UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2019/2020

COURSE NAME : HEAT TRANSFER

COURSE CODE : BDA 30603

PROGRAMME : BDD

EXAMINATION DATE : JULY 2020

DURATION : 3 HOURS

INSTRUCTION : ANSWER **FIVE (5)** QUESTIONS **ONLY**

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

TERBUKA

Q1 (a) Consider a very long rectangular fin attached to a flat surface such that the temperature at the end of the fin is essentially that of the surrounding air, i.e. 20°C. Its width is 5.0 cm; thickness is 1.0 mm; thermal conductivity is 200 W/m·K; and base temperature is 40°C. The heat transfer coefficient is 20 W/m^2.K. You can use Table 1(a) for assistance.

(i) Estimate the fin temperature at a distance of 5.0 cm from the base, and;
(ii) Calculate the rate of heat loss from the entire fin.

(8 marks)

(b) A plane wall with surface temperature of 350°C is attached with straight rectangular fins (k=235 W/m.K) The fins are exposed to an ambient air condition of 25°C and the convection heat transfer coefficient is h=154 W/m^2.K. Each fin has a length of 50 mm, a base of 5 mm thick a width of 100 mm (as shown in **Figure 1(c)**). Determine the efficiency, heat transfer rate, and effectiveness of each fin, using

(i) Table 1(b) and;
(ii) Figure 1(b).

(12 marks)

Q2 (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) 8mm 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)

Q3 (a) A pump is used to pump oil to a tank located 10-m high at room temperature. The oil flow is laminar. Now, if the oil is pre-heated while the oil flowrate is maintained, discuss whether the pumping power of the pump will increase or decrease.

(3 marks)

(b) Consider two tubes, one with smooth inner surface while the other one with rough inner surface. Which tube is better in terms of heat transfer and state why.

(3 marks)

(c) A new research office in FKMP called "Zero Energy Office" was designed with a cooling system to reduce it's temperature during daytime. The cooling system uses a duct which introduces cool air to the office, in which is the air was pre-cooled in a water pond at 15°C. The duct length is 15 m and it's diameter is 200 mm. Air enters the underwater section of the duct at 25°C at a velocity of 3 m/s as in as in Figure Q3 (c). Assuming the surface of the duct is having same temperature of water, determine the outlet temperature of air, entering the office.

(14 marks)

Q4 (a) A person extends his uncovered arms into the windy air outside at 10°C and 50 km/h like the wings of an aeroplane. Initially, the skin temperature of the arm is 30°C. Treating the arm as a 0.6 m long and 7.5 cm diameter cylinder, analyze the following:

(i) Find the Reynolds number and the corresponding Nusselt number,
(ii) Calculate the heat transfer coefficient, and;
(iii) Determine the rate of heat loss from the arm.

(10 marks)

(b) An actual aircraft is cruising at -55.4°C, 18.8 kPa and 900 km/h. A heating system keeps the wings just above freezing temperatures of 0°C. Should the wing diameter evaluated as D = 0.5m, the following are to be determined:

(i) Estimate the suitable Nusselt number for this situation,
(ii) Compute the average convection heat transfer coefficient on the wing surface, and;
(iii) Evaluate the average rate of heat transfer per unit surface area.

(10 marks)

Q5 (a) Under what condition is the effectiveness-NTU method definitely preferred over the LMTD method in heat exchanger analysis?

(5 marks)

(b) The radiator in an automobile is a cross flow heat exchanger (U.As = 10 000 W/K) that uses air (Cp = 1 000 J/kg. K) to cool the engine-coolant fluid (Cp = 4 000 J/kg. K). The engine fan draws 30 °C air through this radiator at a rate of 10 kg/s while the coolant pump circulates the engine coolant at a rate of 5 kg/s. The coolant enters this radiator at 80 °C. Under these conditions, the effectiveness of the radiator is 0.4. Determine;

(i) The outlet temperature of the air; and;
(ii) The rate of heat transfer between the two fluids.

(15 marks)

Q6 (a) How does the log mean temperature difference [LMTD] for a heat exchanger differ from the arithmetic mean temperature difference (AMTD)? For specified inlet and outlet temperatures, which one of these two quantities is larger?

(2 marks)

(b) In a thin-walled double-pipe heat exchanger, when is the approximation $U = hi$ a reasonable one? Here U is the overall heat transfer coefficient and hi is the convection heat transfer coefficient inside the tube.

(3 marks)

(c) A shell-and-tube heat exchanger with 1-shell pass and 14-tube passes as shown **Figure Q6 (c)**, is used to heat water in the tubes with geothermal steam condensing at 120°C (hfg = 2203 kJ/kg) on the shell side. The tubes are thin-walled and have a diameter of 2.4 cm and length of 3.2 m per pass. Water (Cp = 4180 J/kg · °C) enters the tubes at 22°C at a rate of 3.9 kg/s. If the temperature difference between the two fluids at the exit is 46°C, determine

(i) The rate of heat transfer,
(ii) The rate of condensation of steam, and;
(iii) The overall heat transfer coefficient.

(15 marks)

-END OF QUESTION-

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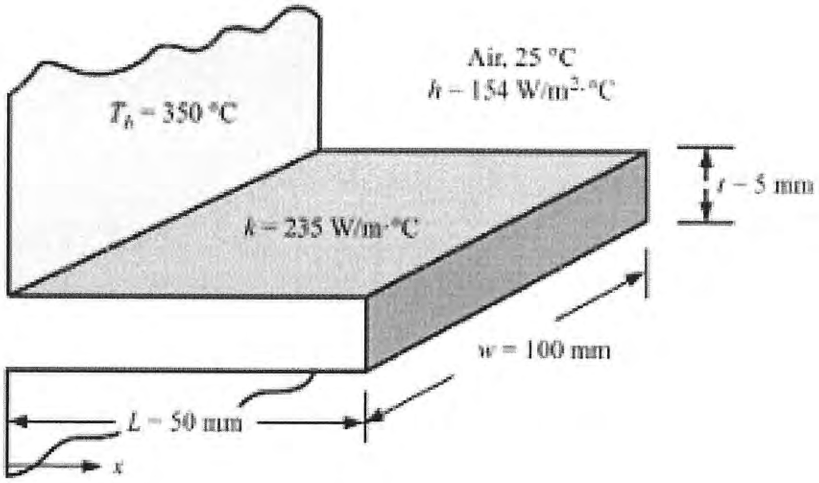

Figure Q1 (b)

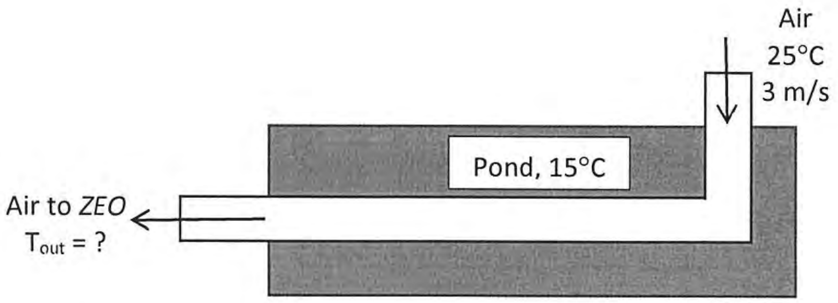

Figure Q3 (c)

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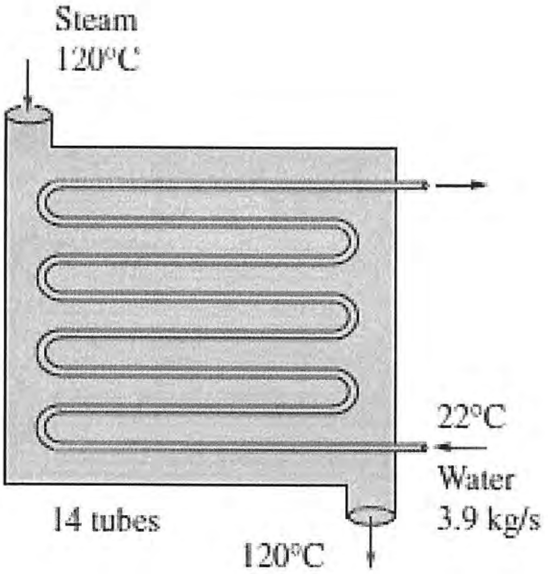

Figure Q6 (c)

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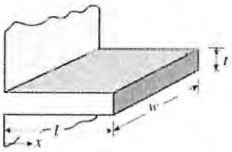
Efficiency and surface areas of common fin configurations

Straight rectangular fins

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

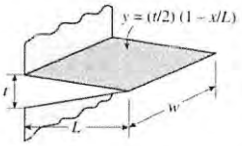
$$\eta_{\text{fin}} = \frac{\tanh mL_c}{mL_c}$$



Straight triangular fins

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

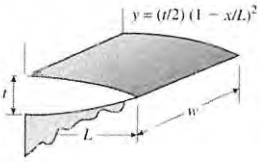
$$\eta_{\text{fin}} = \frac{1}{mL}\frac{I_1(2mL)}{I_0(2mL)}$$



Straight parabolic fins

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

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

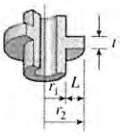


Circular fins of rectangular profile

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

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

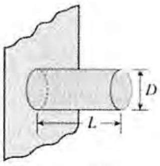
$$C_2 = \frac{2r_1/m}{r_{2c}^2 - r_1^2}$$



Pin fins of rectangular profile

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

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

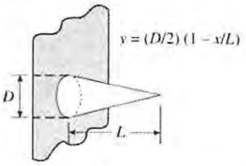


Pin fins of triangular profile

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

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

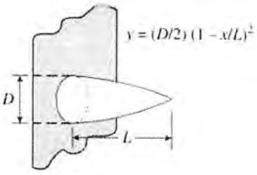
$I_2(x) = I_0(x) - (2/x)I_1(x)$ where $x = 2mL$



Pin fins of parabolic profile

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

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



Pin fins of parabolic profile (blunt tip)

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

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

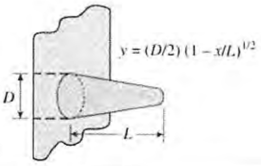


Table 1(b)

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Table 1(a)

Temperature distribution and heat loss for fins of uniform cross section

Case	Tip Condition ($x = L$)	Temperature Distribution θ/θ_b	Fin Heat Transfer Rate q_f
A	Convection heat transfer: $h\theta(L) = -kd\theta/dx\|_{x=L}$	$\dfrac{\cosh m(L-x) + (h/mk)\sinh m(L-x)}{\cosh mL + (h/mk)\sinh mL}$ (3.75)	$M\dfrac{\sinh mL + (h/mk)\cosh mL}{\cosh mL + (h/mk)\sinh mL}$ (3.77)
B	Adiabatic: $d\theta/dx\|_{x=L} = 0$	$\dfrac{\cosh m(L-x)}{\cosh mL}$ (3.80)	$M\tanh mL$ (3.81)
C	Prescribed temperature: $\theta(L) = \theta_L$	$\dfrac{(\theta_L/\theta_b)\sinh mx + \sinh m(L-x)}{\sinh mL}$ (3.82)	$M\dfrac{(\cosh mL - \theta_L/\theta_b)}{\sinh mL}$ (3.83)
D	Infinite fin ($L \rightarrow \infty$): $\theta(L) = 0$	e^{-mx} (3.84)	M (3.85)

$\theta \equiv T - T_\infty$ $m^2 \equiv hP/kA_c$

$\theta_b = \theta(0) = T_b - T_\infty$ $M \equiv \sqrt{hPkA_c}\,\theta_b$

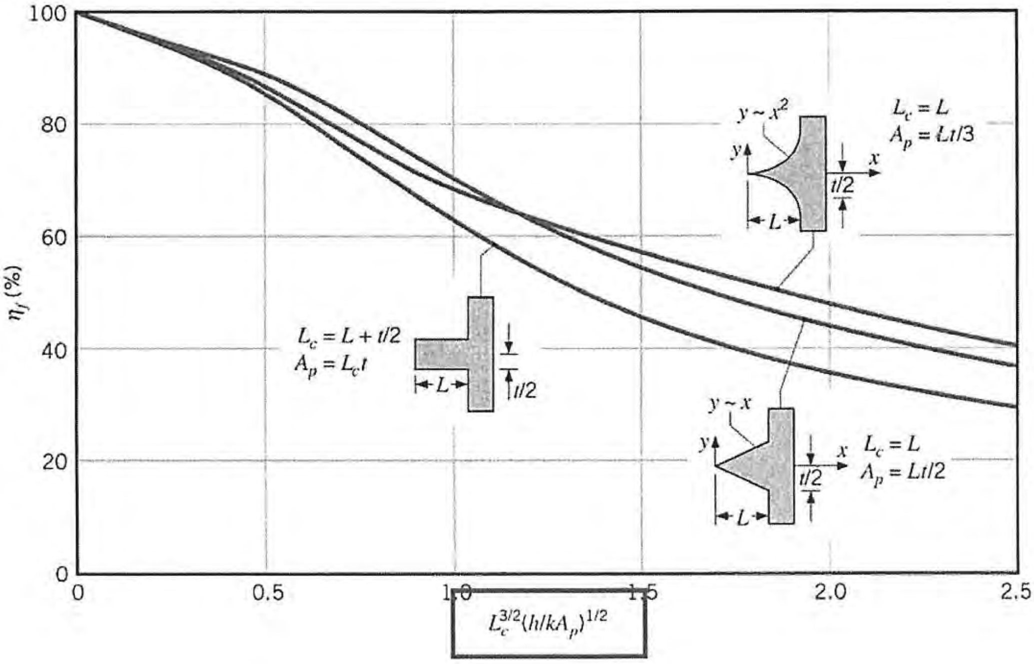

Figure 1(b)