UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2014/2015

COURSE NAME : MASS TRANSFER
COURSE CODE : BNQ 20303
PROGRAMME : 2 BNN
EXAMINATION DATE : JUNE 2015/JULY 2015
DURATION : 3 HOURS
INSTRUCTION : ANSWER **FOUR (4)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

Q1 (a) Describe the term "transport analogy".

(2 marks)

(b) Explain the term "conduction, convection and radiation heat transfers".

(3 marks)

(c) Define briefly the Black and Gray Body terms.

(5 marks)

(b) Explain the differences of steady state and unsteady state mass transfers.

(5 marks)

(c) State **FIVE (5)** types of dimensionless number that usually used in convective mass transfer.

(5 marks)

Q2 Hot oil at a flow rate of 3 kg/s (Cp = 1.92 kJ/kg.K) enters an existing counter flow exchanger at 400 K and is cooled by water entering at 325 K (under pressure) and flowing at a rate of 0.7 kg/s. The overall U = 350 $W/m^2.K$ and A = 12.9 m^2. Cp water = 4.196 kJ/kg.K. Assume water outlet Tc_o= 374 K. Referring to **FIGURE Q2,**

(a) Calculate the heat transfer rate.

(15 marks)

(b) Propose the exit oil temperature, $T_{Ho.}$

(5 marks)

Q3 A horizontal oxidized steel pipe carrying steam and having an OD of 0.1683 m has a surface temperature of 374.9 K and is exposed to air at 297.1 K in a large enclosure.

(a) Calculate the convection and radiation heat transfer coefficients, h_r and h_c (σ=5.676 $W/m^2.K^4$).

(12 marks)

(b) Calculate the heat loss for 0.305 m of pipe from natural convection plus radiation ($\varepsilon_{steel\ pipe}$= 0.79).

(8 marks)

Q4 A very thick slab has a uniform concentration of solute A of $c_o = 1.0 \times 10^{-2}$ kg mol A/m^3. Suddenly, the front face of the slab is exposed to a flowing fluid having a concentration $c_1 = 0.1$ kg mol A/m^3 and a convective coefficient $k_c = 2 \times 10^{-7}$ m/s. The equilibrium distribution coefficient $K = c_{Li}/c_i = 2.0$ and the diffusivity in the solid is $D_{AB} = 4 \times 10^{-9}$ m^2/s. Assuming that the slab is a semi-infinite solid, calculate the concentration in the solid at the surface at the following distance from the surface after $t = 3 \times 10^4$ s by referring to **FIGURE Q4** and **TABLE Q4.**

(a) $x = 0$ m

(10 marks)

(b) $x = 0.01$ m

(10 marks)

Q5 Pure water at 26.1 °C is flowing at a velocity of 0.0305 m/s in a tube having an inside diameter of 6.35 mm. The tube is 1.829 m long, with the last 1.22 m having the walls coated with benzoic acid. The solubility of benzoic acid in water is 0.02948 kg mol/m^3. Assuming that the velocity profile is fully developed,

(a) illustrate and label the diagram of the tube.

(3 marks)

(b) calculate the average concentration of benzoic acid at the outlet.
$\mu = 8.71 \times 10^{-4}$ Pa.s, $\rho = 996$ kg/m^3, $D_{AB} = 1.245 \times 10^{-9}$ m^2/s.

(17 marks)

- END OF QUESTION –

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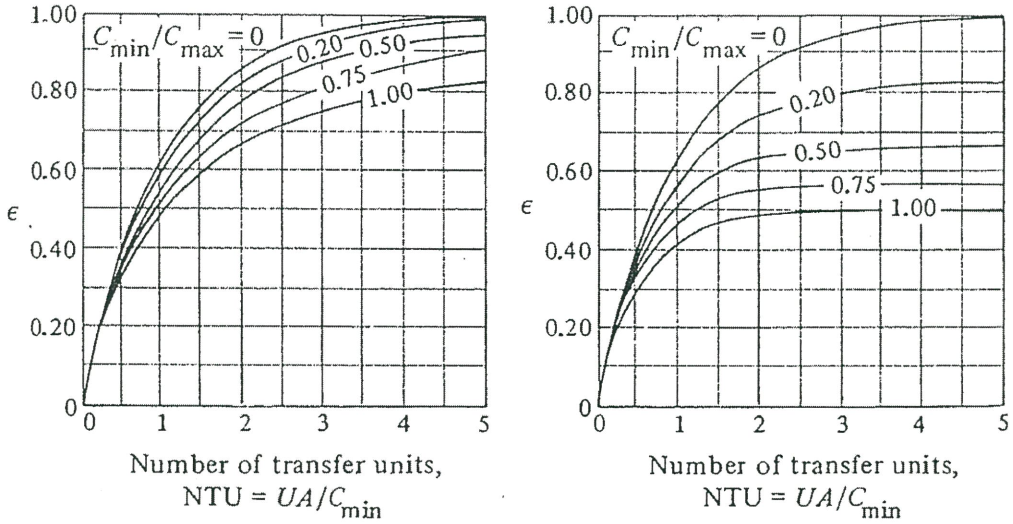

(a) (b)

FIGURE 4.9-7. *Heat-exchanger effectiveness ε: (a) counterflow exchanger, (b) parallel flow exchanger.*

FIGURE Q2

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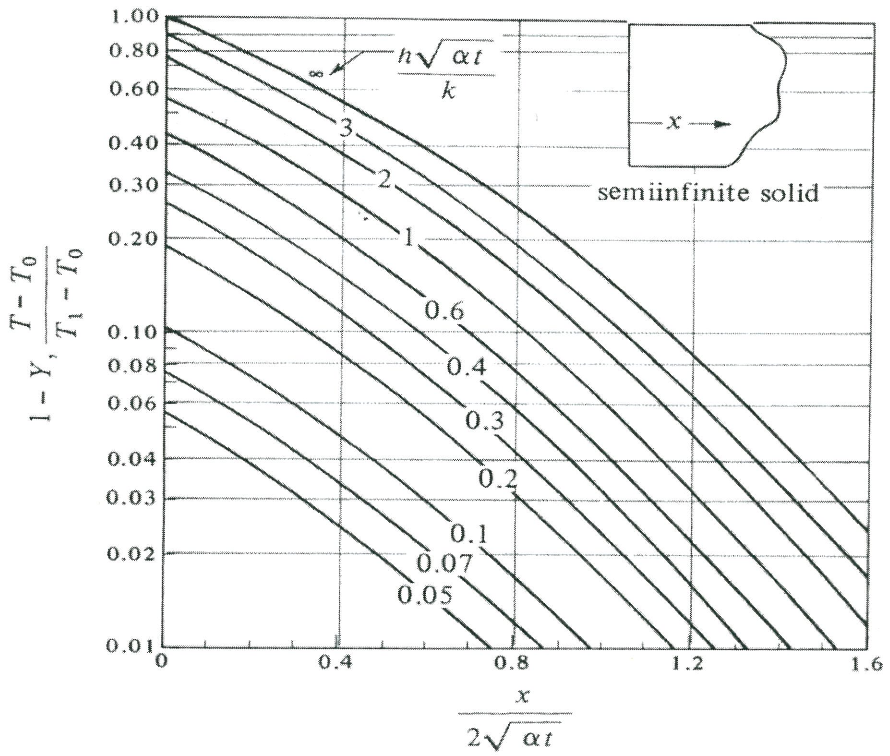

FIGURE 5.3-3. *Unsteady-state heat conducted in a semiinfinite solid with surface convection. Calculated from Eq. (5.3-7)(SI).*

FIGURE Q4

TABLE 7.1-1. *Relation Between Mass- and Heat-Transfer Parameters for Unsteady-State Diffusion**

	Mass Transfer	
Heat Transfer	$K = c_L/c = 1.0$	$K = c_L/c \neq 1.0$
$Y, \dfrac{T_1 - T}{T_1 - T_0}$	$\dfrac{c_1 - c}{c_1 - c_0}$	$\dfrac{c_1/K - c}{c_1/K - c_0}$
$1 - Y, \dfrac{T - T_0}{T_1 - T_0}$	$\dfrac{c - c_0}{c_1 - c_0}$	$\dfrac{c - c_0}{c_1/K - c_0}$
$X, \dfrac{\alpha t}{x_1^2}$	$\dfrac{D_{AB} t}{x_1^2}$	$\dfrac{D_{AB} t}{x_1^2}$
$\dfrac{x}{2\sqrt{\alpha t}}$	$\dfrac{x}{2\sqrt{D_{AB} t}}$	$\dfrac{x}{2\sqrt{D_{AB} t}}$
$m, \dfrac{k}{h x_1}$	$\dfrac{D_{AB}}{k_c x_1}$	$\dfrac{D_{AB}}{K k_c x_1}$
$\dfrac{h}{k}\sqrt{\alpha t}$	$\dfrac{k_c}{D_{AB}}\sqrt{D_{AB} t}$	$\dfrac{K k_c}{D_{AB}}\sqrt{D_{AB} t}$
$n, \dfrac{x}{x_1}$	$\dfrac{x}{x_1}$	$\dfrac{x}{x_1}$

* x is the distance from the center of the slab, cylinder, or sphere; for a semiinfinite slab, x is the distance from the surface. c_0 is the original uniform concentration in the solid, c_1 the concentration in the fluid outside the slab, and c the concentration in the solid at position x and time t.

TABLE Q4

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FORMULA

i)

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} \qquad = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln\left(\frac{T_{hi} - T_{co}}{T_{ho} - T_{ci}}\right)}$$

$$\Delta T_m = \Delta T_{lm} F_T$$

$$\varepsilon = \frac{q_{actual}}{q_{\max}} = \frac{\Delta T_{\min \text{ fluid}}}{\Delta T_{\max}}$$

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

$$q_{\max} = (\dot{m}c_p)_{\min}(T_{hi} - T_{ci}) = C_{\min}(T_{hi} - T_{ci}) = C_{\min}\Delta T_{\max}$$

$$q_{actual} = \varepsilon(\dot{m}c_p)_{\min}(T_{hi} - T_{ci})$$

where $C_{\min} = \varepsilon(\dot{m}c_p)_{\min}$

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ii)

$$h_c = 1.32\left(\frac{\Delta T}{D}\right)^{1/4}$$

$$h_r = \varepsilon\sigma\frac{(T_1/100)^4 - (T_2/100)^4}{T_1 - T_2}$$

$$q = q_{conv} + q_{rad} = (h_c + h_r)A_1(T_1 - T_2)$$

iii)

$$N_{\mathrm{Re}} = \frac{D\upsilon\rho}{\mu}$$

$$N_{Sc} = \frac{\mu}{\rho D_{AB}}$$

$$\left(\frac{W}{D_{AB}\rho L}\right) = N_{\mathrm{Re}} N_{Sc}\frac{D}{L}\frac{\pi}{4}$$

$$\frac{c_A - c_{Ao}}{c_{Ai} - c_{Ao}} = 5.5\left(\frac{W}{D_{AB}\rho L}\right)^{-2/3}$$