

**Sixth Semester B.E. Degree Examination, Jan./Feb. 2021**  
**Heat and Mass Transfer**

Time: 3 hrs.

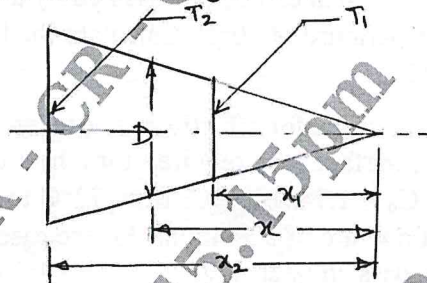
Max. Marks:100

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

**PART - A**

- 1 a. Derive the general three-dimensional conduction equation in Cartesian coordinates and mention the assumptions made. (08 Marks)  
b. What do you mean by initial and boundary conditions of the three kinds? (04 Marks)  
c. The diagram in Fig.Q.1(c) shows a conical section made of a material with  $K = 3.46 \text{ W/m.K}$ . It is of circular cross section with diameter  $D = ax$ , where  $a = 0.25$  and  $x$  is the distance measured from the apex of the cone. The smaller diameter end is at  $x_1 = 50\text{mm}$  and the larger diameter end is at  $x_2 = 250\text{mm}$  with the corresponding temperatures being  $T_1 = 400\text{K}$  and  $T_2 = 600\text{K}$ . The lateral surface of the cone is well insulated.  
i) Derive an expression for the temperature distribution  $T(x)$  assuming one dimensional steady state condition in  $x$ -direction only.  
ii) Calculate the rate of heat transfer through the cone. (08 Marks)

Fig.Q.1(c)



- 2 a. Obtain an expression for heat transfer through a plane wall in which thermal conductivity is given by  $K = K_0 [1 + \beta T]$ , where  $\beta$  is constant,  $K_0$  thermal conductivity at some reference temperature and  $T$  is the temperature. (08 Marks)  
b. An electric cable of 10mm diameter is to be laid in atmosphere at  $20^\circ\text{C}$ . The estimated surface temperature of the cable due to heat generation is  $65^\circ\text{C}$ . Find the maximum percentage increase in heat dissipation when the wire is insulated with rubber having  $K = 0.155 \text{ W/m.K}$ . Take  $h = 8.5 \text{ W/m}^2\text{K}$ . (06 Marks)  
c. One end of a long aluminum rod is connected to a wall at  $140^\circ\text{C}$ ; while the other end protrudes into a room whose air temperature is  $15^\circ\text{C}$ . The rod is 3mm in diameter and the heat transfer coefficient between the rod surface and environment is  $300 \text{ W/m}^2 \text{ }^\circ\text{C}$ . Estimate the total heat dissipated by the rod taking its thermal conductivity as  $150 \text{ W/m }^\circ\text{C}$ . (06 Marks)
- 3 a. A mild steel sphere of 15mm in diameter initially at  $625^\circ\text{C}$  is exposed to a current of air at  $25^\circ\text{C}$  with convection coefficient of  $120 \text{ W/m}^2\text{K}$ . Calculate:  
i) Time required to cool the sphere to  $100^\circ\text{C}$   
ii) Initial rate of cooling in  $^\circ\text{C/S}$   
iii) Instantaneous heat transfer rate at the end of one minute after the start of cooling  
Take properties of mild steel as  
 $K = 43 \text{ W/m.K}$        $\rho = 7850 \text{ kg/m}^3$   
 $C = 474 \text{ J/kg.K}$        $\alpha = 0.045 \text{ m}^2/\text{s}$ . (10 Marks)

- b. A large slab of wrought iron is at a uniform temperature of  $375^{\circ}\text{C}$ . The temperature of one surface of this slab is suddenly changed to  $75^{\circ}\text{C}$ . Calculate the time required for the temperature to reach  $275^{\circ}\text{C}$  at a depth of 5cm from the surface and the quantity of energy transferred per unit area of the surface during this period. Take  $K = 60\text{W/mK}$  and  $\alpha = 1.626 \times 10^{-5} \text{m}^2/\text{s}$ . (10 Marks)
- 4 a. What do you mean by hydrodynamic and thermal boundary layer? How does the ratio  $\delta/\delta_t$  vary with Prandtl number. (06 Marks)
- b. Distinguish between laminar and turbulent flow. (04 Marks)
- c. Air at  $20^{\circ}\text{C}$  and at a atmospheric pressure flows over a flat plate at a velocity of 3m/s. If the plate is 30cm length and at a temperature of  $60^{\circ}\text{C}$ , calculate:
- Velocity and thermal boundary layer thickness at 0.3m
  - Average heat transfer coefficient
  - Total drag force on the plate, per unit width
- Take the following properties of air  
 $\rho = 1.18\text{kg/cm}^3$ ,  $\nu = 17 \times 10^{-6} \text{m}^2/\text{s}$ ,  $k = 0.0272\text{W/mK}$ ,  $C_p = 1.007\text{kJ/kg K}$ ,  $P_r = 0.705$   
 (10 Marks)

**PART – B**

- 5 a. With the help of dimensional analysis, derive expression for the Reynolds number, Prandtl number and Nusselt number. (10 Marks)
- b. Assuming that a man can be represented by a cylinder 30cm in diameter and 1.7m high with a surface temperature of  $30^{\circ}\text{C}$ . Calculate the heat he would lose while standing in a 36km/h wind at  $10^{\circ}\text{C}$ . (10 Marks)
- 6 a. Derive an expression for effectiveness of parallel flow heat exchanger. (10 Marks)
- b. Calculate the surface area required for a heat exchanger which is required to cool 3200kg/hr of benzene,  $C_p = 1.74\text{kJ/kg }^{\circ}\text{C}$ , from  $72^{\circ}\text{C}$  to  $42^{\circ}\text{C}$ . The cooling water  $C_p = 4.18\text{kJ/kg }^{\circ}\text{C}$  at  $15^{\circ}\text{C}$  has a flow rate of 2200kg/hr, for the cases,
- Single pass counter flow
  - 1-4 exchange (one shell pass and 4-tube passes)
- Overall heat transfer coefficient for each configuration,  $U = 0.28 \text{ kW/m}^2 \text{ }^{\circ}\text{C}$ . (10 Marks)
- 7 a. Sketch a pool boiling curve for water and explain briefly various regimes in boiling heat transfer. (08 Marks)
- b. Write a short note on filmwise and dropwise condensation. (04 Marks)
- c. Dry saturated steam at a pressure of 2.45 bar condenses on the surface of a vertical tube of height 1m. The tube surface temperature is kept at  $117^{\circ}\text{C}$ . Estimate the thickness of condensate film and local heat transfer coefficient at a distance of 0.2m from the upper end of the tube. (08 Marks)
- 8 a. State the following laws of radiation:
- Plank's law
  - Kirchoff's law
  - Wein's displacement law
- (06 Marks)
- b. Explain the following:
- Absorptivity
  - Reflectivity
  - Transmissivity
- (06 Marks)
- c. An industrial furnace in the form of a black body emits radiation at 3000K. Calculate the following:
- Mono chromatic emissive power at  $1 \mu\text{m}$  wave length
  - Wavelength at which the emission is the maximum
  - Maximum emissive power
  - Total emissive power.
- (08 Marks)

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