Heat Transfer

1. What are the different modes of heat transfer? Explain with examples.
2. State Fourier's Law of heat conduction? Write some of their applications.
3. State the effect of variation of temperature on thermal conductivity in the following cases:
   a) Pure metals
   b) Alloys
   c) Glasses
   d) Liquids
4. How does the thermal conductivity of materials vary with temperature?
5. Discuss the mechanism of thermal conduction in gases and solids. Name some good conductors and poor conductors of heat.
6. Define the overall heat transfer coefficient?
7. Define thermal contact resistance?
8. What do you understand by critical radius of insulation?
9. What do you mean by log mean area?
10. State the required properties of insulating materials?
11. Differentiate between steady state and unsteady state heat transfer?
12. Why fins are used? State some of its applications.
13. Explain straight and annular fins? Write down some of its application.
14. Define effectiveness of a fin. Does the effectiveness of a fin always increases? Justify?
15. How the effectiveness of a fin can be increased?
16. Write a short note on fin effectiveness?
17. Differentiate between steady state and transient heat conduction.
18. State few examples of heat conduction under unsteady state.
19. Define response time of a thermocouple. What does it signify?
20. State the significance of Biot number and Fourier number?
21. State some applications of heat transfer by convection.
22. State the Newton's law of viscosity?
23. Differentiate between laminar and turbulent flows?
24. Why mean film temperature is considered in convective heat transfers?
25. Define the term local heat transfer coefficient and average heat transfer coefficient?
26. Define the term Reynolds analogy?
27. Write a short note on radiation?
28. Define following terms:
    a) Total emissive power of a surface
    b) Black body and grey body
29. Define intensity of radiation?
30. What do you mean by green house effect?
31. Write a short note on electrical network for radiative heat exchange.
32. Write a short note on radiation shields.
33. What is a heat exchanger?
34. What is compact heat exchanger? What are its applications?
35. What do you understand by mixed and unmixed flow?
36. Write a short note on selection and design aspects of heat exchangers?
37. Define and explain condensation?
38. What do you understand by boiling? What factors affect the boiling?
39. What is critical flux? How it is useful to designers of evaporators.
40. What do you mean by forced convection boiling?

41. What do you mean by mechanism of heat transfer by conduction?
42. What do you mean by thermal diffusivity?
43. State Newton's law of cooling?
44. What do you mean by Stefan-Boltzmann law of radiation?
45. State the overall heat transfer coefficient?
46. State thermal contact resistance?
47. Define thermal insulation and write down some properties of insulating materials?
48. What do you mean by fin efficiency?
49. What is the significance of Fourier's Number?
50. Define continuity equation. Write down some of its applications?
51. Explain in brief the analogy between the heat flow and electricity with its significance?
52. Define the expression for heat conduction through a wall also through a thick wall by varying thermal conductivity?
53. Temperature of air in reservoir is measured with the help of mercury-in-glass thermometer placed in a protective wall filled with oil. Thermometer shows a temperature of 86 ºC at the end of the wall. Find out error in measurement, if temperature at the base of the wall is 40 ºC. The wall is 12cm long, 1.5mm thick having thermal conductivity of 56W/m K, h may be taken as $20W/m^2K$.
54. A horizontal plate (K = 30 W/m K) 600mm x 900mm x 30mm is maintained at 300° C. The air at 30° C flows over the plate, if the convective co-efficient of air over the plate is 22 W/m^2 K and 250 W heat is lost from the plate by radiation, Calculate the bottom surface temperature of the plate.
55. Derive the general heat conduction equation in Cartesian co-ordinates for isotropic materials.
56. Write the three dimensional general heat conduction equation for isotropic materials and deduce them as Poisson's, Fourier's and Laplace equations, by specifying the required conditions for these equations.
57. A tubular heat exchanger is to be designed for cooling oil from a temperature of 80 ºC to 30 ºC by a large body of stagnant water which may be assumed to remain constant at a temperature of 20 ºC. The heat transfer coefficient consists of 30m long straight tube of 2cm inside diameter, c_p of oil = 2.5 KJ/Kg K and specific gravity 0.8, the velocity of oil is 50cm/s. Calculate the overall heat transfer coefficient.
58. Write the equations for conductive and convective resistance? Draw an equivalent circuit for heat transfer by conduction and convection in a composite wall.
59. The engine of an automobile can be considered as box of length of 0.7m width 0.23m and height 0.1 m its surface temperature is maintained at 60 ºC, when the automobile moves at a velocity of 30m/s the air at 20 ºC passes over the crankcase at relative speed. Assuming the flow to be turbulent with $NU_L = 0.036 Re_L^{0.8} P_r^{1/3}$, find the rate of heat transfer from all sides of the crankcase.
    Take ρ = 1.09 Kg/m3, v = 20.1 x 10^{-6}, K = 0.027 W/m K, Pr = 0.7.
60. Prove that the heat conduction through a hollow long cylinder is given by:

$$Q = \frac{T1 - T2}{\frac{ln\left(\frac{r2}{r1}\right)}{2\pi KL}}$$

61. A standard cast iron pipe (d_1 = 50mm, d_0 = 55mm) is insulated with 85% magnesium insulation (k = 0.02 W/m ° C. Temperature at the interface between the pipe and insulation is 300° C. The allowable loss through the pipe is 600 W/m Length for the safety. The temperature of outside surface for insulation must not exceed 100 ° C. Determine:
    a) Maximum thickness of insulation.
    b) Temperature of inside surface of the pipe assuming the internal conductivity 20 W/m°C.

c) Derive the formula used.

62. A solid cylinder and a solid sphere are of the same radius and material. These have the same outside surface temperature with same amount of heat generation. Determine the maximum temperature in each case.

63. Derive an expression for steady state temperature distribution in a plane wall having heat generation g(W/m^3) and maintained at temperatures T_1 and T_2 on its sides is given as:

$$T = \frac{-g}{2K}L^2\left(\frac{x^2}{L^2} - \frac{x}{L}\right) + T_1$$

Deduce that the maximum temperature occurs at the centre of slab in case $T_1 = T_2$.

64. A solid sphere of radius R, thermal conductivity k has the uniform heat generation rate of g (W/m^3), show that

a) Temperature distribution in the sphere is given by,

$$T = \frac{g}{6K}(R^2 - r^2) + T_w$$

If outer surface is maintained at T_W temperature

b) $T = \frac{g}{6K}(R^2 - r^2) + \frac{gR}{3h} + T_w$

If there is convective heat transfer from outer surface to fluid maintained at $T_{W.}$

65. An aluminum conductor carries a current of 800amp. The square cross-section of the conductor is 6.25 cm^2 and the three sides are perfectly insulated. The exposed surface is in contact with air at 30° C and h = 16.28 W/m^2K. Calculate the maximum temperature of the conductor at steady state. Specific resistance of aluminum is 5 x $10^{-4}\Omega$ cm^2/m and k = 203.5 W/m K. Derive the equation you use.

66. Show that the heat transfer rate in case of infinite long fin is given as:
Q = $\sqrt{h.P.k.A}\theta_0$

67. What do you understand by overall fin effectiveness? Show that the total efficiency of the fin is

$$\eta_{total=1-\frac{A_{fin}}{A_{total}}(1-\eta)}$$

68. Show that the error in temperature measurement (T_∞ - T_L) equals to $\sqrt{\frac{h}{K.t}}$

69. A thermocouple junction is in the form of 4mm diameter sphere. The properties of junction material are c = 420 J/Kg K, ρ = 8000 Kg/m^3, K = 40W/m K, surface film coefficient h = 40 W/m^2K. The junction initially at 40 ºC is inserted in a stream of hot air at 300 ºC, find

1) Time constant
2) Thermocouple is taken out from the hot air after 10 seconds and is kept instill air at 30 ºC. Assuming the heat coefficient in still air as 10 W.m^2K, Find the temperature attained by junction 20 seconds after removing it from hot air stream.

70. One end of the long rod 35mm in diameter is inserted into a furnace with the other end projected in the outside air. After the steady state is reached, the temperature of the rod is measured at two points 180mm apart and found to be 180° C and 145° C. The atmospheric air temperature is 25°C , if the heat transfer coefficient is 65 W/$m^{2\circ}$ C. Calculate the thermal conductivity of the rod. Derive the formula used.

71. Prove that for quenching of a billet by lumped heat capacity method is given as

$$\frac{T_1 - T_\infty}{T_1 - T_\infty} = \exp(-hAt/\rho cV$$

72. State the relationship between Nusselt, Grashoff and Prandtl numbers in case of heat transfer by natural convection from a vertical plate.

73. Prove that in case of grey body:

J = ρ. G + ε .$e_b$where, notations have their used meaning.

74. Show that the radiant heat exchange between two parallel infinite plane surface is given as:

$$Q_{12} = \frac{\sigma . A(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

75. Define solid angle. Derive an expression for solid angle between two elementary areas.
76. Two very long concentric pipes 250mm and 350mm in diameter, with the space between them evacuated are maintained at 550ºC and 270 ºC respectively. Obtain the radiative heat exchange between two pipes. Also calculate the shape factors for the two pipes.
77. State and derive Wein Displacement law from Planks equation.
78. An aluminum alloy plate 0.5m x 0.5m and 5cm thick is maintained at 300ºC it is suddenly put in surrounding at 30 ºC. Assume ρ = 7000Kg/m^3, Specific heat, c = 300J/Kg K, thermal conductivity, k = 200 W/m K and convection heat transfer coefficient, h = 60W/m^2 k. Determine the time taken for the slab to reach a temperature of 120 ºC.
79. Show that LMTD for parallel flow heat exchangers is given as:

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$$

80. Show that $\varepsilon = \frac{NTU}{NTU+1}$ for a counter flow heat exchanger when capacity ratio = 1.
81. Steam enters a counter flow heat exchanger dry saturated at 10 bar (t_s = 180 ºC) and leaves at 350ºC. The mass flow of steam is 800 Kg/min. The gas enters the heat exchanger at 650 ºC and mass flow rate of 1350 Kg/min, if the tubes are 30mm diameter and 3m long. Determine the number of tubes required. Neglect the resistance offered by metallic tubes. Use the following data:
    For steam C_p = 2.71, h_g = 600 W/m^2ºC
    For glass C_p = 1.0, h_g = 250 W/m^2ºC
82. Prove that counter flow heat exchanger the expression for LMTD is given by:

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$$

83. Obtain the relationship for effectiveness of counter flow heat exchanger. Also explain how and when NTU method is applied.
84. Prove that the thickness of film at a distance x in case of laminar flow in a vertical plate is given as :

$$\delta = \left[\frac{4k_f(T_s - T_w)\mu . x}{\rho^2 . g . h_{fg}}\right]^{1/4}$$

Hence, the average heat transfer coefficient

$$h = 0.943 \left[\frac{\rho^2 . g . h_{fg} . k_f^3}{\mu L(T_s - T_w)}\right]^{1/4}$$

85. With the help of boiling curve for water explain the regimes of boiling.
86. An egg with mean diameter of 4cm and initially at 25 ºC is placed in a boiling water pan for 4 minutes and found to be boiled to the consumer's taste. For how long should a similar egg for same consumer be boiled when taken from a refrigerator at 5 ºC? Assume following properties
    K = 12 W/m K, h = 125 W/m^2K, specific heat, c = 2 KJ/Kg K, Density, ρ = 1250 Kg/m^3
87. Explain in detail the various segments of boiling pool regimes in case of change of phase.
88. Obtain the equation for mass flow rate and heat flux for laminar film condensation on vertical plate.
89. Two large parallel plates 'A' and 'D' are maintained at temperatures of 1500K and 600K respectively. Their emissivities are 0.9 and 0.4 respectively. Two radiation shields 'B' with emissivity = 0.5 and 'C'

with emissivity = 0.2 are inserted in between them, such that A, B, C, and D are placed one after the other, calculate

a) Heat transfer rate without radiation shields
b) Heat transfer rate with radiation shields
c) Temperature attained by planes 'B' and 'C'.

90. The space between the two infinite parallel plates having emissivity's 0.4 and 0.8 respectively is evacuated. A polished aluminum shields with emissivity of 0.06 is inserted between them. What will be the % reduction in the heat transfer rate due to insertion of radiation shield?
91. Two small surface 'A' and 'B' are placed in an isothermal enclosure maintained at constant temperature considered as black body. The irradiation to the surface by the enclosure is 8000W/$m^2$and 6800 W/m^2 .Under the conditions of steady state find:
    a) Absorptivity of each surface
    b) The temperature and heat flux to each surface
    c) Emissive power of each surface and their emissivity.
92. Air moving at 0.15m/s blows over the top of a flat surface. The top of the freezer 1.2m x 2.5m and is poorly insulated so that the surface remains at 30ºC , if the temperature of the air is 40 ºC , make calculations for the maximum heat transfer by forced convection from the top of the flat surface.
93. The CPU of a personal computer has dimensions of 10cm x 50cm x 40cm height. Its surface temperature is 39 ºC , it is kept in still air at 15ºC . Neglecting heat transfer from its bottom surface. Find the rate of heat transfer from
    a) All 4 vertical surfaces, b) Its top surface, Properties at mean film temperature of 300K are ρ = 1.1614 Kg/m^3, C_p= 1007 J/Kg/K, v = 15.89 x 10^{-6} m^2/s, K = 0.0263 W/m K, Pr = 0.707

Surface	**Correlation**	**Range of Ra**
Vertical	Nu = 0.59 $Ra^{1/4}$ = 0.1 $Ra^{1/3}$	10^4 - 10^9 10^9 – 10^{13}
Horizontal	Nu = 0.54 $Ra^{1/4}$ = 0.14$Ra^{1/3}$	10^5 - 2 x 10^7 2 x 10^7 – 2 x 10^{10}

94. Consider a thin square plate of 0.6m x 0.6m in dimensions, kept in a room temp at 30ºC. One surface of the plate is maintained at 74 ºC while the other plate is insulated. Determine the rate of heat transfer from the plate if the plate is held vertical. What is the change in rate of heat transfer if the plate is kept horizontal with hot surface facing up? Properties of air at mean film temperature:
    μ = 196. 4 x 10^{-7} Na/m^2, K = 28.15 x 10^{-3} W/m K, Pr = 0.7035, v = 18.405 x 10^{-6} m^2/s.
95. Experiments were conducted on a turbine blade of chord length 50mm. The heat flux was found to be 80000 W/m^2 .The gas surrounding the blades is maintained at 1200 ºC.
    The blade is cooled so as to maintain its surface temperature at 750 ºC.
    Find:
    1) The heat flux if the surface temperature of the blade is to be maintained at 700 ºC by increasing the coolant flow rate.
    2) The heat flux in case the chord length is increased to 100mm length and the gas temperature, surface temperature and Reynolds number are kept the same by varying the gas velocity.
96. Determine the radiant energy loss from a 1cm diameter opening in a thin- walled furnace located in a large enclosure, if the temperature within the furnace is 900 ºC and the surrounding are at 20 ºC.
97. What is the net radiant exchange between the floor of a furnace 5m x 6m and a side wall 5m x 2.5m, if the temperature of the floor and the wall are 600 ºC and 310 ºC respectively? Assume both surface are black.

98. A horizontal heated plate at 200 ºC and facing upwards has been placed in still air at 20 ºC if the plate measures 1.5m x 1m, calculate the heat loss by natural convection. Take h = 3.02$(\theta)^{1/4}$ W/m^2K.
99. Derive the expression for heat transfer rate through cylinder, sphere, and composite cylinder.
100. Stream at 935bar flows through a pipe. The unit surface conductance of the steam side film is 5640 W/m^2 K and that of outside film at pipe is 30 W/m^2 K if the pipe is placed in a room as a temperature of 25 ºC. Find the temperature at the outer surface of the pipe.