KATHMANDU UNIVERSITY
End Semester Examination [C]
June/July 2024

Level : B.Tech.
Year : III
Time : 2 hrs. 30 mins.

0 7 JUL 2024

Course : MEEG 306
Semester : I
F.M. : 55

SECTION "B"

Attempt *ALL* questions. Assume suitable data if missing. Figures in the bracket refer to marks the question carries. **Use of a data book is allowed.**

1.

a. Consider heat conduction equation as [2]

$$\frac{d^2T}{dx^2} + \frac{d^2T}{dy^2} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

(i)Is heat transfer steady or transient?
(*ii*) Is heat transfer one-, two-, or three-dimensional?
(*iii*) Is there heat generation in the medium?
(*iv*) Is the thermal conductivity of the medium constant or variable?

b. An electric current is passed through a wire 1 mm in diameter and 10 cm long. The wire is submerged in liquid water at atmospheric pressure and the current is increased until the water boils. For this situation $h = 5000\ ^{W}/_{m^2}$ °C. And the water temperature will be100°C. How much electric power must be supplied to the wire to maintain the wire surface at 114°C? [2]

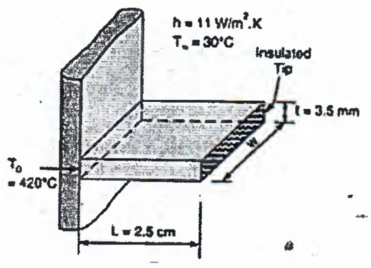
c. Consider a large plate of thickness L and thermal conductivity k in which heat is generated uniformly at a rate of $\dot{q}_{gen}$. One side of the plate is insulated while the other side is exposed to an environment at T with a heat transfer coefficient of h. (*a*) Express the differential equation and the boundary conditions for steady one-dimensional heat conduction through the plate, (*b*) determine the variation of temperature in the plate, and (*c*) obtain relations for the temperatures on both surfaces and the maximum temperature rise in the plate in terms of given parameters. [6]

d. What are various modes of heat transfer? Explain them briefly. [3]

2.

a. Steam at $T_{\infty,1}$ = 320°C flows in a cast iron pipe (k = 80 W/m·K) whose inner and outer diameters are D_1= 5 cm and D_2 = 5.5 cm, respectively. The pipe is covered with 3-cm-thick glass wool insulation with k = 0.05 W/m·K. Heat is lost to the surroundings at $T_{\infty,2}$ = 5°C by natural convection and radiation, with a combined heat transfer coefficient of h_2 = 18 W/m²·K. Taking the heat transfer coefficient inside the pipe to be h_1 = 60 W/m²·K, determine the rate of heat loss from the steam per unit length of the pipe. Also, determine the temperature drops across the pipe shell and the insulation. [5]

b. An aluminum alloy fin (k = 200 W/mK), 3.5 mm thick and 2.5 cm long protrudes from a wall. The base is at 420°C and the ambient air temperature is 30°C. The heat transfer coefficient may be taken as 11 W/m²K. Find the heat loss and fin efficiency, if the heat loss from the fin tip is negligible. [3]



P.T.O.

c. The steady-state temperature distribution in a one-dimensional wall of thermal conductivity 50 W/m K and thickness 50 mm is observed to be $T(°C) = a + bx^2$, where $a = 200°C$, $b = -2000°C/m^2$, and x is in meters. Determine the heat fluxes at the two wall faces. In what manner are these heat fluxes related to the heat generation rate? [1+1+1]

3.

a. At a particular axial station, velocity and temperature profiles for laminar flow in a parallel plate channel have the form

$$u(y) = 0.75\left[1-(y/y_0)^2\right]$$

$$T(y) = 5 + 95.66(y/y_0)^2 - 47.83(y/y_0)^4$$

Determine corresponding values of the mean velocity, u_m, and mean (or bulk) temperature, T_m. Plot the velocity and temperature distributions (by taking a few points). Do your values of u_m and T_m appear reasonable? [6]

b. Consider a 0.6-m × 0.6-m thin square plate in a room at 30°C. One side of the plate is maintained at a temperature of 90 °C, while the other side is insulated. Determine the rate of heat transfer from the plate if the plate is vertical. [4]

c. The non-dimensional fluid temperature profile near the surface of a convectively cooled flat plate is given by $\frac{T_w - T}{T_w - T_\infty} = a + b\frac{y}{L} + c\left(\frac{y}{L}\right)^2$ where y is measured perpendicular to the plate, L is the length, and a, b, c are arbitrary constants. T_w and T_∞ are wall and ambient temperatures respectively. If the thermal conductivity of the fluid is k and wall heat flux is q'' . Find the value of Nusselt number. [4]

4.

The counter flow heat exchanger has a heat transfer area A = 10m² and a corresponding overall heat transfer coefficient $U = 500\ W/m^2K$. It is used to cool 1.5 kg/s of hot oil initially at 100° C, by contact with 0.5 kg/s stream of cold water whose inlet temperature is 15° C. The c_p values of oil and water are 2.25 kJ/kg. K and 4.18 kJ/kg. K, respectively. Find the heat transfer rate and outlet temperatures. [4]

5.

A cylindrical heating element with a diameter of 1 cm and length of 30 cm is immersed horizontally in a pool of saturated water at atmospheric pressure. The cylindrical surface plated with copper. Calculate the heat flux q_w'' and the total heat transfer rate from the cylinder to the water pool q_w, when the surface temperature is T_w= 108° C. Calculate also the critical heat flux q''_{max}. Justify the values obtained with boiling regime curve. [4]

6.

a. Two black parallel plates 0.5 m by 1.0 m are spaced 0.5 m apart. One plate is maintained at 1000°C and other is maintained at 500°C. What is net radiant heat exchange between the two plates? [3]

b. For the Figure shown, determine F_{12}. [2]

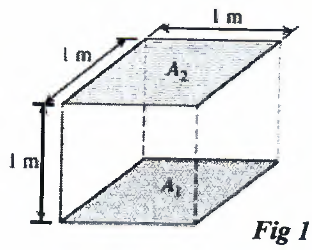


Fig 1

c. A spectral emissivity of an opaque surface at 800 K is approximated as shown in the figure below. Determine the average emissivity of the surface, maximum wavelength, and emissive power. [4]

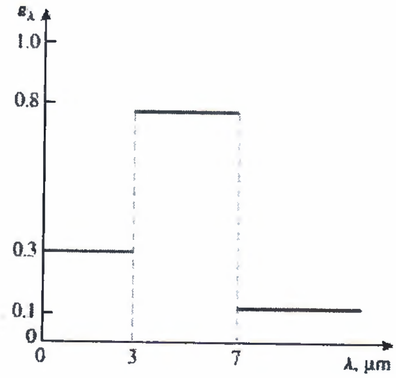


Fig 2

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Marks Scored:

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F. M. : 20

Registration No.:

Date 07 JUL 2024

SECTION "A"

[20Q. × 1 = 20 marks]

Choose and mark [X] the most appropriate option from each set of choices.

1. The two end temperatures of a slab are maintained at 100°C and 50°C in presence of a heat source. The temperature profile obtained when the heat transfer takes place is
[ ] Linear [ ] Parabolic [ ] Exponential [ ] Hyperbolic

2. The unit of thermal conductivity k and heat transfer coefficient h are ………………… respectively.
[ ] $\frac{W}{mK}$ *and* $\frac{W}{m^2K}$ [ ] $\frac{W}{m^2K}$ *and* $\frac{W}{mK}$ [ ] $\frac{W}{K}$ *and* $\frac{W}{m^2K}$ [ ] $\frac{W}{mK}$ *and* $\frac{W}{K}$

3. Critical insulation radius for a cylinder is
[ ] $r_{o,c} = \frac{k}{h}$ [ ] $r_{o,c} = \frac{2k}{h}$ [ ] $r_{o,c} = \frac{h}{k}$ [ ] $r_{o,c} = \frac{2h}{k}$

4. The temperature of the fin in case of long fin varies
[ ] Linearly [ ] Hyperbolically [ ] Exponentially [ ] Parallel

5. Consider steady one-dimensional heat conduction through a plane wall, a cylindrical shell, and a spherical shell of uniform thickness with constant thermophysical properties and no thermal energy generation. The geometry in which the variation of temperature in the direction of heat transfer will be linear
[ ] Plane wall [ ]Cylindrical shell [ ] Spherical shell [ ]All of them

6. Thermal diffusivity of a substance is
[ ] Inversely proportional to thermal conductivity
[ ] Direct proportional to thermal conductivity
[ ] Direct proportional to the square of thermal conductivity
[ ] Inversely proportional to the square of thermal conductivity

7. The Nusselt number for the flow of water at 25 ^{0}C (velocity = 2 m/s) over a hot metallic sphere (d= 5 cm) of 95 ^{0}C can be expressed as

$$Nu = 2 + \left[0.4 \times \sqrt{\mathrm{Re}} + 0.06 \times \mathrm{Re}^{\frac{2}{3}}\right] \mathrm{Pr}^{0.4} \left(\frac{\mu}{\mu_w}\right)^{0.25}$$

What will be the value of Nusselt number if the plate is placed in a stagnant pool of water at 45 ^{0}C? Where Pr = 7.86 (at 45 ^{0}C) ; $\left(\frac{\mu}{\mu_w}\right)$ = 1.15 (at 45 ^{0}C)
[ ] 2 [ ] 3.65 [ ] 3.9 [ ] none of the options

8. The transition from laminar flow to turbulent flow in a forced convection situation is determined by which one of the following dimensionless numbers?

[ ] Rayleigh number
[ ] Peclet number
[ ] Grashof number
[ ] Reynolds number

9. For flow of viscous fluid over a flat plate, if the fluid temperature is the same as the plate temperature, the thermal boundary layer is

[ ] Thinner than the velocity boundary layer
[ ] Thicker than the velocity boundary layer
[ ] Of the same thickness as the velocity boundary layer
[ ] Not formed at all

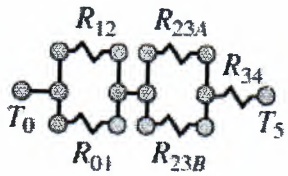
10. The temperatures at the inner and outer surfaces of a 15-cm-thick plane wall are measured to be 40°C and 28°C, respectively. The expression for steady, one-dimensional variation of temperature in the wall is

[ ] $T(x) = 28x + 40$ [ ] $T(x) = -40x + 28$ [ ] $T(x) = 40x + 28$ [ ] $T(x) = -80x + 40$

11. Two finned surfaces with long fins are identical, except that the convection heat transfer coefficient for the first finned surface is twice that of the second one. What statement below is accurate for the efficiency and effectiveness of the first finned surface relative to the second one?

[ ] Higher efficiency and higher effectiveness
[ ] Higher efficiency but lower effectiveness
[ ] Lower efficiency but higher effectiveness
[ ] Lower efficiency and lower effectiveness

12. The equivalent thermal resistance for the thermal circuit shown here is



(a) $R_{12}R_{01} + R_{23A}R_{23B} + R_{34}$

(b) $R_{12}R_{01} + \left(\dfrac{R_{23A}R_{23B}}{R_{23A} + R_{23B}}\right) + R_{34}$

(c) $\left(\dfrac{R_{12}R_{01}}{R_{12} + R_{01}}\right) + \left(\dfrac{R_{23A}R_{23B}}{R_{23A} + R_{23B}}\right) + \dfrac{1}{R_{34}}$

(d) $\left(\dfrac{R_{12}R_{01}}{R_{12} + R_{01}}\right) + \left(\dfrac{R_{23A}R_{23B}}{R_{23A} + R_{23B}}\right) + R_{34}$

[ ] a [ ] b [ ] c [ ] d

13. One can expect the heat transfer coefficient for turbulent flow to be ____________ for laminar flow

[ ] Greater than
[ ] Less than
[ ] Same as
[ ] The flow conditions must be stated to answer.

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14. Air enters a duct at 20°C at a rate of 0.08 m^3/s, and is heated to 150°C by steam condensing outside at 200°C. The error involved in the rate of heat transfer to the air due to using arithmetic mean temperature difference instead of logarithmic mean temperature difference is

[ ] 5.4% [ ] 8.1% [ ] 10.6% [ ] 13.3%

15. Internal force flows are said to be fully developed once the ____ at a cross section no longer changes in the direction of flow

[ ] Temperature distribution
[ ] Velocity distribution
[ ] The given condition is not enough to determine
[ ] Energy distribution

16. Air at 208C flows over a 4-m long and 3-m wide surface of a plate whose temperature is 808C with a velocity of 5 m/s. The length of the surface for which the flow remains laminar is (For air, use k = 0.02735 W/m.K, Pr = 0.7228, $\vartheta = 1.798\times 10^{-5}$ m^2/s)

[ ] 1.3m [ ] 1.8 m [ ] 2.2 m [ ] 3.7 m

17. When boiling a saturated liquid, one must be careful while increasing the heat flux to avoid burnout. Burnout occurs when the boiling transitions from _____ boiling.

[ ] Convection to nucleate [ ] Convection to film
[ ] Film to nucleate [ ] Nucleate to film

18. An air handler is a large unmixed heat exchanger used for comfort control in large buildings. In one such application, chilled water (cp = 4.2 kJ/kg.K) enters an air handler at 5^0C and leaves at 12^0C with a flow rate of 1000 kg/hr. This cold water cools air (cp = 1.0 kJ/kg.K) from 25^0C to 15^0C. The rate of heat transfer between the two streams is

[ ] 8.2 kW [ ] 10.2 kW [ ] 12.2 kW [ ] 12.8 kW

19. The wavelength at which the blackbody emissive power reaches its maximum value at 300 K is

[ ] 5.1 µm [ ] 9.7 µm [ ] 13.8 µm [ ] 14.6 µm

20. A hollow enclosure is formed between two infinitely long concentric cylinders of radii 1m and 2m, respectively. Radiative heat exchange takes place between the inner surface of the larger cylinder (surface-2) and the outer surface of the smaller cylinder (surface-1). The radiating surfaces are diffuse, and the medium in the enclosure is non-participating. The fraction of the thermal radiation leaving the larger surface and striking itself is __________