BITS Pilani, Pilani campus

Mid-semester examination, Second semester 2021-2022

ME F220 Heat Transfer

Total marks: 50, Weightage: 25%, and Date & Time: 09/03/2022 & 2:00 pm to 3:30 pm.

(i) It's an open book examination but Heat transfer textbook by Holman & Bhattacharyya, class slides, and handwritten notes are only permitted. (ii) Assume any missing data and state the assumptions if any.

Q1. The walls of a refrigerator are typically constructed by sandwiching a layer of insulation between sheet metal panels. Consider a wall made from fiberglass insulation of thermal conductivity $k_i = 0.046$ W/m.K and thickness $L_i = 50$ mm and steel panels, each of thermal conductivity $k_p = 60$ W/m. K and thickness $L_p = 3$ mm. If the wall separates refrigerated air at $T_{\infty,i} = 4$ ºC from ambient air at $T_{\infty,o} = 25$ ºC, what is the heat gain per unit surface area? Coefficients associated with natural convection at the inner and outer surfaces may be approximated as $h_i = h_o = 5$ W/m^2. K. [5 marks]

Q2. Mathematically formulate the governing equations and boundary conditions for analysing heat transfer in a rectangular fin (constant cross section) with insulated tip. Assume there is heat loss from the fins due to both convection and radiation heat transfer. Also, suggest a method of solution. [5 marks]

Q3. Consider a long resistance wire of radius $r_1 = 0.2$ cm and thermal conductivity k = 15 W/m·K in which heat is generated uniformly as a result of resistance heating at a constant rate of 50 W/cm^3. The wire is embedded in a 0.5cm thick layer of ceramic whose thermal conductivity is k = 1.2 W/m·K. If the outer surface temperature of the ceramic layer is measured to be $T_s = 45$ °C, determine the temperatures at the center of the resistance wire and the interface of the wire and the ceramic layer under steady conditions. [10 marks]

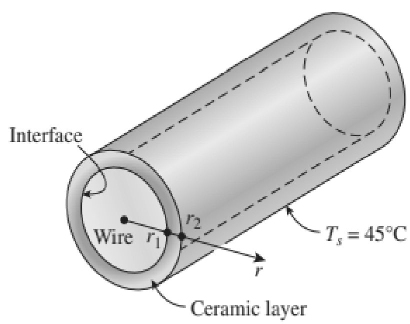

Fig. 1. Problem description for Q3

Q4. A pipe 600 mm in diameter carrying steam at a temperature of 180 °C for heating the house in winter and another pipe of 180 mm diameter carrying supply water at 12 °C are buried under the ground with thermal conductivity of the soil as 0.45 W/m.°C. The length of each pipe is 90 m and the average velocity of water in the pipe is 0.05 m/s. The heat transfer between the pipe results in the rise in temperature of the water flowing in supply water line. Assume that the pipes run parallel to each other, the earth is infinite medium, and the thermal resistance of pipe material is negligible. Calculate the (a) net rate of heat transfer between the pipe and (b) spacing between the pipes such that the rise in the temperature of the supply water should not exceed by 2 °C. Density and specific heat of water can be taken as 1000 kg/m^3 and 4.2 kJ/kg.°C, respectively. [10 marks]

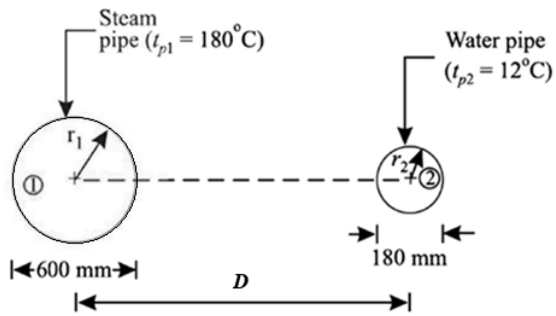

Fig. 2. Problem description for Q4

Q5. Metal plates (k = 180 W/m·K, ρ = 2800 kg/m^3, and C_p = 880 J/kg·K) with a thickness of 2 cm exiting an oven are conveyed through a 10 m long cooling chamber at a speed of 4 cm/s. The plates enter the cooling chamber at an initial temperature of 700 °C. The air temperature in the cooling chamber is 15 °C, and the plates are cooled with blowing air and the convection heat transfer coefficient is given as a function of the air velocity, $h = 33V^{0.8}$, where h is in W/m^2·K and V is in m/s. To prevent any incident of thermal burn, it is necessary to design the cooling process such that the plates exit the cooling chamber at a relatively safe temperature of 50 °C or less. Check if the lumped heat capacity method can be applied here? Also, determine the air velocity and the heat transfer coefficient such that the temperature of the plates exiting the cooling chamber is at 50 °C.

[10 marks]

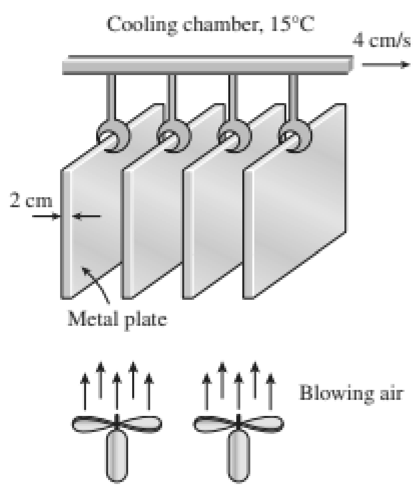

Fig. 3. Problem description for Q5

Q6. A long cylindrical bar with k = 17.4 W/m K and ∝ = 0.019 m^2/hr of radius 80mm comes out of an oven at 830 °C throughout and it cooled by quenching it in a large bath of 40 °C coolant. The surface heat transfer coefficient between bar surface and coolant is 180 W/m^2°C. Determine a) time taken by shaft center to reach 120 °C and surface temperature of the shaft when its center temperature is 120 °C.

[10 marks]