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UNIVERSITY COLLEGE TATI

UNIVERSITY COLLEGE TATI (UC TATI)

FINAL EXAMINATION QUESTION BOOKLET

COURSE CODE	: BCE 2114
COURSE	: TRANSPORT PROCESSES
SEMESTER/SESSION	: 1 / 2024-25
DURATION	: 3 HOURS

Instructions:

1. This booklet contains 4 questions. Answer **ALL** questions.
2. All answers should be written in the answer booklet.
3. Write legibly and draw sketches wherever required.
4. If in doubt, raise your hands and ask the invigilator.
5. You are allowed to bring 1 A4-sized page(1 sided only) of lecture notes.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

THIS BOOKLET CONTAINS 7 PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

a) Suppose you have a 60 g egg at a refrigerator temperature of 5°C, and you want to cook it by raising its temperature to 70°C. Compute the amount of heat required to raise the temperature of the egg to 70°C. Refer to Appendix 2 for the value of the heat capacity. (5 marks)

b) Water at 25°C flows through a pipe with varying diameters. The pipe narrows from a diameter of 0.15 m to 0.05 m over a length of 10 m. The inlet velocity of the water at the wider section is 2 m/s. Assuming steady, incompressible flow, determine the Reynolds number at both the wider section and the narrow section of the pipe. Use the properties of water at 25°C with a density of 997 kg/m^3 and a dynamic viscosity of 8.9×10^{-4} Pa.s. (20 marks)

QUESTION 2

a) A sealed container holds a mixture of three gases: oxygen, nitrogen, and carbon dioxide. The mole fraction of oxygen in the mixture is 0.25, the mole fraction of nitrogen is 0.5, and the mole fraction of carbon dioxide is 0.25. If the total pressure inside the container is 3 atm, calculate the partial pressures of each gas (O_2, N_2 & CO_2) in the mixture. (8 marks)

b) Suppose you have a heat exchanger where: (10 marks)

- Hot fluid: Mass flow rate ($\dot{m}_H$) is 1 kg/s and specific heat (C_p)is 4.18 kJ/kg·K.
- Cold fluid: Mass flow rate ($\dot{m}_C$) is 2 kg/s and specific heat (C_p) is 3.98 kJ/kg·K.
- The inlet temperature of the hot fluid: T_{Hi}=150°C
- The outlet temperature of the hot fluid: T_{Ho}=100° C
- The inlet temperature of the cold fluid: T_{Ci}=30° C

Calculate the effectiveness of the heat exchanger.

c) In a closed chamber with an oxygen gradient, the concentration at one end is 0.2 mol/m^3 and 0.05 mol/m^3 at the other end, 1 m apart. The diffusion coefficient for oxygen in air is 2.1×10^{-5} m^2/s. Calculate the flux of oxygen. (10 marks)

QUESTION 3

a) A mixture of He and N_2 gas is contained in a pipe at 298 K and 1 atm total pressure that is constant throughout. At one end of the pipe at point 1, the partial pressure p_{A1} of He is 0.60 atm and at the other end, it is 0.2 m (20 cm) p_{A2} = 0.20 atm. Evaluate the flux of He at a steady state if the D_{AB} of the He–N_2 mixture is 0.687 × $10^{-4} m_2/s$ (0.687 cm^2/s). Given R = 8.314 $m^3 \cdot$ Pa/mol $\cdot$ K (15 marks)

b) Calculate the enthalpy change when 1 kg of water is heated from 21.1°C to 60°C at a pressure of 1 atm. Refer to Appendix 3. (7 marks)

QUESTION 4

a) A parallel flow heat exchanger is used to cool oil using water. Determine the effectiveness of the heat exchanger. The following data is given: (10 marks)

Hot oil

- Inlet temperature: T_{Hi}=120°C
- Outlet temperature: T_{Ho}=80° C
- Mass flow rate ($\dot{m}_H$) is 0.5 kg/s
- Specific heat (C_p)is 4.18 kJ/kg·K

Cold water

- Inlet temperature: T_{Ci}=20° C
- Outlet temperature: T_{Co}=60° C
- Mass flow rate ($\dot{m}_C$) is 1 kg/s
- Specific heat (C_p)is 4.18 kJ/kg·K

b) A wall consists of two layers: a 0.1 .m thick layer of brick (thermal conductivity k_1=0.7 W/mK and a 0.05 m thick layer of insulation (thermal conductivity k_2=0.04 W/mK. The wall has a cross-sectional area of 5 m². If the temperature on one side of the brick is 100°C and on the other side of the insulation is 20°C, calculate the rate of heat transfer. (15 marks)

--End of question--

Appendix 1

FORMULA

$$Q = mC\Delta T$$

$$x_A = \frac{p_A}{P} = \frac{p_A}{p_A + p_B + p_C + \dots}$$

$$A_1V_1 = A_2V_2$$

$$Re = \frac{\rho VD}{\mu}$$

$$C_H = \dot{m}_H \times c_p$$

$$C_C = \dot{m}_C \times c_p$$

$$\varepsilon = \frac{C_{\min}(T_{Hi} - T_{Ho})}{C_{\max}(T_{Hi} - T_{Ci})}$$

$$J = -D \frac{dC}{dx}$$

$$J = D \frac{C1 - C2}{l}$$

$$\frac{n}{V} = \frac{P}{RT} = c(conc\ of\ gas)$$

$$U_i = \frac{1}{R_{\text{total}}}$$

$$R_{\text{conv}} = \frac{1}{hA}$$

$$R_{\text{cond}} = \frac{\Delta x}{kA}$$

$$R_{\text{total}} = R_{\text{conv,inside}} + R_{\text{cond}} + R_{\text{conv,outside}}$$

$$q = \frac{\Delta T}{Rtotal}$$

Appendix 2

Table A.4-1. *Heat Capacities of Foods (Average c_p 273–373 K or 0–100°C)*

Material	*H_2O (wt %)*	*c_p (kJ/kg · K)*
Apples	75–85	3.73–4.02
Apple sauce		4.02*
Asparagus		
Fresh	93	3.94†
Frozen	93	2.01‡
Bacon, lean	51	3.43
Banana purée		3.66§
Beef, lean	72	3.43
Bread, white	44–45	2.72–2.85
Butter	15	2.30¶
Cantaloupe	92.7	3.94†
Carrot	88.2	3.81–3.94
Cheese, Swiss	55	2.68†
Corn, sweet		
Fresh		3.32†
Frozen		1.77‡
Cream, 45–60% fat	57–73	3.06–3.27
Cucumber	97	4.10
Eggs		
Fresh		3.18†
Frozen		1.68‡

Appendix 3

Table A.2-9a. *Properties of Saturated Steam and Water (Steam Table), SI Units*

Temperature (°C)	Vapor Pressure (kPa)	Specific Volume (m^3/kg) Liquid	Specific Volume (m^3/kg) Sat'd Vapor	Enthalpy (kJ/kg) Liquid	Enthalpy (kJ/kg) Sat'd Vapor	Entropy (kJ/kg · K) Liquid	Entropy (kJ/kg · K) Sat'd Vapor
0.01	0.6110	0.0010002	206.14	0.00	2501.4	0.00	9.1555
10	1.2260	0.0010003	106.31	42.02	2519.2	0.1511	8.8998
15	1.7051	0.0010009	77.881	62.98	2528.4	0.2245	8.7804
20	2.3371	0.0010018	57.761	83.92	2537.5	0.2965	8.6661
25	3.169	0.0010030	43.341	104.84	2546.5	0.3673	8.5568
30	4.246	0.0010044	32.882	125.75	2555.6	0.4368	8.4521
35	5.6236	0.0010060	25.208	146.64	2564.6	0.5052	8.3518
40	7.384	0.0010079	19.517	167.54	2573.5	0.5724	8.2557
45	9.593	0.0010099	15.253	188.44	2582.5	0.6386	8.1634
50	12.349	0.0010121	12.028	209.34	2591.3	0.7038	8.0749
55	15.759	0.0010145	9.5649	230.24	2600.1	0.7680	7.9899
60	19.940	0.0010171	7.6677	251.15	2608.8	0.8312	7.9082
65	25.03	0.0010199	6.1938	272.08	2617.5	0.8935	7.8296
70	31.19	0.0010228	5.0397	293.02	2626.1	0.9550	7.7540
75	38.58	0.0010258	4.1291	313.97	2634.6	1.0156	7.6812
80	47.39	0.0010290	3.4053	334.95	2643.0	1.0754	7.6110
85	57.83	0.0010324	2.8259	355.95	2651.3	1.1344	7.5434

Appendix 4

Unit Conversion Table

Name, Symbol, Dimensions			Conversion Formula
Length	L	L	1 m = 3.281 ft = 1.094 yd = 39.37 in = km/1000 = 10^6 μm 1 ft = 0.3048 m = 12 in = mile/5280 = km/3281 1 mm = m/1000 = in/25.4 = 39.37 mil = 1000 μm = 10^7 Å
Speed	V	L/T	1 m/s = 3.600 km/hr = 3.281 ft/s = 2.237 mph = 1.944 knots 1 ft/s = 0.3048 m/s = 0.6818 mph = 1.097 km/hr = 0.5925 knots
Mass	m	M	1 kg = 2.205 lbm = 1000 g = slug/14.59 = (metric ton or tonne or Mg)/1000 1 lbm = lbf·s^2/(32.17ft) = kg/2.205 = slug/32.17 = 453.6 g = 16 oz = 7000 grains = short ton/2000 = metric ton (tonne)/2205
Density	ρ	M/L^3	1000 kg/m^3 = 62.43 lbm/ft^3 = 1.940 slug/ft^3 = 8.345 lbm/gal (US)
Force	F	ML/T^2	1 lbf = 4.448 N = 32.17 lbm·ft/s^2 1 N = kg·m/s^2 = 0.2248 lbf = 10^5 dyne
Pressure	P	M/LT^2	1 Pa = N/m^2 = kg/m · s^2 = 10^{-5} bar = 1.450 × 10^{-4} lbf/in^2 = inch H_2O/249.1 = 0.007501 torr = 10.00 dyne/cm^2 1 atm = 101.3 kPa = 2116 psf = 1.013 bar = 14.70 lbf/in^2 = 33.90 ft of water = 29.92 in of mercury = 10.33 m of water = 760 mm of mercury = 760 torr 1 psi = atm/14.70 = 6.895 kPa = 27.68 in H_2O = 51.71 torr
Volume	$\forall$	L^3	1 m^3 = 35.31 ft^3 = 1000 L = 264.2 U.S. gal 1 ft^3 = 0.02832 m^3 = 28.32 L = 7.481 U.S. gal = acre-ft/43,560 1 U.S. gal = 231 in^3 = barrel (petroleum)/42 = 4 U.S. quarts = 8 U.S. pints = 3.785 L = 0.003785 m^3
Volume Flow Rate (Discharge)	Q	L^3/T	1 m^3/s = 35.31 ft^3/s = 2119 cfm = 264.2 gal (US)/s = 15850 gal (US)/m 1 cfs = 1 ft^3/s = 28.32 L/s = 7.481 gal (US)/s = 448.8 gal (US)/m
Mass Flow Rate	$\dot{m}$	M/T	1 kg/s = 2.205 lbm/s = 0.06852 slug/s
Energy and Work	E, W	ML^2/T^2	1 J = kg·m^2/s^2 = N·m = W·s = volt·coulomb = 0.7376 ft·lbf = 9.478 × 10^{-4} Btu = 0.2388 cal = 10^7 erg = kWh/3.600 × 10^6
Power	$P, \dot{E}, \dot{W}$	ML^2/T^3	1 W = J/s = N·m/s = kg·m^2/ s^3 = 1.341 × 10^{-3} hp = 0.7376 ft · lbf/s = 1.0 volt-ampere = 0.2388 cal/s = 9.478 × 10^{-4} Btu/s 1 hp = 0.7457 kW = 550 ft·lbf/s = 33,000 ft·lbf/min = 2544 Btu/h

Transport process