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06ME65

Sixth Semester B.E. Degree Examination, June-July 2009
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 transfer data hand book is permitted.

PART – A

1 a. Derive an expression for the temperature distribution and the rate of heat transfer for a hollow cylinder. **(10 Marks)**

b. An electrical resistance of mattress type is inserted in between two slabs of different materials on a panel heater. On one side, the material has a thermal conductivity of 0.174W/m °K and 10mm thick. On the other side of the heater the material has a thermal conductivity of 0.05W/m °K and 25mm thick. The convection heat transfer co-efficient from the thinner and thicker slabs are 23.26 and 11.63 W/m^2 °K. The temperature of the surrounding air on both the sides is 15°C. If the energy dissipation for each square meter of the mattress is 5kW, neglecting edge effects, find (i) The surface temperature of the slab. (ii) The temperature of the mattress assuming it to be the same as the inner surface of the slabs. **(10 Marks)**

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

b. A steel pipe of 220mm OD is carrying steam at 280°C. It is insulated with a material with K=0.06[1 + 0.0018T] where 'K' is in W/m °K. Thickness of insulation is 50mm and the outer surface temperature is 50°C. Determine the heat flow per 'm' length of the pipe and the temperature at the mid thickness of the pipe. **(12 Marks)**

3 a. Derive an expression for the instantaneous and total heat flow in terms of the product of Biot Number and Fourier Number in one dimensional transient heat conduction. **(08 Marks)**

b. A 5cm thick iron plate with K = 60 W/m °K, C_p = 460 J/kg °C, ρ = 7850 kg/m^3, $\alpha=1.6\times10^{-5}$ m^2/s is initially at 225°C. Suddenly both the surfaces are exposed to an environmental temperature of 25°C with a convective heat transfer co-efficient of 500W/m^2 °K. Calculate
i) the centre temperature at t = 2 min after start of cooling
ii) the temperature at a depth of 1 cm from the surface at t = 2 min after the start of cooling
iii)the energy removed from the plate per m^2 during this time. **(12 Marks)**

4 a. The exact expression for local Nusselt Number for the laminar flow along a surface is given by $N_{ux} = \frac{h_x.x}{K} = 0.332\,\text{Pr}^{1/3}\,\text{Re}_x^{\ 1/2}$. 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 value at x=L. **(08 Marks)**

b. A tube of 0.036m OD and 40cm length is maintained at a uniform temperature of 100°C. It is exposed to air at a uniform temperature of 20°C. Determine the rate of heat transfer from the surface of the tube when (i) the tube is vertical (ii) the tube is horizontal. **(12 Marks)**

PART – B

5 a. Explain the physical significance of i) Prandtl Number ii) Reynold's Number iii) Nusselt Number iv) Grashoff Number. **(08 Marks)**

b. The surface temperature of a thin plate located parallel to air stream is 90°C. The free stream velocity is 60m/s and the air temperature is 10°C. The plate is 60cmwide and 45cm long in the direction of air stream. Assuming that the transitional Reynold's number is 4×10^5, determine i) The average heat transfer co-efficient in laminar and turbulent regions ii) Rate of heat transfer for the entire plate considering both the sides of the plate. Given that the correlations for the local Nusselt Number are $0.332\ (Re_x)^{1/2}\ Pr^{1/3}$ for laminar flow and $0.028(Re_x)^{0.8}\ Pr^{1/3}$ for turbulent flow. **(12 Marks)**

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

b. A cross flow heat exchanger in which both fluids are unmixed is used to heat water with an engine oil. Water enters at 30°C and leaves at 85°C at a rate of 1.5 kg/s, while the engine oil with C_p = 2.3 kJ/kg °K enter at 120°C with a mass flow rate of 3.5 kg/s. The heat transfer surface area is 30 m^2. Calculate the overall heat transfer co-efficient by using LMTD method. **(10 Marks)**

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

b. Define i) Mass concentration
ii) Molar concentration **(04 Marks)**

c. Air free saturated steam at a temperature of 65°C (p = 25.03kPa) condenses on a vertical outer surface of a 3m long vertical tube maintained at a uniform temperature of 35°C. Assuming film condensation, calculate the average heat transfer co-efficient over the entire length of the surface. Calculate the average heat transfer co-efficient and rate of condensate flow (taking the data same as for a vertical tube) for a horizontal tube of 2.5cm outer diameter. **(10 Marks)**

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

b. Two large parallel plates with $\in$ = 0.5 each, are maintained at different temperatures and are exchanging heat only by radiation. Two equally large radiations shields with surface emissivity 0.05 are introduced in parallel to the plates. Find the percentage reduction in net radiative heat transfer. **(10 Marks)**

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06ME65

Sixth Semester BE Degree Examination, Dec.09-Jan.10
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 transfer data hand book permitted.

PART – A

1 a. State the assumptions and derive general 3 – dimensional heat conduction equation in Cartesian co-ordinates. **(08 Marks)**

b. Two bodies of thermal conductivity K_1 and K_2 are brought into thermal contact. Neglect the thermal contact resistance. Formulate this as steady – state, one – dimensional, no heat generation problem. **(04 Marks)**

c. A wall of a furnace is made up of inside layer of silica brick 120mm thick covered with a layer of magnesite brick 240 mm thick. The temperatures at the inside surface of silica brick wall and outside surface of magnesite brick wall are 725°C and 110°C respectively. The contact thermal resistance between the two walls at the interface is 0.0035°C/w per unit wall area. If thermal conductivities of silica and magnesite bricks are 1.7w/m°c and 5.8w/m°c, Calculate : i) The rate of heat loss unit area of walls and
ii) The temperature drop at the interface. **(08 Marks)**

2 a. Design critical thickness of insulation and derive an expression for critical thickness of insulation for a cylinder. **(10 Marks)**

b. A wire of 6.5 mm diameter at a temperature of 60°C is to be insulated by a material having K = 0.174 w/m°c. Convection heat transfer coefficient = 8.722 w/m^{2o}c. The ambient temperature is 20°C. For maximum heat loss, what is the minimum thickness of insulation and heat loss per metre length? Also find percentage increase in heat dissipation. **(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 conduction problems. **(06 Marks)**

c. A 12cm diameter long bar initially at a uniform temperature of 40°C is placed in a medium at 650°C with a convective coefficient of 22 w/m^{2}k. Calculate the time required for the bar to reach 255°C.
Take K = 20 w/mk, ρ = 580 kg/m^3 and c = 1050 J/kgk. **(08 Marks)**

4 a. Briefly explain:
i) Hydrodynamic boundary layer ii) Thermal boundary layer. **(06 Marks)**

b. Define:
i) Nusselt number ii) Prandtl number
iii) Stanton number iv) Grashof number. **(04 Marks)**

c. A square plate (0.5m x 0.5m) with one surface insulated and the other surface maintained at temperature of 385K is placed in ambient air at a temperature of 315K. Calculate the average heat transfer coefficient for free convection for the following orientations of the hot surface:
i) The plate is horizontal and hot surface faces up.
ii) The plate is horizontal and the hot surface faces down. **(10 Marks)**

PART – B

5 a. Using dimensional analysis, obtain the dimensionless parameters in forced convection heat transfer. **(10 Marks)**

b. Water at a velocity of 1.5 m/s enters a 2cm diameter heat exchanger tube at 40°C. The heat exchanger tube wall is maintained at a temperature of 100°C. If the water is heated to a temperature of 80°C in the heat exchanger tube, find the length of the exchanger tube required. **(10 Marks)**

6 a. Define LMTD and obtain an expression for LMTD for parallel flow heat exchanger. **(10 Marks)**

b. The flow rate of hot and cold flux streams running through a parallel flow heat exchanger are 0.2 kg/s and 0.5 kg/s respectively. The inlet temperatures on the hot and cold sides are 75°C and 20°C respectively. The exit temperature of hot water is 45°C. If the individual heat transfer coefficients on both sides are 650 w/m^2c, calculate the area of heat transfer. **(10 Marks)**

7 a. Sketch and explain boiling curve. **(06 Marks)**

b. Saturated water at T_{sat} =100°C is boiled inside a copper pan having a heating surface area $5 \times 10^{-2} m^2$ which is maintained at uniform surface temperature T_s = 110°C. Calculate :

i) The surface heat flux (q)

ii) The rate of evaporation (m). **(08 Marks)**

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

8 a. State and explain the following:

i) Stefan – Boltzman law.

ii) Kirchoff's law.

iii) Planck's law

iv) Wien's displacement law

v) Lambert's cosine law. **(10 Marks)**

b. For a black body enclosed in a hemispherical space, prove that emissive power of the black body is π times the intensity of radiation. **(10 Marks)**

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06ME65

Sixth Semester B.E. Degree Examination, May/June 2010
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 transfer data handbook is permitted.

PART – A

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

b. Derive the general three-dimensional conduction equation in Cartesian coordinates and state the assumptions made. **(08 Marks)**

c. A composite wall is made up of three layers of thicknesses 25 cm, 10 cm and 15 cm of material A, B and C respectively. The thermal conductivities of A and B are 1.7 W/mK and 9.5 W/mK respectively. The outside surface is exposed to air at 20°C with convection coefficient of 15 W/m^2K and the inside is exposed to gases at 1200°C with a convection coefficient of 28 W/m^2K and the inside surface is at 1080°C. Determine the unknown thermal conductivity of layer made up of material C. **(06 Marks)**

2 a. It is desired to increase the heat dissipation over the surface of an electronic device of spherical shape of 5mm radius exposed to convection with h = 10 W/m^2K by encasing it in a transparent spherical sheath of K = 0.04 W/mK. Determine the diameter of the sheath for maximum heat flow. For a temperature drop of 120°C from the device surface, determine the heat flow for bare and sheathed device. **(10 Marks)**

b. A rod (K = 200 W/mK) 5mm in diameter and 5cm long has its one end maintained at 100°C. The surface of the rod is exposed to ambient air at 25°C with convection heat transfer coefficient of 100 W/m^2K. Assuming other end insulated, determine
i) The temperature of the rod at 20mm distance from the end at 100°C.
ii) Heat dissipation rate from the surface of the rod and
iii) Effectiveness. **(10 Marks)**

3 a. A thermocouple junction, which may be approximated as a sphere, is to be used for temperature measurement in a gas stream. The convection coefficient between the junction surface and the gas is 400 W/m^2K and the junction thermophysical properties are K = 20 W/mK, C_p = 400 J/kgK, ρ = 8500 kg/m^3. Determine the junction diameter needed for the thermocouple to have a time constant of 1 s. If the junction is at25°C and is placed in a gas stream that is at 200°C, how long will it take for the junction to reach 199°C? **(10 Marks)**

b. A large slab of wrought iron is at a uniform temperature of 375°C. The temperature of one surface of this slab is suddenly changed to 75°C. Calculate the time required for the temperature to reach 275°C at a depth of 5 cm from the surface and the quantity of energy transferred per unit area of the surface during this period. Take K = 60 W/mK and $\alpha = 1.626\times10^{-5}\ m^2/s$. **(10 Marks)**

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

b. Air at 20°C flows over both sides of a surface of a flat plate measuring 0.2m×0.2m. The drag force was 0.075 N. Determine the velocity gradient at the surface if kinematic viscosity has a value of 15.06×10^{-6} m^2/s and density = 1.205 kg/m^3. Also determine the drag coefficient, if the free stream velocity is 40 m/s. **(07 Marks)**

c. A horizontal plate 1 m×0.8 m is kept in a water tank, with the top surface at 60°C providing heat to warm stagnant water at 20°C. Determine the value of convection coefficient. Repeat the problem for heating on bottom surface. **(08 Marks)**

PART – B

5 a. Air at 20°C and 1 atm flows over a flat plate at 35 m/s. The plate is 75 cm long and is maintained at 60°C. Assuming unit depth in the z-direction, calculate the heat transfer from the plate. **(08 Marks)**

b. Air at 2 atm and 200°C is heated as it flows through a tube with a diameter of 25 mm at a velocity of 10 m/s. Calculate the heat transfer per unit length of tube if 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. How much would the bulk temperature increase over a 3 m length of the tube? **(12 Marks)**

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

b. Water to water heat exchanger of a counter flow arrangement has heating surface area of $2m^2$. Mass flow rates of hot and cold fluids are 2000 kg/hr and 1500 kg/hr respectively. Temperatures of hot and cold fluids at inlet are 85°C and 25°C respectively. Determine the amount of heat transferred from hot to cold water and their temperatures at the exit if the overall heat transfer coefficient U = 1400 W/m^2K. **(12 Marks)**

7 a. Distinguish between the nucleate boiling and film boiling. **(06 Marks)**

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

c. A vertical plate 30cm×30cm, is exposed to steam at atmospheric pressure. The plate temperature is 98°C. Calculate the heat transfer and the mass of steam condensed per hour. **(10 Marks)**

8 a. With reference to thermal radiation, explain the following terms:
i) Black body and gray body ii) Specular and diffuse surface iii) Radiosity and irradiation. **(06 Marks)**

b. Two parallel black plates 0.5m×1m are spaced 0.5m apart. One plate is maintained at 1000°C and the other at 500°C. What is the net radiant heat exchange between the two plates? **(06 Marks)**

c. Two very large parallel planes, with emissivities 0.3 and 0.8 exchange heat. Find the percentage reduction in heat transfer when a polished aluminium radiation shield ($\in$ = 0.04) is placed between them. **(08 Marks)**

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