III B. Tech II Semester Regular Examinations, July -2023
HEAT TRANSFER
(Mechanical Engineering)

Time: 3 hours Max. Marks: 70

Answer any **FIVE** Questions **ONE** Question from **Each unit**
All Questions Carry Equal Marks
*****

UNIT-I

1. a) Derive the general heat conduction equation in the cartesian coordinate system. [7M]
   b) A concrete wall (k=1.4 W/m K) of 10 cm thickness is to be plastered with gypsum (k=0.48 W/m K) so that the heat losses from the wall do not exceed 500 W/m^2 when the inner and outer surfaces of the wall are at 110^{o}C and 40^{o}C, respectively. Determine the thickness of plastering to be added to the concrete wall. [7M]

(OR)

2. a) What is meant by the critical radius of insulation? Derive the relation for the critical radius of insulation of a hollow sphere. [7M]
   b) A steel plate of thickness L = 5 cm and thermal conductivity, k = 20 W/ (m^{o}C) is subjected to a uniform heat flux of 600 W/m^2 on one of its surfaces. It dissipates heat by convection with a heat transfer coefficient h = 80 W/m^{2o}C from the other surface into the ambient air at 25^{0}C. What is the temperature of the surface dissipating heat by convection? [7M]

UNIT-II

3. a) What is a lumped system? Derive an expression for the temperature variation of a body which varies with time. [7M]
   b) A thick stainless-steel slab $\alpha = 1.6x10^{-5}$m^2/s and $k = 60$ W/m C is initially at a uniform temperature of 150^{o}C. Its surface is suddenly lowered to 20^{o}C. By treating this as a one-dimensional transient heat conduction problem in a semi-infinite medium, determine the temperature at a depth 2 cm from the surface and the heat flux at the surface 1 min after the surface temperature is lowered. [7M]

(OR)

4. a) Discuss the role of dimensional analysis as a tool in experimental investigations. [7M]
   b) A 20 cm in diameter steel cylinder and 5 m length is initially at 50^0 C. It is suddenly immersed in an oil bath maintained at 20^0 C. The properties of steel are $\rho = 1700$ kg/m^3, $C_p = 500$ J/kg K and $k = 41$ W/m K. Assuming a heat transfer coefficient of 1200 W/m^2 K, calculate after the cylinder has been exposed to the cooling process for 12 min, i) the temperature at the centerline and ii)the heat lost per unit length of the cylinder. [7M]

UNIT-III

5. a) Explain the concept of boundary layers. Discuss the influence of Prandtl number on thermal boundary layer thickness. [7M]
   b) A vertical pipe of 10 cm outer diameter is at 100^{o}C. It is in a room where the air temperature is 20^{o}C. The pipe is 3 m long. What is the rate of heat loss per meter length of the pipe under free convection? [7M]

(OR)

6. a) Discuss the relation between the drag and heat transfer coefficients for fluid flow over a surface. [7M]
   b) Determine the heat transfer rates by free convection from a plate 0.3 m by 0.3 m whose surface is insulated while the other is maintained at 100^{o}C and exposed to quiescent atmospheric air at 30^{o}C when the plate is vertical. [7M]

UNIT-IV

7. a) With a neat sketch, explain the various regimes of the pool boiling phenomenon. [7M]

   b) A shell and tube heat exchanger is used to cool oil at a flow rate of 6 kg/s and Cp=2000 J/kg K from 65^{o}Cto 35^{o}C by using 10kg/s of water at an inlet temperature of 20^{o}C. The average heat transfer coefficient is 600 W/m^{2o}C. Calculate the heat transfer surface area under counterflow conditions. Take water Cp = 4200 J/kg ^{o}C. [7M]

(OR)

8. a) Discuss the role of heat exchangers in a thermal power plant. [7M]

   b) Water at 100^{o}C is boiled inside a copper pan with a surface area of 0.005m^2, maintained at a uniform temperature of 110^{o}C. Estimate the surface heat flux and the rate of evaporation. [7M]

UNIT-V

9. a) Discuss the properties of absorptivity, reflectivity, and transmissivity concerning semitransparent materials. [7M]

   b) A spherical enclosure inner surface is maintained at 600K. Determine the emission rate of radiative energy through an opening of 0.25 cm diameter. [7M]

(OR)

10. a) Discuss the concept of the shape factor. What are its applications? [7M]

    b) Consider two large parallel plates, one at 980K with an emissivity of 0.8 and the other at 320K with an emissivity of 0.6. A radiation shield is placed between them. The shield has an emissivity of 0.10 on the side facing the hot plate and an emissivity of 0.25 on the side facing the cold plate. Calculate the reduction in heat transfer between the hot and cold plates. [7M]

III B. Tech II Semester Regular Examinations, July -2023
HEAT TRANSFER
(Mechanical Engineering)

Time: 3 hours Max. Marks: 70

Answer any **FIVE** Questions **ONE** Question from **Each unit**
All Questions Carry Equal Marks
*****

UNIT-I

1. a) Explain the three boundary conditions employed in heat transfer problems with examples. [7M]

   b) Set up an expression for temperature distribution during steady-state heat conduction in a slab with internal heat generation of g_o W/m^3. The boundary surface at x=0 is insulated while the surface at x=L loses heat by convection with a heat transfer coefficient of 'h' to a fluid at T_∞. Calculate the temperature of the insulated surface for $k = 40$ W/m K, $g_o = 10^6$ W/m^3, L = 0.1 m. [7M]

(OR)

2. a) What is meant by the overall heat transfer coefficient? Where are its applications? [7M]

   b) How to estimate an error in the measurement of temperature? Explain with a suitable diagram. [7M]

UNIT-II

3. a) Explain the significance of non-dimensional numbers in convection heat transfer. [7M]

   b) A pebble bed for storing thermal energy in a solar heating system has pebbles that can be approximated as 5 cm diameter spheres. The bed is initially at 300 K, and cold air at 250 K is admitted. If the heat transfer coefficient is 80 W/ m^2 K, how long will it take for the pebbles at the inlet of the bed to lose 95 % of their available energy? Take k = 1.6 W/m K and α = 0.7 x 10^{-6} m^2/s for the pebbles. [7M]

(OR)

4. a) Explain what is meant by systems with negligible internal resistance. [7M]

   b) An aluminum plate of $\rho = 2790$ kg/m^3 $C_p = 880$J/kg K and $k = 160$ W/m K of thickness 3.0 cm and at a uniform temperature of 225^{o}C is suddenly immersed in a well-stirred fluid maintained at a constant temperature of 25^{o}C. The heat transfer coefficient between the plate and the fluid is 320 W/m^{2}K. Determine the time required for the center of the plate to reach 50^{o}C [7M]

UNIT-III

5. a) Draw the temperature and velocity profiles under free convection from a vertical isothermal plate for i) when the plate is losing heat and ii) when the plate is gaining heat. [7M]

   b) A thin electric strip heater of height 20cm is held vertically. It dissipates heat by free convection from both surfaces into atmospheric air at 20^{o}C. If the surface of the heater should not exceed 225^{o}C, determine the length of the strip to dissipate 1000 W of energy. [7M]

(OR)

6.	a)	Explain the concepts of hydrodynamic and thermal entry length.	[7M]
	b)	Air at 27°C and atmospheric pressure with a velocity of 20m/s flow across a single cylinder of outside diameter 2.5 cm. The surface of the cylinder is maintained at a uniform temperature of 120°C. Determine the average heat transfer coefficient and the heat transfer rate from the tube to air per meter length of the tube.	[7M]

UNIT-IV

7.	a)	Classify heat exchangers. Explain what is meant by the design of a heat exchanger.	[7M]
	b)	Water at saturation temperature and atmospheric pressure is boiled with an electrically heated horizontal platinum wire of 0.127 cm diameter. Determine the boiling heat transfer coefficient and the heat flux for a temperature difference of 650°C between the wall and the liquid.	[7M]

(OR)

8.	a)	Explain the various stages of bubble formation in the nucleate pool boiling phenomenon.	[7M]
	b)	A cross-flow heat exchanger is to heat 2kg/s of air from 10°C to 50°C flowing on the shell side, with hot water entering the tube side at 80°C and leaving at 45°C. Calculate the heat transfer surface area required if both fluids are unmixed. The overall heat transfer coefficient is 250W/m^{2}K.	[7M]

UNIT-V

9.	a)	Explain the black and gray body concept. How is surface emissivity related? Discuss.	[7M]
	b)	Consider two large parallel plates, one at 1000 K with an emissivity of 0.8 and the other at 300K with an emissivity of 0.6. A radiation shield is placed in between, with an emissivity of 0.1 on the side facing the hot plate and 0.3 on the side facing the cold plate. Calculate the reduction in the heat transfer rate between the hot and cold plates because of the radiation shield. Also, determine the equilibrium temperature of the radiation shield.	[7M]

(OR)

10.	a)	State and prove Kirchhoff's law of thermal radiation.	[7M]
	b)	Consider a blackbody at 1449K emitting radiation into the air. Determine the wavelength at which the blackbody monochromatic emissive power is maximum. Estimate the corresponding emissive power. Calculate the radiation exchange per square meter of the area between two infinite parallel black plates at 2000°C and 500°C	[7M]

III B. Tech II Semester Regular Examinations, July -2023
HEAT TRANSFER
(Mechanical Engineering)

Time: 3 hours Max. Marks: 70

Answer any **FIVE** Questions **ONE** Question from **Each unit**
All Questions Carry Equal Marks
*****

UNIT-I

1. a) Explain with examples the use of electrical analogy to solve heat transfer problems. [7M]
   b) The two faces of a slab at x=0 and x=L are kept at uniform temperatures, T_1 and T_2, respectively. The material's thermal conductivity depends on the temperature as $k(T) = k_o(T^2 - T_o^2)$ where k_o and T_o are constants. Find expressions for the temperature variation and heat flow rate per unit area of the slab. [7M]

(OR)

2. a) Develop a one-dimensional from the general 3-dimensional heat conduction equation. List the differential equations for the case of constant thermal conductivity and uniform heat generation in a slab. Discuss the applicability of the equations developed. [7M]
   b) A plane wall of 50 cm thickness is to be constructed from a material having a thermal conductivity that varies linearly with temperature according to the relation, k = 1+ 0.0015 T. Calculate the rate of heat loss per unit area if one side of the wall is maintained at 1000°C and the other at 10°C. [7M]

UNIT-II

3. a) Classify the convective heat transfer systems. Explain [7M]
   b) A long rod of 60 mm diameter and thermo-physical properties $\rho = 8000$ kg/m^3, $C = 500$ J/kg K and $k = 50$ W/m K is initially at a uniform temperature. It is heated in a forced convection furnace maintained at 750 K. The convection coefficient is estimated to be 1000 W/m^2 K. At a particular time, the surface temperature of the rod is measured to be 550 K. What is the corresponding centerline temperature of the rod? [7M]

(OR)

4. a) Explain the concept of infinite and semi-infinite bodies with examples. [7M]
   b) An iron sphere $\rho = 7850$ kg/m^3 $C_p = 460$J/kg K and $k = 60$ W/m K and $\alpha = 1.6x10^{-5}$m^2/s of diameter 5.0 cm is at a uniform temperature of 225°C initially. Suddenly, the sphere's surface is exposed to an ambient at 25°C with a heat transfer coefficient of 500 W/m^2°C. [7M]
      i) Calculate the center temperature 2 min after the start of cooling.
      ii) Calculate the temperature at a depth of 1.0cm from the start 2 min after cooling.
      iii) Calculate the energy removed from the sphere during this period.

UNIT-III

5. a) Show the variation of the boundary layer for the flow of water in a tube. Explain its influence on the heat transfer coefficients. [7M]
   b) Cooling water at 20°C and with a velocity of 2m/s enters a condenser tube and leaves at 30°C. The inside diameter of the tube is 1.7cm. Determine the heat transfer coefficient. [7M]

(OR)

6. a) Explain the development of boundary layer inside a pipe with a neat sketch. [7M]
   b) Water at a mean temperature of 60^{o}C flows inside a 5 cm ID tube with a velocity of 3m/s. Determine the heat transfer coefficient for the fully developed turbulent flow. [7M]

UNIT-IV

7. a) Discuss the phenomenon of drop and film condensation on surfaces. [7M]
   b) Derive the expression for LMTD in case of a parallel flow. [7M]

(OR)

8. a) Derive the expression for LMTD in case of a Counter flow. [7M]
   b) A cylindrical heating element with a diameter of 1 cm and length of 30 cm is immersed horizontally in a pool of water saturated and at atmospheric pressure. The cylindrical surface is plated with nickel. Calculate the heat flux and the total heat transfer rate from the cylinder to the water pool when the surface temperature is 108^{o}C. [7M]

UNIT-V

9. a) Derive Stefan-Boltzmann law for blackbody emissive power. [7M]
   b) A space radiator dissipates heat by thermal radiation into an environment at an absolute temperature of 0 K. If the maximum allowable surface temperature of the radiator is 1500K, what will be the maximum heat transfer rate per square meter of surface area if the surface emissivity is 0.8? [7M]

(OR)

10. a) Explain the Planck's law of radiation. [7M]
    b) Calculate the radiation exchange per square meter of the area between two infinite parallel black plates at 200^{0}C and 50^{0}C. If the surfaces were to be gray, having an emissivity of 0.9 and 0.7, respectively. Estimate the net energy transfer. [7M]

III B. Tech II Semester Regular Examinations, July -2023
HEAT TRANSFER
(Mechanical Engineering)

Time: 3 hours Max. Marks: 70

Answer any **FIVE** Questions **ONE** Question from **Each unit**
All Questions Carry Equal Marks
*****

UNIT-I

1. a) What is a fin? Give classification and explain the application of various fin shapes and configurations for heat transfer augmentation. [7M]
   b) Consider a long, slender copper rod of 1.0cm diameter and thermal conductivity of 380 W/mK, with one end thermally attached to a wall at 200°C. Heat is dissipated from the rod by convection with a heat transfer coefficient of 15 W/m^2K. Determine the heat transfer rate from the rod into the surrounding air at 30°C. [7M]

(OR)

2. a) Discuss the three modes of heat transfer, citing their applicability. [7M]
   b) A thermometer well mounted through the wall of a steam pipe is a steel tube with a 0.25 cm wall thickness, 0.5 OD, 5 cm length, and k = 26 W/mK. The steam flow produces an average heat transfer coefficient of 100 W/m^2 K on the thermometer well. If the thermometer reads 149°C and the temperature of the steam pipe is 65°C, estimate the average steam temperature. [7M]

UNIT-II

3. a) Explain the application of the Buckingham-π method to develop non-dimensional correlation for forced convection problems. [7M]
   b) A solid copper sphere of 10cm diameter $\rho = 8954\ kg/m^3$, $C = 383$ J/kg K and $k = 386$W/m K, initially at a uniform temperature of 250°C, is suddenly immersed in a well-stirred fluid which is maintained at a uniform temperature of 50°C. The heat transfer coefficient between the sphere and the fluid is 200W/m^2 K. Determine the temperature of the copper block 5 min after the immersion. [7M]

(OR)

4. a) Discuss the role of continuity, momentum, and energy equations in convection heat transfer problems. [7M]
   b) A very thick concrete wall $\alpha = 7.0x10^{-7} m^2/s$ is initially at a uniform temperature of 25°C. Suddenly one of its surfaces is raised to 125°C and maintained at that temperature. By treating the wall as a semi-infinite solid, calculate the temperatures at 5,10, and 15 cm from the hot surface 30 min after raising the surface temperature. [7M]

UNIT-III

5. a) Determine the hydrodynamic and thermal entry lengths for a fully developed laminar flow of engine oil at 60°C with a flow rate of 0.1 kg/s through a circular tube of 1.0 cm diameter. Explain the nature of flow when the flow rate is doubled. [7M]
   b) Water is heated in a straight pipe with an inside diameter of 2.5 cm. The heat flux is uniform at 10^4 W/m^2, and the flow and temperature fields are fully developed. The local difference between the wall temperature and the mean temperature of the stream is 4°C. Calculate the mass flow rate of the water stream and verify that the flow is turbulent. Evaluate the properties at 20°C. [7M]

(OR)

6. a) Determine the thickness of the velocity boundary layer and the local shear stress at 2m from the leading edge of a flat plate for the boundary layer flow of air at atmospheric pressure and 80^oC with a velocity of 2m/s. [7M]
   b) Water at 20^oC with a mass flow rate of 5kg/s enters a 5 cm ID, 10m long tube whose surface is maintained at a uniform temperature of 80^oC. Calculate the outlet temperature of the water. [7M]

UNIT-IV

7. a) Give a brief note on film boiling. [7M]
   b) A two-shell pass, four-tube pass heat exchanger is used to cool processed water from 75^oC to 25^oC on the tube side at a rate of 5 kg/s, with cold water entering the shell side at 10^oC at a rate of 6 kg/s. Calculate the heat transfer surface and the outlet temperature of the coolant water. The overall heat transfer coefficient is 750 W/m^2K. [7M]

(OR)

8. a) Differentiate between boiling and condensation. [7M]
   b) A cross-flow heat exchanger is used to heat water with hot exhaust gas. The hot gas enters the exchanger at 300^oC and a flow rate of 1 kg/s, while the pressurized water enters at 30^oC and leaves at 130^oC with a flow rate of 0.25kg/s. The heat transfer area is 3 m2. Calculate the overall heat transfer coefficient if both fluids are unmixed. [7M]

UNIT-V

9. a) Define monochromatic emissive power and radiation intensity. Hence derive an expression for the total emissive power of a black body. [7M]
   b) A black body of 2000 cm^2 area has an effective temperature of 800 K. Calculate i) The total energy emission, ii) the Intensity of normal radiation, iii) the Intensity of radiation along a direction of 60 degrees to the normal, and iv) The wavelength of maximum monochromatic emissive power. [7M]

(OR)

10. a) Explain the electrical analogy to radiation networks. [7M]
    b) A small object at 47^oC is placed in a large furnace whose interior is maintained at a temperature of 927^oC. Using the following data estimate the rate of absorption by and emission of radiation from the small object. [7M]

α	0.78	0.67	0.55
$T(K)$	320	600	1200