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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2018/2019

COURSE NAME	:	HEAT TRANSFER
COURSE CODE	:	BNQ 20203
PROGRAMME CODE	:	BNN
EXAMINATION DATE	:	JUNE/JULY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **THIRTEEN (13)** PAGES

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Q1 (a) (i) There are two types of boiling which are pool and flow boiling. Provide definition for each of the boiling.

(4 marks)

(ii) There are four main parts in pool boiling which represent each of the boiling steps. Illustrate each part of the boiling with detail explanation on the processes.

(8 marks)

(b) (i) Any heating surfaces can be heated electrically or by hot condensing fluid on the other side of the heated surface. Name **TWO (2)** types of condensation.

(2 marks)

(ii) Differentiate the condensation and explain the condensation with larger heat transfer coefficient.

(6 marks)

(c) Explain on how industries choose the types of heat exchanger in the plan operation, whether co-current or counter current heat exchanger (based on their strength).

(5 marks)

Q2 In an industrial facility, air need 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 is 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 Q2 (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)

Q3 (a) A small copper wire with a diameter of 0.792 mm and initially at 366.5 K is suddenly immersed into a liquid held constant at 311 K. The convectioncoefficient, h = 11.36 W/m^2.K. The physical properties are k = 374 W/m.K, c_p = 0.389 kJ/kg.K and ρ = 8890 kg/m^3.

(i) Determine the time (s) for the average temperature of the wire to drop to 338.8 K.

(10 marks)

(ii) Calculate the total amount of heat removed for a wire 1 m long.

(5 marks)

(b) In orange-growing areas, the freezing of the oranges on the trees during cold nights is economically important. If the oranges are initially at a temperature of 21.1 °C, calculate the center temperature of the orange if exposed to air at -3.9 °C for 6 h. The oranges have 102 mm diameter and the convective coefficient is 11.4 W/m^2.K. The thermal conductivity is 0.431 W/m.K and α is 4.65 x 10^{-4} m^2/h. Use **Figure Q3 (b)** and **Table Q3 (b)** for references.

(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. Calculate the heat transfer rate and the exit oil temperature

(a) Sketch the situation mentioned above.

(5 marks)

(b) Based on **Figure Q4 (b)**, determine the heat transfer rate of the system.

(10 marks)

(c) Calculate the exit oil temperature.

(10 marks)

- END OF QUESTIONS-

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2018/2019 PROGRAMME CODE : BNN
COURSE NAME : HEAT TRANSFER COURSE CODE : BNQ 20203

Unit Conversion

R value

R= 8.31451 J K^{-1} mol^{-1} = 8.20578×10^{-2} L atm K^{-1} mol^{-1} = 8.31451×10^{-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

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2018/2019 PROGRAMME CODE : BNN
COURSE NAME : HEAT TRANSFER COURSE CODE : BNQ 20203

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

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2018/2019 PROGRAMME CODE : BNN
COURSE NAME : HEAT TRANSFER COURSE CODE : BNQ 20203

Table Q2 (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}	$\beta \times 10^3$ ($1/K$)	$g\beta\rho^2$ ($1/K \cdot$
−17.8	255.4	1.379	1.0048	1.62	0.02250	0.720	3.92	2.79 ›
0	273.2	1.293	1.0048	1.72	0.02423	0.715	3.65	2.04 ›
10.0	283.2	1.246	1.0048	1.78	0.02492	0.713	3.53	1.72 ›
37.8	311.0	1.137	1.0048	1.90	0.02700	0.705	3.22	1.12 ›
65.6	338.8	1.043	1.0090	2.03	0.02925	0.702	2.95	0.775 ›
93.3	366.5	0.964	1.0090	2.15	0.03115	0.694	2.74	0.534 ›
121.1	394.3	0.895	1.0132	2.27	0.03323	0.692	2.54	0.386 ›
148.9	422.1	0.838	1.0174	2.37	0.03531	0.689	2.38	0.289 ›
176.7	449.9	0.785	1.0216	2.50	0.03721	0.687	2.21	0.214 ›
204.4	477.6	0.740	1.0258	2.60	0.03894	0.686	2.09	0.168 ›
232.2	505.4	0.700	1.0300	2.71	0.04084	0.684	1.98	0.130 ›
260.0	533.2	0.662	1.0341	2.80	0.04258	0.680	1.87	0.104 ›

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2018/2019 PROGRAMME CODE : BNN
COURSE NAME : HEAT TRANSFER COURSE CODE : BNQ 20203

Table Q2 (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 Q2 (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.

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2018/2019 PROGRAMME CODE : BNN
COURSE NAME : HEAT TRANSFER COURSE CODE : BNQ 20203

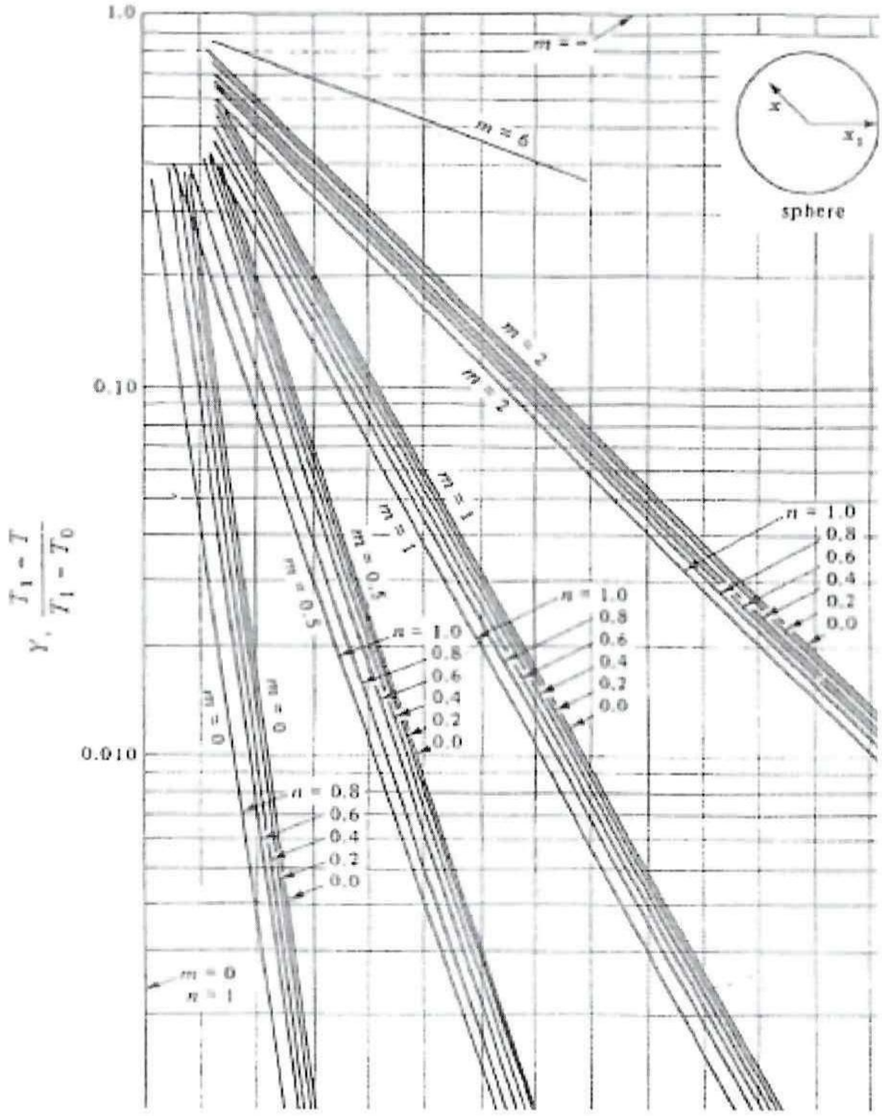

Figure Q3 (b) Unsteady-state heat conduction in a sphere

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2018/2019 PROGRAMME CODE : BNN
COURSE NAME : HEAT TRANSFER COURSE CODE : BNQ 20203

Table Q3 (b) Dimensionless parameters for use in unsteady state conduction charts

$$Y = \frac{T_1 - T}{T_1 - T_0} \qquad m = \frac{k}{hx_1}$$

$$1 - Y = \frac{T - T_0}{T_1 - T_0} \qquad n = \frac{x}{x_1}$$

$$X = \frac{\alpha t}{x_1^2}$$

SI units: $\alpha = \mathrm{m^2/s}$, $T = \mathrm{K}$, $t = \mathrm{s}$, $x = \mathrm{m}$, $x_1 = \mathrm{m}$, $k = \mathrm{W/m \cdot K}$, $h = \mathrm{W/m^2 \cdot K}$

English units: $\alpha = \mathrm{ft^2/h}$, $T = {}^\circ\mathrm{F}$, $t = \mathrm{h}$, $x = \mathrm{ft}$, $x_1 = \mathrm{ft}$, $k = \mathrm{btu/h \cdot ft \cdot {}^\circ F}$, $h = \mathrm{btu/h \cdot ft^2 \cdot {}^\circ F}$

Cgs units: $\alpha = \mathrm{cm^2/s}$, $T = {}^\circ\mathrm{C}$, $t = \mathrm{s}$, $x = \mathrm{cm}$, $x_1 = \mathrm{cm}$, $k = \mathrm{cal/s \cdot cm \cdot {}^\circ C}$,

T_1 = Environment temperature
T_0 = Initial temperature
T = Temperature at 'x' length

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2018/2019 PROGRAMME CODE : BNN
COURSE NAME : HEAT TRANSFER COURSE CODE : BNQ 20203

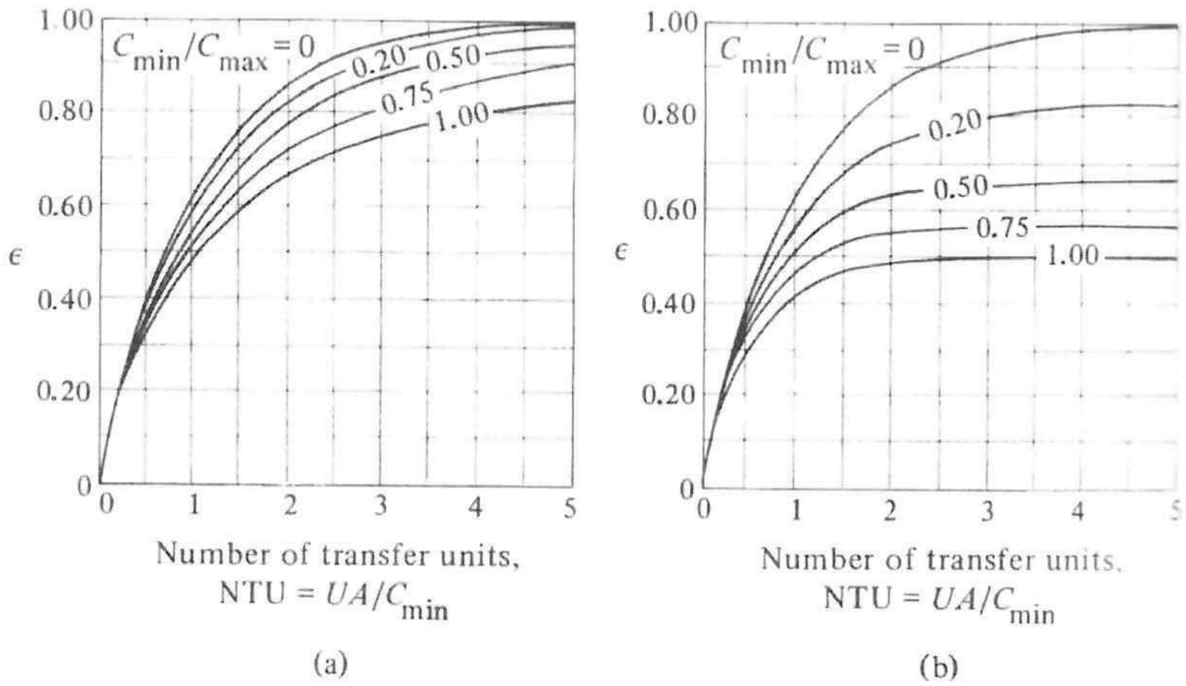

Figure Q4 (b) Heat exchanger effectiveness: (a) counterflow exchanger, (b) parallel flow exchanger

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2018/2019 PROGRAMME CODE : BNN
COURSE NAME : HEAT TRANSFER COURSE CODE : BNQ 20203

FORMULA

Flow Past Banks of Tubes or Cylinders

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

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

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

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

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

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

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2018/2019 PROGRAMME CODE : BNN
COURSE NAME : HEAT TRANSFER COURSE CODE : BNQ 20203

Unsteady State Heat Transfer

BIOT NUMBER $N_{Bi} = \frac{hx_1}{k}$ $x_1 = \frac{V}{A_s}$

x_1 - characteristic length, m
h - heat transfer coefficient
k - conductivity of the bodys/solid
V - volume of the solid
As - surface area o the solid

For sphere,

$$x_1 = \frac{V}{A} = \frac{4\pi r^3}{12\pi r^2} = \frac{r}{3}$$

For a long cylinder,

$$x_1 = \frac{V}{A} = \frac{\pi D^2 L}{4\pi DL} = \frac{D}{4} = \frac{r}{2}$$

For a long square rod,

$$x_1 = \frac{V}{A} = \frac{(2x)^2 L}{4(2x)L} = \frac{x}{2} \text{ (x = ½ thickness)}$$

$$\frac{(T - T_\infty)}{(T_o - T_\infty)} = e^{-(hA/\rho Vc_p).t}$$

T = Temperature at t=t
T_o = Initial temperature, t=0
T_∞ = Temperature which held constant with time

$$Q = \rho Vc_p(T_o - T_\infty)\left[1 - e^{-(hA/\rho Vc_p)t}\right]$$

FINAL EXAMINATION

SEMESTER/SESSION	: SEM II/2018/2019	PROGRAMME CODE	: BNN
COURSE NAME	: HEAT TRANSFER	COURSE CODE	: BNQ 20203

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

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

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