



[4658] – 513

Seat No.	
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T.E. (Mechanical) (Semester – I) Examination, 2014
HEAT TRANSFER
(2012 Course)

Time : 3 Hours

Max. Marks : 70

- Instructions :**
- 1) Solve Q. 1 or Q. 2, Q. 3 or Q. 4, Q. 5 or Q. 6, Q. 7 or Q. 8, Q. 9 or Q. 10.
 - 2) Draw **neat** diagrams wherever necessary.
 - 3) Use of scientific calculator is allowed.
 - 4) Assume suitable data wherever necessary.
 - 5) Figures to the right indicate full marks.

1. Derive a general three dimensional heat conduction equation in Cartesian coordinate system. Reduce it as
 - a) Poisson equation
 - b) Fourier equation and
 - c) Laplace equation.

10

OR

2. a) List two examples of heat conduction with heat generation.

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- b) A long cylindrical rod of diameter 200 mm with thermal conductivity of 0.5 W/mK experiences uniform volumetric heat generation of 24000 W/m³. The rod is encapsulated by a circular sleeve having an outer diameter of 400 mm and a thermal conductivity of 4 W/mK. The outer surface of sleeve is exposed to cross flow of air at 27°C with a convection coefficient of 25 W/m²K. Find the temperatures at the interface between the rod and sleeve and on the outer surface. What is the temperature at the centre of the rod ?

8

3. a) What do you mean by response of thermocouple ?

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- b) A thermocouple junction of spherical form is to be used to measure the temperature of a gas stream. The junction is initially at 20°C and is placed in gas stream which is at 200°C. Determine the junction diameter needed for the thermocouple to have thermal time constant of 1 second. Also calculate the time required for the thermocouple to reach temperature of 197°C. Assume thermophysical properties as

$$k = 20 \text{ W/mK}, h = 350 \text{ W/m}^2\text{K}, C = 400 \text{ J/kgK}, \rho = 8000 \text{ kg/m}^3.$$

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OR

4. a) Hot water is to be cooled as it flows through the tubes exposed to atmospheric air. Fins are to be attached in order to enhance heat transfer. Would you recommend attaching the fins inside or outside the tubes ? Why ?

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- b) A steel rod ($k= 30 \text{ W/m}^\circ\text{C}$) 1cm in diameter and 5 cm long protrudes from a wall which is maintained at 100°C. The rod is exposed to an environment with temperature 30°C and $h = 50 \text{ W/m}^2\text{K}$. Calculate fin efficiency, temperature at the tip of fin and rate of heat dissipation from the base of the fin. Assume insulated tip condition, for fin analysis.

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5. a) Define and give the significance of dimensionless numbers used in Convection. 8
- b) Liquid mercury flows at a rate of 1.6 kg/s through a copper tube of 20 mm diameter. The mercury enters the tube at 15°C and leaves at 35°C. Calculate the tube length if the tube wall temperature is 50°C. The properties of mercury at 25°C are 8
 $\rho = 13582 \text{ kg/m}^3$, $C_p = 140 \text{ J/kgK}$, $k = 8.69 \text{ W/mK}$, $\nu = 1.5 \times 10^{-7} \text{ m}^2/\text{s}$, $Pr = 0.0248$
 Use $Nu = 7 + 0.025 (RePr)^{0.8}$.
- OR
6. a) Differentiate between Biot number and Nusselt number. 4
- b) Calculate the coefficient of heat transfer by free convection and the maximum current intensity for a nichrome wire 2.5 mm in diameter with the condition that its temperature should not exceed 95°C. The wire is exposed to still air at 25°C and the resistance per metre length of the wire is 6 ohm/m. Use $Nu = 1.18 (GrPr)^{1/8}$. The properties of air at 60°C are $\nu = 18.97 \times 10^{-6} \text{ m}^2/\text{s}$, $Pr = 0.696$, $k = 0.02896 \text{ W/mK}$. 8
- c) Explain concept of thermal boundary layer. 4
7. a) What is a gray body ? How does it differ from a black body ? What is a diffuse gray surface ? 4
- b) The outlet header of a high pressure steam superheater consists of a pipe ($\epsilon = 0.8$) of diameter 27.5 cm. Its surface temperature is 500°C. Calculate the loss of heat per unit length by radiation if it is placed in a large enclosure at 30°C. If the header is now enveloped in a steel screen of diameter 32.5 cm and emissivity 0.7 and the temperature of the screen is 240°C, find the reduction in heat by radiation. 8
- c) Write the statements and mathematical expressions of the following laws in radiation heat transfer : 6
- a) Planck's law
- b) Wien's law
- c) Kirchhoff's law.
- OR
8. a) What do you mean by radiation shape factor ? List any 4 properties/ rules of radiation shape factor. 6
- b) A furnace of boiler is laid from fire clay brick with outside lagging form plate steel. The distance between the two is quite small compared with the size of the furnace. The brick setting is at an average temperature of 365 K while the steel lagging is at 290 K. Calculate radiation heat transfer per unit area. Assume $\epsilon_{brick} = 0.85$ and $\epsilon_{steel} = 0.65$. What will be the reduction in heat loss if a steel screen having an emissivity value of 0.6 on both the sides is placed between the brick and the steel setting ? Also calculate the desired emissivity of the screen if the radiation loss is to be limited to 100 W/m². 10
- c) A black body emits radiation of maximum intensity at a wavelength of 0.5 μm . Calculate its surface temperature and emissive power. 2



9. a) Draw a labeled sketch of pool boiling curve. Explain the following terms with reference to this curve :

- a) Nucleate boiling
- b) Critical heat flux.

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- b) Two fluids 'A' and 'B' exchange heat in a counter flow heat exchanger. Fluid 'A' enters at 420°C and has a mass flow rate of 1 kg/s. Fluid 'B' enters at 20°C and has a mass flow rate of 1 kg/s. The effectiveness of heat exchanger is 75%.

Determine :

- i) heat transfer rate and
- ii) the exit temperature of fluid 'B'. Specific heat of fluid 'A' is 1 kJ/kgK and that of the fluid 'B' is 4 kJ/kgK.

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- c) Define NTU and effectiveness of heat exchanger.

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OR

10. a) Establish expression for LMTD for counter flow heat exchanger.

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- b) Engine oil ($C_p = 2100 \text{ J/kg}^{\circ}\text{C}$) is to be heated from 20°C to 60°C at a rate of 0.3 kg/s in a 2 cm diameter thin walled copper tube by condensing steam outside at a temperature of 130°C ($h_{fg} = 2174 \text{ kJ/kg}$). For an overall heat transfer coefficient of $650 \text{ W/m}^2 \text{ }^{\circ}\text{C}$, determine the rate of heat transfer and the length of the tube required to achieve it.

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- c) Consider a water-to-water double-pipe heat exchanger whose flow arrangement is not known. The temperature measurements indicate that the cold water enters at 20°C and leaves at 50°C , while the hot water enters at 80°C and leaves at 45°C . Do you think this is a parallel-flow or counter-flow heat exchanger ? Justify your answer.

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