MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING

Chemical and Processing Engineering Department

HEAT TRANSFER

CODE: HCHE 313

SESSIONAL EXAMINATIONS
FEBRUARY 2021

DURATION: 3 HOURS

EXAMINER : T. C. NKHOMA

INFROMATION AND INSTRUCTIONS

1. The question paper consists of 5 printed pages
2. Answer **ALL** questions

QUESTION 1

a) Define thermal conductivity and explain its significance . **[2]**

b) A 0.3-cm-thick, 12-cm-high, and 18-cm-long circuit board houses 80 closely spaced logic chips on one side, each dissipating 0.06 W. The board is impregnated with copper fillings and has an effective thermal conductivity of 16 W/m°C. All the heat generated in the chips is conducted across the circuit board and is dissipated from the back side of the board to the ambient air. Determine the temperature difference between the two sides of the circuit board. **[8]**

c) Consider a large plane wall of thickness L = 0.3 m, thermal conductivity k = 2.5 W/m °C, and surface area A = 12 m^2. The left side of the wall at x = 0 is subjected to a net heat flux of q_0 = 700 W/m^2 while the temperature at that surface is measured to be T_1 = 80°C. Assuming constant thermal conductivity and no heat generation in the wall,

i. Express the differential equation and the boundary conditions for steady one-dimensional heat conduction through the wall, **[5]**

ii. Obtain a relation for the variation of temperature in the wall by solving the differential equation, **[6]**

iii. Evaluate the temperature of the right surface of the wall at $x = L$. **[3]**

d) Differentiate fin effectiveness from fin efficiency **[1]**

QUESTION 2

a) Explain the mechanism of heat transfer by convection **[2]**

b) What is the physical significance of the Prandtl number and what factors govern it? **[4]**

c) A 25-cm-diameter stainless steel ball (ρ = 8055 kg/m^3, C_p = 480 J/kg °C) is removed from the oven at a uniform temperature of 300°C. The ball is then subjected to the flow of air at 1 atm pressure and 25°C with a velocity of 3 m/s. The surface temperature of the ball eventually drops to 200°C. Determine:

i. the average convection heat transfer coefficient during this cooling process **[9]**

ii. Estimate how long the process will take **[10]**

QUESTION 3

a) Differentiate thermal radiation from other forms of electromagnetic radiation **[1]**

b) Consider the 5-m by 5-m by 5-m cubical furnace shown in Figure 3.1, whose surfaces closely approximate black surfaces. The base, top, and side surfaces of the furnace are maintained at uniform temperatures of 800 K, 1500 K, and 500 K, respectively. Determine:

i. The net rate of radiation heat transfer between the base and the side surfaces **[5]**

ii. The net rate of radiation heat transfer between the base and the top surface **[3]**

iii. The net radiation heat transfer from the base surface. **[2]**

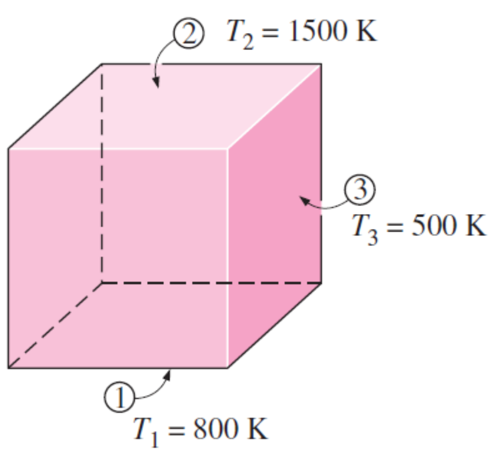

Fig 3.1: Cubical furnace block

a) Consider a 20-cm-diameter spherical ball at 800 K suspended in air. Assuming the ball closely approximates a blackbody, determine

i. The total blackbody emissive power, **[4]**

ii. The total amount of radiation emitted by the ball in 5 min, **[5]**

iii. The spectral blackbody emissive power at a wavelength of 3 μm. **[5]**

QUESTION 4

a) Give three classifications of heat exchangers by flow pattern and illustrate them using diagrams **[6]**

b) A heat exchanger is to be selected to cool a hot liquid chemical at a specified rate to a specified temperature. Explain six factors to be considered in the selection process **[6]**

c) In a dairy plant, milk is pasteurized by hot water supplied by a natural gas furnace. The hot water is then discharged to an open floor drain at 80°C at a rate of 15 kg/min. The plant operates 24 h a day and 365 days a year. The furnace has an efficiency of 80 percent, and the cost of the natural gas is $0.40 per therm (1 therm = 105,500 kJ). The average temperature of the cold water entering the furnace throughout the year is 15°C. The drained hot water cannot be returned to the furnace and recirculated, because it is contaminated during the process. In order to save energy, installation of a water-to-water heat exchanger to preheat the incoming cold water by the drained hot water is proposed. Assuming that the heat exchanger will recover 75 percent of the available heat in the hot water, determine:

i. The heat transfer rating of the heat exchanger that needs to be purchased and suggest a suitable type **[5]**

ii. The amount of money this heat exchanger will save the company per year from natural gas savings. **[8]**

DATA AND EQUATIONS

Heat conduction equation in rectangular coordinates:

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+\dot{g}=\rho C\frac{\partial T}{\partial t}$$

Nusselt Number ,$Nu=\frac{hL_c}{k}$

$$Nu=2+\left[0.4(Re^{1/2}+0.06Re^{2/3}\right]Pr^{0.4}\left(\frac{\mu_\infty}{\mu_s}\right)^{1/4}$$

Prandtl number, Pr $=\frac{\mu C_p}{k}$

Reynolds number, $Re=\frac{\rho uL}{\mu}$

Stanton number, $St=\frac{NuRe}{Pr}$

Planck's distribution law $E_{b\lambda}=\frac{C_1}{\lambda^5\left[exp\left(\frac{C_2}{\lambda T}\right)-1\right]}$

Table 1:Air properties

Property	**Value**	**Conditions**
Dynamic viscosity, μ	$2.67*10^{-5}\ kg/m.s$	250°C
Dynamic viscosity, μ	$1.849*10^{-5}$ kg/m s	25°C and 1 atm
Prandtl number, Pr	0.7296	25°C and 1 atm
Thermal conductivity, k	0.02551 W/m · °C	25°C and 1 atm
Kinematic viscosity	$1.562*10^{-5}$ m^2/s	25°C and 1 atm