UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2021/2022

COURSE NAME	:	HEAT TRANSFER
COURSE CODE	:	BDA 30603
PROGRAMME	:	BDD
EXAMINATION DATE	:	JULY 2022
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER ALL QUESTIONS. 2. THIS FINAL EXAMINATION IS AN **ONLINE** ASSESSMENT AND CONDUCTED VIA **OPEN BOOK**.

THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

Q1 (a) Circular copper rods of diameter D = 1 mm and length L = 25 mm are used to enhance heat transfer from a surface that is maintained at T_1 = 100 °C. One end of the rod is attached to this surface at x = 0 mm, while the other end (x = 25 mm) is joined to a second surface which is at T_2 = 0 °C. Air flowing between the surfaces and over the rods is also set at T_∞ = 0 °C, and a convection coefficient of h = 100 W/m^2·K is maintained. What is the rate of heat transfer by convection from a single copper rod to the air?

(16 marks)

(b) For the same parameters as given in Q1(a), what is the total rate of heat transfer from a 1 m by 1 m section of the surface at 100 °C, if a bundle of the rods is installed at every 4 mm on the surface?

(4 marks)

Q2 (a) The forming section of a plastic plant puts out a continuous sheet of plastic that is 1.2 m wide and 0.1 cm thick at a velocity of 9 m/min (Figure 2a). The temperature of the plastic sheet is 95°C when it is exposed to the surrounding air, and a 0.6-m-long section of the plastic sheet is subjected to air flow at 25°C at velocity of 3 m/s on both sides along its surfaces normal to the direction of motion of the plastic sheet as shown in the Figure 2a. The plastic sheet observed to vibrates during the cooling process. Taken the density, specific heat and emissivity of the plastic sheet to be ρ = 1200 kg/m3, C_p = 1.7 kJ/kg·°C, and ε = 0.9, determine:

i) the rate of heat transfers from the plastic sheet to air by forced convection;

ii) the rate of heat transfers from the plastic sheet to air by radiation; and

iii) the temperature of the plastic sheets.

(12 marks)

(b) Hot air at 60°C leaving a furnace of a house flow through a 12-m-long section sheet metal duct of rectangular cross section 20 cm x 20 cm at an average velocity of 4 m/s (Figure 2b). The thermal resistance of the duct is negligible, and the outer surface of the duct, whose emissivity is 0.3, is exposed to the cold air at 10 °C in the basement, with a convection heat transfer coefficient of 10 W/m^2·K. Taking the walls of the basement to be at 10°C and the bulk mean temperature of 50°C, determine heat transfer coefficient of the hot air inside the sheet metal duct.

(8 marks)

Q3 (a) A 4-mm-diameter spherical ball at 50°C is covered by a 1-mm-thick plastic insulation (k = 0.13 W/m·K). The ball is exposed to a medium at 15°C, with a combined convection and radiation heat transfer coefficient of 20 W/m^2.K.

i) Calculate the critical radius of the plastic insulation; and

ii) Explain whether the plastic insulation on the ball will help or hurt heat transfer from the ball.

(6 marks)

(b) Carbon steel balls (ρ=7833 kg/m^3, k=54 W/m.K, C_p=0.465 kJ/kg.C and α=1.474 x 10^{-6} m^2/s) 8 mm in diameter are annealed by heating them first to 900°C in a furnace and then allowing them to cool slowly to 100°C in ambient air at 35°C. If the average heat transfer coefficient is 75 W/m^2.K,

i) Determine if this problem should be treated with lumped system analysis;

ii) Determine how long the annealing process will take; and

iii) Determine the total rate of heat transfer from the ball to the ambient air.

(14 marks)

Q4 (a) A 12-m-long section of a 5-cm-diameter horizontal hot water pipe passes through a large room whose temperature is 27°C. If the temperature and the emissivity of the outer surface of the pipe are 73°C and 0.8, respectively, determine the rate of heat loss from the pipe by natural convection.

(8 marks)

(b) A shell-and-tube heat exchanger with 2-shell passes and 12-tube passes is used to heat water (C_p = 4180 J/kg·K) in the tubes from 25°C to 75°C at a rate of 4.5 kg/s. Heat is supplied by hot oil (C_p = 2300 J/kg·K) that enters the shell side at 165°C at a rate of 10 kg/s. For a tube-side overall heat transfer coefficient of 350 W/m^2·K, determine the heat transfer surface area on the tube side.

(12 marks)

Q5 (a) In a biomass processing plant, an engineer plans to use a cross-flow heat exchanger to recover heat form hot air to pre-heat water as in Figure 5a. The total surface area is about 10 m^2 while its overall heat transfer coefficient is 0.2116 W/m^2.°C The hot air flows into the heat exchanger at a temperature of 100°C, 0.92 kg/s to pre-heat water which enters at 30°C with a flow rate of 0.42 kg/s. If the specific heats of hot air and water can be taken as $C_{p,air}$ = 1.01 kJ/kg°C and $C_{p,water}$ = 4.18 kJ/kg°C respectively, determine:

i) the effectiveness of the heat exchanger;

ii) the heat exchange rate between hot air and water;

iii) the outlet temperatures of bot hot air and water; and

iv) state two (2) parameters that you adjust to increase the heat transfer rate without changing the heat exchanger's design.

(20 marks)

- END OF QUESTION -

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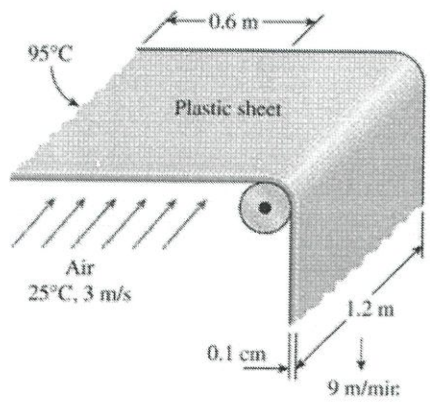

Figure 2a

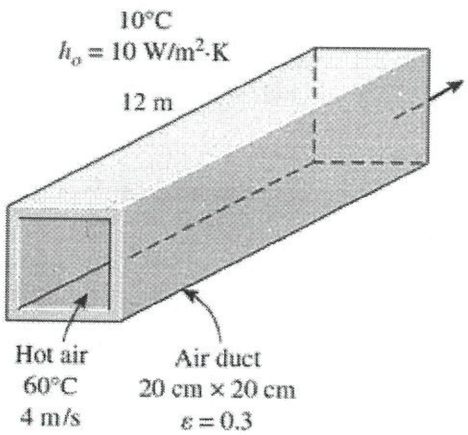

Figure 2b

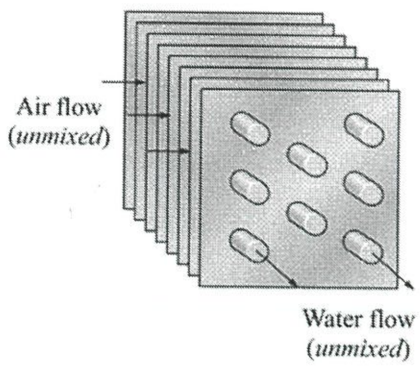

Figure 5a

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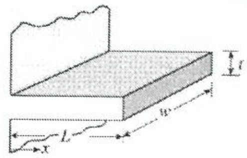
TABLE 3–3

Efficiency and surface areas of common fin configurations

Straight rectangular fins

$m = \sqrt{2h/kt}$
$L_c = L + t/2$
$A_{fin} = 2wL_c$

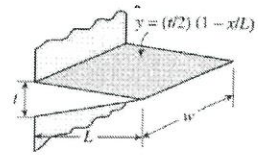
$$\eta_{fin} = \frac{\tanh mL_c}{mL_c}$$



Straight triangular fins

$m = \sqrt{2h/kt}$
$A_{fin} = 2w\sqrt{L^2 + (t/2)^2}$

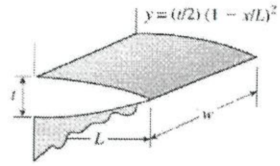
$$\eta_{fin} = \frac{1}{mL}\frac{I_1(2mL)}{I_0(2mL)}$$



Straight parabolic fins

$m = \sqrt{2h/kt}$
$A_{fin} = wL[C_1 + (L/t)\ln(t/L + C_1)]$
$C_1 = \sqrt{1 + (t/L)^2}$

$$\eta_{fin} = \frac{2}{1 + \sqrt{(2mL)^2 + 1}}$$

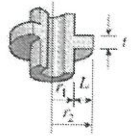


Circular fins of rectangular profile

$m = \sqrt{2h/kt}$
$r_{2c} = r_2 + t/2$
$A_{fin} = 2\pi(r_{2c}^2 - r_1^2)$

$$\eta_{fin} = C_2\frac{K_1(mr_1)I_1(mr_{2c}) - I_1(mr_1)K_1(mr_{2c})}{I_0(mr_1)K_1(mr_{2c}) + K_0(mr_1)I_1(mr_{2c})}$$

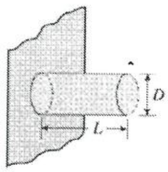
$$C_2 = \frac{2r_1/m}{r_{2c}^2 - r_1^2}$$



Pin fins of rectangular profile

$m = \sqrt{4h/kD}$
$L_c = L + D/4$
$A_{fin} = \pi DL_c$

$$\eta_{fin} = \frac{\tanh mL_c}{mL_c}$$

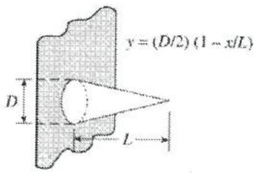


Pin fins of triangular profile

$m = \sqrt{4h/kD}$
$A_{fin} = \frac{\pi D}{2}\sqrt{L^2 + (D/2)^2}$

$$\eta_{fin} = \frac{2}{mL}\frac{I_2(2mL)}{I_1(2mL)}$$

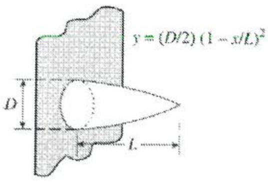
$I_2(x) = I_0(x) - (2/x)I_1(x)$ where $x = 2mL$



Pin fins of parabolic profile

$m = \sqrt{4h/kD}$
$A_{fin} = \frac{\pi L^3}{8D}\left[C_3C_4 - \frac{L}{2D}\ln(2DC_4/L + C_3)\right]$
$C_3 = 1 + 2(D/L)^2$
$C_4 = \sqrt{1 + (D/L)^2}$

$$\eta_{fin} = \frac{2}{1 + \sqrt{(2mL/3)^2 + 1}}$$



Pin fins of parabolic profile (blunt tip)

$m = \sqrt{4h/kD}$
$A_{fin} = \frac{\pi D^4}{96L^2}\left\{[16(L/D)^2 + 1]^{3/2} - 1\right\}$

$$\eta_{fin} = \frac{3}{2mL}\frac{I_1(4mL/3)}{I_0(4mL/3)}$$

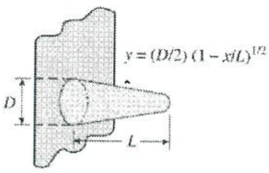


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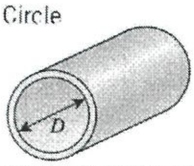
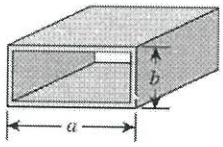
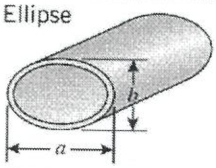
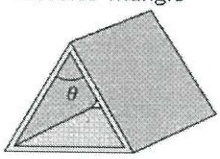
TABLE 8–1

Nusselt number and friction factor for fully developed laminar flow in tubes of various cross sections ($D_h = 4A_c/p$, $\text{Re} = V_{avg}D_h/\nu$, and $\text{Nu} = hD_h/k$)

Tube Geometry	a/b or $\theta°$	Nusselt Number T_s = Const.	Nusselt Number $\dot{q}_s$ = Const.	Friction Factor f
Circle 	—	3.66	4.36	64.00/Re
Rectangle 	a/b			
	1	2.98	3.61	56.92/Re
	2	3.39	4.12	62.20/Re
	3	3.96	4.79	68.36/Re
	4	4.44	5.33	72.92/Re
	6	5.14	6.05	78.80/Re
	8	5.60	6.49	82.32/Re
	∞	7.54	8.24	96.00/Re
Ellipse 	a/b			
	1	3.66	4.36	64.00/Re
	2	3.74	4.56	67.28/Re
	4	3.79	4.88	72.96/Re
	8	3.72	5.09	76.60/Re
	16	3.65	5.18	78.16/Re
Isosceles Triangle 	θ			
	10°	1.61	2.45	50.80/Re
	30°	2.26	2.91	52.28/Re
	60°	2.47	3.11	53.32/Re
	90°	2.34	2.98	52.60/Re
	120°	2.00	2.68	50.96/Re

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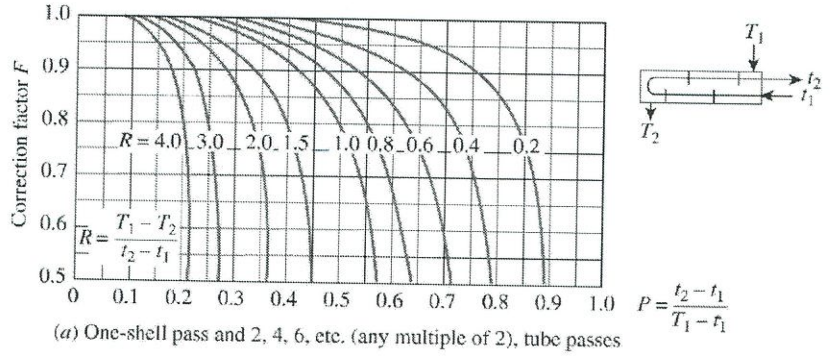
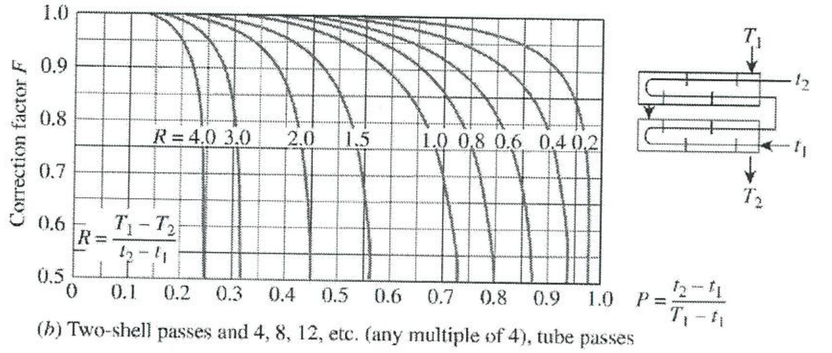
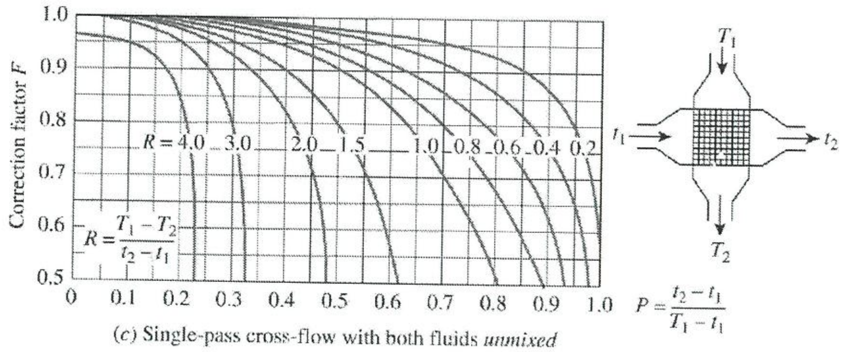


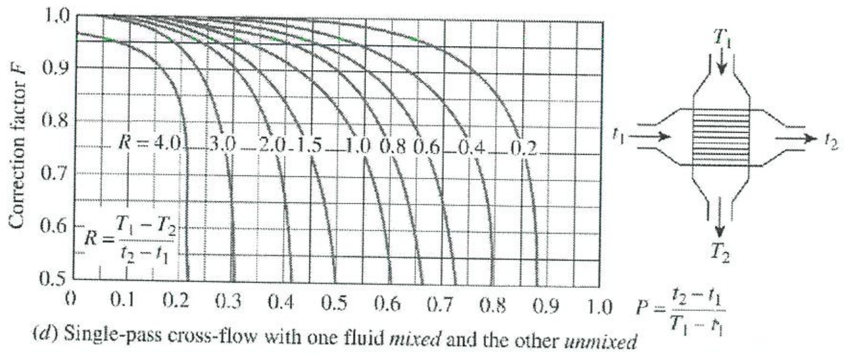
(*a*) One-shell pass and 2, 4, 6, etc. (any multiple of 2), tube passes



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



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



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

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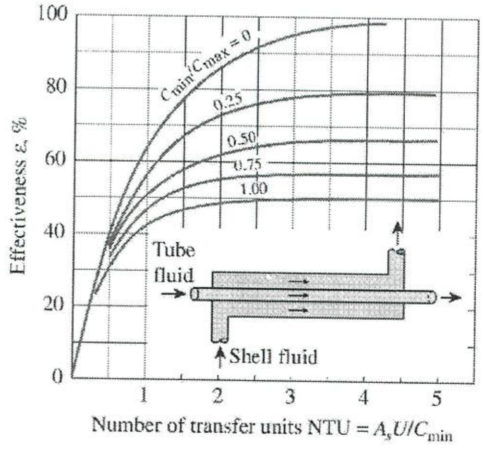
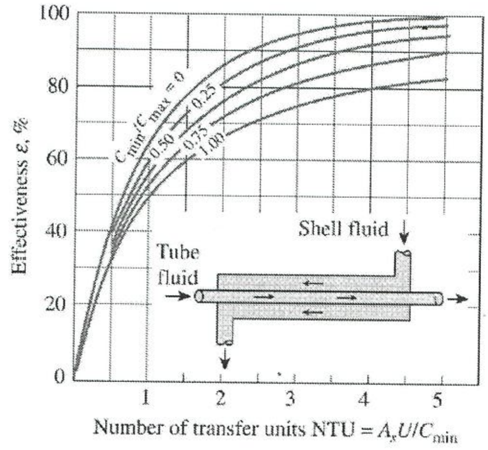
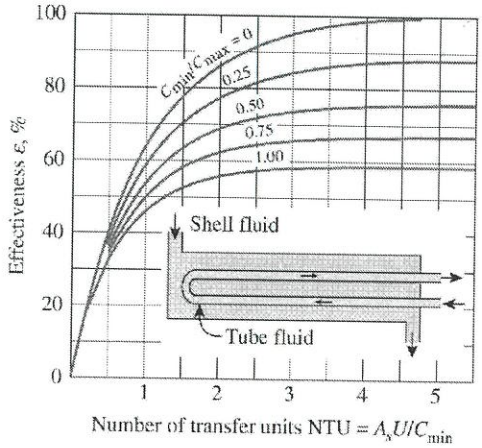


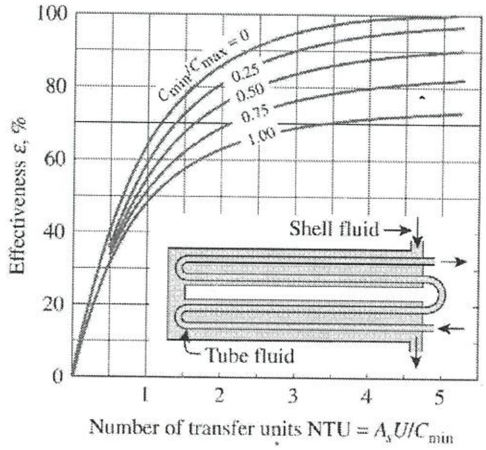
(*a*) Parallel-flow



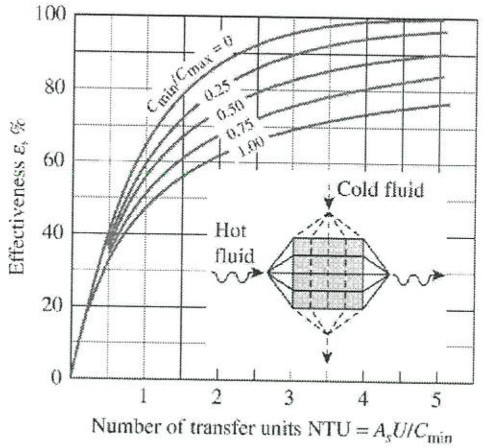
(*b*) Counter-flow



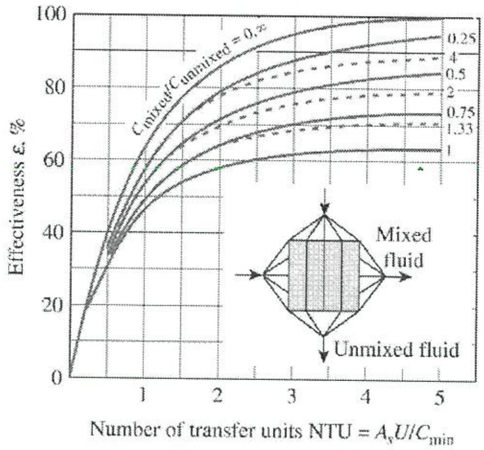
(*c*) One-shell pass and 2, 4, 6, … tube passes



(*d*) Two-shell passes and 4, 8, 12, … tube passes



(*e*) Cross-flow with both fluids unmixed



(*f*) Cross-flow with one fluid mixed and the other unmixed

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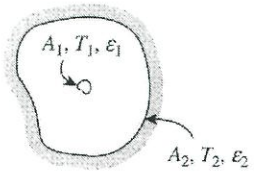
TABLE 13–3

Radiation heat transfer relations for some familiar two-surface arrangments.

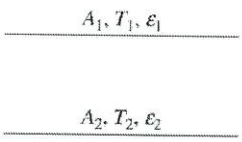
Small object in a large cavity



$$\frac{A_1}{A_2} \approx 0 \qquad F_{12} = 1$$

$$\dot{Q}_{12} = A_1\sigma\varepsilon_1(T_1^4 - T_2^4) \qquad (13\text{–}37)$$

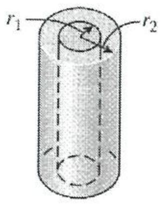
Infinitely large parallel plates



$$A_1 = A_2 = A \qquad F_{12} = 1$$

$$\dot{Q}_{12} = \frac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \qquad (13\text{–}38)$$

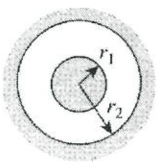
Infinitely long concentric cylinders



$$\frac{A_1}{A_2} = \frac{r_1}{r_2} \qquad F_{12} = 1$$

$$\dot{Q}_{12} = \frac{A_1\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1-\varepsilon_2}{\varepsilon_2}\left(\frac{r_1}{r_2}\right)} \qquad (13\text{–}39)$$

Concentric spheres



$$\frac{A_1}{A_2} = \left(\frac{r_1}{r_2}\right)^2 \qquad F_{12} = 1$$

$$\dot{Q}_{12} = \frac{A_1\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_2} + \frac{1-\varepsilon_2}{\varepsilon_2}\left(\frac{r_1}{r_2}\right)^2} \qquad (13\text{–}40)$$