Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER 2
SESSION 2018/2019

COURSE NAME	:	HEAT TRANSFER
COURSE CODE	:	BDA 30603
PROGRAMME	:	BDD
EXAMINATION DATE	:	JUNE/ JULY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FIVE (5)** QUESTIONS **ONLY**

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

Q1 (a) Does the efficiency and effectiveness of a fin increase or decrease as the fin length is increased.

(2 marks)

(b) Explain how the fins enhance heat transfer from a surface. Also explain how the addition of too many fins may actually decrease the heat transfer from a surface.

(3 marks)

(c) 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 Q1 (c-i)**). Determine the efficiency, heat transfer rate, and effectiveness of each fin, using

(i) **Table Q1 (c)** and;

(ii) **Figure Q1 (c-ii)**.

(15 marks)

Q2 (a) What is the physical significance of the biot number? Is the biot number more likely to be larger for highly conducting solids or poorly conducting ones?

(2 marks)

(b) Consider heat transfer between two identical hot solid bodies and the air surrounding them. The first solid is cooled by a fan while the second one is allowed to cool naturally. For which solid is the lumped system analysis more likely to be applicable? Explain why.

(3 marks)

(c) 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, determine how long the annealing process will take.

(15 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) Consider a hot boiled egg in a spacecraft that is filled with air at atmospheric pressure and temperature at all times. Will the egg cool faster or slower when the spacecraft is in space instead of on the ground? Explain.

(4 marks)

(b) A 15 cm diameter horizontal cylinder has a surface temperature that is maintained at 120°C. Water at 40°C is flowing across the cylinder with a velocity of 0.2 m/s. Show that this is a case of mixed convection and determine the Nusselt number if the water is flowing upwards and downwards as shown in **Figure Q4 (b)**.

(16 marks)

Q5 (a) Consider a heat exchanger that has an NTU of 0.5. Someone proposes to triple the size of the heat exchanger and thus triple the NTU to 1.5 in order to increase the effectiveness of the heat exchanger and thus save energy. Would you support this proposal?

(2 marks)

(b) How does a cross-flow heat exchanger differ from a counter-flow one? What is the difference between mixed and unmixed fluids in cross-flow?

(3 marks)

(c) A cross-flow heat exchanger shown in **Figure Q5 (c)** consists of 40 thin walled tubes of 1-cm diameter located in a duct of 1 m x 1 m cross-section. There are no fins attached to the tubes. Cold water (Cp = 4180 J/kg · °C) enters the tubes at 18°C with an average velocity of 3 m/s, while hot air (Cp = 1010 J/kg · °C) enters the channel at 130°C and 105 kPa at an average velocity of 12 m/s. If the overall heat transfer coefficient is 130 W/m^2 · °C, determine the outlet temperatures of both fluids and the rate of heat transfer.

(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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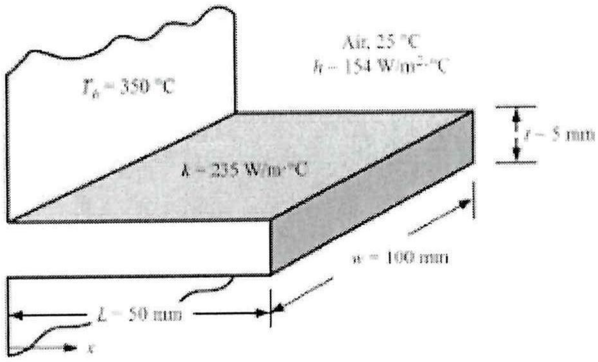

Figure Q1 (c-i)

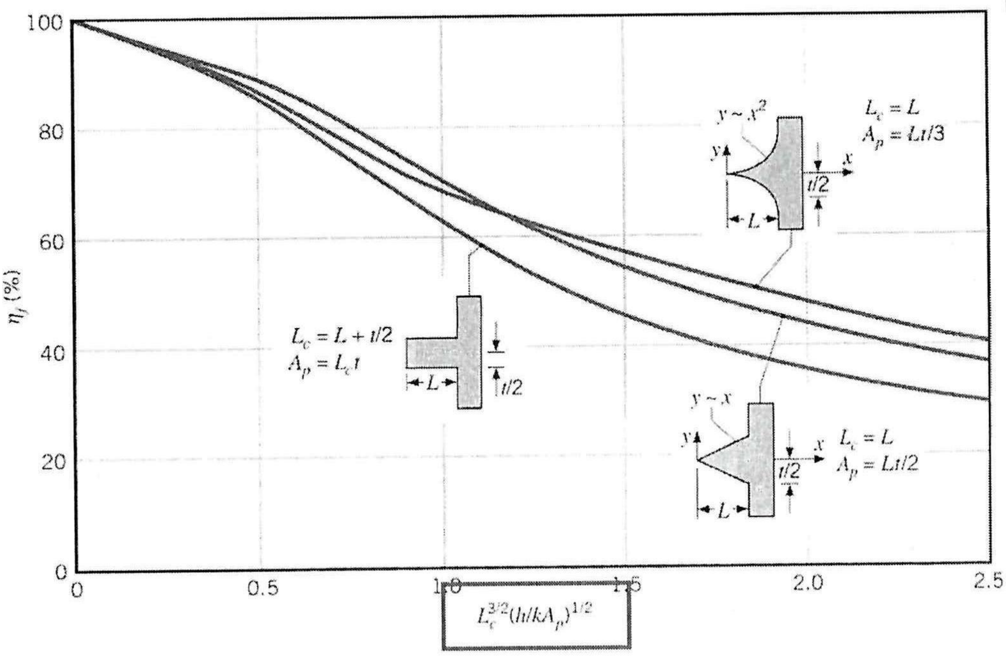

Figure Q1 (c-ii)

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Table Q1 (c)

Efficiency and surface areas of common fin configurations

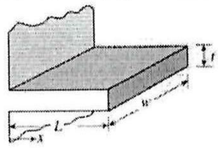
Straight rectangular fins

$m = \sqrt{2h/kt}$

$L_c = L + t/2$

$A_{fin} = 2wL_c$

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

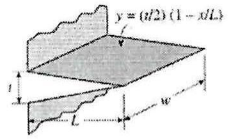


Straight triangular fins

$m = \sqrt{2h/kt}$

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

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



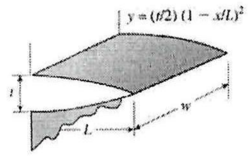
Straight parabolic fins

$m = \sqrt{2h/kt}$

$A_{fin} = wL[C_1 + (L/t)\ln(t/L + C_1)]$

$C_1 = \sqrt{1 + (t/L)^2}$

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



Circular fins of rectangular profile

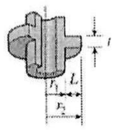
$m = \sqrt{2h/kt}$

$r_{2c} = r_2 + t/2$

$A_{fin} = 2\pi(r_{2c}^2 - r_1^2)$

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

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



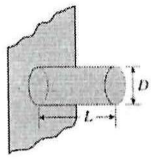
Pin fins of rectangular profile

$m = \sqrt{4h/kD}$

$L_c = L + D/4$

$A_{fin} = \pi DL_c$

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



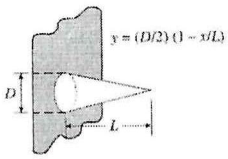
Pin fins of triangular profile

$m = \sqrt{4h/kD}$

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

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

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



Pin fins of parabolic profile

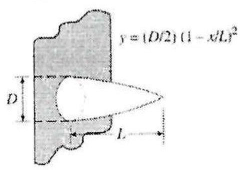
$m = \sqrt{4h/kD}$

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

$C_3 = 1 + 2(D/L)^2$

$C_4 = \sqrt{1 + (D/L)^2}$

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

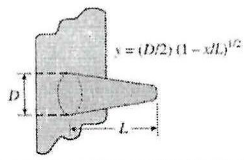


Pin fins of parabolic profile (blunt tip)

$m = \sqrt{4h/kD}$

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

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



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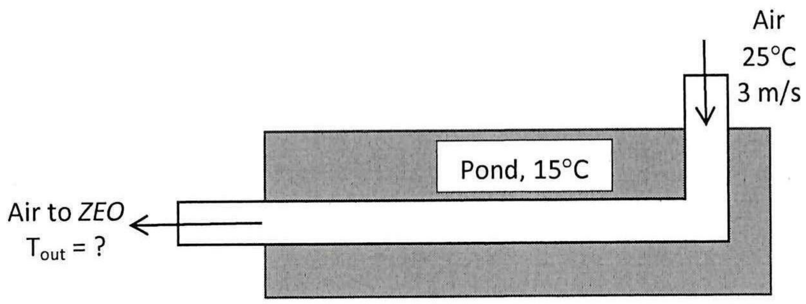

Figure Q3 (c)

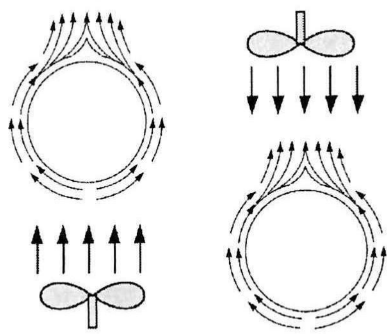

Figure Q4 (b)

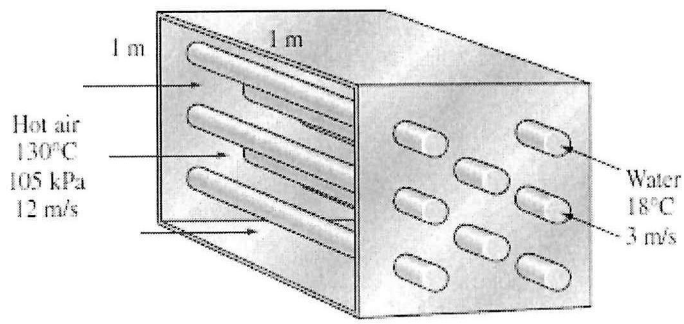

Figure Q5 (c)

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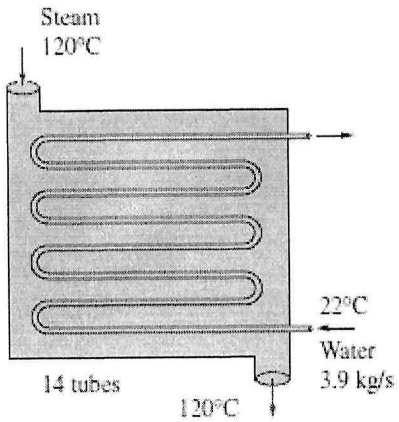

Figure Q6 (c)