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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2021/2022

COURSE NAME	:	HEAT TRANSFER
COURSE CODE	:	BNQ 20203
PROGRAMME CODE	:	BNN
EXAMINATION DATE	:	JULY 2022
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS 2.THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.** 3.STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

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

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Q1 (a) 'It is more practical to consider conduction+convection instead of conduction alone in the calculation of heat transfer rate in solid for certain condition'. Explain this statement.

(4 marks)

(b) (i) Mariam is confused between steady state and unsteady state heat transfer. State the differences and come out with simple example to differentiate both of them.

(5 marks)

(ii) Propose a complete lab work procedure with illustration on how to determine the heat transfer coefficient for unsteady state heat transfer.

(6 marks)

(c) **Figure Q1 (c)** shows commonly-employed design elements and a subcomponent in shell-and-tube heat exchanger.

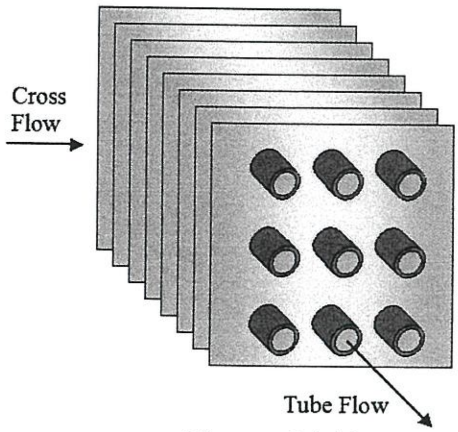

Figure Q1 (c)

(i) Name the design and list **TWO (2)** types of different arrangements for shell-and-tube heat exchanger design.

(3 marks)

(ii) Explain the need of correction factor in the calculation of heat transfer coefficient (h) for shell-and-tube heat exchanger design.

(2 marks)

(iii) Discuss the advantages of the design and explain the use of maximum velocity instead of the inlet velocity in the Reynolds number calculation.

(5 marks)

Q2 An electric cable has the properties as below:

Diameter: 5.3 mm
Length: 20 m
Insulation: 3 mm
Thermal conductivity: 0.35 W/m.°C
Current: 21 A
Voltage: 6 V
Surrounding temperature: 35 °C
Surrounding heat transfer coefficient: 20 W/m^2.°C

(a) Sketch and label the electric cable system.

(5 marks)

(b) Calculate the total thermal resistance of the electric cable with the insulation.

(5 marks)

(c) Determine the temperature at the interface of the cable.

(5 marks)

(d) Predict the trend of interface temperature if the insulation thickness was doubled.

(10 marks)

Q3 In an industrial facility, air needed to be preheated before entering a furnace. Consider a case where air is heated by a bank of tubes at 120 °C. Air enters the system at 20 °C and 1 atm with a mean velocity of 4.5 m/s, and flows over the tubes in a normal direction. The outer diameter and length of the tubes are 1.5 cm and 1 m respectively. The tubes are arranged in line with longitudinal and transverse pitches of S_n=S_p=2.25 cm. There are 6 rows in the flow direction (horizontal) with 10 tubes in the vertical arrangement. By referring to **Table Q3 (i), (ii) and (iii)**,

(a) Draw and label in detail the bank of tubes system as mentioned above. The air temperature leaving the tube bank is T_o = 60 °C.

(5 marks)

(b) Determine **FOUR (4)** physical properties of air and calculate the maximum velocity together with the Reynolds number.

(10 marks)

(c) Determine the heat transfer coefficient and the heat transfer between air and the tubes.

(10 marks)

Q4 Hot oil at a flow rate of 3 kg/s (c_p= 1.92 kJ/kg.K) enters an existing counterflow exchanger at 400 K and is cooled by water (c_p=4.196 kJ/kg.K) entering at 325 K and flowing at a rate of 0.7 kg/s. The overall U = 350 W/m^2.K. and A=12.9 m^2.

(a) Sketch the situation mentioned above.

(5 marks)

(b) Determine the heat transfer rate of the system by referring to **Table Q4(b).**

(10 marks)

(c) Calculate the exit oil temperature.

(10 marks)

- END OF QUESTIONS-

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Unit Conversion

R value

R= 8.31451 J K^{-1} mol^{-1} = 8.20578x10^{-2} L atm K^{-1} mol^{-1} = 8.31451x10^{-2} L bar K^{-1} mol^{-1}
= 8.31451 Pa m^3 K^{-1} mol^{-1} = 62.364 L Torr K^{-1} mol^{-1} = 1.98722 cal K^{-1} mol^{-1}

Liquid water properties at 4 °C (277.2 K)

Density (ρ) = 1000 kg/m^3
= 1 g/cm^3
= 62.43 lb_m/ft^3

Temperature

K = °C + 273.15
°F= 32 + 1.8(°C)
°R= °F + 459.67
100 °C = 212 °F + 373.15 K = 671.67 °R
0 °C = 32 °F = 273.15 K = 491.67 °R

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Table 1: Unit Conversion Factors

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz 1 lb_m = 16 oz = 5×10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10^6 μm = 10^{10} Å 1 m = 39.37 in = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m^3 = 1000 liters = 10^6 cm^3 = 10^6 ml 1 m^3 = 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal = 1056.68 qt 1 ft^3 = 1728 in^3 = 7.4805 gal = 0.028317 m^3 = 28.317 liters = 28317 cm^3
Force	1 N = 1 kg·m/s^2 = 10^5 dynes = 10^5 g·cm/s^2 = 0.22481 lb_f 1 lb_f = 32.174 lb_m·ft/s^2 = 4.4482 N
Pressure	1 atm = 1.01325×10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bars 1 atm = 1.01325×10^6 dynes/cm^2 1 atm = 760 mmHg at 0°C (torr) = 10.333 m H_2O at 4°C = 14.696 lb_f/in^2 (psi) 1 atm = 33.9 ft H_20 at 4°C = 29.921 inHg at 0°C
Energy	1 J = 1 N·m = 10^7 ergs = 10^7 dyne·cm = 2.778×10^{-7} kW·h 1 J = 0.23901 cal = 0.7376 ft-lb_f = 9.486×10^{-4} Btu
Power	1 W = 1 J/s = 1.341×10^{-3} hp

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Table Q3 (i) Physical properties of Air at 101.325 kPa (1 Atm Abs) in SI units

T (°C)	T (K)	ρ (kg/m^3)	c_p ($kJ/kg \cdot K$)	$\mu \times 10^5$ ($Pa \cdot s$, or $kg/m \cdot s$)	k ($W/m \cdot K$)	N_{Pr}	$\beta \times 10^3$ ($1/K$)	$g\beta\rho^2/\mu^2$ ($1/K \cdot m^3$)
−17.8	255.4	1.379	1.0048	1.62	0.02250	0.720	3.92	2.79×10^8
0	273.2	1.293	1.0048	1.72	0.02423	0.715	3.65	2.04×10^8
10.0	283.2	1.246	1.0048	1.78	0.02492	0.713	3.53	1.72×10^8
37.8	311.0	1.137	1.0048	1.90	0.02700	0.705	3.22	1.12×10^8
65.6	338.8	1.043	1.0090	2.03	0.02925	0.702	2.95	0.775×10^8
93.3	366.5	0.964	1.0090	2.15	0.03115	0.694	2.74	0.534×10^8
121.1	394.3	0.895	1.0132	2.27	0.03323	0.692	2.54	0.386×10^8
148.9	422.1	0.838	1.0174	2.37	0.03531	0.689	2.38	0.289×10^8
176.7	449.9	0.785	1.0216	2.50	0.03721	0.687	2.21	0.214×10^8
204.4	477.6	0.740	1.0258	2.60	0.03894	0.686	2.09	0.168×10^8
232.2	505.4	0.700	1.0300	2.71	0.04084	0.684	1.98	0.130×10^8
260.0	533.2	0.662	1.0341	2.80	0.04258	0.680	1.87	0.104×10^8

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Table Q3 (ii) Values of C and m

	$\frac{S_n}{D} = \frac{S_p}{D} = 1.25$		$\frac{S_n}{D} = \frac{S_p}{D} = 1.50$		$\frac{S_n}{D} = \frac{S_p}{D} = 2.0$	
Arrangement	*C*	*m*	*C*	*m*	*C*	*m*
In-line	0.386	0.592	0.278	0.620	0.254	0.632
Staggered	0.575	0.556	0.511	0.562	0.535	0.556

Source : E. D. Grimison, *Trans. ASME*, **59**, 583 (1937).

Table Q3 (iii) Correction factors

N	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Ratio for staggered tubes	0.68	0.75	0.83	0.89	0.92	0.95	0.97	0.98	0.99	1.00
Ratio for in-line tubes	0.64	0.80	0.87	0.90	0.92	0.94	0.96	0.98	0.99	1.00

Source : W. M. Kays and R. K. Lo, *Stanford Univ. Tech. Rept. 15*, Navy Contract N6-ONR-251 T.O.6, 1952.

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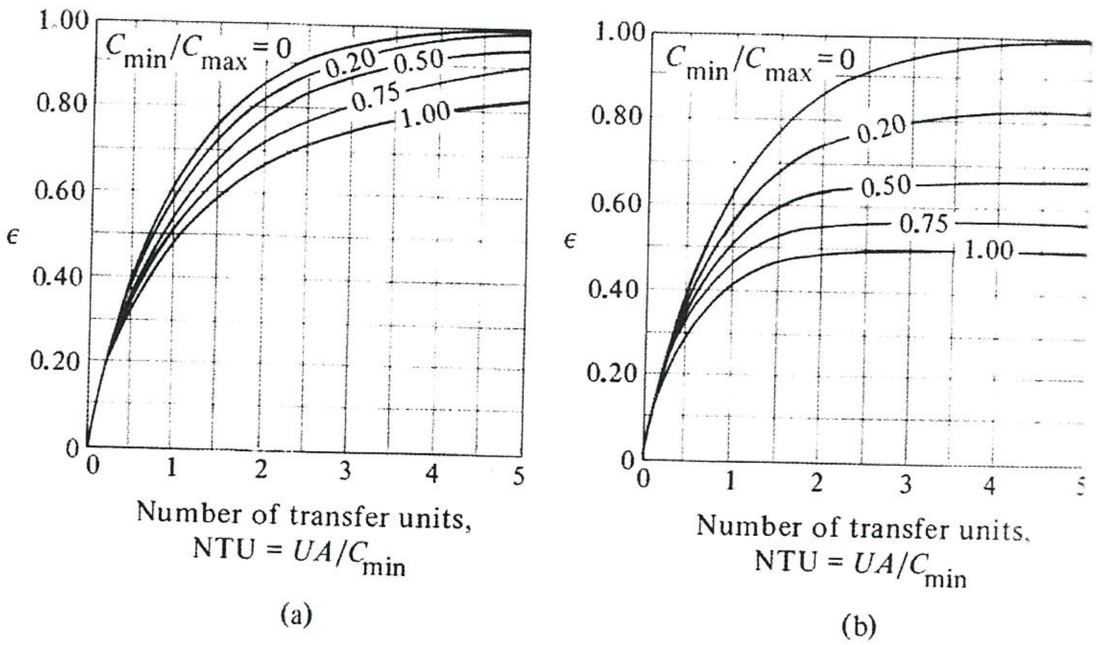

Figure Q4 (b) Heat exchanger effectiveness: (a) counterflow exchanger, (b) parallel flow exchanger

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FORMULA

CRITICAL THICKNESS OF INSULATION FOR A CYLINDER

circular pipe:-

$$r_{cr} = \frac{k}{h_o}$$

sphere:-

$$r_{cr} = \frac{2k}{h_o}$$

$$q = I^2 R_c = IV$$

$$q = h_o A(T_2 - T_o)$$

$$q = \frac{2\pi L(T_1 - T_o)}{\frac{\ln(r_2 / r_1)}{k} + \frac{1}{r_2 h_o}}$$

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Flow Past Banks of Tubes or Cylinders

$$N_{NU} = C N_{RE}{}^{m} N_{\mathrm{Pr}}{}^{\frac{1}{3}}$$

$$N_{RE,\max} = \frac{\rho V_{\max} D}{\mu}$$

$$V_{\max} = \frac{V S_n}{S_n - D}$$

$$N_{NU}\Big|_{N<10} = c_1 N_{NU}$$

$$N_{NU_D} = \frac{hD}{k}$$

$$q = Ah(T_w - T_b)$$

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Heat Exchanger

$$q_{actual} = \varepsilon(\dot{m}c_p)_{\min}(T_{hi} - T_{ci}) = (mc_p)_H(T_{hi} - T_{ho}) = (mc_p)_C(T_{Co} - T_{Ci})$$

where $C_{\min} = \varepsilon(\dot{m}c_p)_{\min}$

$\therefore \mathrm{C}_{\min}$ = fluid having lower $(\dot{m}c_p)$

$\therefore C_{\max}$ = fluid having higher $(\dot{m}c_p)$