Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER 1
SESSION 2019/2020

COURSE NAME	:	HEAT TRANSFER
COURSE CODE	:	BDA 30603
PROGRAMME	:	BDD
EXAMINATION DATE	:	DECEMBER 2019 /JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FIVE (5)** QUESTIONS **ONLY**

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** 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 hot surface at 100°C is to be cooled by attaching 3 cm long, 0.25 cm diameter aluminum pin fins ($k = 237\ W/m°C$) to it, with a center-to-center distance of 0.6cm. The temperature of the surrounding medium is 30°C, and the heat transfer coefficient on the surfaces is 35 $W/m^2\,°C$ (as shown in **Figure Q1(c)**). By using **Table Q1(c)**, determine the rate of heat transfer from the surface for a 1-m x 1-m section of the plate. Also determine the overall effectiveness of the fins.

(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) In a manufacturing facility, 5 cm diameter brass balls ($k = 111\ W/m°C$, $\rho = 8522\ kg/m^3$, and $C_p = 385\ J/kg°C$) initially at 120 °C are quenched in a water bath at 50 °C for a period of 2 min at a rate of 120 balls per minute(as shown in **Figure Q2(c)**). If the convection heat transfer coefficient is $238\ W/m^2\,°C$, determine the temperature of the balls after quenching and the rate at which heat needs to be removed from the water in order to keep its temperature constant at 50 °C.

(15 marks)

Q3 (a) What is natural convection? How does it differ from forced convection? What force causes natural convection currents?

(2 marks)

(b) Physically, what does the Grashof number represent? How does the Grashof number differ from the Reynolds number?

(3 marks)

(c) A 400-W cylindrical resistance heater is 1 m long and 0.5 cm in diameter as shown in **Figure Q3(c)**. The resistance wire is placed horizontally in a fluid at 20°C. Ignore any heat transfer by radiation. Use properties at 500°C for air. Determine the outer surface temperature of the resistance wire in steady operation if the fluid is

i) air and assume surface temperature $T_s =$ 1200°C for the calculation of h; and

ii) the surface temperature to be 40°C for water.

(15 marks)

Q4

(a) When neither natural nor forced convection is negligible, is it correct to calculate each independently and add them to determine the total convection heat transfer?

(4 marks)

(b) Engine oil at 80°C flows over a 6-m-long flat plate whose temperature is 30°C with a velocity of 3 m/s. Determine the total drag force and the rate of heat transfer over the entire plate per unit width.

(6 marks)

(a) A 3-m-internal-diameter spherical tank made of 1-cmthick stainless steel (k = 15 W/m · °C) is used to store iced water at 0°C as shown in **Figure Q4(c)**. The tank is located outdoors at 30°C and is subjected to winds at 25 km/h. Assuming the entire steel tank to be at 0°C and thus its thermal resistance to be negligible, determine Disregard any heat transfer by radiation.

i) the rate of heat transfer to the iced water in the tank ; and

ii) the amount of ice at 0°C that melts during a 24-h period. The heat of fusion of water at atmospheric pressure is h_{if} = 333.7 kJ/kg.

(10 marks)

Q5 (a) What are the heat transfer mechanisms involved during heat transfer in a liquid-to liquid heat exchanger from the hot to the cold fluid?

(4 marks)

(b) Consider the case shown in **Figure Q5(b)** between co-flow and counter-flow heat exchanger. For the same heat duty, which type of heat exchanger requires the least area?

(6 marks)

(c) A long thin-walled double-pipe heat exchanger with tube and shell diameters of 1.0 cm and 2.5 cm, respectively, is used to condense refrigerant-134a by water at 20°C. The refrigerant flows through the tube, with a convection heat transfer coefficient of h_i = 4100 W/m^2.K. Water flows through the shell at a rate of 0.3 kg/s. Determine the overall heat transfer coefficient of this heat exchanger.

(10 marks)

Q6 (a) What does the effectiveness of a heat exchanger represent? Can effectiveness be greater than one? On what factors does the effectiveness of a heat exchanger depend?

(4 marks)

(b) Can the temperature of the hot fluid drop below the inlet temperature of the cold fluid at any location in a heat exchanger? Explain.

(6 marks)

(c) Ethanol is vaporized at 78°C (h_{fg} = 846 kJ/kg) in a double-pipe parallel-flow heat exchanger at a rate of 0.03 kg/s by hot oil (C_p = 2200 J/kg.K) that enters at 115°C. If the heat transfer surface area and the overall heat transfer coefficients are 6.2 m^2 and 320 W/m^2.K, respectively, determine the outlet temperature and the mass flow rate of oil using either the LMTD method or the ε-NTU method.

(10 marks)

- END OF QUESTION -

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Table 1(c) Efficiency and surface areas of common fin configurations

Efficiency and surface areas of common fin configurations

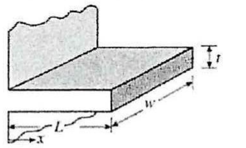
Straight rectangular fins

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

$L_c = L + t/2$

$A_{fin} = 2wL_c$

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

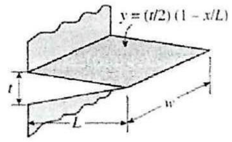


Straight triangular fins

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

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

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



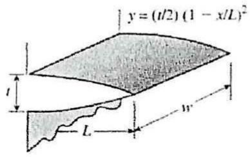
Straight parabolic fins

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

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

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

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



Circular fins of rectangular profile

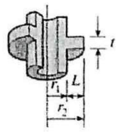
$m = \sqrt{2h/kt}$

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

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

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

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



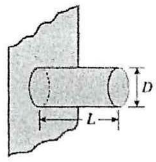
Pin fins of rectangular profile

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

$L_c = L + D/4$

$A_{fin} = \pi DL_c$

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



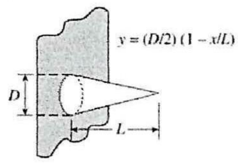
Pin fins of triangular profile

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

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

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

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



Pin fins of parabolic profile

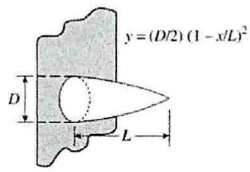
$m = \sqrt{4h/kD}$

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

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

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

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

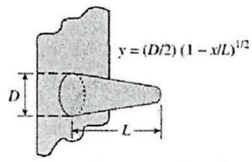


Pin fins of parabolic profile (blunt tip)

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

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

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



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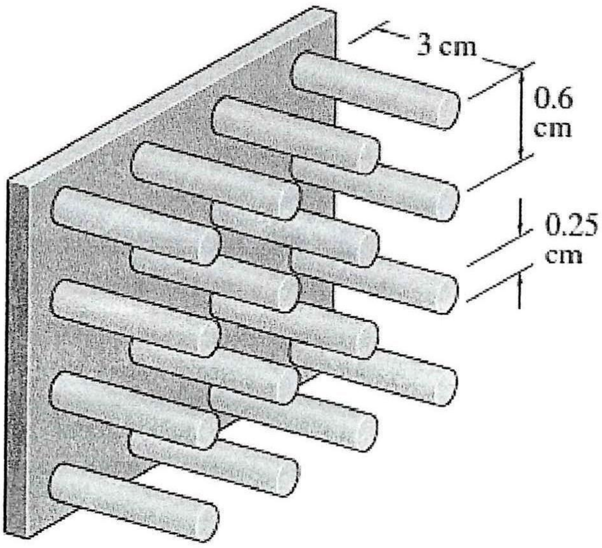

Figure Q1(c)

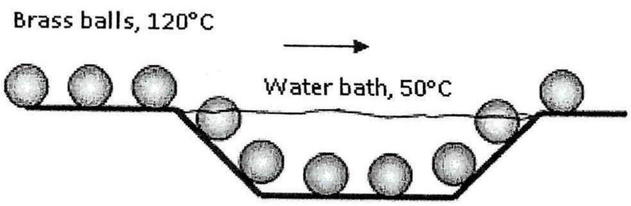

Figure Q2(c)

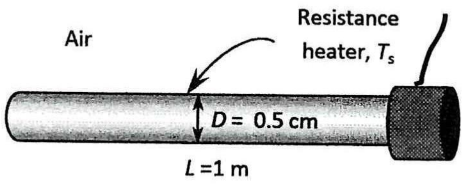

Figure Q3(c)

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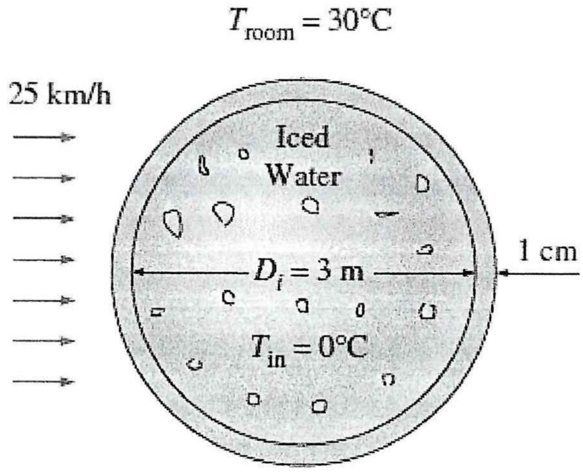

Figure Q4(c)

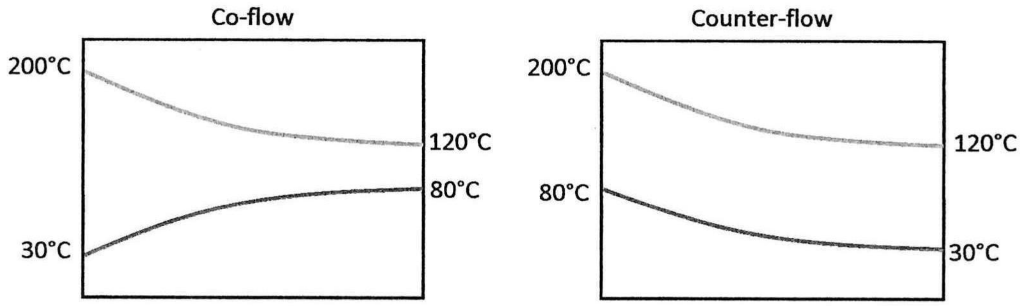

Figure Q5(b)