L. E. College, Morbi
Mechanical Engineering Department
B. E. Semester 5 Mechanical
Heat Transfer (BE05000291)

Assignment 1: CO1 (Conduction)

1. Write general heat conduction equation in cartesian co-ordinates and deduce the equation for (a) steady state conduction (b) no heat generation (c) no heat generation and steady state condition (d) one-dimensional heat conduction equation without heat generation under steady state.
2. Explain the terms thermal conductivity and thermal resistance.
3. With suitable examples, explain the significance of the concept of critical radius of insulation.
4. What is thermal diffusivity? Write its unit.
5. Explain the concept of overall heat transfer coefficient.
6. Explain how fins can increase the rate of heat transfer. Mention the most common types of fins and sketch them. Give some practical examples of fins.
7. How is the thermal performance of a fin measured?
8. 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 adding fins to the inside or outside the tubes? Why?
9. What is lumped capacity analysis? When is it applicable? What is the physical significance of the Biot number?
10. Consider a hot boiled potato kept on a plate and cooled by natural convection in air. During the first minute, the temperature drops by 10°C. During the second minute, will the temperature drop be more than, less than or same as that during the first minute?
11. An exterior wall of a house may be approximated by a 0.1 m layer of common brick (k = 0.7 W/m K) followed by a 0.04 m layer of gypsum plaster (k = 0.41 W/m K). What thickness of loosely packed rock wool insulation (k = 0.065 W/m K) should be added to reduce heat loss or gain through the wall by 90%?
12. A 240 mm diameter steam pipe, 200 meter long is covered with 50 mm of high temperature insulation of thermal conductivity 0.092 W/m K and 50 mm of low temperature insulation of thermal conductivity 0.062 W/m K. The inner and outer surface temperatures are maintained at 340°C and 35°C respectively. Calculate: (a) the total heat loss per hour (b) the heat loss per m^2 of pipe surface (d) the temperature between interfaces of two layers of insulation. Neglect heat conduction through pipe material.
13. A steel fin (k = 54 W/m K) with a cross section of an equilateral triangle, 5 mm in side and 80 mm long. It is attached to a plane wall maintained at 400°C. The ambient air temperature is 50°C and convective heat transfer coefficient at surface is 90 W/m^2K. Calculate the heat dissipation rate from the rod.
14. A copper rod 0.5 cm diameter and 50 cm long protrudes from a wall maintained at a temperature of 500°C. The surrounding temperature is 30°C and convection heat transfer coefficient is 40 W/m2K and thermal conductivity of fin material is 300 W/m K. Show that this fin can be considered as infinite long fin. Determine total heat transfer rate from the rod.
15. A solid copper sphere of 10 cm diameter having density = 8954 kg/m^3, specific heat = 383 J/kg K and thermal conductivity = 386 W/m K, initially at uniform temperature of 250°C is suddenly immersed in a well stirred fluid of 50°C. Heat transfer coefficient between fluid and sphere is 200 W/m2 K. Calculate the temperature of copper block at 5 minutes after immersion.

Assignment 2: CO2 (Convection)

1. Describe the types of convection and recognize these processes in real-life applications?
2. Discuss Grashoff number and Rayleigh number in natural convection process.
3. Explain Reynolds analogy.
4. Show physical significance of Following non-dimensional numbers: Nu (Nusselt Number), Gr (Grashoff Number) and Pr (Prandtl Number), Re (Reynold Number).
5. Define and discuss velocity boundary layer and thermal boundary layer over a flat plate. Show the thickness of these layers for different Prandtl numbers.
6. A cylinder in vertical position is having dimension of 18 cm diameter and length 1.5 m is maintained at a temperature of 100°C. It is kept in atmosphere having temperature 20°C. Calculate the heat lost by cylinder surface to the atmosphere by free convection.
7. Steam at 350°C flowing in a pipe (k=80 W/mK) 5 cm ID, 5.6 cm OD is covered with 3 cm thick insulation (k=0.05 W/mK). Heat is lost to the surroundings at 5°C by natural convection and radiation with combined h = 20 W/m^2K and h_i=60 W/m^2K. Find: (a) the rate of heat loss from the pipe per unit length (b) the temperature drops across the pipe and the insulation.
8. Following data are obtained from a metallic cylinder of 15 mm diameter and 100 mm in length heated internally by an electric heater and subjected to cross flow of air in a low-speed wind tunnel: velocity of free stream air = 15 m/s, temperature of free stream air = 25°C, average temperature of cylinder surface = 130°C, power dissipation by heater is 63 W. Calculate the experimental convective heat transfer coefficient for such a system. Compare this value with that obtained from the correlation suitable for this arrangement.
   $Nu = 0.26\, Re^{0.6}\, Pr^{0.36}(Pr/Pr_s)^{0.25}$
   Thermophysical properties of air at the mean bilk temperature at 25°C are: k =2.6325 × 10^{-2} W/m^2K, ν = 15.53 × 10-6 m^2/s, Pr = 0.702, Pr_s = 0.685
9. A copper pipe (temperature 55°C) is kept in atmosphere (temperature 35°C). The length and diameter of pipe are 1 m and 50 mm respectively. The air velocity is 3 m/s. Calculate heat loss from the pipe. Use the co-relation Nu= 0.0239 $(Re)^{0.805}$
10. Air at 27°C is flowing across a tube with a velocity of 25 m/s. The tube could be either a square of 5 cm side or circular cylinder of 5 cm diameter. Compare the rate of heat transfer in each case if the tube surface is at 127°C. Use the correlation: Nu = C Re^n $Pr^{1/3}$
    C = 0.027, n = 0.805 for cylinder, C = 0.102, N = 0.675 for square tube
    Use following properties of air: ρ = 0.955 kg/m^3, k_f = 0.03W/m K, ν = 20.92 × 10^{-6} m^2/s, c_p = 1.009 kJ/kg K, Pr = 0.7

Assignment 3: CO3 (Radiation)

1. Two large parallel plates with ε = 0.4 each are maintained at different temperatures and are exchanging heat only by radiation. Two equally large radiation shields with surface emissivity 0.04 are introduced in parallel to the plates. Find the percentage reduction in net radiation heat transfer.
2. Two concentric spheres 25 cm and 35 cm in diameter with the space between them evacuated are used to store liquid air (-150°C) in a room at 20°C. The surfaces of the spheres are flushed with aluminium (ε = 0.04). Calculate the rate of evaporation of liquid air if the latent heat of vaporization of liquid air is 218 kJ/kg. Assume that other modes of heat transfer are absent.
3. The sun emits maximum radiation at λ = 0.52 μm. Assuming sun to be a black body, calculate the surface temperature of sun and the total emissive power of the sun's surface at that temperature.

4. Assuming the sun to be black body having a surface temperature of 5800 K, calculate (a) the total emissive power, (b) the wavelength at which the maximum spectral intensity occurs (c) the maximum value of $E_{b\lambda}$,(d) the total amount of radiant energy emitted by the sun per unit time if its diameter can be assumed to be 1.391×10^9 m.
5. Two parallel plates placed 1 m apart have dimensions of 200 cm × 100 cm. The plates have temperature of 727°C ($\varepsilon = 0.3$) and 227°C ($\varepsilon = 0.5$) respectively. The plates are placed in a large room, for which walls are at 27°C. Determine the rate of heat loss by radiation from each plate and the heat gain by walls. Take $F_{12} = 0.232$

Assignment 4: CO4 (Heat Exchanger)

1. Water (c_p = 4.187 kJ/kg K) is heated at the rate of 1.4 kg/s from 40°C to 70°C by an oil (c_p = 1.9 kJ/kg K) entering at 110°C and leaving at 60°C in a counter flow heat exchanger. If U_o = 350 W/m^{2}K, calculate the surface area required. Using the same entering fluid temperature and the same oil flow rate, calculate the exit temperature of oil and water and the rate of heat transfer, when the water flow rate is halved.
2. Saturated steam at 120°C is condensing on the outer tube surface of a single pass heat exchanger. The overall heat transfer coefficient is 1800 W/m^2 K. Determines the surface area of a heat exchanger capable of heating 1000 kg/h of water from 20°C to 90°C. Also calculate the rate of condensation of steam. Assume latent heat of steam is 2200 kJ/Kg.
3. In a counter flow double pipe heat exchanger, water is heated from 25°C to 65°C by oil with specific heat of 1.45 kJ/kg K and mass flow rate of 0.9 kg/s. The oil is cooled from 230°C to 160°C. If overall heat transfer coefficient is 420 W/m^2°C. calculate (a) The rate of heat transfer (b) The mass flow rate of water, and (c) The surface area of heat exchanger
4. A heat exchanger is to be designed to condense 8 kg/sec of an organic liquid (t_{sat}=80°C, h_{fg} = 600 KJ/kg) with cooling water available at 15°C and at a flow rate of 60 kg/sec. The overall heat transfer coefficient is 480 W/m^2°C. Calculate: (a) The number of tubes required. The tubes are to be of 25 mm outer diameter, 2 mm thickness and 4.85 m length (b) The number of tube passes. The velocity of the cooling water is not to exceed 2 m/sec.
5. A parallel flow heat exchanger has its tubes of 5 cm internal and 6 cm external diameter. The air flows inside the tubes and receives heat from hot gases circulated in the annular space of the tube at the rate of 100 kW. Inside and outside heat transfer coefficients are 250 W/m^{2}K and 400 W/m^{2}K respectively. Inlet temperature of hot gases is 500°C, outlet temperature of hot gases is 300°C, inlet temperature of air 50°C, exit temperature of air 140 °C. Calculate: (a) Overall heat transfer coefficient based on outer surface area (b) Length of the tube required to affect the heat transfer rates. Neglect the thermal resistance of the tube. (c) If each tube is 3 m length find the number of tubes required.

Assignment 5: CO5 (Two-phase heat transfer)

1. Differentiate between pool boiling and forced convection boiling
2. What is boiling? Explain different regimes of boiling.
3. Define condensation? Explain film-wise condensation and drop-wise
4. Draw temperature variation for condenser and evaporator of thermal power plant.
5. During the summer season, vegetable vendors are sprinkling water to keep the vegetable fresh. Evaluate in light of heat transfer.