TECHNICAL UNIVERSITY OF MOMBASA

Faculty of Engineering & Technology

DEPARTMENT OF MECHANICAL & AUTOMOTIVE ENGINEERING

UNIVERSITY EXAMINATIONS FOR
THE DEGREE OF BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

(Y5 S1)

EMG 2502 HEAT TRANSFER

END OF SEMESTER EXAMINATIONS

SERIES: DECEMBER 2016

TIME: 2 HOURS

INSTRUCTIONS TO CANDIDATES:

1. You should have **Answer Booklet** for this examination.
2. This paper contains **FIVE** questions. Answer **ANY THREE** questions.
3. All diagrams should be clearly drawn and labeled.
4. This paper consists of **FOUR** printed pages.

Supplied: *Thermophysical and Transport Properties of Fluids (SI Edition)*, by Y.R. Mayhew and G.F.C. Rogers. The Stefan-Boltzmann constant: $\sigma = 56{\cdot}7 \times 10^{-12}$ kW/m^2 K^4

Question 1

(a) Consider the plane wall separating hot and cold fluids at temperatures $T_{\infty,1}$ and $T_{\infty,2}$ respectively. Using surface energy balance and boundary conditions at $x = 0$ and $x = L$;

(i) Derive an expression for the temperature distribution within the wall and

(ii) Obtain an expression for the heat flux across the plane wall in terms of $T_{\infty,1}$, $T_{\infty,2}$,

h_1, h_2 and L. **(10 marks)**

(b) A composite wall consisting of five sections is as shown in Figure 1(b). The thermal conductivities of the walls are: $k_1 = k_3 = 80$ W/m·K, $k_2 = 120$ W/m·K, $k_4 = 100$ W/m·K and $k_5 = 150$ W/m·K, The temperature on the left-side of the wall, $T_{\infty,1} = 80^oC$ and the temperature on the right-side, $T_{\infty,2} = 20^oC$. The convection coefficient, $h = 15$ W/m^2·K on both sides.

(i) Construct the thermal circuit model for the system.

(ii) Calculate the heat transfer rate through the wall.

(10 marks)

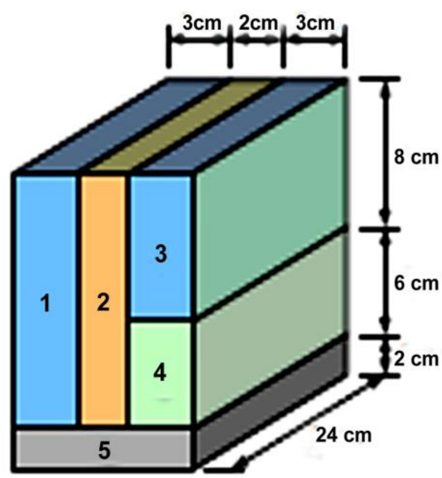

Figure Q1 (b)

Question 2

(a) A rectangular fin of width W, length L, thickness t, and thermal conductivity k is exposed to an ambient fluid at temperature T_∞ and having a convection heat transfer coefficient, h. The fin base is maintained at temperature T_o, and the fin is of finite length and looses heat by convection from its tip.

(i) Starting with the general fin equation: $\frac{d^2\theta}{dx^2} - m^2\theta = 0$, derive an expression for temperature distribution $T_{(x)}$ in the fin. Hint: Assume $m^2 = \frac{hP}{kA_c}$

(ii) Derive an expression for the heat transfer rate through the fin.

(14 marks)

(b) An aluminium alloy fin of rectangular profile (k = 180 W/m·K) has a base thickness of t = 1 mm and a length of L = 10 mm. Its base temperature is T_o = 100°C, and it is exposed to a fluid for which T_∞ = 25°C and h = 100 W/m^2·K. For the foregoing conditions and a fin of unit width, calculate:

(i) The heat transfer rate through the fin,

(ii) The efficiency of the fin. **(6 marks)**

<u>Question 3</u>

(a) Derive an expression for *log-mean temperature difference* (LMTD) for a parallel flow heat-exchanger. State all assumptions you make in your derivation. `**(10 marks)**

(b) A two-shell-pass, four-tube-pass heat-exchanger uses 20 kg/s of river water at 10°C on the shell side to cool 8 kg/s of processed water from 80 to 25°C on the tube side. The overall heat transfer coefficient for a tube side U is 800 W/m^2·K.

(i) At what temperature will the coolant be returned to the river?

(ii) Calculate the heat transfer surface area on the tube side. **(10 marks)**

<u>Question 4</u>

(a) Starting with the integral boundary layer equation for laminar flow over a flat plate in the form:

$$\rho \frac{d}{dx}\int_0^\delta (u_\infty - u)u\, dy = \tau_w = \mu \frac{\partial u}{\partial y}\bigg]_{y=0}$$

And using a cubic parabola velocity profile distribution; $\frac{u}{u_\infty} = \left[\frac{3}{2}\frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3\right]$

obtain an expression for the boundary-layer thickness, expressing your result in terms of the local Reynolds number. **(12 marks)**

(b) Air at 30°C flows over a flat plate at a velocity of 2 m/s. The plate is 2 m long and 1.5 m wide. Calculate:

(i) The thermal boundary layer thickness at the trailing edge of the plate.

(ii) The total mass flow rate through the boundary between x = 40 cm and x = 85 cm.

(8 marks)

<u>Question 5</u>

(a) Show that the net radiant heat-transfer rate between two grey surfaces is given by the following expression:

$$Q_{1-2} = \frac{A_1 \sigma (T_1^4 - T_2^4)}{\frac{1-\varepsilon_1}{A_1\varepsilon_1} + \frac{1}{A_1 F_{1-2}} + \frac{1-\varepsilon_2}{A_2\varepsilon_2}}$$

where the symbols have the usual meaning.

Further, show how $Q_{1\text{-}2}$ can be represented as an electrical network.

(13 marks)

(b) Two circular discs, each 20 cm diameter are parallel to and directly opposite each other at a distance 2 m apart. The discs are maintained at 800°C and 300°C respectively and their corresponding emissivities are 0.3 and 0.5. Assume the discs to be grey surfaces and the radiation heat exchange takes place between the discs only. Calculate the radiant heat exchange between the discs. **(7 marks)**

APPENDIX 1: Correction Factors for Heat Exchangers

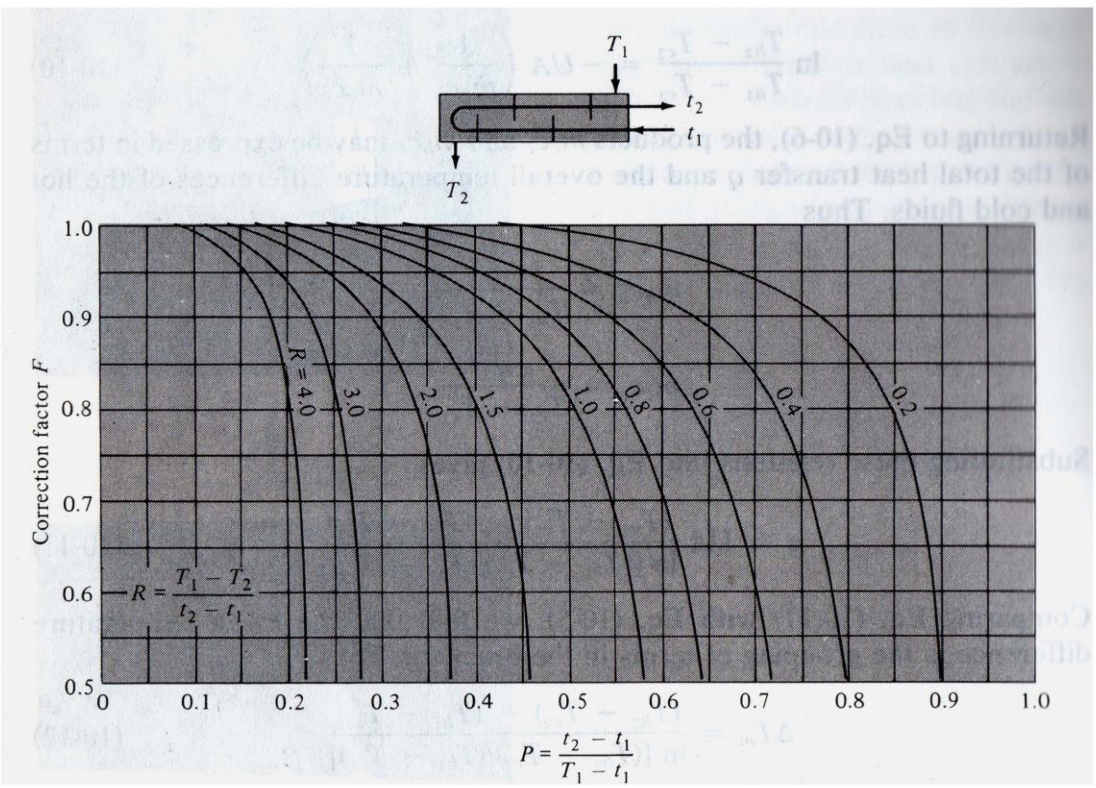

Figure 1 – Correction-factor plot for exchanger with one-shell pass and two, four or any multiple of tube passes

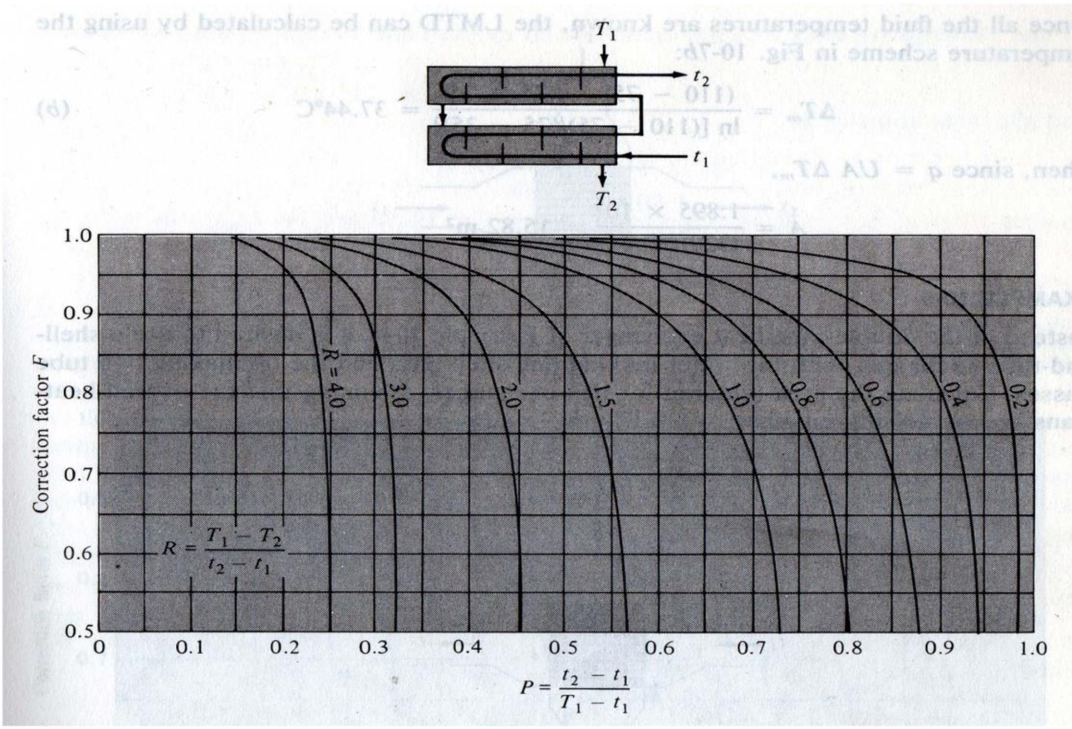

Figure 2 – Correction-factor plot for exchanger with two-shell passes four, eight and any multiple of tube passes

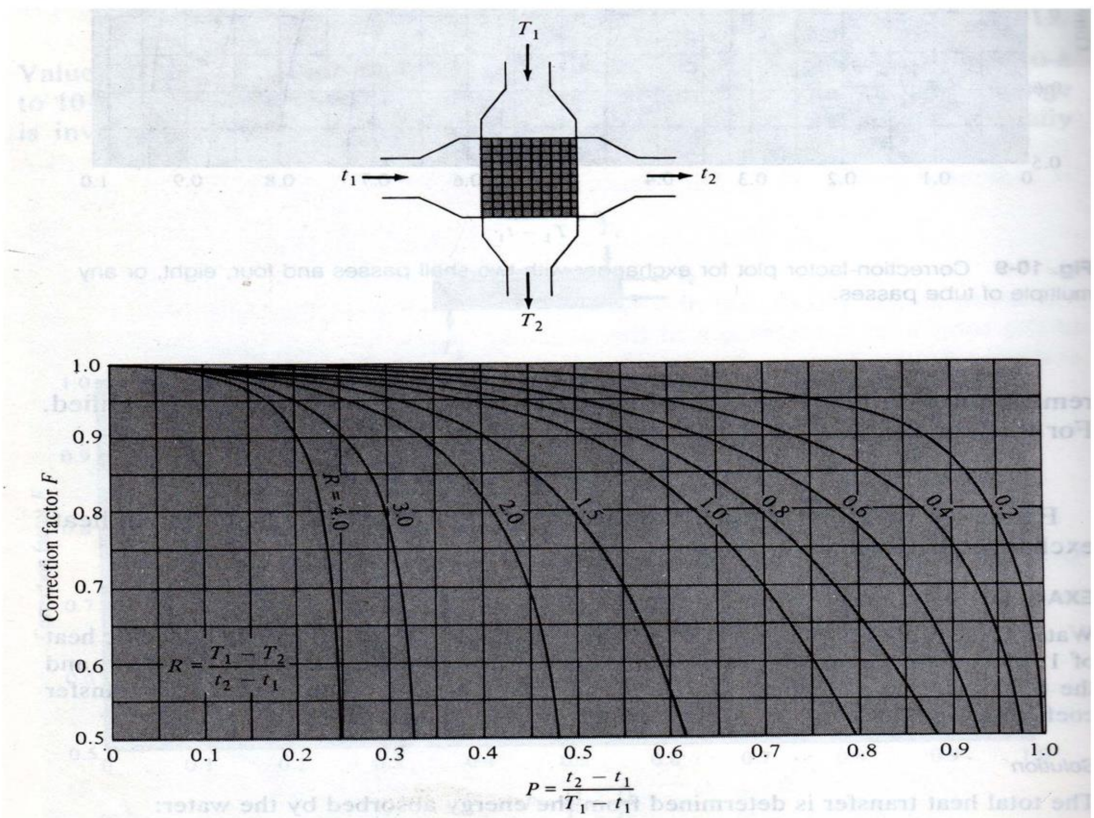

Figure 3 – Correction-factor plot for exchanger for single-pass cross-flow exchanger both tube unmixed

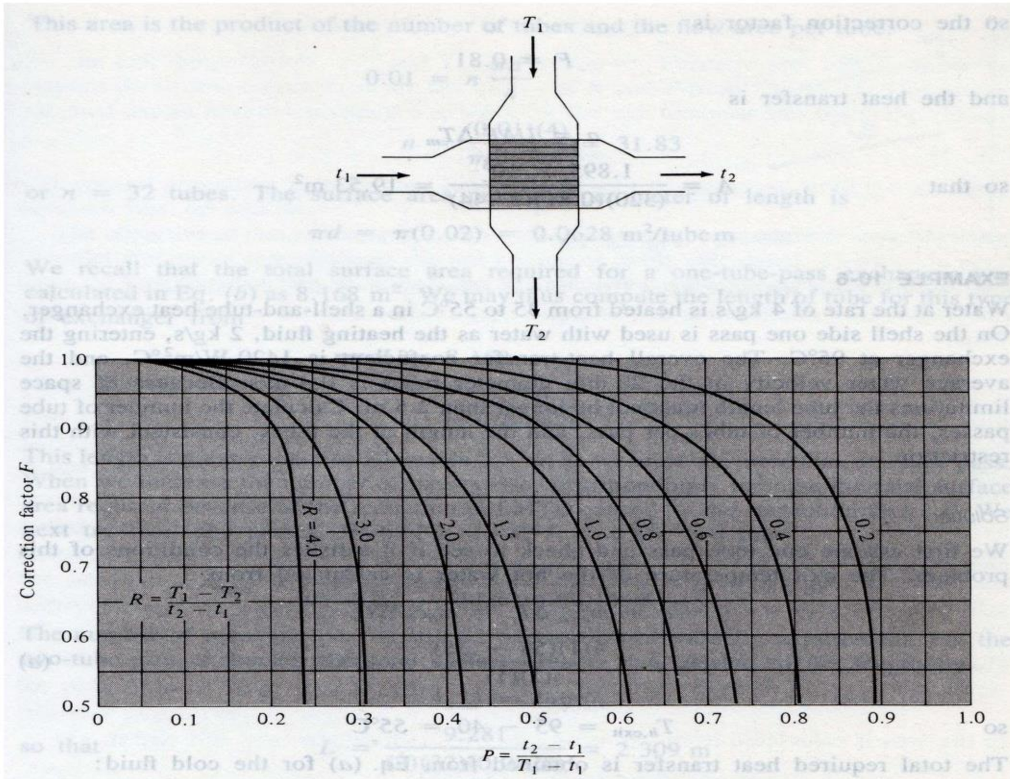

Figure 4 – Correction-factor plot for exchanger single-pass cross-flow exchanger, one fluid mixed, the other unmixed

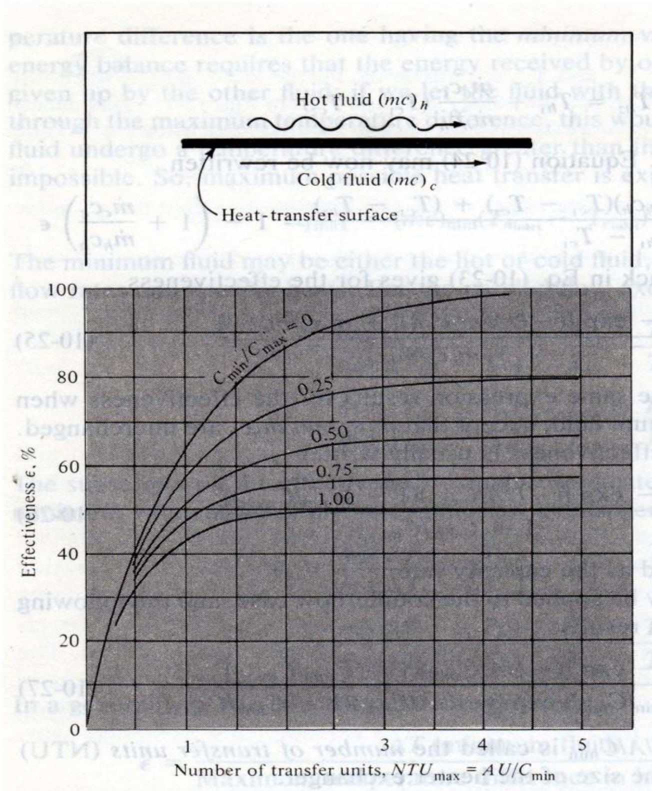

Figure 5 – Effectiveness for parallel-flow exchanger performance

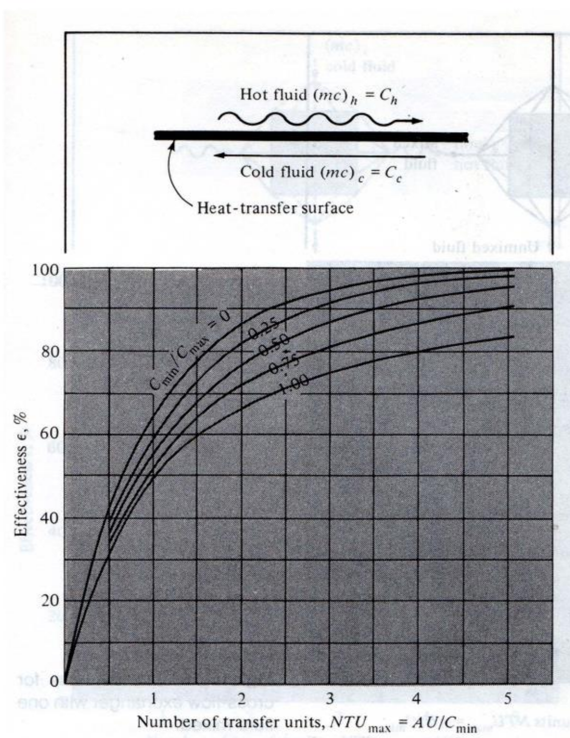

Figure 6 – Effectiveness for parallel-flow exchanger performance

APPENDIX 2: