

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

Time: 3 hrs.

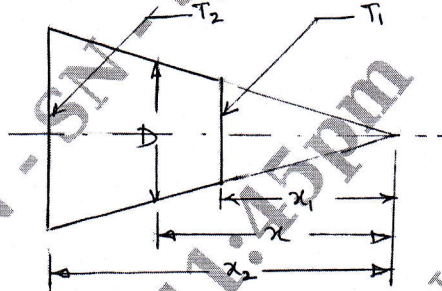
Max. Marks:100

**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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