Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2021/2022

COURSE NAME	:	HEAT TRANSFER
COURSE CODE	:	BDA 30603
PROGRAMME	:	BDD
EXAMINATION DATE	:	JANUARY / FEBRUARY 2022
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER ONLY FIVE **(5)** QUESTIONS. 2. THIS FINAL EXAMINATION IS A **ONLINE** ASSESSMENT AND CONDUCTED VIA **OPEN BOOK.**

THIS QUESTION PAPER CONSISTS OF **TWELVE (12)** PAGES

Q1 (a) Addition of fins may not necessarily increase the heat transfer from a surface; it may even decrease the heat transfer. Comment on this statement.

(3 marks)

(b) A long rod of AISI 4130 steel initially at a uniform temperature of 400°C is suddenly exposed to 20°C air, where the heat transfer coefficient is 15 $W/m^2 \cdot K$. The rod has a diameter of 4.8 cm. How long after being exposed to the 20°C air will the steel rod reach a temperature of 60°C? The properties of the rod are $\rho = 7840$ kg/m^3, $Cp = 460$ J/kg.K and $k = 43$ W/m.K.

(8 marks)

(c) A pin fin of AISI 302 stainless steel ($k = 15.1$ W/m.K) is attached to a surface whose temperature is 160°C. The diameter of the pin fin is 3.4 mm, and surrounding the fin is 30°C air, where the heat transfer coefficient is 20 $W/m^2.K$. Find the required fin height if the fin is to transfer 3 W.

(9 marks)

Q2 (a) Consider a large plane wall of thickness L = 0.4 m, thermal conductivity k = 1.8 W/m·K, and surface area A = 30 m^2. The left side of the wall is maintained at a constant temperature of T_1 = 90°C while the right side loses heat by convection to the surrounding air at T_∞ = 25°C with a heat transfer coefficient of h = 24 W/m^2.K. Assuming constant thermal conductivity and no heat generation in the wall,

i) express the differential equation and the boundary conditions for steady one-dimensional heat conduction through the wall;

ii) obtain a relation for the variation of temperature in the wall by solving the differential equation; and

iii) evaluate the rate of heat transfer through the wall.

(14 marks)

(b) Assuming constant thermal conductivity, express the most suitable heat conduction equation for the each of the following cases;

i) A thin circular disc with uniform steady heat flow from the top face to the bottom face;

ii) A long insulated circular copper cable with steady heat flowing from one end to another; and

iii) A cylindrical battery with time-dependent exothermic chemical reaction at the core.

(6 marks)

Q3 (a) A thin flat plate of length 1 m separates two air streams flowing in parallel over the opposite surfaces of the plate. One air stream has a temperature of 200°C and a velocity of 60 m/s, whereas the other has a temperature of 25°C and a velocity of 10 m/s. Assuming negligible conduction resistances and the surface temperature of the plate is 188°C,

i) determine the convection heat transfer coefficient of each stream at the mid-point of the plate; and

ii) estimate the value of heat flux at the mid-point of the plate.

(12 marks)

(b) Water flows at 2 kg/s through a 40 mm diameter tube to be heated from 25°C to 75°C. The tube surface is maintained at a temperature of 100°C. What is the required length of the tube?

(8 marks)

Q4 (a) Illustrate example of heat exchanger with baffle. Explain the role of the baffles in a shell-and-tube heat exchanger?

(3 marks)

(b) Explain how does the presence of baffles affect the heat transfer and the pumping power requirements.

(3 marks)

(c) A shell-and-tube heat exchanger with 2-shell passes and 12-tube passes is used to heat water (Cp = 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 (Cp = 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 $W/m^2 \cdot K$, determine the heat transfer surface area on the tube side.

(14 marks)

Q5 (a) Counter flow heat exchangers and generally known to provide higher heat transfer compared to parallel flow heat exchangers. Evaluate, under what conditions that a parallel flow heat exchanger may have advantages in comparison to a counter flow heat exchanger

(5 marks)

(b) A kenaf pulp processing mill produces wastewater (Cp = 4300 J/kg·K) at 85°C. This wastewater has potentials to be used to preheat supply water into the mill (Cp = 4180 J/kg·K) at 25°C in a double-pipe counter-flow heat exchanger. The flowrates of wastewater and supply water are both same at 3.05 x 10-4 m^3/s. The heat transfer surface area of the heat exchanger is 1.5 m^2 and the overall heat transfer coefficient is 625 $W/m^2 \cdot K$. Calculate the outlet temperatures of wastewater and supply water as well as the heat transfer in the heat exchanger.

(15 marks)

Q6 (a) Absorptivity, reflectivity and transmissivity are three main properties in radiation heat transfer. With the help of illustration distinguished the different between these three properties and conclude the relationship between them.

(7 marks)

(b) The absorber surface of a solar collector (**Figure Q6b**) is made of aluminum coated with black chrome ($\alpha_s = 0.87$ and $\varepsilon = 0.09$). Solar radiation is incident on the surface at a rate of 720 W/m^2. The air and the effective sky temperatures are at 25°C and 15°C respectively and the convection heat transfer coefficient is 10 W/m^2·K. If the absorber surface temperature is at 70°C, determine the net rate of solar energy delivered by the absorber plate to the water circulating behind it.

(9 marks)

(c) Two very large parallel plates are maintained at uniform temperature of T_1 = 950K and T_2 = 500K and have emissivity of $\varepsilon_1 = 1$ and $\varepsilon_2 = 0.55$, respectively. Determine the net rate of heat transfer between the two plates.

(4 marks)

- END OF QUESTION -

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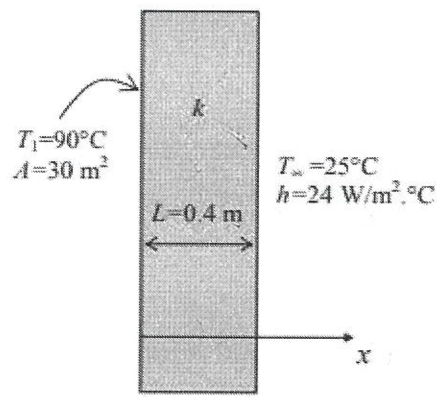

Figure Q2a

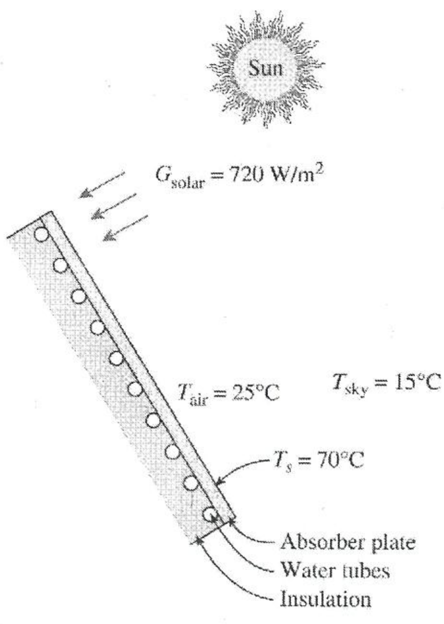

Figure Q6b

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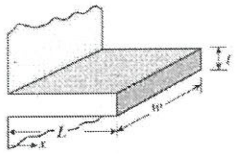
TABLE 3–3

Efficiency and surface areas of common fin configurations

Straight rectangular fins

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

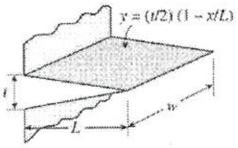
$$\eta_{fin} = \frac{\tanh mL_c}{mL_c}$$



Straight triangular fins

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

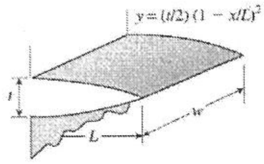
$$\eta_{fin} = \frac{1}{mL}\frac{I_1(2mL)}{I_0(2mL)}$$



Straight parabolic fins

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

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

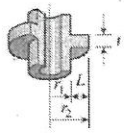


Circular fins of rectangular profile

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

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

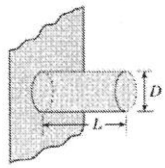
$$C_2 = \frac{2r_1/m}{r_{2c}^2 - r_1^2}$$



Pin fins of rectangular profile

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

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

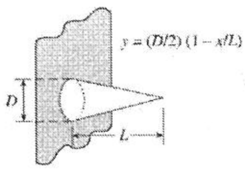


Pin fins of triangular profile

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

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

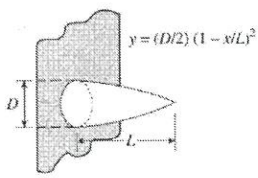
$I_2(x) = I_0(x) - (2/x)I_1(x)$ where $x = 2mL$



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)

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

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

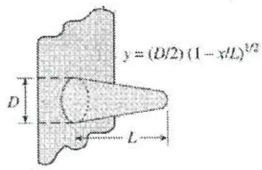


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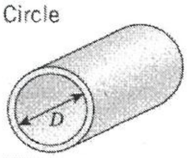
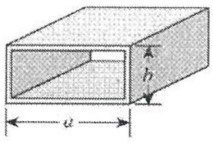
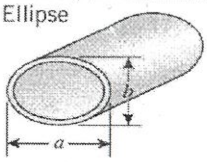
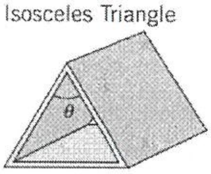
TABLE 8–1

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

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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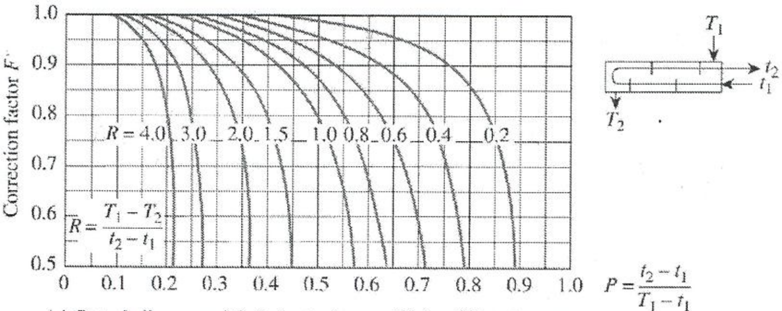
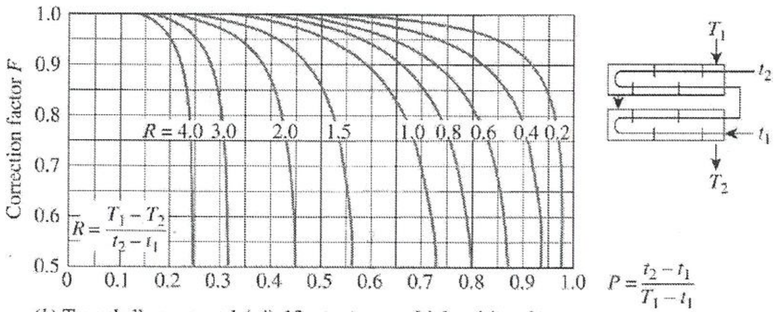
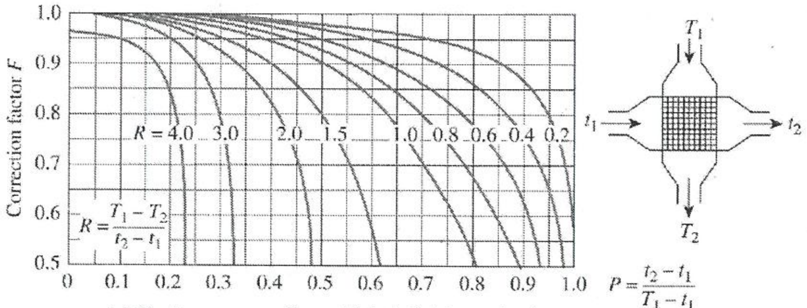


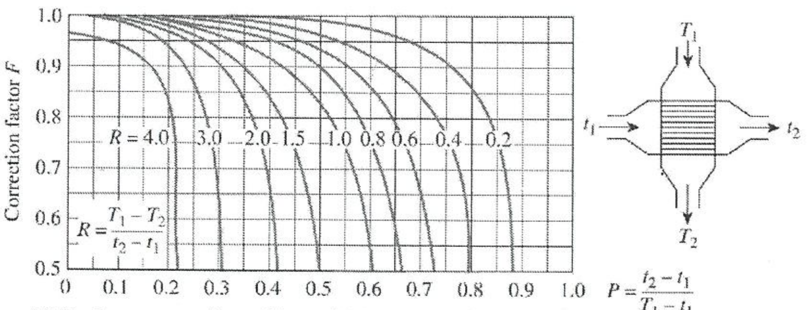
(a) One-shell pass and 2, 4, 6, etc. (any multiple of 2), tube passes



(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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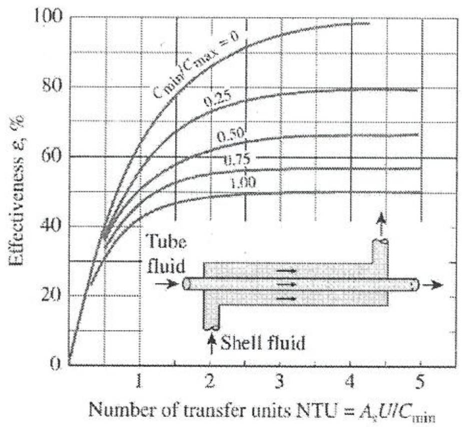
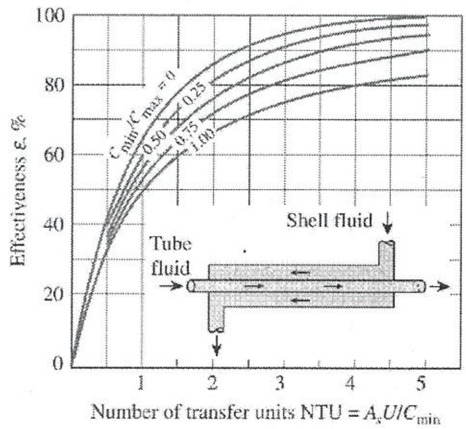
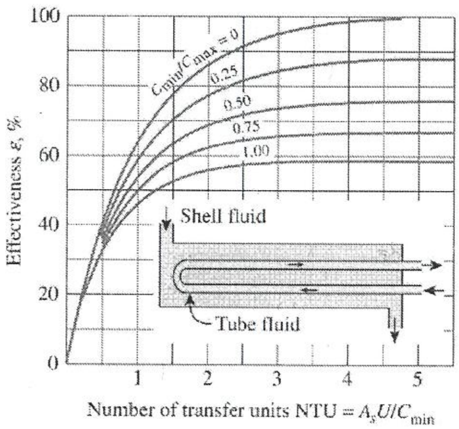


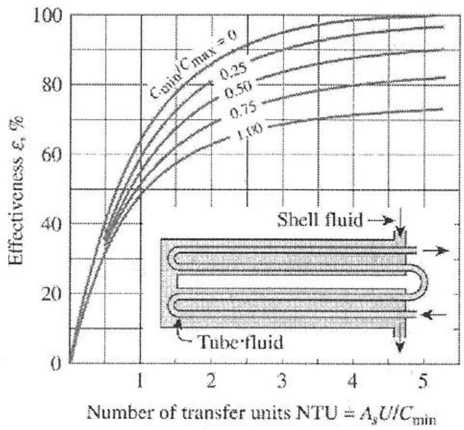
(*a*) Parallel-flow



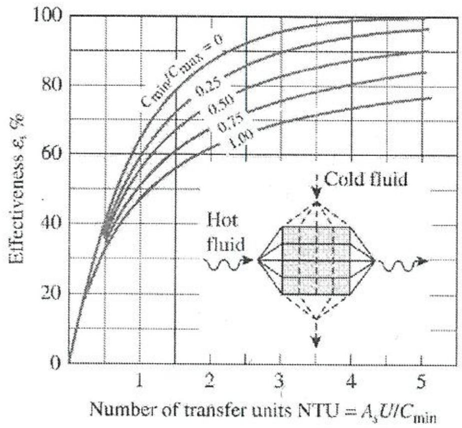
(*b*) Counter-flow



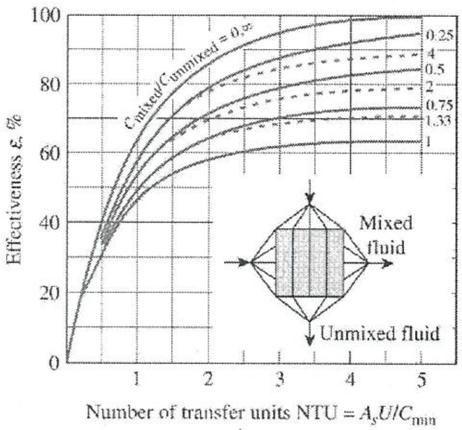
(*c*) One-shell pass and 2, 4, 6, … tube passes



(*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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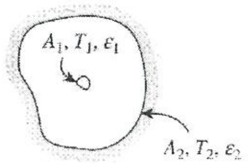
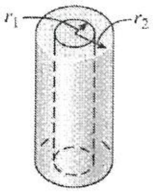
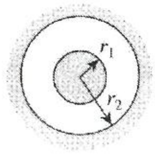
TABLE 13–3

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

Arrangement	Figure	Relations	Heat transfer	Eq.
Small object in a large cavity		$\frac{A_1}{A_2} \approx 0$, $F_{12} = 1$	$\dot{Q}_{12} = A_1\sigma\varepsilon_1(T_1^4 - T_2^4)$	(13–37)
Infinitely large parallel plates	A_1, T_1, ε_1 / A_2, T_2, ε_2	$A_1 = A_2 = A$, $F_{12} = 1$	$\dot{Q}_{12} = \dfrac{A\sigma(T_1^4 - T_2^4)}{\dfrac{1}{\varepsilon_1} + \dfrac{1}{\varepsilon_2} - 1}$	(13–38)
Infinitely long concentric cylinders		$\frac{A_1}{A_2} = \frac{r_1}{r_2}$, $F_{12} = 1$	$\dot{Q}_{12} = \dfrac{A_1\sigma(T_1^4 - T_2^4)}{\dfrac{1}{\varepsilon_1} + \dfrac{1-\varepsilon_2}{\varepsilon_2}\left(\dfrac{r_1}{r_2}\right)}$	(13–39)
Concentric spheres		$\frac{A_1}{A_2} = \left(\frac{r_1}{r_2}\right)^2$, $F_{12} = 1$	$\dot{Q}_{12} = \dfrac{A_1\sigma(T_1^4 - T_2^4)}{\dfrac{1}{\varepsilon_2} + \dfrac{1-\varepsilon_2}{\varepsilon_2}\left(\dfrac{r_1}{r_2}\right)^2}$	(13–40)