 90^0C.
ii) Instantaneous heat transfer rate 2 minutes after start of cooling.
iii) Total energy transferred from the sphere during the first 2 minutes.
For Mild steel take : ρ = 7850 kg/m^3, C_p = 475 J/kg ^{0}C and α = 0.045 m^2/hr. **(10 Marks)**

4 a. Using Buckingham's π – theorem, obtain the relationship between various dimensionless numbers ($N_u = \phi (P_r) (G_r)$ for free convection heat transfer. **(08 Marks)**

b. Air at 20^0C and at a pressure of 1 bar is flowing over a flat plate at a velocity of 3m/sec if the plate is 280 mm wide and 56^0C. Calculate the following quantities at x = 280mm, given that the properties of air at bulk mean temperature = 38^0C are : ρ = 1.1374 kg/m^3, K = 0.02732 W/m ^{0}C , C_p = 1.005 kJ/kg ^{0}K, γ = 16.768 $\times$ 10^{-6} m^2/sec , P_r = 0.7.
i) Boundary layer thickness ii) Thickness of boundary layer iii) Local convective heat transfer coefficient iv) Average convective heat transfer coefficient v) Rate of heat transfer by convection vi) Total drag force on the plate. **(12 Marks)**

PART - B

5 a. Explain the significance of i) Reynold's number ii) Prandtl number iii) Nusselt number iv) Stanton number. **(10 Marks)**

b. A refrigerated truck is moving on a highway at 90km/hr in a desert area, where the ambient air temperature is 50^0C. The body of the truck is a rectangular box measuring 10mtr (length) $\times$ 4m(width) $\times$ 3m(height). Assume that the boundary layer on the four walls is turbulent. The heat transfer takes place only from the four surfaces and the wall surfaces of the truck is maintained at 10^0C. Neglecting heat transfer from front and back and assuming flow to be parallel to 10m long side, calculate : i) A heat lost from the four surfaces ii) The power required to overcome the resistance acting on the four surfaces.
The properties of air (at t_f = 30^0C) are: ρ = 1.165kg/m^3 , C_p = 1.005 kJ/kg ^{0}C , K = 0.02673W/m ^{0}C , γ = 16 $\times$ 10^{-6} m^2/S , P_r = 0.701. **(10 Marks)**

6 a. Derive an expression for LMTD of counter flow heat exchanger. State the assumptions made. **(10 Marks)**

b. 8000 kg/hr of air at 100^0C is cooled by passing it through a single pass cross flow heat exchanger. To what temperature is the air cooled, if water entering a 15^0C flows through the tubes unmixed at the rate of 7500 kg/hr. Take , U = 500kJ/hr – m^2 ^{0}C , A = 20m^2 , C_p of air = 1kJ/kg ^{0}C , C_p of water = 4.2 kJ/kg ^{0}C. [Fig.Q6(a)] **(10 Marks)**

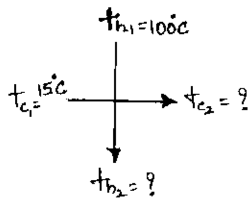


Fig.Q6(a)

7 a. Define i) Pool boiling ii) Forced convection boiling iii) Sub cooled iv) Local boiling iv) Saturated boiling. **(08 Marks)**

b. Explain Fick's law of diffusion. **(04 Marks)**

c. A vertical tube (Taking Experimental value) of 60mm OD and 1.2mtr long is exposed to steam at atmospheric pressure. The outer surface of the tube is maintained at a temperature of 50^0C by circulating cold water through the tubes. Calculate i) Rate of heat transfer to the coolant ii) The rate of condensation of steam. Assuming the condensation film is Laminor and TPP of water at 75^0C are: ρ_L = 975 kg/m^3, μ_L = 375 $\times$ 10^{-6} N-S/m^2 , K = 0.67W/m^0 C. The properties of saturated vapor t_{sat} = 100^0C , ρ_v = 0.596 kg/m^3, h_{fg} = 2257kJ/kg. **(08 Marks)**

8 a. For a Black body enclosed in a hemispherical space, show that emissive power of Black body is π times the Intensity of Radiation. **(08 Marks)**

b. State and explain i) Kirchoff's law ii) Planck's law iii) Wein's displacement law iv) Lambert's cosine law. **(08 Marks)**

c. Explain briefly the concept of a Blackbody. **(04 Marks)**

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10ME63

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

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 HMT data handbook is permitted.***

PART – A

1 a. Explain briefly the mechanism of conduction, convection and radiation heat transfer. **(03 Marks)**

b. Derive the three dimensional general heat conduction equation in Cartesian co-ordinates. **(08 Marks)**

c. The wall of a house in a cold region consists of three layers, an outer brick work 20cm thick, an inner wooden panel 1.4cm thick and an intermediate layer made of an insulating material 10cm thick. The inside and outside temperatures of the composite wall are 28^0C and -12^0C respectively. The thermal conductivity of brick and wood are 0.7W/m/K and 0.18 W/mK respectively. If the layer of insulation has a thermal conductivity of 0.023W/mK, find i) The heat loss per unit area of the wall ii) Overall heat transfer coefficient. **(09 Marks)**

2 a. Obtain an expression for temperature distribution and heat flow through a fin of uniform cross section with the end insulated. **(10 Marks)**

b. The aluminum square fins (0.6mm × 0.6mm), 12mm long are provided on the surface of a semi conductor electronic device to carry 2W of energy generated. The temperature at the surface of the device should not exceed 85^0C, when the surrounding is at 35^0C. Given K = 200 W/ m K, h = 15W/m^2 K. Determine the number of fins required to carry out the above duty. Neglect the heat loss from the end of the fin. **(10 Marks)**

3 a. Obtain an expression for instantaneous heat transfer and total heat transfer using lumped heat analysis for unsteady state heat transfer from a body to the surroundings. **(10 Marks)**

b. An Aluminum sphere weighting 6 kg and initially at a temperature of 420^0C is suddenly immersed in a fluid at 18^0C. The convective heat transfer coefficient is 45W/m^2 K. Estimate the time required to cool the sphere to 120^0C. Also find the total heat flow from the sphere to the surroundings when it cools from 300^0C to 120^0C. (For Aluminum, ρ = 2700 kg/m^3, C = 900 J/kg K , K = 200W/m K). **(10 Marks)**

4 a. Using dimensional analysis show that for free convection heat transfer $Nu = B\ Gr^a\ Pr^b$ with usual notations. **(10 Marks)**

b. A vertical plate 4m high and 6m wide is maintained at 60^0C and exposed to atmospheric air at 10^0C. Calculate the heat transfer from both sides of the plate. For air at 35^0C, take K = 0.027W/m K , $\gamma = 16.5 \times 10^{-6}$ m^2/s, Pr = 0.7. **(10 Marks)**

PART – B

5 a. Explain the significance of
i) Reynolds number ii) Prandtl number iii) Grashoff number iv) Stanton number v) Nusselt number. **(10 Marks)**

b. Water flows at a velocity of 12m/s in a straight tube of 60mm diameter. The tube surface temperature is maintained at 70^0C and the flowing water is heated from the in let temperature of 15^0C to an outlet temperature of 45^0C. Taking the physical properties of water at the mean bulk temperate of 30^0C as $\rho = 995.7 kg/m^3$, Cp = 4.174 kJ/kg K, K = 0.61718 W/m K , $\gamma = 0.805 \times 10^{-6}\ m^2/s$ and Pr = 5.42. Calculate i) heat transfer coefficient from the tube surface to the water ii) the heat transferred and iii) the length of the tube. **(10 Marks)**

6 a. Derive the expression for LMTD for a parallel flow heat exchanger. List out the assumptions made. **(10 Marks)**

b. Saturated steam at 140^0C is condensing on the outer surface of a single pass heat exchanger. The overall heat transfer coefficient is $1500 W/m^2$ K. Determine the surface area of the heat exchanger required to heat 2000 kg/h of water from 20^0C to 45^0C. Also determine the rate of condensation of steam in kg/h. Assume the latent heat of steam to be 2145 kJ/kg. **(10 Marks)**

7 a. With a neat sketch, explain the different regimes of pool boiling. **(10 Marks)**

b. Define Mass transfer coefficient. **(05 Marks)**

c. State Fick's law of diffusion. What are its limitations? **(05 Marks)**

8 a. Explain i) Stefan – Boltzman law ii) Wein's displacement law iii) Radiation shield iv) Radiosity v) Black body. **(10 Marks)**

b. Two large parallel plates having emissivity's of 0.3 and 0.6 are maintained at a temperature of 900^0C and 250^0C. A radiation shield having an emissivity of 0.05 on both sides is placed between the two plates. Calculate
i) Heat transfer without shield.
ii) Heat transfer with shield.
iii) Percentage reduction in the heat transfer due to shield.
iv) Temperature of the shield. **(10 Marks)**

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