MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING,SCIENCE AND TECHNOLOGY

DEPARTMENT: CHEMICAL AND PROCESSING ENGINEERING

MODULE: HEAT TRANSFFER

CODE: CHEP 311

SESSIONAL EXAMINATIONS
JUNE 2023

DURATION: 3 HOURS

EXAMINER: MISS NYATHI

INSTRUCTIONS

1. *Answer **ALL** Questions in Section **A** and any **three** in Section **B***
2. *Show all your working clearly*
3. *Start a new question on a fresh page*
4. *Total marks 100*

***Additional material(s):** Calculator*

Section A: Answer <u>all</u> questions [40 marks]

QUESTION 1

(i) What are the factors that affect thermal conductivity? [5]

(ii) Distinguish between steady state and unsteady state heat transfer. [3]

(iii) Briefly describe **two** applications of heat exchangers. [4]

(iv) Explain how heat is transferred in a shell and tube heat exchanger. [3]

(v) Differentiate between a gray and black body. [2]

(vi) A double-walled thermos flask may be assumed to be equivalent to two infinite parallel plates. The emissivities of wall are 0.3 and 0.7 respectively. Space between them is evacuated. Find the heat transfer rate by radiation through the flask if inside surface temperature is 90°C and outside surface at 30°C under steady state. [5]

QUESTION 2

Water flows through a cast steel pipe (k = 50W/mK) with an outer diameter of 104 mm and 2mm wall thickness.

i) Calculate the heat loss by convection and conduction per metre length of uninsulated pipe when the water temperature is 15 °C, the outside temperature is -10 °C, the water side heat heat transfer coefficient is 30 kW/m^2K and the outside heat transfer coefficient is 20 W/m^2K. [5]

ii) Calculate the corresponding heat loss when the pipe is lagged with insulation having an outer diameter of 300mm, and thermal conductivity of k = 0.05 W/mK [5]

QUESTION 3

a) A straight fin of rectangular profile is constructed of stainless steel (18% Cr, 8% Ni) and has a length of 5 cm and a thickness of 2.5 cm. The base temperature is maintained at 100°C and the fin is exposed to a convection environment at 20°C with $h = 47\ W/m^2.\ °C$. Calculate the heat lost by the fin per meter of depth if $k = 200 W/mK$. [5]

b) A shell-and-tube heat exchanger employs a liquid in the shell that is heated from 30°C to 55°C by a hot gas in the tubes that is cooled from 80°C to 60°C. Calculate the effectiveness of the heat exchanger. [3]

Section B: Answer any <u>three</u> questions [60 marks]

QUESTION 5

In a manufacturing process, a transparent film is being bonded to a substrate as shown in Fig.B3. To cure the bond at a temperature T_o, a radiant source is used to provide a heat flux q_o (W/m^2), all of which is absorbed at the bonded surface (q_o is completely transmitted in the transparent film). The back of the substrate is maintained at T_1 while the free surface of the film is exposed to air at T_∞, and a convection heat transfer coefficient of h. The thickness of the bond can be neglected.

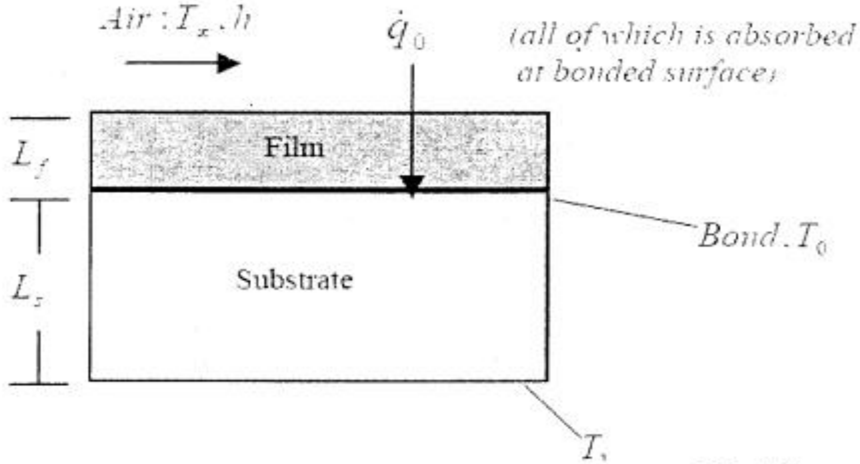


Fig.B3

$L_f = 0.25\ mm,\ k_f = 2.5 \times 10^{-2} W/mK,\ L_S = 1.0\ mm,\ k_S = 5.0 \times 10^{-2} W/mK$

a) Sketch the thermal circuit representing the steady state heat transfer situation. Be sure to label all elements, nodes, and heat rates. [8]

b) Calculate all thermal resistance in your thermal circuit. [8]

c) For conditions of T_o, = 20° C, h = 50W/m^2 K and T_1 = 30° C, calculate the heat flux q_o required to maintain the bonded surface at T_o = 60°C. [4]

QUESTION 6

a) An exterior wall of a house may be approximated by a 4-in layer of common brick (k=0.7 W/m°C) followed by a 1.5-in layer of gypsum plaster (k=0.48 W/m°C). What thickness of loosely packed rock-wool insulation (k=0.065 W/m°C) should be added to reduce the heat loss (or gain) through the wall by 80 percent? [10]

b) A shell-and-tube heat exchanger operates with two shell passes and four tube passes. The shell fluid is ethylene glycol, which enters at 140°C and leaves at 80°C with a flow rate of 4500 kg/h. Water flows in the tubes, entering at 35°C and leaving at 85°C. The overall heat-transfer coefficient for this arrangement is 850 W/m^2.°C. Calculate the flow rate of water required and the area of the heat exchanger. [10]

(Cp_{water} = 4200J/kg.°C, Cp_{glycol} = 2742K/kg.°C)

QUESTION 7

An electric current of 34000 A flows along a flat steel plate 1.25 cm thick and 10 cm wide. The temperature of one surface of the plate is 80°C and that of the other is 95°C.

(a) Find the temperature distribution across the plate [8]

(b) The value and position of the maximum temperature [7]

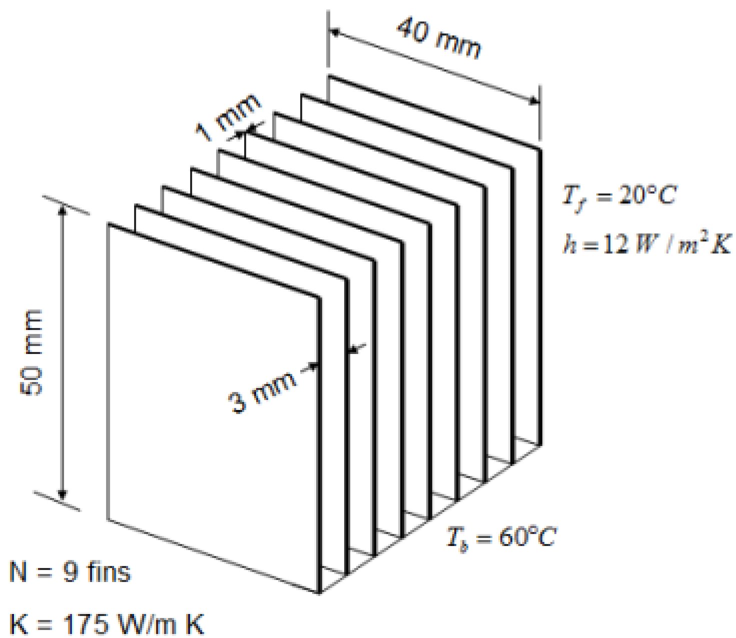
(c) Calculate the total amount of heat generated from each surface of the plate. [5]

It may be assumed that no heat flows across short sides of the plate and the ohmic heating is generated uniformly across the section.

The resistivity of the steel is $\rho = 12 \times 10^{-6}$ Ωcm and its thermal conductivity is k = 54 W/m. K.

QUESTION 8

A diagram of a heat sink to be used in an electronic application is shown below. There are a total of 9 aluminium fins (k = 175 W/mK, C = 900J/kgK, ρ = 2700kg/m^3) of rectangular cross-section, each 60mm long, 40mm wide and 1mm thick. The spacing between adjacent fins, s, is 3mm. The temperature of the base of the heat sink has a maximum design value of T_b= 60 °C, when the external air temperature T_f is 20°C. Under these conditions, the external heat transfer coefficient, h, is 12 W/m^{2}K. The fin may be assumed to be sufficiently thin so that the heat transfer from the tip can be neglected.



Determine,

a) the total convective heat transfer from the heat sink [10]

b) the fin effictiveness [5]

c) the fin efficiency [5]

END OF EXAMINATION

Formulae and Constants

$\sigma = 5.67 \times 10^{-8}$ W/ m^{4}K^4

$Q = hA(T_w - T_\infty)$, where $h = k_{fluid}/\delta'$

Q = $2\pi kL \frac{T_1 - T_2}{ln(\frac{r_2}{r_1})}$

Q = $\frac{T_1 - T_2}{R}$, where R = L/kA

m = $\sqrt{(\frac{hP}{kA})}$

Q_f = $\sqrt{(hPkA)}\ \Delta T\ tanh\ (mL)$

$NTU = \frac{UA}{C_{min}}$

Q = εq_{max}

$\varepsilon = \frac{q}{q_{max}}\ or\ \frac{\Delta T}{T_{max}}$

For counterflow,

$\Delta T_{LMTD} = \frac{(T_1 - t_2) - (T_2 - t_1)}{ln(\frac{T_1 - t_2}{T_2 - t_1})}$

R = $\frac{T_1 - T_2}{t_2 - t_1}$

S = $\frac{t_2 - t_1}{T_1 - t_1}$

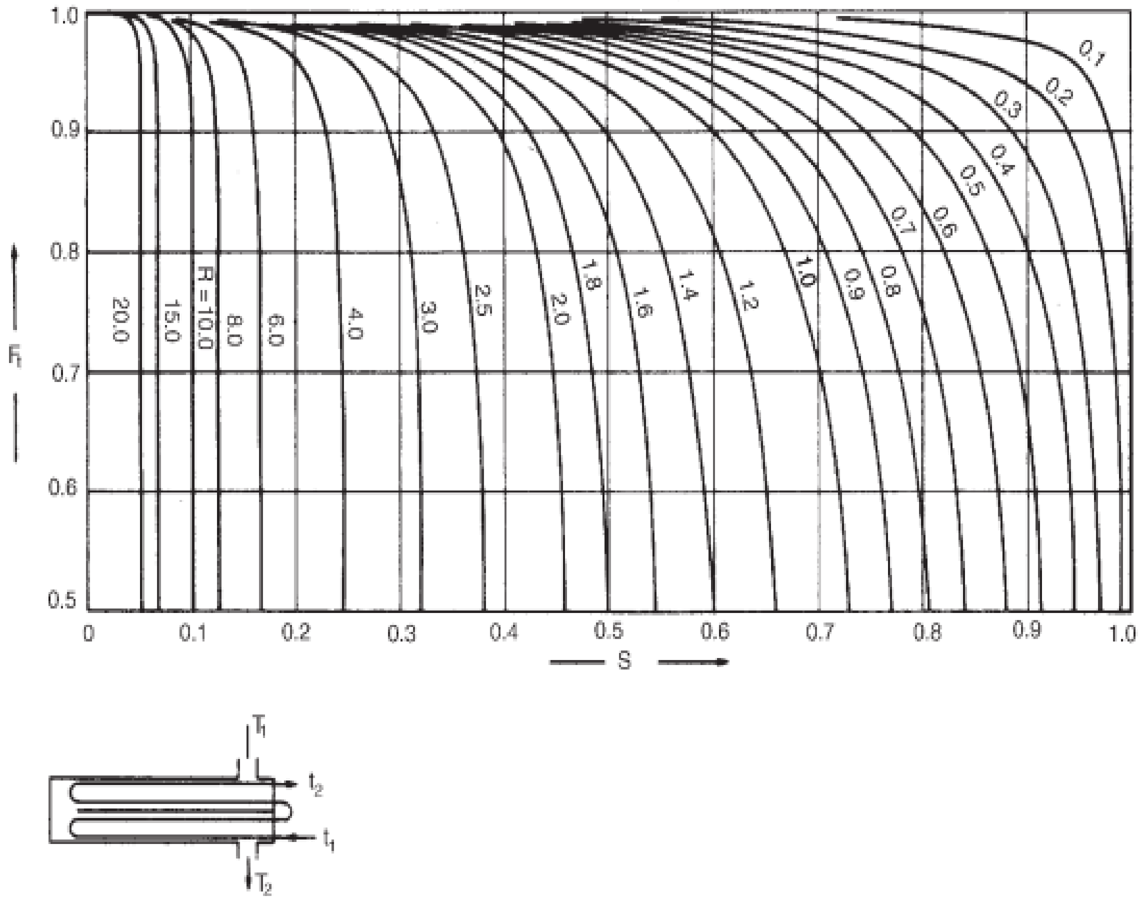


Figure 12.20. Temperature correction factor: two shell passes; four or multiples of four tube passes