UNIVERSITY
OF
JOHANNESBURG

PROGRAM	:	*BACHELOR OF ENGINEERING TECHNOLOGY* CHEMICAL ENGINEERING
SUBJECT	:	*CHEMICL ENGINEERING FUNAMENTALS*
CODE	:	*CEFCHB1*
DATE	:	21 *NOVEMBER 2017 (SUMMER EXAMINATION)*
DURATION	:	12:30 - 15:30 (SESSION2)
WEIGHT	:	40: 60
TOTAL MARKS	:	100
FULL MARKS	:	100

EXAMINERS	:	MR ISHMAEL RAMATSA
MODERATOR	:	DR KAPIL MOOTHI
NUMBER OF PAGES	:	EIGHT (8) INCLUDING THIS COVER PAGE AND APPENDICES

INSTRUCTIONS	:	ANSWER ALL QUESTION : NUMBER ALL QUESTIONS IN ANY ORDER : UNIVERSITY EXAM RULES APPLY
REQUIREMENTS	:	NON PROGRAMEBLE CALCULATOR

QUESTION 1 (30)

1.1 A 0.50-molar aqueous solution of sulfuric acid flows into a process unit at a rate of 1.25m^3/min. The specific gravity of the solution is 1.03.

Calculate

1.1.1 The mass concentration of H_2SO_4 in kg/m^3 (3)

1.1.2 The mass flow rate of H_2SO_4 in kg/s. (3)

1.1.3 The mass fraction of H_2SO_4. (5)

1.2 The heat capacity of ammonia, defined as the amount of heat required to raise the temperature of a unit mass of ammonia by precisely 1°F at a constant pressure, is, over a limited temperature range, given by the following expression.

$$C_p\left(\frac{\text{Btu}}{\text{lb}_m \cdot {}^\circ\text{F}}\right) = 0.487 + 2.29 \times 10^{-4} T({}^\circ\text{F})$$

1.2.1 Determine the expression for *Cp* in J/(g °C) in terms of *T*(°C). (10)

1.3 Convert 23 lbm ft/min^2 to its equivalent in kg cm/s^2. (2)

1.4 Consider the interval from 20°F to 80°F, for the following

1.4.1 Calculate the equivalent temperatures in °C and the interval between them. (4)

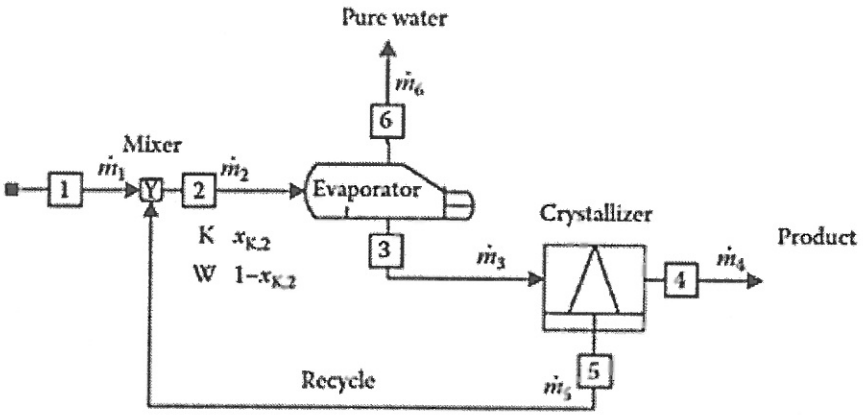
QUESTION 2 (30)

2.1 Fresh feed stream flowing at 27.77g/s contains 20% by weight KNO_3 (K) in H_2O (W). The fresh feed stream is combined with a recycle stream and is fed to an evaporator. The concentrated liquid solution exiting the evaporator contains 50% KNO_3 which is fed to a crystallizer. The crystals obtained from the crystallizer are 96% KNO_3 and the balance as water. The liquid from the crystallizer constitutes the recycle stream and contains 0.6 kg KNO_3 per 1000g of H_2O.

2.1.1 Calculate the degree of freedom around all the units and the process. (10)

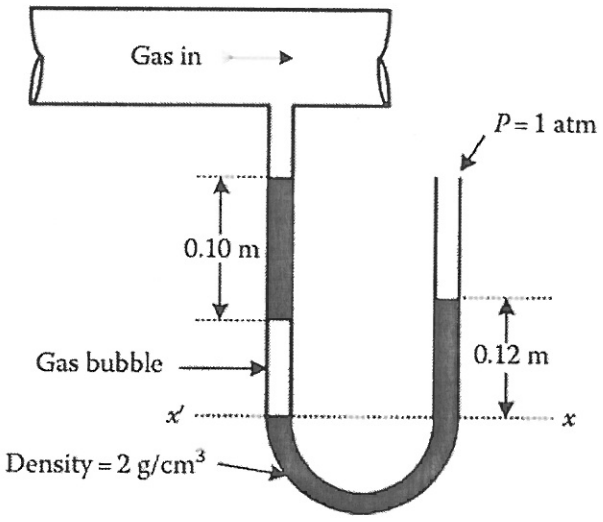
2.1.2 Re-draw the diagram and calculate all stream flow rate values in kg/h (12)

2.1.3 Calculate the compositions of water and the salt in stream 2 (8)



QUESTION 3 (15)

3.1 An open-end manometer is connected to a pipe in which a gas is flowing as shown (Figure below). The manometer fluid density is 2.00 g/cm^3. A gas bubble is trapped in the left leg of the manometer (as shown). What is the pressure of the flowing gas inside the pipe (in atm)? Is this pressure a gauge pressure or an absolute pressure? How do you know?
Assume that the density of the bubble is zero.



QUESTION 4 (25)

4.1 The feed to a compressor is superheated steam at 300°C and 20 bar absolute pressure. It enters the compressor at a velocity of 20 m/s. The pipe inlet inside diameter is 0.10 m. The discharging pipe, after the compressor, has a smaller inside diameter and the discharge velocity is 170 m/s. The exit of the compressor is superheated steam at 350°C and 60 bar absolute pressure. Heat loss from the compressor to the surroundings is 5 kW. Determine the compressor horsepower.
(15)

4.2 A closed rigid vessel that contains 200 kg of a fluid is heated from 20°C to 150°C. Calculate the heat required for this purpose. The constant volume heat capacity of the fluid is given by the following relation: (10)

$$C_v\left(\frac{\text{kJ}}{\text{kg}\cdot^\circ\text{C}}\right) = a + bT = 0.855 + 9.42\times10^{-4}T$$

Mass	1 lb_m = 5 × 10^{-4} t = 0.453593 kg = 453.593 g = 16 oz
	1 kg = 1000 g = 2.20462 lb_m = 0.001 t
	1 t = 2000 lb_m; 1 t = 1000 kg
Length	1 ft = 12 in.; 1 ft = 0.3048 m = 30.48 cm; 1 in. = 2.54 cm; 1 mile = 5280 ft
	1 m = 10^{10} Å = 39.37 in. = 3.2808 ft = 1.0936 yd = 0.0006214 mi
Volume	1 ft^3 = 7.481 gal = 1728 in.^{3} = 28.317 L = 28,317 cm^3
	1 gal = 231 in.^{3}; 1 in.^{3} = 16.387 cm^3
	1 cc = 1 cm^3 = 1 mL; 1000 mL = L
	1000 L = 1 m^3 = 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal = 1056.68 qt
	8 fl oz = 1 cup; 4 cup = 1 quart; 4 quart = 1 gal = 128 fl oz
Density	1 g/cm^3 = 1 kg/L = 1000 kg/m^3 = 62.428 lb/ft^3 = 8.345 lb_m/gal
Force	1 lb_f = 32.174 lb_m-ft/s^2 = 4.448222 N = 4.4482 × 10^5 dynes
	1 N = 1 kg-m/s^2 = 10^5 dynes = 10^5 g-cm/s^2 = 0.22481 lb_f
Pressure	1 bar = 10^5 Pa = 100 kPa = 10^5 N/m^2
	Pascal (Pa) is defined as 1 N/m^2 = 1 kg/m-s^2
	1 atm = 1.01325 bar = 14.696 lb_f/in.^{2} = 760 mmHg at 0°C (torr) = 29.92 in Hg at 0°C
	1 psi = 1 lb$_f$/in.^{2}; psia (absolute) = psig (gauge) + 14.696
Temperature	1 K = 1.8°R (absolute temperature)
	T (°C) = T (K) − 273.15
	T (°F) = T (°R) − 459.67
	T (°F) = 1.8T (°C) + 32
Energy	1 J = 1 N-m = 1 kg-m^2/s^2 = 10^7 ergs = 10^7 dyne-cm = 2.778 × 10^{-7} kW-h
	= 0.2390 cal = 0.7376 ft-lb_f = 9.486 × 10^{-4} Btu
	1 cal = 4.1868 J; 1 Btu = 778.17 ft-lb_f = 252.0 cal
	1 Btu/lb_m-F = 1 cal/g-°C
Power	1 hp = 550 ft-lb/s = 0.74570 kW
	1 W = 1 J/s = 0.2390 cal/s = 0.7376 ft-lb_f/s = 9.486 × 10^{-4} Btu/s
	1 kW = 1000 J/s = 3412.1 Btu/h = 1.341 hp

THE GAS CONSTANT (R)

8.314 m^3-Pa/(mol-K)

0.08314 L-bar/(mol-K)

0.08206 L-atm/(mol-K)

62.36 L-mm Hg/(mol-K)

0.7302 ft^3-atm/(lb-mole-°R)

10.73 ft^3-psia/(lb-mole-°R)

8.314 J/(mol-K)

1.987 cal/(mol-K)

1.987 Btu/(lb-mole-°R)

TABLE A.5 (*Continued*)

Properties of Superheated Steam

P (bar) (T_{sat} °C)		Saturated Water	Saturated Steam	Temperature (°C) 50	75	100	150	200	250	300	350
40	h	1087.4	2800.3	212.7	317.1	422.0	634.3	853.4	1085.8	2962	3095
(250.3)	u	1082.4	2601.3	208.6	313.0	417.8	630.0	848.8	1080.8	2727	2929
	v	0.00125	0.04975	0.00101	0.00102	0.00104	0.00109	0.00115	0.00125	0.0588	0.0665
60	h	1213.7	2785.0	214.4	318.7	423.5	635.6	854.2	1085.8	2885	3046
(275.6)	u	1205.8	2589.4	206.3	312.6	417.3	629.1	847.3	1078.3	2668	2792
	v	0.00132	0.0325	0.00101	0.00103	0.00104	0.00109	0.00115	0.00125	0.0361	0.0422
80	h	1317.1	2759.9	216.1	320.3	425.0	636.5	855.1	1085.8	2787	2969
(295.0)	u	1306.0	2571.7	208.1	312.3	416.7	625.2	843.9	1075.5	2593	2750
	v	0.00139	0.0235	0.00101	0.00102	0.00104	0.00109	0.00115	0.00124	0.0245	0.0298
100	h	1408.0	2727.7	217.8	322.9	426.5	638.1	855.9	1085.8	1343.4	2926
(311.0)	u	1393.5	2547.3	207.8	311.7	416.1	627.3	844.4	1071.4	1329.4	2702
	v	0.00145	0.0181	0.00101	0.00102	0.00104	0.00109	0.00115	0.00124	0.0140	0.0224
150	h	1611.0	2685.0	222.1	326.0	430.3	641.3	858.1	1086.2	1338.2	2695
(342.1)	u	1586.1	2459.9	207.0	310.7	414.7	625.0	841.0	1067.7	1317.6	2523
	v	0.00166	0.0103	0.00101	0.00102	0.00104	0.00108	0.00114	0.00123	0.00138	0.0135
200	h	1826.5	2418.4	226.4	330.0	434.0	644.5	860.4	1086.7	1334.3	1647.1
(365.7)	u	1785.7	2200.8	206.3	309.7	413.2	622.9	837.7	1062.2	1307.1	1613.7
	v	0.00204	0.005875	0.00100	0.00102	0.00103	0.00108	0.00114	0.00122	0.00136	0.00167
221.2(*c*)	h	2108	2108	228.2	331.7	435.7	645.8	861.4	1087.0	1332.8	1635.5
(374.15 K)	u	2037.8	2037.8	206.0	309.2	412.8	622.0	836.3	1060.9	1302.9	1600.3
	v	0.0047	0.0047	0.00100	0.00102	0.00103	0.00108	0.00114	0.00122	0.00135	0.00163
250	h	—	—	230.7	334.0	437.8	647.7	862.8	1087.5	1331.1	1625.0
(—)	u	—	—	205.7	308.7	412.1	620.8	834.4	1057.0	1297.5	1583.0
	v	—	—	0.00100	0.00101	0.00103	0.00108	0.00113	0.00122	0.00135	0.00160
300	h	—	—	235.0	338.1	441.6	650.9	865.2	1088.4	1328.7	1609.9
(—)	u	—	—	205.0	307.7	410.8	618.7	831.3	1052.1	1288.7	1563.3
	v	—	—	0.0009980	0.00101	0.00103	0.00107	0.00113	0.00121	0.00133	0.00155
500	h	—	—	251.9	354.2	456.8	664.1	875.4	1093.6	1323.7	1576.3
(—)	u	—	—	202.4	304.0	405.8	611.0	819.7	1034.3	1259.3	1514.1
	v	—	—	0.0009611	0.00100	0.00102	0.00106	0.00111	0.00119	0.00129	0.00144
1000	h	—	—	293.9	384.3	485.1	698.0	903.5	1115.0	1335.7	1585.5
(—)	u	—	—	146.5	295.7	393.1	594.4	795.3	999.0	1207.1	1419.0
	v	—	—	0.0009737	0.0009852	0.00100	0.00104	0.00108	0.00114	0.00122	0.00131

P (bar) (T_{sat} °C)		Saturated Water	Saturated Steam	Temperature (°C) 400	450	500	550	600	650	700	750
0.0	h	—	—	3280	3384	3697	3597	3506	3816	3929	4043
	u	—	—	2969	3090	3132	3217	3303	3390	3480	3691
	v	—	—	—	—	—	—	—	—	—	—
0.1	h	191.8	2584.8	3280	3384	3697	3596	3506	3816	3929	4043
(45.81	u	191.8	2438.0	2969	3090	3132	3217	3303	3390	3480	3571
	v	0.0010	14.7	21.1	23.3	25.7	28.0	30.3	32.6	34.8	37.2
0.5	h	340.6	2646.0	3279	3383	3697	3596	3505	3816	3929	4043
(81.3)	u	340.6	2484.0	2969	3089	3132	3216	3302	3390	3480	3571
	v	0.0010	3.24	4.21	4.67	5.14	5.59	6.06	6.53	6.91	7.43
1.0	h	417.5	2675.4	3278	3382	3698	3596	3505	3816	3928	4042
(99.6)	u	417.5	2506.1	2968	3089	3132	3216	3302	3390	3479	3570
	v	0.0010	1.69	2.11	2.33	2.57	2.80	4.03	4.26	4.48	4.72

(*Continued*)