MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING

DEPARTMENT: CHEMICAL AND PROCESSING ENGINEERING

MODULE: HEAT TRANSFER

CODE: CHEP 311/HCHE 313

SESSIONAL EXAMINATIONS
DECEMBER 2022

DURATION: 3 HOURS

EXAMINER: MISS L. 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) State the Fourier's law of heat conduction. [1]

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

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

(iv) Explain the difference between the parallel and counter flow heat exchanger. [3]

(v) Explain why coastal areas are usually windy. [4]

QUESTION 2

Water at 80 °C is pumped through 100 m of stainless steel pipe (k=16 W/K) of inner and outer radii 47 mm and 50 mm, respectively. The heat transfer coefficient due to water is 2000 W/m^2K. The outer surface of the pipe loses heat by convection to air at 20 °C and the heat transfer coefficient is 200 W/m^2K.

(i) Calculate the heat flow through the pipe. [5]

(ii) Determine the heat flow through the pipe when a layer of insulation, k=0.1 W/mK and 50 mm radial thickness, is wrapped around the pipe. [5]

QUESTION 3

A circumferential fin of rectangular profile is constructed of aluminium and surrounds a 3-cm-diameter tube. The fin is 2 cm long and 1 mm thick. The tube wall temperature is 200 °C, and the fin is exposed to a fluid at 20 °C with a convection heat-transfer coefficient of 80 $W/m^2 °C$. Calculate the heat loss from the fin. [8]

QUESTION 4

A shell-and-tube heat exchanger employs a liquid in the shell that is heated from 30 to 55 °C by a hot gas in the tubes that is cooled from 100 to 60 °C. Calculate the effectiveness of the heat exchanger. [6]

Section B

Answer any <u>three</u> questions (60 marks)

QUESTION 5

The temperature distribution across a wall 0.3 m thick at a certain instant of time is given by:

$$T(x) = a + bx + cx^2,$$

where T is in °C and x in metres, a = 200 °C, b = -200 °C/m, and c = 30 $°C/m^2$.

The wall has a thermal conductivity of 1 W/m·K.

(i) On a unit surface area basis, determine the rate of heat transfer into the wall on the left face. [5]

(ii) On a unit surface area basis, determine the rate of heat transfer out of the wall on the right face. [5]

(iii) Determine the rate of change of energy stored by the wall. [5]

(iv) If the cold surface is exposed to a fluid at 100 °C, what is the convection coefficient h ($W/m^2.k$)? [5]

QUESTION 6

Describe an experiment that can be used to determine the thermal conductivity of a material, taking into consideration:

(i) Diagram of apparatus [5]

(ii) Experimental procedure [10]

(iii) Calculations involved [5]

QUESTION 7

A plane metal plate 12 cm thick generates heat at the rate of 5×10^5 W/m^3 when an electrical current is passed through it. If the surface temperatures on left and right side to be maintained at 200 °C and 150 °C, respectively, find :

(i) The temperature distribution across the plate section. [10]

(ii) The position and magnitude of maximum temperature. [5]

(iii) Heat flow rate from each surface of the plate. [5]

QUESTION 8

i) 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]

ii) The cooling system of an electronic package has to dissipate 0.153 kW from the surface of an aluminium plate 100 mm × 150 mm **(Fig. 1).** It is proposed to use eight fins, each 150 mm long and 1 mm thick. The temperature difference between the plate and the surroundings is 50 K, the thermal conductivity of plate and fins is 0.15 kW/m·K and the heat transfer coefficient is 0.04 kW/m^2K.

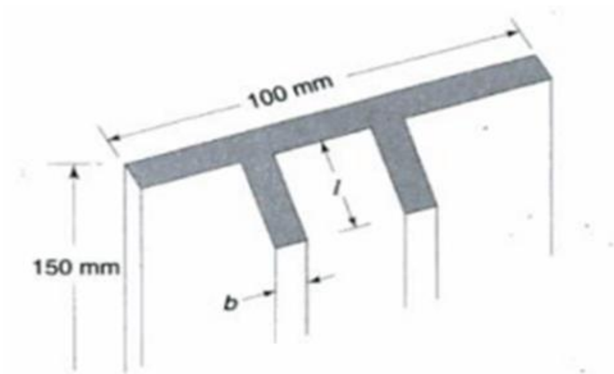


Fig. 1

Calculate the height of fins required. [10]

END OF EXAMINATION

FORMULAE AND CONSTANTS

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

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

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

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

$Q = \varepsilon q_{max}$

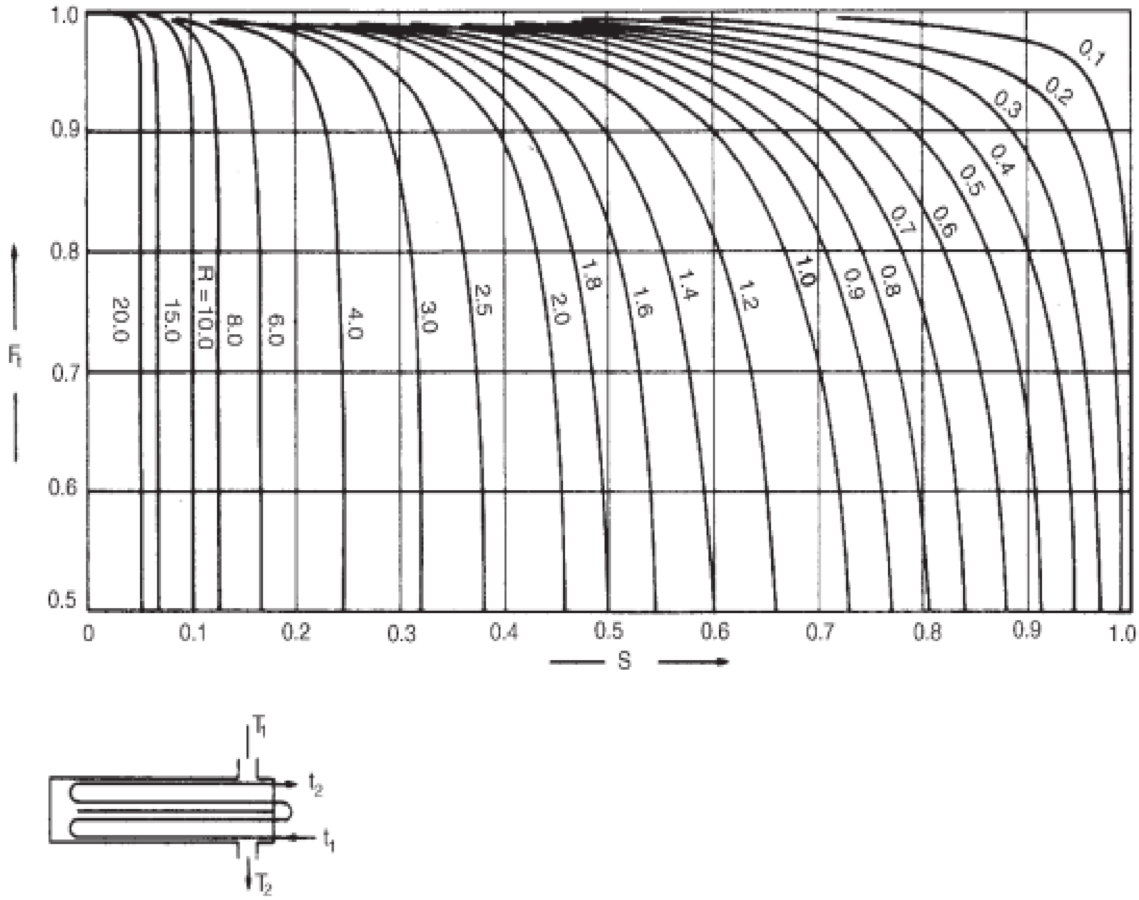
$\varepsilon = \frac{q}{q_{max}}\ or\ \frac{\Delta T}{T_{max}}$

For counterflow,

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

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

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



Temperature correction factor: two shell phases; four multiple of four tube passes