Reg. No.										

INTERNATIONAL CENTRE FOR APPLIED SCIENCES

(Manipal University)

IV SEMESTER B.S. DEGREE EXAMINATION – MAY 2016

SUBJECT: HEAT TRANSFER OPERATIONS (CHM 242)

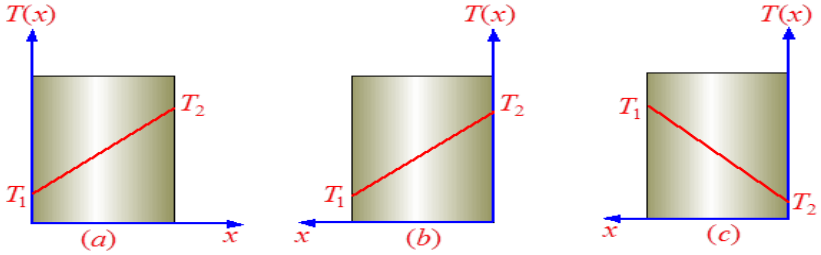
(BRANCH: CHEMICAL)

27TH MAY, 2016

Time: 3 Hours **Max. Marks: 100**

- ✓ **Answer ANY FIVE full Questions and all questions carry equal marks.**
- ✓ **Missing data, if any, may be assumed suitably.**

1A. Consider a plane wall 100mm thick and of thermal conductivity 100 W/m.K. Steady state conditions are known to exist with T_1= 400 K and T_2= 600 K . Determine the heat flux q_x'' and the temperature gradient dT/dx for the co-ordinate systems shown below:



(12 marks)

1B. Radioactive wastes are packed in a long thin walled cylindrical container. The wastes generate thermal energy non-uniformly according to the relation $\dot{q} = \dot{q}_o\left[1-\left(\frac{r}{r_o}\right)^2\right]$, where $\dot{q}$ is the local rate of energy generation per unit volume, $\dot{q}_o$ is a constant, and r_o is the radius of the container. Steady state conditions are maintained by submerging the container in a liquid that is at T_∞ and provides a uniform heat transfer coefficient. Obtain an expression for the total rate at which energy is generated in a unit length of the container. Use this result to obtain an expression for the temperature T_s of the container wall.

(8 marks)

2A. An electrically heated sphere with diameter D = 6 cm is exposed to ambient air at $T_\infty = 25°C$ providing a heat transfer coefficient of 20 W/m^2-K. The surface of the sphere is to be maintained at temperature $T_i = 125°C$. Calculate the heat loss for the following cases:

a. The bare sphere (uninsulated)
b. Sphere covered with an insulation (k = 1 W/m-K) having a radius corresponding to the critical radius of insulation for the sphere

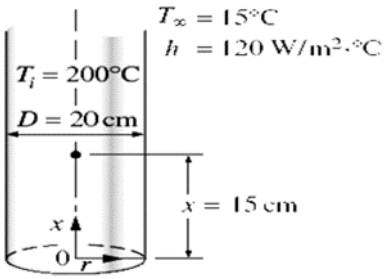
(8 marks)

2B. Stainless steel ball of diameter 3 cm is uniformly heated to a temperature of 800°C. It is to be hardened by first cooling in an oil bath to a temperature of 100°C and The heat transfer coefficient and the oil bath temperature are 700 W/m^2-K and 40°C respectively. What is the time required for this process? If 100 balls are to be quenched per minute, determine the heat removal rate from the oil

(12 marks)

bath per minute so that its temperature remains constant at 40°C. Properties of Stainless steel are: k = 61 W/m-K, ρ= 7865 kg/m^3, c_p = 0.46 kJ/kg-K.

3A. A semi-infinite aluminum cylinder of diameter D = 20 cm is initially at a uniform temperature T_i = 200°C. The cylinder is now placed in water at 15°C where heat transfer takes place by convection, with a heat transfer coefficient of 120 W/m^2.°C. Determine the temperature at the center of the cylinder 15 cm from the end surface 5 min after the start of the cooling. (k = 237 W/m.K, α = 9.71 × 10^{-6} m^2/s). **(10 marks)**



3B. Starting with the two dimensional Navier Stokes equation, listing all assumptions, and performing an order of magnitude analysis, show that for flow over a flat plate, the pressure is a function of x alone **(10 marks)**

4A. Water at a flow rate of 0.215 kg/s is cooled from 70°C to 30°C by passing it through a thin walled tube of diameter 50 mm and maintaining a coolant at $T_\infty = 15$°C in cross flow over the tube. What is the required tube length if the cooling fluid is air with a velocity of 20 m/s?

Properties: Water at 50°C

$$\rho = 988.1 kg/m^3, c_p = 4181 J/kg, \Pr = 3.55, k = 0.644 W/m-K$$

$$\nu = 0.547 \times 10^{-6} m^2/s$$

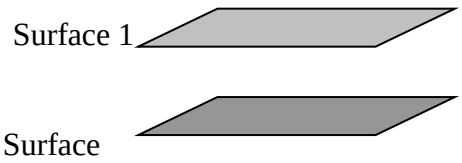
Air at 15°C **(12 marks)**

$$\rho = 1.225 kg/m^3, c_p = 1007 J/kg, \Pr = 0.7353, k = 0.02476 W/m-K$$

$$\nu = 1.47 \times 10^{-5} m^2/s$$

4B. A copper fin of diameter 4 mm and length 25 mm is used to transfer heat from a base surface at a temperature of 350 K to ambient air at 300 K by natural convection. Calculate the ratio of heat transfer rate. Assume the fin tip to be adiabatic.Properties of air over the working temperature range: $\nu = 18.41 \times 10^{-6}$ m^2/s, Pr = 0.704, k = 0.0282 W/m-K and $\beta = 0.003$ K^{-1}. Properties of copper over the working temperature range: k = 400 W/m-K. **(8 marks)**

5A. Two parallel plates 0.5 m by 1 m, spaced 0.5 m apart as shown in the figure below. One plate is maintained at 1000°C and the other plate is at 500°C. The emissivities of the plates are 0.2 and 0.5 respectively. The plates are located in a very large room whose walls are maintained at 27°C. The plates exchange heat with each other and the room, BUT only the plate surfaces facing each other need to be considered in the analysis. Find the net transfer to each plate and to the room. **(10 marks)**



5B. Cold water leading to a shower enters a thin walled double pipe counter flow heat exchanger at 0.25 kg/s at 15°C and is heated to 45°C by hot water that enters at 100°C and 3 kg/s. If the overall heat transfer coefficient is 950 W/m^2-K, determine the heat transfer rate and the area of the heat exchanger by $\varepsilon - NTU$ method. Assume specific heat of water to be 4180 J/kg-K. **(10 marks)**

6A. Explain condensation heat transfer and critical radius of insulation in detail **(12 marks)**

6B. Describe boiling point curve and different types of boiling **(8 marks)**

7A. A composite wall is composed of 1 cm thick iron (k = 60 W/m-K), 4 cm thick fibre glass (k = 0.02 W/m-K) and 0.4 cm thick asbestos sheet (k = 0.2 W/m-K). Determine the overall heat transfer coefficient. What is the heat transfer rate per unit area through the composite wall for a temperature difference of 400°C? Sketch the complete thermal circuit diagram for this problem. **(8 marks)**

7B. Water enters a 3.5 cm internal diameter thin copper tube of a heat exchanger at a rate of 0.3 kg/s, and is heated by steam condensing outside at a temperature of 110° C . If the average heat transfer coefficient is 900 W/m^2.K, determine the length of the tube required in order to heat the water to 105 ° C . **(12 marks)**

8A. Answer any FOUR of the following

(i) Natural Convection
(ii) Internal flow
(iii) Nusselt Number
(iv) Biot Number
(v) Fin Effectiveness **(5 x 4) =20 marks**