



UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF CHEMICAL & BIOENGINEERING
TECHNOLOGY

FINAL EXAMINATION
OCTOBER 2025 SEMESTER

COURSE CODE : CLB 21204
COURSE NAME : TRANSPORT PROCESS PRINCIPLE
PROGRAMME NAME : BACHELOR OF CHEMICAL ENGINEERING
TECHNOLOGY
DATE : 31 JANUARY 2026
TIME : 2.00 PM – 5.00 PM
DURATION : 3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper has information printed on both sides of the paper.
3. This question paper consists of one section: Section A.
4. Section A consist of five questions. Answer FOUR (4) questions ONLY.
5. Please write your answers on the answer booklet provided.
6. Appendices have been appended for your reference.
7. Answer all questions in English language ONLY.

THERE ARE 12 PAGES OF QUESTIONS, EXCLUDING THIS PAGE.

SECTION A (Total: 100 marks)

INSTRUCTION: Answer ONLY FOUR (4) questions.

Please use the answer booklet provided.

Question 1

- (a) You are working as an Environmental, Safety and Health (ESH) Technologist at a chemical processing plant in Malaysia. The management team is planning to install a new air pollution control system to comply with the requirements of the Department of Environment (DOE). Currently, the plant emits pollutants through industrial exhaust streams, including **particulates and harmful gases** that pose risks to both the environment and human health. As the ESH Technologist and a member of the technical team, you are required to **propose** a suitable type of air pollution control equipment, referred to as Equipment X, to be installed in the plant to address these pollution issues. The proposal should include the following:
- i. name of equipment X. (1 marks)
 - ii. complete diagram of the equipment X with labels. (5 marks)
 - iii. working principle of the equipment X. (6 marks)
 - iv. two advantages of installing equipment X in the plant. (4 marks)
- (b) Wind at 55 km/h is blowing parallel to a 4 meter high and 10 meter long wall of a house. If the air outside is at 5°C and the surface temperature of the wall is 19°C, determine the rate of heat loss from that wall by convection. Given $Re = 1.740 \times 10^5$ and $k = 0.02625$ W/m.°C. (9 marks)

Question 2

- (a) A distillation column treats a mixture containing 40 mol% of component A and 60 mol% of component B at total pressure of 1 kPa. The mixture was separated through distillation process to give a distillate containing 90 mol% of component A and bottom containing 85 mol% of component B. The feed is liquid at its boiling point. Given molecular weight for A and B are 78 kg/kmol and 92 kg/kmol respectively. Based on the Table 1 below,

Table 1: Equilibrium Data

X_A	0	0.03	0.10	0.21	0.34	0.44	0.60	0.79	1
Y_A	0	0.09	0.22	0.40	0.56	0.68	0.81	0.91	1

- i. determine the minimum reflux ratio, $R_{\min}$.
(7 marks)
 - ii. by using the same graph paper, determine the number of stages if the reflux ratio, R is 4.32 times minimum reflux ratio, $R_{\min}$ by using McCabe-Thiele Method.
(11 marks)
- (b) Solid-liquid extraction (leaching) is a process of extracting substance from a solid by dissolving it in a liquid solvent. It can be executed naturally or through an industrial process. Several factors, including size particle, affect solid-liquid extraction in industrial operations. Discuss the effect of decreasing particle size on solid-liquid extraction efficiency.
(4 marks)
- (c) List three applications of solid-liquid extraction in industry.
(3 marks)

Question 3

- (a) Explain four stages of liquid-liquid extraction (LLE) process. (8 marks)
- (b) Distillation and gas absorption are the unit operations used in the purification process as shown in Figure 1 below.

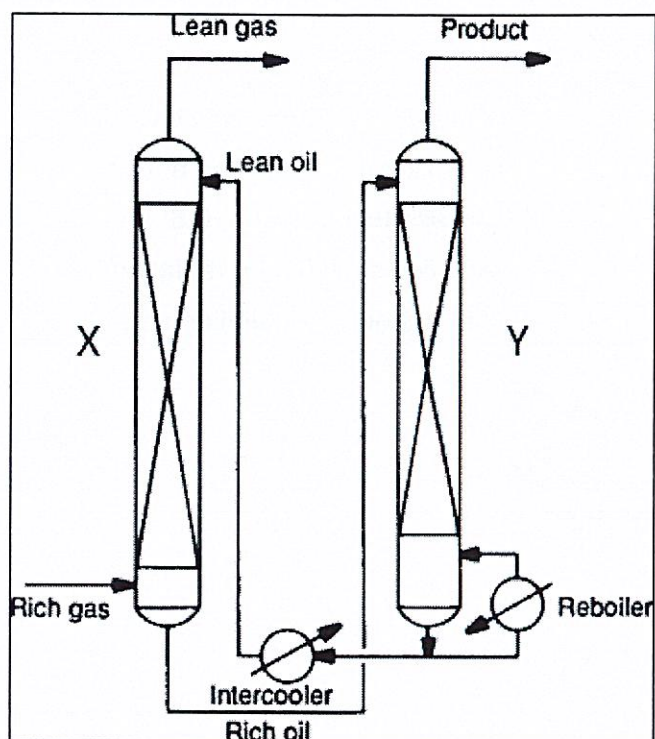


Figure 1 Separation process of gas and oil purification process

Based on Figure 1,

- name equipment X and equipment Y. (2 marks)
- explain the function of equipment X. (3 marks)
- explain the function of equipment Y. (3 marks)
- discuss two differences between equipment X and Y. (4 marks)

- (c) Gas X and gas Y are diffusing in equimolar counter diffusion through a straight glass tube 2.0 ft at 298 K and 101.32 kPa. Both ends of the tube are connected to large mixed chambers. The partial pressure of X in one chamber is constant at 25 kPa and 6.666 kPa in other chamber. The diffusivity coefficient is $2.45 \times 10^{-5} \text{ m}^2/\text{s}$. Calculate the diffusion flux of Y.

(5 marks)

Question 4

- (a) A radiation shield that has the same emissivity ϵ_3 on both sides is placed between two large parallel plates, which are maintained at uniform temperatures of $T_1 = 650 \text{ K}$ and $T_2 = 400 \text{ K}$ and have emissivities of $\epsilon_1 = 0.6$ and $\epsilon_2 = 0.9$ respectively. Determine the emissivities of the radiation shield if the radiation heat transfer between the plates is to be reduced to 35% of that without the radiation shield.

(11 marks)

- (b) Ternary systems are represented on two types of triangular diagrams which are right-triangle phase diagrams and equilateral triangular diagram (as in Figure 2 below).

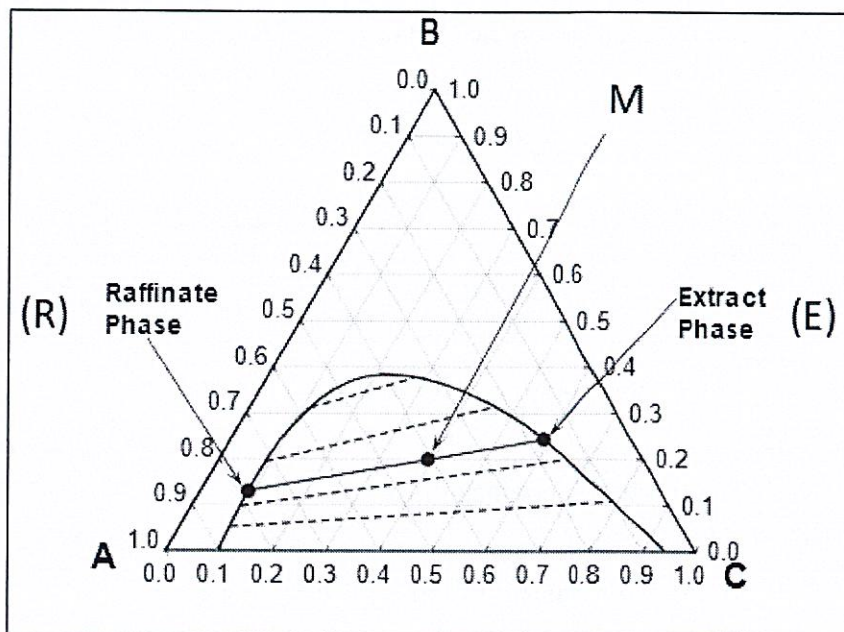


Figure 2: Equilateral triangular coordinates

Based on Figure 2,

- i. explain the function of equilateral triangular coordinates. (2 marks)
- ii. determine the composition of pure A, B and C. (3 marks)
- iii. determine the composition (mole fraction of X_A , X_B and X_C) of mixture points **M**, **R** and **E**. (9 marks)

Question 5

- (a) A heat exchanger containing two shell pass and two tubes passes heats 2.52 kg/s of water from 21.1°C to 59°C by using hot water (4.2 kg/s) entering tube at 115°C. The length of the tubes in the exchanger is 0.92 m and diameter is 0.05 m. Given $C_{p, \text{water}} = 4.180 \text{ kJ/kg} \cdot ^\circ\text{C}$. Calculate:

i. the rate of heat transfers (in kJ/s).

(4 marks)

ii. the log mean temperature difference ΔT_{lm} in the heat exchanger.

(6 marks)

iii. overall heat transfer coefficient, U .

(6 marks)

- (b) In separating vapor or gas from liquid mixture, distillation process always be a popular option. However, in some situations, liquid-liquid extraction (LLE) is a better option compared to distillation. Discuss two situations that make LLE is more preferable from distillation.

(4 marks)

- (c) Consider a spherical container of inner radius $r_1 = 8 \text{ cm}$, outer radius $r_2 = 10 \text{ cm}$ and thermal conductivity $k = 45 \text{ W/mK}$. The inner and outer surfaces of the container are maintained at constant temperatures of $T_1 = 200^\circ\text{C}$ and $T_2 = 80^\circ\text{C}$ respectively as a result of some chemical reactions occurring inside. Determine the rate of heat loss from the container.

(5 marks)

END OF EXAMINATION PAPER

APPENDICES
(MASS TRANSFER)

$$1 \text{ m} = 3.2808 \text{ ft}$$

$$y_A = \frac{\alpha_{AB} x_A}{1 + (\alpha_{AB} - 1)x_A}$$

$$y^* = \frac{R_{\min}}{R_{\min} + 1} x^* + \frac{1}{R_{\min} + 1} x_D$$

$$R_{\min} = \frac{x_D - y^*}{y^* - x^*}$$

$$y_{n+1} = \frac{R}{R+1} x_n + \frac{1}{R+1} x_D$$

$$y_q = \frac{q}{q-1} x_q - \frac{x_F}{q-1}$$

$$N_{\min} = \frac{\log \left(\frac{x_D}{(1-x_D)} \cdot \frac{(1-x_B)}{x_B} \right)}{\log \alpha_{av}}$$

$$y_{n+1} = x_n$$

$$L_N = \frac{L'}{1 - x_N}$$

$$V_N = \frac{V'}{1 - y_N}$$

$$V' = V_{N+1}(1 - y_{N+1})$$

$$J_A = \frac{D_{AB}(p_{A1} - p_{A2})}{RT(z_2 - z_1)}$$

$$y_{n+1} = \frac{L_n x_n}{V_{n+1}} + \frac{V_1 y_1 - L_0 x_0}{V_{n+1}}$$

$$L \left(\frac{x_2}{1 - x_2} \right) + V' \left(\frac{y_1}{1 - y_1} \right) = L \left(\frac{x_1}{1 - x_1} \right) + V' \left(\frac{y_2}{1 - y_2} \right)$$

$$R = 8.314 \frac{\text{m}^3 \cdot \text{kPa}}{\text{kgmol} \cdot \text{K}}$$

$$(1-x)_{iM} = \frac{(1-x_1) - (1-x_{i1})}{\ln[(1-x_1)/(1-x_{i1})]}$$

$$(x_i - x)_M = \frac{(x_{i1} - x_1) - (x_{i2} - x_2)}{\ln[(x_{i1} - x_1)/(x_{i2} - x_2)]}$$

$$m = \frac{-k'_x a / (1 - x_1)}{k'_y a / (1 - y_1)}$$

$$m = \frac{-k'_x a / (1 - x)_{iM}}{k'_y a / (1 - y)_{iM}}$$

$$x_{CM} = \frac{F x_{FC} + S y_{SC}}{F + S}$$

$$x_{AM} = \frac{F x_{FA} + S y_{SA}}{F + S}$$

$$\frac{L_{av}}{S} (x_1 - x_2) = k'_x a z (x_i - x)_M$$

$$L_{av} = \frac{(L_1 + L_2)}{2}$$

$$p_A = H \cdot x_A$$

$$p_A = H \cdot x_A$$

APPENDICES (HEAT TRANSFER)

$$1 \text{ W} = 1 \text{ J/s}$$

$$\beta = \frac{1}{T_f}$$

$$q_x = kA \frac{[T_1 - T_2]}{x_2 - x_1}$$

$$\text{Density of water} = 1000 \text{ kg/m}^3$$

$$T_f = \frac{T_w + T_b}{2}$$

$$q = \frac{\Delta T}{R_{total}}$$

$$q = \frac{k_A A}{\Delta x_A} (T_1 - T_2) = \frac{k_B A}{\Delta x_B} (T_2 - T_3) = \frac{k_C A}{\Delta x_C} (T_3 - T_4)$$

$$q_r = 2\pi kL \frac{[T_i - T_o]}{\ln\left(\frac{r_o}{r_i}\right)}$$

$$q = 2\pi L \frac{(T_1 - T_4)}{\left(\frac{\ln\left(\frac{r_2}{r_1}\right)}{k_A}\right) + \left(\frac{\ln\left(\frac{r_3}{r_2}\right)}{k_B}\right) + \left(\frac{\ln\left(\frac{r_4}{r_3}\right)}{k_C}\right)}$$

$$T - T_w = \frac{\dot{q}}{4k} (R^2 - r^2) \quad q(t) = hA_s (T(t) - T_\infty)$$

$$q_r = 4\pi k \frac{[T_i - T_o]}{\left(\frac{1}{r_i} - \frac{1}{r_o}\right)}$$

$$q = mC_p (T(t) - T_i)$$

$$m = \rho V$$

$$q_{max} = mC_p (T_\infty - T_i)$$

$$q_{max} = mC_p (T_\infty - T_i) = \rho V C_p (T_\infty - T_i)$$

$$q = hA (T_w - T_\infty)$$

$$\text{Re} = \frac{\rho V D}{\mu} = \frac{V D}{\nu}$$

$$\text{Ra} = \text{Gr Pr} = \frac{g\beta(T_s - T_\infty)Lc^3}{\nu^2} \text{Pr}$$

$$\text{Nu} = \frac{hLc}{k}$$

$$\text{Gr} = \frac{g\beta(T_s - T_\infty)Lc^3}{\nu^2}$$

$$q = \frac{T_1 - T_4}{\frac{\Delta x_A}{k_A A} + \frac{\Delta x_B}{k_B A} + \frac{\Delta x_C}{k_C A}}$$

$$q = \frac{\Delta T}{R_A + R_B + R_C} = \frac{\Delta T}{R_{TH}}$$

$$R_{convection} = \frac{1}{hA}$$

$$R_{conduction} = \frac{\Delta x}{kA}$$

$$\text{NTU} = \frac{UAs}{C_{min}} = \frac{UAs}{(mC_p)_{min}}$$

$$q = UA(\Delta T)_{lm} \quad q = UAF (\Delta T)_{lm} \quad C_h = m_h C_{ph} \quad C_c = m_c C_{pc}$$

$$q = (m)_{hot} (C_p)_{hot} (\Delta T)_{hot} \quad \Delta T_{lm} = \frac{\theta_1 - \theta_2}{\ln\left(\frac{\theta_1}{\theta_2}\right)} \quad c = \frac{C_{min}}{C_{max}}$$

$$q = (m)_{cold} (C_p)_{cold} (\Delta T)_{cold}$$

Parallel $\theta_2 = T_{ho} - T_{co} \quad \theta_1 = T_{hi} - T_{ci}$

Counter-flow $\theta_1 = T_{hi} - T_{co} \quad \theta_2 = T_{ho} - T_{ci}$

$$Q = m_c C_{pc} (T_{c,out} - T_{c,in}) = m_h C_{ph} (T_{h,in} - T_{h,out})$$

$$\Delta T_{max} = T_{h,in} - T_{c,in}$$

$$Q_{max} = (mCp)_{min} (T_{h,inlet} - T_{c,inlet})$$

$$Q = \varepsilon Q_{max} = \varepsilon (mCp)_{min} (T_{h,inlet} - T_{c,inlet})$$

Horizontal plate

$$Nu = 0.54 Ra^{1/4} \quad 10^4 < Ra < 10^7 \quad \text{Upper surface of a hot plate}$$

$$Nu = 0.15 Ra^{1/3} \quad 10^7 < Ra < 10^{11} \quad \text{Upper surface of a hot plate} \quad Lc = As / p$$

$$Nu = 0.27 Ra^{1/4} \quad 10^5 < Ra < 10^{11} \quad \text{Lower surface of a hot plate}$$

$$Re = \frac{VLc}{\nu} = \frac{\rho VLc}{\mu} \quad Pr = \frac{\nu}{\alpha} = \frac{\mu Cp}{k}$$

$$Nu = \left\{ 0.825 + \frac{0.387 Ra_L^{1/6}}{\left[1 + (0.492 / Pr)^{9/16} \right]^{8/27}} \right\}^2 \quad \text{Vertical plate} \quad D \geq \frac{35L}{Gr_L^{1/4}}$$

$$Nu = \left\{ 0.6 + \frac{0.387 Ra_D^{1/6}}{\left[1 + (0.559 / Pr)^{9/16} \right]^{8/27}} \right\}^2 \quad \text{Horizontal cylinder}$$

$$Nu = 2.0 + \frac{0.589 Ra_D^{1/4}}{\left[1 + (0.469 / Pr)^{9/16} \right]^{4/9}} \quad \text{Sphere}$$

Plates

$$\text{Re} < 5 \times 10^5 \quad Nu = \frac{hL}{k} = 0.664 \text{Re}^{0.5} \text{Pr}^{1/3} \quad \text{Laminar}$$

$$\text{Re} > 5 \times 10^5 \quad Nu = \frac{hL}{k} = 0.0366 \text{Re}^{0.8} \text{Pr}^{1/3} \quad \text{Turbulent}$$

$$Nu = \frac{hD}{k} = 0.3 + \frac{0.62 \text{Re}^{1/2} \text{Pr}^{1/3}}{\left[1 + (0.4/\text{Pr})^{2/3}\right]^{1/4}} \left[1 + (\text{Re}/282000)^{5/8}\right]^{4/5} \quad \text{Cylinder}$$

$$Nu = \frac{hD}{k} = 2.0 + 0.6 \text{Re}^{0.5} \text{Pr}^{1/3} \quad \text{Sphere}$$

Properties of air at 1 atm pressure

T (°C)	ρ (kg m ⁻³)	ν (m ² s ⁻¹)	Pr	k (W m ⁻¹ K ⁻¹)	μ (kg m ⁻¹ s ⁻¹)
12	1.292	1.338 × 10 ⁻⁵	0.7362	0.02364	1.729 × 10 ⁻⁵
35	1.145	1.655 × 10 ⁻⁵	0.7268	0.02625	1.895 × 10 ⁻⁵

Properties of water at 1 atm pressure

T (°C)	ρ (kg m ⁻³)	Pr	k (W m ⁻¹ K ⁻¹)	μ (kg m ⁻¹ s ⁻¹)
12	999.8	13.5	0.561	1.729 × 10 ⁻⁵
35	994	4.83	0.623	0.720 × 10 ⁻⁵

$$1 \text{ W} = 1 \text{ J/s}$$

$$q = A\sigma T^4$$

$$q = \varepsilon A \sigma (T_1^4 - T_2^4)$$

$$\sigma = 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$$

$$E_b(T) = \sigma T^4$$

$$q_{12, \text{plates (no.shield)}} = \frac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

$$q_{12,one\ shield} = \frac{A\sigma(T_1^4 - T_2^4)}{\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right) + \left(\frac{1}{\varepsilon_{3,1}} + \frac{1}{\varepsilon_{3,2}} - 1\right)}$$

$$q_{12,N-shields} = \frac{A\sigma(T_1^4 - T_2^4)}{(N+1)\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right)} = \frac{1}{N+1} Q_{12,no-shields}$$

$$J_A = -\frac{cD_{AB}}{(z_2 - z_1)}(y_{A2} - y_{A1})$$

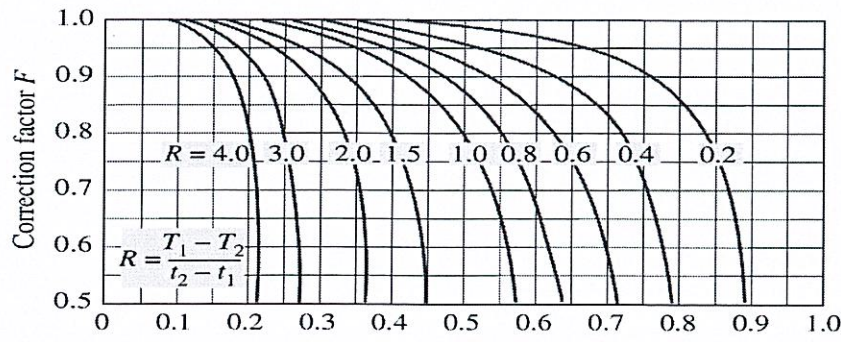
$$R = 8314.34 \frac{m^3.Pa}{kgmol.K}$$

$$D_{AB} = D_{BA}$$

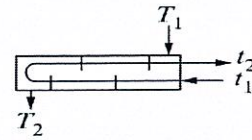
$$J_A = \frac{D_{AB}(p_{A1} - p_{A2})}{RT(z_2 - z_1)}$$

$$P = p_{A1} + p_{B1}$$

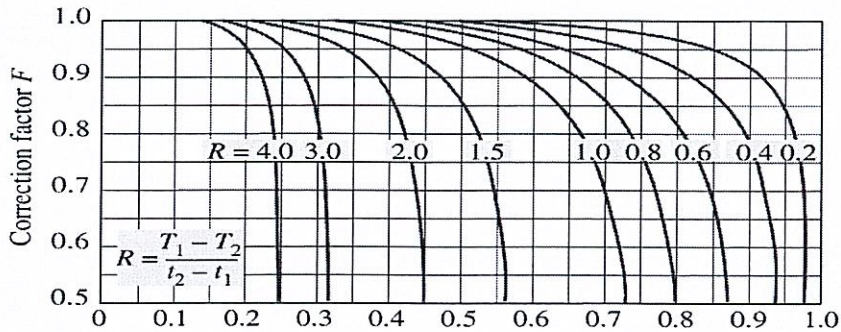
$$J_A = -J_B$$



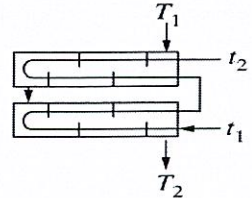
(a) One-shell pass and 2, 4, 6, etc. (any multiple of 2), tube passes



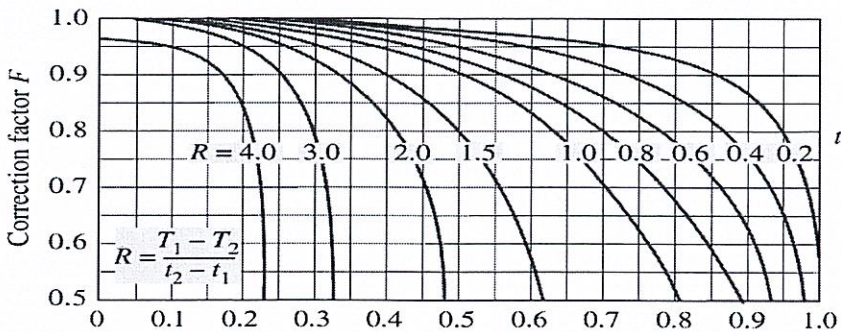
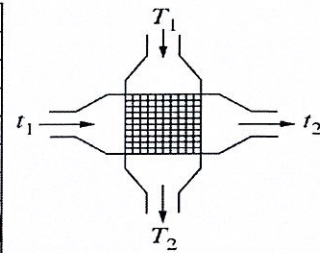
$$P = \frac{t_2 - t_1}{T_1 - t_1}$$



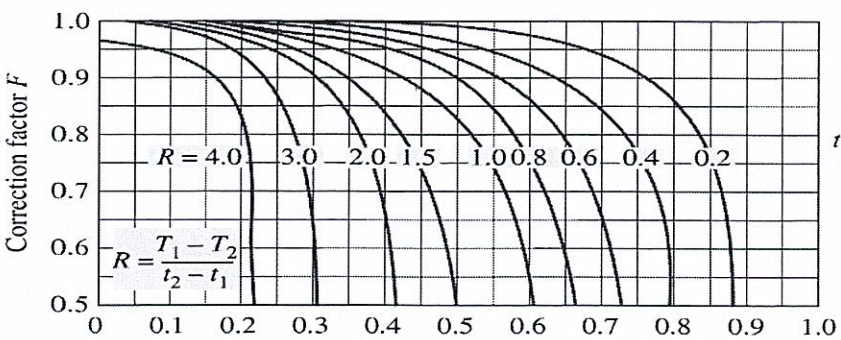
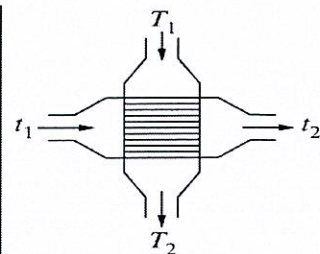
(b) Two-shell passes and 4, 8, 12, etc. (any multiple of 4), tube passes



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

(c) Single-pass cross-flow with both fluids *unmixed*

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

(d) Single-pass cross-flow with one fluid *mixed* and the other *unmixed*

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