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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER 1
SESSION 2020/2021

COURSE NAME	:	HEAT TRANSFER
COURSE CODE	:	BDA 30603
PROGRAMME	:	BDD
EXAMINATION DATE	:	JANUARY/ FEBRUARY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

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Q1 (a) One of the important step in the design of a fin is to determine the appropriate length of the fin. With the help of illustration, conclude the consideration for proper length of a fin.

(3 marks)

(b) A 4 mm thick and 10 cm long straight aluminum parabolic fin (k – 273 W/m·°C) is attached to a surface. The heat transfer coefficient of the surrounding air is 20 W/m^2·K. Taken the width of the fin at 1 m, determine the efficiency of the fin.

(5 marks)

(c) A hot surface at 150 °C is installed with 10 units of fins mentioned in Q1(b). The hot surface dimension is 1 m × 0.5 m. If the fins are expose to ambient air at 50 °C, determine the overall fin effectiveness of the arrangement.

(7 marks)

(d) Briefly describe the equation used to determine Biot number and justify its important in transient heat conduction analysis.

(3 marks)

(e) Cooper cube (ρ = 8,933 kg/m^3, k = 401 W/m·°C, c_p = 385 kJ/kg·°C, and α = 117 × 10^{-6} m^2/s) having a cube side length 5 cm is to be quenched in water. The cube leaves the oven at a uniform temperature of 900 °C and are exposed to air at 30°C for a while before they are dropped into the water. If the temperature of the cube is not to fall below 850 °C prior to quenching and the heat transfer coefficient in the air is 125 W/m^2·°C, evaluate how long the cube can stand in the air before being dropped into the water.

(7 marks)

Q2 (a) Reynolds number often used to represent flow characteristics; laminar or turbulent flow. With the help of illustration, differentiate between these two flow categories.

(3 marks)

(b) Flow resistance is unavoidable in a fluid flow and often represented in terms of drag coefficient. Differentiate between friction drag and pressure drag, and at the same time establish the relationship between the two.

(3 marks)

(c) The forming section of a plastics plant puts out a continuous sheet of plastic that is 1.2 m wide and 2 mm thick at a rate of 15 m/min (Figure 2). The temperature of the plastic sheet is 90 °C when it exposed to the surrounding air, and the sheet is subjected to air flow at 30 °C at a velocity of 9 m/s on both sides along its surfaces normal to the direction of motion of the sheet. The width of the air cooling section is such that a fixed point on the plastic sheet passes through that section in 2 s. Determine the rate of heat transfer from the plastic sheet to the air.

(11 marks)

(d) Establish the physical significant of Grashof number in natural convection and its relation with Rayleigh number

(4 marks)

(e) Consider the forming section mentioned in Q2(c) experience blower malfunctioning. Discuss the effect of the situation on the cooling process of the plastic sheet and conclude the situation in terms of the plastic surface temperature leaving the section.

(4 marks)

Q3 (a) In the analysis of internal force heat convection, it is important to acknowledge the existence of developing flow at the entrance of a pipe. With the help of an illustration, establish the difference between developing and developed flow from the aspect of boundary layer development of the flow.

(4 marks)

(b) Air at 20 °C and average velocity of 0.05 m/s enters a 15 m section of an aluminum ellipse duct (k = 205 W/m °C) whose major axis and minor axis are at 0.75 m and 0.25 m, respectively. The duct wall is an isothermal surface maintained at 40 °C. Determine,

i) the heat transfer rate from the duct wall to the air;
ii) the pressure drop of the air along the duct length; and
iii) the exit temperature of the air from the duct.

(13 marks)

(c) Consider the duct in Q3(b) to be replace with circular duct whose diameter is at 0.5 m. The outer surface of the duct (ε = 0.7) is exposed to the hot air at 55 °C, with a convection heat transfer coefficient of 12 W/m^2·K. Taking the surrounding surface temperature of the duct also at 55 °C, determine the insulation thickness of the duct to minimize heat transfer from the surrounding to the air inside the duct.

(8 marks)

Q4 (a) Cross flow heat exchanger involves two fluids that move perpendicular to each other and can be classified into two; mixed-unmixed and unmixed-unmixed. With the help of illustration, distinguish the difference between these two classification.

(4 marks)

(b) A single pass cross flow heat exchanger with both fluid unmixed is used for cooling oil (c_p = 2.0 kJ/kg·K) from 125 °C to 55 °C. The coolant is water, which enters the heat exchanger at 25 °C and leaves at 46 °C. The overall heat transfer coefficient of the heat exchanger is 900 W/m^2·K. Considering the oil flow rate at 10 kg/s, determine:

i) the cooling water flow rate; and
ii) the heat transfer area of the heat exchanger

(8 marks)

(c) Glycerin with c_p = 2,400 J/kg·K at 20 °C and 0.3 kg/s is to be heated by ethylene glycol with c_p = 2,500 J/kg·K at 60 °C and the same flowrate in a thin-walled single passes (both unmixed) flow heat exchanger. If the overall heat transfer coefficient is 380 W/m^2·K and heat transfer surface area is 5.3 m^2, determine:

i) the rate of heat transfers inside the heat exchanger;
ii) the outlet temperature of the glycerin; and
iii) the outlet temperature of the ethylene.

(13 marks)

Q5 (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.

(8 marks)

(b) The absorber surface of a solar collector (Figure 5) 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.

(8 marks)

(c) Considering the solar collector in Q5(b) to be malfunction in which the water inside the pipe has not been able to be circulated. Provide your conclusion on the surface temperature of the absorber in comparison its initial value, and justify your answer.

(3 marks)

(d) View factor is one of the important variable in determining heat radiation rate between two surfaces. With a help of an illustration describe the summation rule on the view factor between two surfaces.

(3 marks)

(e) Two very long concentric cylinders of diameters $D_1 = 0.35$ m and $D_2 = 0.5$ m are maintained at uniform temperature of $T_1 = 950$ K and $T_2 = 500$ K and have emissivity of $\varepsilon_1 = 1$ and $\varepsilon_2 = 0.55$, respectively. Determine the net rate of heat transfer between the two cylinders.

(3 marks)

END OF QUESTION

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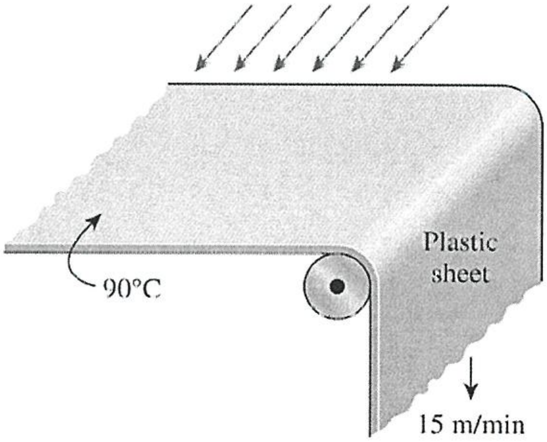

Figure 2

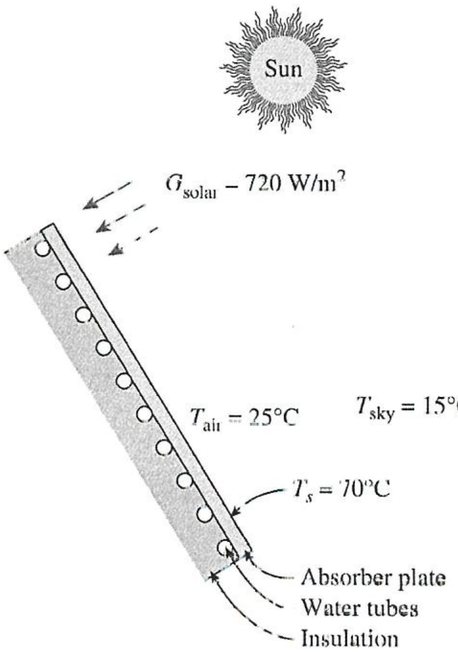

Figure 5

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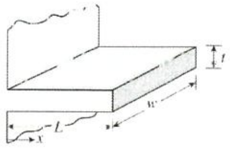
TABLE 3–3

Efficiency and surface areas of common fin configurations

Straight rectangular fins

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

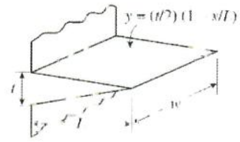
$$\eta_{fin} = \frac{\tanh mL_c}{mL_c}$$



Straight triangular fins

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

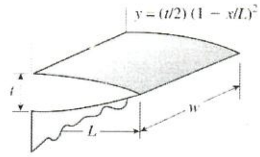
$$\eta_{fin} = \frac{1}{mL}\frac{I_1(2mL)}{I_0(2mL)}$$



Straight parabolic fins

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

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

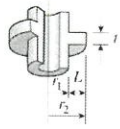


Circular fins of rectangular profile

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

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

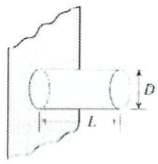
$$C_2 = \frac{2r_1/m}{r_{2c}^2 - r_1^2}$$



Pin fins of rectangular profile

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

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

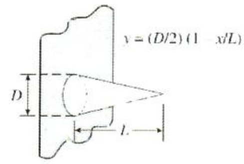


Pin fins of triangular profile

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

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

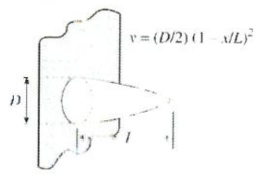
$I_2(x) = I_0(x) - (2/x)I_1(x)$ where $x = 2mL$



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)

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

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

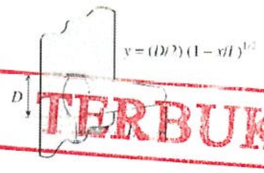


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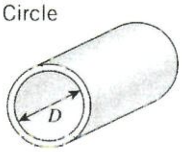
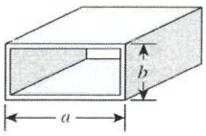
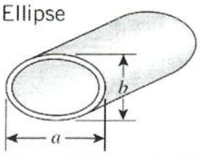
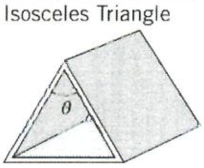
TABLE 8–1

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 θ°	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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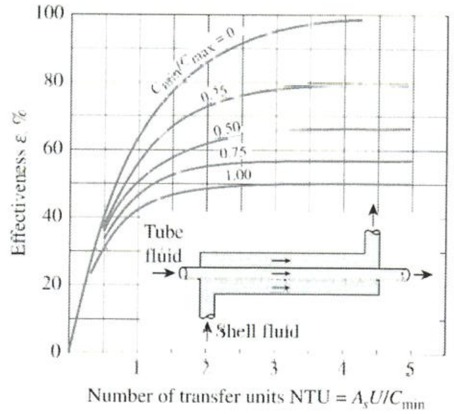
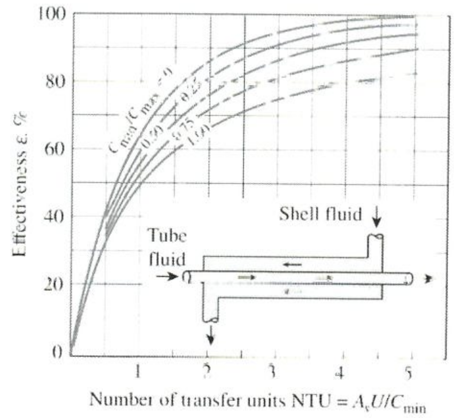
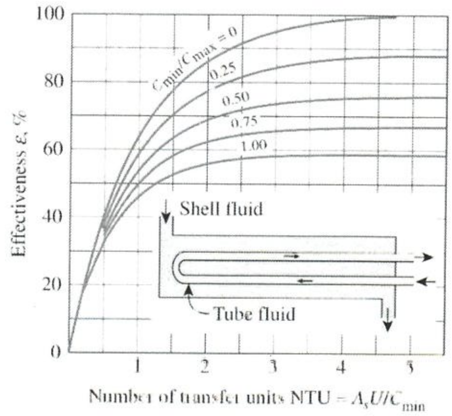


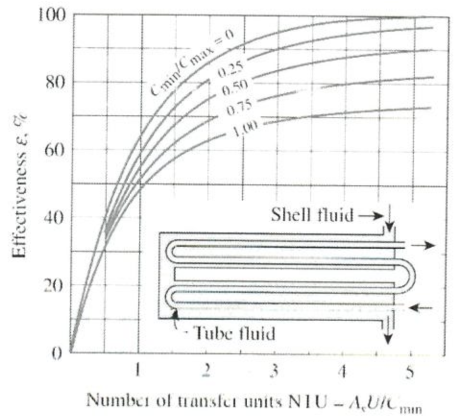
(a) Parallel-flow



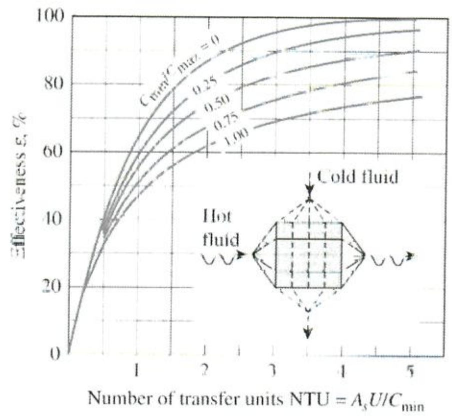
(b) Counter-flow



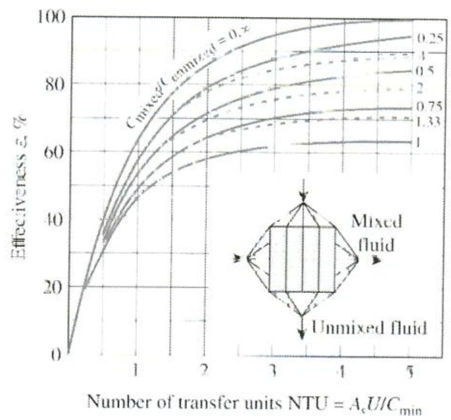
(c) One shell pass and 2, 4, 6, … tube passes



(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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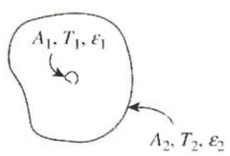
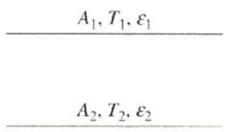
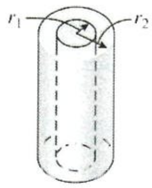
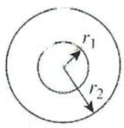
TABLE 13–3

Radiation heat transfer relations for some familiar two surface arrangements.

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 	$A_1 = A_2 = A$, $F_{12} = 1$	$\dot{Q}_{12} = \dfrac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$	(13–38)
Infinitely long concentric cylinders 	$\frac{A_1}{A_2} = \frac{r_1}{r_2}$, $F_{12} = 1$	$\dot{Q}_{12} = \dfrac{A_1\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1 - \varepsilon_2}{\varepsilon_2}\left(\frac{r_1}{r_2}\right)}$	(13–39)
Concentric spheres 	$\frac{A_1}{A_2} = \left(\frac{r_1}{r_2}\right)^2$, $F_{12} = 1$	$\dot{Q}_{12} = \dfrac{A_1\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_2} + \frac{1 - \varepsilon_2}{\varepsilon_2}\left(\frac{r_1}{r_2}\right)^2}$	(13–40)