Government College of Engineering, Amravati

(An Autonomous Institute of Government of Maharashtra)

Sixth Semester B. Tech. (Mechanical Engineering)

Summer – 2018

Course Code: MEU603

Course Name: Heat Transfer

Time: 2 Hrs. 30 Min. **Max. Marks: 60**

Instructions to Candidate

1) All questions are compulsory.
2) Assume suitable data wherever necessary and clearly state the assumptions made.
3) Diagrams/sketches should be given wherever necessary.
4) Use of logarithmic table, drawing instruments and non-programmable calculators is permitted.
5) Figures to the right indicate full marks.

1. **a** A furnace wall is made up of refractory brick, fire brick and an outside plaster. There is an air gap with a thermal resistance of 0.15 m^2 W/K between the refractory brick and the fire brick. The refractory brick, 120 mm thick, has thermal conductivity 1.58 W/m K. The fire brick, 120 mm thick, has thermal conductivity 0.3 W/m K. The outside plaster, 15 mm thick has thermal conductivity 0.15 W/m K. The two extreme temperature of this wall are 1000°C and 100°C. Determine **1.** Heat flow rate in KJ/h m^2 **2.**The interface temperature **6**

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b A plane wall of thickness 2L has an internal heat generation that varies according to $Q = Q_o \cos ax$ where Q_o is the heat generated per unit volume at the center of the wall and 'a' is a constant. If both side are maintain at constant temperature of T_s. Derive an expression for the total heat loss from the wall per unit surface area 6

2. a The handle of a ladle used for pouring molten lead at 327°C is 30 cm long. Originally the handle was made of 2.5 cm × 1.5 cm mild steel bar stock. In order to reduce grip temperature it is proposed to form a hollow handle of 1.5 mm thick mild steel tubing to the same rectangular shape. The average heat transfer coefficient over the handle surface is 14.5 W/m² °C, when the ambient air temperature is 27°C. The thermal conductivity of mild steel is 43 W/m °C. Determine the reduction in the temperature of the grip. State the assumption 6

b Stainless steel ball bearing (k = 22.2 W/m K, α = 4.85 × 10^{-6} m²/s) which have uniformly been heated to 850°C are hardened by quenching them in an oil bath that is maintained at 40°C. The ball diameter is 20 mm, and the convection coefficient associated with the oil bath is 600 W/m² K. Calculate 1.Time required for ball to reach 100°C 2. If 10000 ball are to be quenched per hour, what is the rate at which energy must be removed by the oil bath cooling system in order to maintain its temperature at 40°C 6

3. **Solve any two**

a Water is heated in an economizer from 40°C to 160°C. The tube wall is at 360°C. Determine the length of tube of 0.05 m diameter tube if flow velocity is 1 m/s. And also calculate pressure drop and power required 6

b The surface temperature of a thin flat plate located parallel to an air stream is 90°C. The free stream velocity is 60 m/s and its temperature is 0°C. The plate is 60 cm wide and 45 cm long in the direction of the air stream. Assuming critical Reynolds number of 4 × 10^5 and neglecting end effect, determine 1.Average heat transfer coefficient 2. Rate of heat transfer 6

c Derive the integral momentum equation for the thermal boundary layer over flat plate 6

4. **Solve any two**

a Explain and write its significance 6
   1. Nusselt number
   2. Prandtl number
   3. Grashof number

b Estimate the heat transfer rate from 100 W an incandescent bulb at 140°C to an ambient at 24°C. Approximate the bulb as 60 cm diameter sphere. Calculate the percentage power lost by natural convection 6

c A double pipe parallel flow heat exchanger is to be used to cool oil (0.25 kg/s at 115°C), using sea water (0.5 kg/s at 15°C). The area of heat exchanger is 11.5 m² and the overall heat transfer coefficient is 36.5 W/m² K. What are the exit states of the oil and sea water from the heat exchanger? For oil, C_p = 2131 J/kg K and for sea water, C_p = 4178 J/kg K 6

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2/2

5. **Solve any two**

a Derive an expression for effectiveness of a parallel flow heat exchanger. Show that effectiveness, **6**

$$\varepsilon = \frac{1}{2}\left(1 - e^{-2NTU}\right)$$

if the capacity rate of the hot and cold fluids are equal

b Explain shape factor and variation of spectral blackbody emissive power with wavelength **6**

c Two parallel discs 50 mm in diameter are spaced 40 cm apart with one disc located directly above the other disc. One disc is maintained at 500°C and other at 227°C. The emissivities of the disc are 0.2 and 0.4, respectively. The discs are located in a very large room whose wall maintained at 67°C. Determine the rate of heat loss by radiation from the inside surface of each disc. Take $F_{1-2} = 0.24$ **6**

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a Explain briefly 6
i. Thermal contact resistance
ii. Critical radius of insulation

b A composite slab is made of three layers 15 cm, 10 cm and 12 cm thickness. The first layer is of material with thermal conductivity 1.45 W / mK for 60% of the area and rest is of material with conductivity of 2.5 W / mK. The second layer is made of material with conductivity of 12.5 W / mK for 50% area and of material with conductivity 18.5 W / mK is used for the other 50%. The third layer is of single material of thermal conductivity 0.76 W / mK. The slab is exposed 6

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on one side to warm air at 26°C and to cold air at -20°C on the other side. The convection coefficients are 15 and 20 W / m^2K respectively. Determine the heat flow and interface temperatures.

2\. a A slab of thickness L is insulated in x = 0 plane, heat is generated at any plane as per $Q_g = Q_o(e^{-ax})$. Determine the temperature distribution, heat flow at any section and the heat flow at the surface. 6

b A wall 40 mm thick has its surfaces maintained at 0°C and 100°C. The heat generation rate is 3.25×10^5 W/ m^3. If the thermal conductivity of the material is 2 W /mK, determine the temperature at the mid plane, the location and the value of the maximum temperature and the heat flow at the either end. 6

3\. **Solve any two**

a Assuming the following velocity and temperature profiles, Derive an expression for the local heat transfer coefficient 6

i) $u = u_\infty$ for all values

ii) $T - T_\infty / T_w - T_\infty = 3/2\ (y/\ \delta t) - 1/2\ (y/\ \delta t)^3$, δt – thermal boundary layer thickness

b In the flow of liquid metal in a pipe of radius R the velocity is constant all through the section. The temperature variation at a section is parabolic and given by 6

$$T - T_s = C\,[\,1 - (\,r / R\,)^2\,]$$

Where, T_s = Wall temperature

C = Constant and r is the radius at which temperature is T. Derive the value of Nusselt number (hD/k) at this location.

c A square duct of 0.2 m side and 8 m long passes through an attic with air flowing at 80°C at a rate of 0.15 m^3/s in it. The duct surface temperature under steady conditions is 60°C. Determine the air exit temperature and the rate of heat flow out. 6

Solve any two

a Plate types of coolers are used to cool the oil in a transformer. The design specified 0.6 m high and 0.2 m wide plates. The surface temperature was 80°C and ambient temperature was 20°C. During installation, 0.2 m side was placed vertical by mistake. Determine change in convection coefficient and heat loss. 6

b Sketch and explain the flow pattern in natural convection. 6

c Derive the integral momentum equation for boundary layer over a flat plate 6

Solve any two

An economizer in a boiler has flow of water inside the pipes and hot gases on the outside flowing across the pipes. The flow rate of gases is 2000 tons/hr and the gases are cooled from 390°C to 200°C. The specific heat of the gas is 1005 J/kg K. Water is heated (under pressure) from 100°C to 220°C. Assuming an overall heat transfer coefficient of 35 W/m^2 K, determine the area required by NTU method and check the same by LMTD method. Assume that air flow is mixed. Take F = 0.8 6

b Two parallel plates each 0.5 m × 1 m are spaced 0.5 m apart. One plate is maintained at 1000°C and the other at 500°C. The emissivities of the plates are 0.2 and 0.5. The plates are located in a very large room, the walls of which are maintained at 27°C. The plate exchange heat with each other and with room, but only the plate surfaces facing each other are to be considered in the analysis. Calculate heat lost by each plate. Take $F_{12} = 0.285$ **6**

c Saturated steam at atmospheric pressure condenses on outer surface of 1 m long, 0.075 m diameter vertical tube maintained at a room temperature of 40°C. Determine **6**

i. condensate thickness at the bottom of the tube

ii. average heat transfer coefficient

iii. rate of condensation.

Government College of Engineering, Amravati
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Fifth Semester B. Tech. (Mechanical)

Summer - 2015

HT-15

Course Code: MEU603

Course Name: HEAT TRANSFER

Time: 2 Hrs. 30 Min. **Max. Marks: 60**

Instructions to Candidate

1) All questions are compulsory.
2) Assume suitable data wherever necessary and clearly state the assumptions made.
3) Diagrams/sketches should be given wherever necessary.
4) Use of logarithmic table, drawing instruments and non-programmable calculators is permitted.
5) Figures to the right indicate full marks.

1. a Show that the thermal resistance offered by hollow long cylinder of constant thermal conductivity is given by 6

$$R_{cyl} = \ln(r_2/r_1)/2\pi kL$$

b A steel pipe 3 cm in diameter has its outer surface at 200°C, is placed in air at 30°C with heat transfer coefficient of 8.5 W/m$^{2\circ}$C. It is proposed to add insulation (k = 0.07 W/m°C) on its outer surface to reduce heat loss by 40%. Estimate the thickness of insulation required if pipe temperature and heat transfer coefficient remains unchanged. 6

Solve any two

a A 10 cm thick plane wall of thermal conductivity 6

45 W/m°C has a uniform volumetric heat generation of 8×10^6 W/m^3. The temperature at one surface of the plate is 180°C and that at the other is 120°C. Determine i) value and position and position of maximum temperature, ii) flow of heat from each surface of the plate. Neglect the end effects.

b A 1 m long, 5 cm diameter, cylinder placed in atmosphere of 400°C is provided with 12 longitudinal straight fins(k = 75W/m°C), 0.75 mm thick. The fins protrude 2.5 cm from the cylinder surface. The heat transfer coefficient is 23.3 W/m^{2o}C. Calculate rate of heat transfer if surface temperature of cylinder is at 150°C 6

c In a heat treatment plant, the balls of bearing 10 mm diameter are loaded on conveyor belt. The belt passes through a furnace (inside temperature = 1000°C, with convective coefficient 200 W/m^{2o}C) along its length (L = 3m). If the ball is heated from 30°C to 250°C such that the temperature gradient should not exceed 5%, find the velocity of belt required. The thermo physical properties of steel ball are
ρ = 3000 kg/m^3, C = 500 J/KgK, k = 50 W/mK. 6

3. **Solve any two.** 6

a Explain
i)internal and external flow
ii)hydrodynamic and thermal boundary layer.

b A square duct of 0.2 m side and 8 m long passes through an attic with air flowing at 80°C, at a rate of 0.15 m^3/s in it. The duct surface temperature under steady state conditions is 60°C. Determine the air exit temperature and rate of heat flow 6

c Assuming the following velocity and temperature profile and integral energy equation derive an expression for local heat transfer coefficient. 6
i)$u=u_\infty$ for all values
ii)$T-T_\infty/T_w-T_\infty = 3/2(y/\delta t) - 1/2(y/\delta t)^3$, δt – thermal boundary layer thickness

a Discuss i)filmwise and dropwise condensation 6
ii)LMTD and fouling factor

b Air flow through a long rectangular heating duct of width and height 0.75 m and 0.3 m, respectively, maintain the outer duct surface temperature at 45°C. If the duct is insulated and exposed to air at 15°C, what is the heat loss from the duct surface per unit length? 6

Solve any two

a In an evaporator of a refrigerator, the refrigerant evaporates at -20°C over the tubes. Water flowing inside the tubes enter at 15°C and is cooled to 5°C, The cooling capacity is 5 kW. Determine the cooling rate if the water flow is increased by 25% keeping the inlet temperature to be same. 6

b Two parallel plates are at 1000K and 600K. Determine the heat exchange per unit area. i)if both surfaces are black ii)if hot surface has an emissivity of 0.5 and the cooler surface has 0.5 iii) if a large plate of an emissivity 0.2 is inserted between these two plate. 6

c Explain i)working of heat pipe 6
ii) view factor and surface resistance

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Instructions to Candidate

1) All questions are compulsory.
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5) Figures to the right indicate full marks.

1. a) Why are the heat transfer coefficients for natural convection much less than those in forced convection? **05**

OR

b) What is physical significance of Grashoff number **05**

c) A rectangular plate is 120 cm long in the direction of flow and 200 cm wide. The plate is maintained at 80^0C when placed in nitrogen that has a velocity of 2.5 m/s and a temperature of 0^0C. Determine (a) the average heat transfer coefficient and (b) the total heat transfer from the plate. The properties of nitrogen at 40^0C are $\rho = 1.142$ kg/m^3, $C_p = 1.04$ kJ/kg K , $\nu = 15.63 \times 10^{-6}$ m^2 /s and k= 0.0262 W/m K. **07**

2. a) What is the physical significance of Biot number? Is the Biot number more likely to be large for highly conducting solid or poorly conducting ones? Justify. 05

OR

b) State and explain the most widely used correlation for the Nusselt for flow across the cylinders 05

c) An electrical wire of 1 mm diameter is covered with a 2 mm thick layer of plastic insulation (k=0.5 W/m K). Air surrounding the wire is at 25^0C and h = 10 W/m^2 K. The wire temperature is 100^0C, and it is not affected by the presence of insulation. Estimate the rate of heat dissipation from the wire per unit length with and without the insulation. Find the radius of insulation when the rate of heat dissipation is maximum. What is the maximum value of this heat dissipation? 0

16

3 a) Classify the types of Heat Exchangers, What is LMTD?

OR

b) Discuss the various concepts in boiling heat transfer with the help of boiling curve.

c) Derive Wine's displacement law

4. a) Differentiate between film wise and drop wise condensation

b) Two very large parallel planes with emissivities 0.3 and 0.8 exchange radiative energy. Determination the percentage reduction in radiative energy transfers when a polished aluminum radiation shield $(\varepsilon = 0.04)$ is placed between them.

5. a) How are the heat pipes used for heat removal from Electronic equipment ?What are the merits of those devices 05

b) Derive an expression for LMTD in Counter Flow heat Exchangers 07

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