Code : 102502

B.Tech 5th Semester Exam., 2020
(New Course)

HEAT TRANSFER

Time : 3 hours *Full Marks* : 70

Instructions :

(i) The marks are indicated in the right-hand margin.

*(ii) There are **NINE** questions in this paper.*

*(iii) Attempt **FIVE** questions in all.*

*(iv) Question No. **1** is compulsory.*

(v) Students should be allowed to use the heat transfer charts.

1. Choose the correct answer of the following (any *seven*) : 2×7=14

   (a) Which of the following is the case of heat transfer by radiation?

   (i) Blast furnace

   (ii) Heating of building

   (iii) Cooling of parts in furnace

   (iv) Heat received by a person from fireplace

   (v) All of the above

   (b) On a heat transfer surface, fins are provided to

   (i) increase temperature gradient so as to enhance heat transfer

   (ii) increase turbulence in flow for enhancing heat transfer

   (iii) increase surface area to promote the rate of heat transfer

   (iv) decrease the pressure drop of the fluid

   (c) Consider two walls, *A* and *B*, with the same surface areas and the same temp. drops across their thickness. The ratio of *K* is $K_A / K_B = 4$ and the ratio of $L_A / L_B = 2$. The ratio of heat transfer rates through the walls Q_A / Q_B is

   (i) 0·5

   (ii) 1

   (iii) 2

   (iv) 4

(d) The thermal resistance of a hollow cylinder is represented as

(i) $\dfrac{2\pi kL}{\ln\left(\dfrac{r_2}{r_1}\right)}$

(ii) $\dfrac{r_2 - r_1}{4\pi r_2 r_1 k}$

(iii) $\dfrac{\ln\left(\dfrac{r_2}{r_1}\right)}{2\pi kL}$

(iv) $\dfrac{\ln\left(\dfrac{r_2}{r_1}\right)}{2\pi r_2 r_1 kL}$

(e) The Biot number can be thought of as the ratio of

(i) the conduction to convection thermal resistance

(ii) the convection to conduction thermal resistance

(iii) the thermal energy storage capacity to conduction resistance

(iv) the thermal energy storage capacity to convection resistance

(f) The free convection heat transfer is significantly affected by

(i) Reynolds number

(ii) Grashof number

(iii) Prandtl number

(iv) Stanton number

(g) In a counterflow heat exchange, cold fluid enters at 30 °C and leaves at 50 °C, whereas the hot fluid enters at 150 °C and leaves at 130 °C. The mean temperature difference for this case is

(i) 20 °C

(ii) 80 °C

(iii) 100 °C

(iv) indeterminate

(h) What is the basic equation of radiation from which all other equations of radiation can be derived?

(i) Stefan-Boltzmann equation

(ii) Planck's equation

(iii) Wien's equation

(iv) Rayleigh-Jeans formula

(i) The hydrodynamic and thermal boundary layers are identical at Prandtl number equal to

(i) 0·5

(ii) 1

(iii) 10

(iv) 50

(j) The normal automobile radiator is a heat exchanger of the type

(i) direct contact

(ii) parallel flow

(iii) counterflow

(iv) cross-flow

2. *(a)* What are the different modes of heat transfer? How does heat conduction differ from heat convection?

(b) State the Fourier's law of heat conduction.

(c) A plane wall is a composite of two materials, *A* and *B*. The wall material *A* has uniform heat generation $q_g = 1 \cdot 5 \times 10^6 \ \mathrm{W/m^3}$, $k_A = 75 \ \mathrm{W/mK}$

and thickness $L_A = 50$ mm. The wall material *B* has no heat generation with $k_B = 150 \ \mathrm{W/mK}$ and thickness $L_B = 20$ mm. The inner surface of material *A* is well-insulated, while the outer surface of material *B* is cooled by a water stream with $T_\infty = 30\ ^\circ\mathrm{C}$ and $h = 1000 \ \mathrm{W/m^2K}$. Determine the temperature of the insulated surface and the temperature of the cooled surface. 4+2+8=14

3. *(a)* Adding insulation on a cylindrical surface will always decrease heat transfer rate— True or False. Explain.

(b) In a cylindrical fuel element for a gas-cooled nuclear reactor, the generation rate of thermal energy within the fuel element due to fission can be approximated by the relation

$$q(r) = q_0 \left[1 - \left(\frac{r}{a} \right)^2 \right] \mathrm{W/m^3}$$

where *a* is the radius of the fuel element and q_0 is constant. The boundary surface at $r = a$ is maintained at a uniform temperature T_0.

(i) Assuming one-dimensional, steady-state heat flow, develop a relation for the temperature drop from the centerline to the surface of the fuel element.

(ii) For a radius of $a = 30$ mm, the thermal conductivity $k = 10 \text{ W}/(\text{m}\,°\text{C})$ and $q_0 = 2 \times 10^7 \text{ W}/\text{m}^3$, calculate the temperature drop from the centerline to the surface. 4+10=14

4. *(a)* What is boundary condition? Mention the different types of boundary conditions.

(b) A thin fin of length L has its two ends fixed to two parallel walls at temperatures T_1 and T_2, the temperature of the environment being T_∞. Show that the expression for one-dimensional temperature distribution along the length of the fin can be represented in the Fig. 1 below :

$$\theta = \theta_1 \frac{\sinh m(L-x)}{\sinh mL} + \theta_2 \frac{\sinh mx}{\sinh mL}$$ 4+10=14

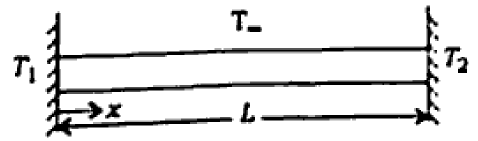

Fig. 1

5. *(a)* What are the inherent dimensionless parameters for forced convection?

(b) In the fully developed region of flow in a circular tube, will the velocity profile change in the flow direction? How about the temperature profile?

(c) Consider the velocity and temperature profiles for a fluid flow in a tube with diameter of 50 mm can be expressed as

$$u(r) = 0{\cdot}05\left[1 - \left(\frac{r}{R}\right)^2\right] \text{ and}$$

$$T(r) = 400 + 80\left(\frac{r}{R}\right)^2 - 30\left(\frac{r}{R}\right)^3$$

with units in m/s and K, respectively. Determine the average velocity and the mean temperature from the given velocity and temperature profiles.

2+4+8=14

6. *(a)* What is the physical significance of Biot number (Bi)? Represent diagrammatically the effect of Bi on steady-state temperature distribution in a plane wall with surface convection.

(b) A long cylinder of radius 150 mm and at an initial uniform temperature of 530 °C is suddenly exposed to an environment at 30 °C. The convection heat transfer coefficient between the surface of the cylinder and the environment is 380 W/m^2K. The thermal conductivity and thermal diffusivity of the cylinder material are 200 W/mK and $8{\cdot}5\times10^{-5}\ m^2/s$ respectively. Determine *(i)* the temperature at a radius of 120 mm and *(ii)* the heat transferred per meter length of the cylinder 265 seconds after the cylinder is exposed to the environment (use Heisler charts). 6+8=14

7\. *(a)* What do you mean by fully developed flow? Explain with suitable diagram.

(b) Derive the 2-D differential form of conservation of energy equation for the boundary layer of laminar, incompressible flow over a flat plate with constant fluid properties.

(c) Physically, what does the Grashof number represent? 4+8+2=14

8\. *(a)* What is fouling factor? Explain its effect in heat exchanger design.

(b) Define heat exchanger effectiveness.

(c) Derive for parallel flow heat exchanger

$$\varepsilon = \frac{1-\exp[-NTU(1+C)]}{1+C}$$

where, $C = \frac{C_{min}}{C_{max}}$, NTU=Number of transfer units.

4+2+8=14

9\. *(a)* State the Fick's law of diffusion.

(b) Determine the view factor of the cylindrical surface with respect to the base, when $L=2r$ (Fig 2). Consider $F_{12}=0{\cdot}16$.

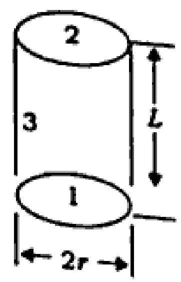

Fig.2

(c) Two infinite parallel plates are maintained at temperatures T_1 and T_2 with $T_1 > T_2$. To reduce the rate of radiation heat transfer between the plates, they are separated by a thin radiation shield which has different emissivities on opposite surfaces. One surface has an emissivity of ε_s and the other surface of $2\varepsilon_s$ where $\varepsilon_s < 0 \cdot 5$. Determine the orientation of the shield, i.e., whether the surface of ε_s or the surface of emissivity $2\varepsilon_s$ would be facing towards the plate at temperature T_1, for the larger value of the shield temperature T_s. 2+4+8=14

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