Total No. of printed pages = 4

ME 181504

06/01/2023

Roll No. of candidate | | | | | | | | | | |

2022

B.Tech. 5th Semester End-Term Examination

ME

HEAT TRANSFER – I

(New Regulation & New Syllabus)

Full Marks – 70 Time – Three hours

The figures in the margin indicate full marks for the questions.

Answer question No. 1 and any *four* from the rest.

1. Choose the correct answer : (10 × 1 = 10)

(i) Fourier's law of heat conduction gives the heat flow for
- (a) Irregular surface
- (b) Non uniform temperature surface
- (c) One dimensional cases only
- (d) Two dimensional cases only

(ii) Thermal diffusivity is a
- (a) Function of temperature
- (b) Physical property of a substance
- (c) Dimensionless parameter
- (d) All of these

(iii) Metals are good conductors of heat flow because
- (a) Their atoms collide frequently
- (b) Their atoms are relatively far apart
- (c) They contain free electron
- (d) They have high density

(iv) The ratio of surface convection resistance to the internal conduction resistance is known as
- (a) Grashoff number
- (b) Biot number
- (c) Nusselt number
- (d) Prandtl number

[Turn over

(v) The critical thickness of insulation for a sphere is

(a) k/h_0

(b) $2k/h_0$

(c) h_0/k

(d) $h_0/2k$

(vi) A composite slab has two layers of different materials with thermal conductivities k_1 and k_2. If each layer has the same thickness, then the equivalent thermal conductivity of the slab will be

(a) $k_1 k_2$

(b) $(k, + k_2)$

(c) $(k_1 + k_2)/k_1 k_2$

(d) $2 k_1 k_2/(k_1 + k_2)$

(vii) The wavelength for maximum emissive power is given by

(a) Planck's law

(b) Wein's law

(c) Kirchhoff's law

(d) Stefan Boltzman's law

(viii) For a gray surface which of the following statements is correct?

(a) Reflectivity equals emissivity

(b) Emissivity is constant

(c) Absorptivity equals reflectivity

(d) Emissivity equals transmissivity

(ix) What is the value of characteristics length for cylinder?

(a) 2R/3

(b) 3R/2

(c) R/3

(d) R/2

(x) The time constant of a thermocouple is the time taken to attain

(a) The final value to be measured

(b) 50% of the value of the initial temperature difference

(c) 62.3% of the value of the initial temperature difference

(d) 37.7% of the value of the initial temperature difference

2. (a) How does steady state heat transfer differ from transient heat conduction? (3)

(b) A furnace wall is made up of three layers of thickness 250 mm, 100 mm and 150 mm with thermal conductivities of 1.65, k and 9.2 $W/m°C$ respectively. The inside is exposed to gases at 1250°C with a convective coefficient of 25 $W/m^2°C$ and the inside surface is at 1100°C, the outside surface is exposed to air at 25°C with convection coefficient of 12 $W/m^2°C$. Determine:

(i) The unknown thermal conductivity

(ii) The overall heat transfer coefficient

(iii) All surface temperatures. (12)

3. (a) A slab of 12 cm thickness and generating heat uniformity at 10^6 W/m^2 has thermal conductivity of 200 $W/m°C$. Both surfaces of the slab are maintained at 150°C. Determine:

(i) The temperature, temperature gradients and heat flow rate at quarter planes.

(ii) Maximum temperature and its location. (8)

(b) A 3 mm diameter stainless steel wire (k = 20 W/m°C, resistivity $\rho = 10 \times 10^{-8}$ Ωm) 100 metres long has a voltage of 100 V impressed on it. The outer surface of the wire is maintained at 100°C. Calculate the centre temperature of the wire. If the heated wire is submerged in a fluid maintained at 50°C, find the heat transfer coefficient on the surface of the wire. (7)

4. (a) Explain the situation, when addition of fins to a surface is not useful. (5)

(b) Find the amount of heat transferred through an iron fin of length 50 mm, width 100 mm and thickness 5 mm. Assume k = 210 kJ/mh°C and h = 42 kJ/m²°C for the material of the fin and the temperature at the base of the fin as 80°C. Also determine the temperature at the tip of the fin, if the atmosphere temperature is 20°C. (10)

5. (a) Prove that the temperature of the body at time t during Newtonian heating and cooling is given by

$$\frac{T - T_0}{T_i - T_0} = e^{-B_i F_o}$$

Where, T_i = Initial temperature of the body

T_o = Ambient temperature

B_i = Biot number

F_o = Fourier number (7)

(b) An aluminium sphere weighing 6 kg and initially at temperature of 350°C is suddenly immersed in a fluid at 30°C with convection coefficient of 60 W/m²K. Estimate time required to cool the sphere to 100°C. Take thermo-physical properties as C = 900 J/kgK; ρ = 2700 kg/m³; k =205 W/mK. (8)

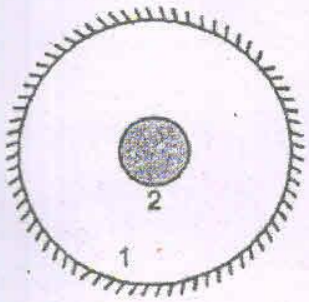
6. (a) Define the following terms. (2+2+2=6)

(i) Total emissive power

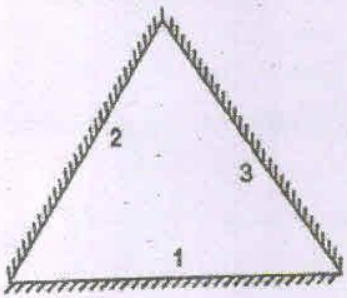
(ii) Monochromatic emissive power

(iii) Radiosity

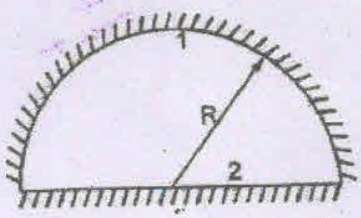
(b) Calculate the shape factor F_{11}, F_{12} and F_{21} for the following geometries. (3+3+3=9)



(i) A black body inside a black encloser



(ii) A tube section is equilateral triangle



(iii) Radiation exchange between a hemisphere and plane surface

7. (a) State and prove Kirchhoff's law of radiation. (5)

(b) Two very large parallel planes with emissivites 0.3 and 0.8 exchange heat. Find the percentage reduction in heat when a radiation shield ($\varepsilon = 0.04$) is placed between them. (10)

8. (a) Explain steady state diffusion through a plane membrane. (5)

(b) A well is 40 m deep and 9 m in diameter is exposed to atmosphere at 25°C. The air at the top has relative humidity of 50%. Calculate the rate of diffusion of water vapour through the wall. Take $D = 2.58 \times 10^{-5} m^2/s$; M_w = 18 kg/kg-mole and the saturation pressure of water vapour corresponding to 25°C is 3.169 kPa. (10)