UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2006/2007

April 2007

EKC 111 – Imbangan Jisim

Masa : 3 jam

Sila pastikan bahawa kertas peperiksaan ini mengandungi ENAM muka surat yang bercetak dan TIGA muka surat Lampiran sebelum anda memulakan peperiksaan ini.

Arahan: Jawab **TUJUH (7)** soalan. Jawab **SEMUA (4)** soalan dari Bahagian A. Jawab mana-mana **TIGA (3)** soalan dari Bahagian B.

PELAJAR DIBENARKAN MENJAWAB SOALAN SAMA ADA DALAM BAHASA MALAYSIA ATAU BAHASA INGGERIS.

...2/-

Section A : Answer ALL questions.
Bahagian A : Jawab SEMUA soalan.

1. Define the following units of operation:

[i] Distillation

[ii] Gas Absorption

[iii] Reactor

[iv] Heat Exchanger

[v] Evaporator

[10 marks]

1. Huraikan unit-unit operasi di bawah ini:

[i] Turus penyulingan

[ii] Penyerapan gas

[iii] Reaktor

[iv] Penukar haba

[v] Penyejat

[10 markah]

2. [a] You have 100 kilograms of gas of the following composition:

CH_4	30%
H_2	10%
N_2	60%

What is the average molecular weight of this gas?

[4 marks]

[b] If the heat capacity of a substance is 5.32 J/(g)(^oC) and its molecular weight is 37.4, what is its heat capacity in

[i] J/(g) (^oF)

[ii] J/(lb) (^oR)

[iii] J/(gmol) (K)

[6 marks]

2. [a] *Anda mempunyai 100 kilogram gas yang mempunyai komposisi berikut:*

CH_4	*30%*
H_2	*10%*
N_2	*60%*

Berapakah purata berat molekul gas ini?

[4 markah]

[b] *Sekiranya muatan haba sesuatu bahan ialah 5.32 J/(g)(°C) dan berat molekulnya ialah 37.4, berapakah muatan haba tersebut dalam unit*

[i] *J/(g) (°F)*

[ii] *J/(lb) (°R)*

[iii] *J/(gmol) (K)*

[6 markah]

3. In the concentration of an orange juice, a fresh extracted and strained juice containing 7.08 wt% solids is fed to a vacuum evaporator. In the evaporator, water is removed and the solids content increased to 58 wt% solids. For 1000 kg/h entering, calculate the amounts of the outlet streams of concentrated juice and water.

[10 marks]

3. *Dalam kepekatan jus oren, jus penyarian segar dan saringan mengandungi 7.08% berat pepejal disuap ke dalam penyejat vakum. Di dalam penyejat, air disingkirkan dan kandungan pepejal meningkat kepada 58% berat pepejal. Untuk 1000 kg/jam suapan yang memasuki penyejat, kirakan jumlah bagi aliran keluaran untuk jus pekat dan air.*

[10 markah]

4. [a] The critical temperature and pressure of isopropanol are T_c = 508.8 K and P_c = 53.0 atm. Isopropanol is in a gaseous state at T = 127 °C and P = 1 atm. Would it be classified as a vapour or gas? Explain. If isopropanol at 550 K and 1 atm is compressed isothermally to 100 atm, will a condensate form at its final condition? What term might you use to refer to the fluid at its initial condition?

[3 marks]

[b] Draw a p–T chart for water. Label the following clearly: vapour-pressure curve, dew-point curve, saturated region, subcooled region and triple point.

[7 marks]

4. *[a] Suhu genting dan tekanan genting bagi isopropanol ialah T_c = 508.8 K dan P_c = 53.0 atm. Isopropanol berkeadaan gas pada T = 127 °C dan P = 1 atm. Adakah ia dikelaskan sebagai wap atau gas? Terangkan. Jika isopropanol pada 550 K dan 1 atm dimampatkan secara sesuhu ke 100 atm, adakah peluwap akan terbentuk pada keadaan akhir? Apakah ungkapan merujuk kepada bendalir tersebut pada keadaan awal?*

[3 markah]

[b] Lukiskan carta p–T untuk air. Labelkan ungkapan-ungkapan berikut: Lengkung wap-tekanan, lengkung titik embun, kawasan tepu, kawasan tersubdingin dan titik bertiga.

[7 markah]

Section B : Answer any THREE questions.
Bahagian B : Jawab mana-mana TIGA soalan.

5. [a] Theoretical relationship for estimating heat transfer coefficient between pure saturated vapour and cold surface is given by:

$$h = 0.943 \left(\frac{k^3 \rho^2 g \lambda}{L \mu \Delta T} \right)^{1/4}$$

where :

h = heat transfer coefficient; Btu/(hr) (ft^2) (°F)
k = thermal conductivity; Btu/(hr) (ft) (°F)
ρ = density; lb_m/ft^3
g = gravitational acceleration; 4.17 x 10^8 ft/hr^2
λ = enthalpy change; Btu/lb_m
L = length of tube; ft
μ = viscocity; lb_m/(hr) (ft)
ΔT = temperature difference; °F

[i] Does the above equation dimensionally consistent?

[ii] Convert the units of each of the parameters in SI unit and express the new heat transfer coefficient relationship in SI.

[10 marks]

[b] An acetone-water solution containing 10% acetone is to be produced in an absorption column. An acetone-air mixture of 100 kmol/h and analyzing 20% acetone is fed to the base of the column. The acetone is not completely removed. The exit gas stream analyses 3% acetone and contains no water. Calculate the amount of water feed to the column.

[10 marks]

5. [a] *Hubungkait secara teori untuk menganggarkan pekali pemindahan haba di antara wap tepu tulen dan permukaan yang sejuk diberikan sebagai:*

$$h = 0.943 \left(\frac{k^3 \rho^2 g \lambda}{L \mu \Delta T} \right)^{1/4}$$

di mana :

h = *pekali pemindahan haba; Btu/(jam) (kaki^2) (^oF)*

k = *konduktiviti terma; Btu/ (jam) (kaki) (^oF)*

ρ = *ketumpatan; lb_m/kaki^3*

g = *pecutan graviti; 4.17 x 10^8 kaki/jam^2*

λ = *perubahan entalpi; Btu/lb_m*

L = *panjang tiub; kaki*

μ = *kelikatan; lb_m/(jam) (kaki)*

ΔT = *perbezaan suhu; ^oF*

[i] *Adakah persamaan di atas konsistan secara dimensinya?*

[ii] *Tukarkan unit bagi setiap parameter dalam unit SI dan terbitkan hubungkait pekali pemindahan haba yang baru dalam unit SI.*

[10 markah]

[b] *Satu larutan aseton-air mengandungi 10% aseton dikeluarkan sebagai produk di dalam turus penyerapan. Satu campuran aseton-udara berkadar aliran 100 kmol/jam dan mengandungi sebanyak 20% aseton disuapkan kepada dasar turus tersebut. Aseton tersebut tidak diserapkan sepenuhnya dan aliran keluar gas mengandungi 3% aseton dan tidak mengandungi air. Kirakan jumlah air yang disuapkan ke dalam turus tersebut.*

[10 markah]

6. A solid material containing 15 wt% moisture is dried so that it contains 7 wt% water by blowing fresh warm air mixed with recycled air over the solid in the dryer. The inlet fresh air has a humidity of 0.01 kg water/kg dry air. The air from the drier that is recycled has a humidity of 0.1 kg water/kg dry air and the mixed air to the dryer is 0.03 kg water/kg dry air. For a feed of 100 kg solid/h fed to the dryer, calculate the kg/h of dried product.

[20 marks]

6. *Suatu bahan pepejal mengandungi kelembapan sebanyak 15% berat dikeringkan supaya hanya mengandungi 7% berat air secara meniup udara panas segar bercampur dengan udara kitar semula melalui pepejal tersebut di dalam pengering. Udara segar masuk mempunyai kelembapan sebanyak 0.01 kg air/kg udara kering. Udara dari pengering yang dikitar semula mempunyai kelembapan sebanyak 0.1 kg air/kg udara kering, dan udara campuran ke pengering mempunyai kelembapan sebanyak 0.03 kg air/kg udara kering. Untuk suapan sebanyak 100 kg pepejal/jam disuap ke pengering, kirakan kg/jam produk kering.*

[20 markah]

...6/-

7. A fuel gas containing 3.1 mol% H_2, 27.2% CO, 5.6% CO_2, 0.5% O_2 and 63.6% N_2 is burned with 20% excess air. The combustion of CO is only 98% complete. For 100 kg mol of fuel gas, calculate the moles of each component in the exit gas.

Given the reactions:

$$CO + ½\ O_2 \rightarrow CO_2$$

$$H_2 + ½\ O_2 \rightarrow H_2O$$

[20 marks]

7. *Suatu gas bahan api mengandungi 3.1% mol H_2, 27.2% CO, 5.6% CO_2, 0.5% O_2 dan 63.6% N_2 dibakar dengan 20% udara lebihan. Pembakaran bagi CO adalah hanya 98% lengkap. Untuk 100 kg mol gas bahan api, kirakan mol bagi setiap komponen dalam gas keluaran.*

Diberi tindakbalas:

$$CO + ½\ O_2 \rightarrow CO_2$$

$$H_2 + ½\ O_2 \rightarrow H_2O$$

[20 markah]

8. A stream of air at 100°C and 710.63 kPa contains 10% water by volume (Basis : 1 mol).

[a] Calculate the dew point of the air and degree of superheat of the water vapour.

[b] The air enters a compressor-condenser at temperature of 15.6 °C and pressure of 9 atm. Calculate the percentage of the vapour that condenses and the final composition of the gas phase.

[c] Instead of undergoing the condition in [b], the gas is only cooled to 80 °C at constant pressure. Calculate the fraction of vapour condensation.

[20 marks]

8. *Satu aliran udara pada keadaan 100°C dan 710.63 kPa mengandungi 10% isipadu air (Asas : 1 mol).*

[a] Kirakan titik embun udara dan darjah panas lampau bagi wap air.

[b] Aliran udara tersebut memasuki pemampat dan pemeluwap pada suhu 15.6 °C dan tekanan 9 atm. Kirakan peratusan wap yang memeluwap dan komposisi akhir fasa gas tersebut.

[c] Jika aliran tersebut tidak melalui keadaan [b], gas tersebut hanya disejukkan ke 80 °C pada tekanan malar. Kirakan pecahan pemeluwapan wap.

[20 markah]

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Lampiran

Table Vapor Pressure of Water[a]

p_v(mm Hg) versus T(°C)

Example: The vapor pressure of liquid water at 4.3°C is 6.230 mm Hg

	T(°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
↓	−14	1.361	1.348	1.336	1.324	1.312	1.300	1.288	1.276	1.264	1.253
	−13	1.490	1.477	1.464	1.450	1.437	1.424	1.411	1.399	1.386	1.373
Ice	−12	1.632	1.617	1.602	1.588	1.574	1.559	1.546	1.532	1.518	1.504
	−11	1.785	1.769	1.753	1.737	1.722	1.707	1.691	1.676	1.661	1.646
	−10	1.950	1.934	1.916	1.899	1.883	1.866	1.849	1.833	1.817	1.800
	−9	2.131	2.122	2.093	2.075	2.057	2.039	2.021	2.003	1.985	1.968
	−8	2.326	2.306	2.285	2.266	2.246	2.226	2.207	2.187	2.168	2.149
	−7	2.537	2.515	2.493	2.472	2.450	2.429	2.408	2.387	2.367	2.346
	−6	2.765	2.742	2.718	2.695	2.672	2.649	2.626	2.603	2.581	2.559
	−5	3.013	2.987	2.962	2.937	2.912	2.887	2.862	2.838	2.813	2.790
	−4	3.280	3.252	3.225	3.198	3.171	3.144	3.117	3.091	3.065	3.039
	−3	3.568	3.539	3.509	3.480	3.451	3.422	3.393	3.364	3.336	3.308
	−2	3.880	3.848	3.816	3.785	3.753	3.722	3.691	3.660	3.630	3.599
	−1	4.217	4.182	4.147	4.113	4.079	4.045	4.012	3.979	3.946	3.913
	−0	4.579	4.542	4.504	4.467	4.431	4.395	4.359	4.323	4.287	4.252
↓	0	4.579	4.613	4.647	4.681	4.715	4.750	4.785	4.820	4.855	4.890
	1	4.926	4.962	4.998	5.034	5.070	5.107	5.144	5.181	5.219	5.256
Liquid	2	5.294	5.332	5.370	5.408	5.447	5.486	5.525	5.565	5.605	5.645
water	3	5.685	5.725	5.766	5.807	5.848	5.889	5.931	5.973	6.015	6.058
	4	6.101	6.144	6.187	6.230	6.274	6.318	6.363	6.408	6.453	6.498
	5	6.543	6.589	6.635	6.681	6.728	6.775	6.822	6.869	6.917	6.965
	6	7.013	7.062	7.111	7.160	7.209	7.259	7.309	7.360	7.411	7.462
	7	7.513	7.565	7.617	7.669	7.722	7.775	7.828	7.882	7.936	7.990
	8	8.045	8.100	8.155	8.211	8.267	8.323	8.380	8.437	8.494	8.551
	9	8.609	8.668	8.727	8.786	8.845	8.905	8.965	9.025	9.086	9.147
	10	9.209	9.271	9.333	9.395	9.458	9.521	9.585	9.649	9.714	9.779
	11	9.844	9.910	9.976	10.042	10.109	10.176	10.244	10.312	10.380	10.449
	12	10.518	10.588	10.658	10.728	10.799	10.870	10.941	11.013	11.085	11.158
	13	11.231	11.305	11.379	11.453	11.528	11.604	11.680	11.756	11.833	11.910
	14	11.987	12.065	12.144	12.223	12.302	12.382	12.462	12.543	12.624	12.706
	15	12.788	12.870	12.953	13.037	13.121	13.205	13.290	13.375	13.461	13.547
	16	13.634	13.721	13.809	13.898	13.987	14.076	14.166	14.256	14.347	14.438
	17	14.530	14.622	14.715	14.809	14.903	14.997	15.092	15.188	15.284	15.380
	18	15.477	15.575	15.673	15.772	15.871	15.971	16.771	16.171	16.272	16.374
	19	16.477	16.581	16.685	16.789	16.894	16.999	17.105	17.212	17.319	17.427
	20	17.535	17.644	17.753	17.863	17.974	18.085	18.197	18.309	18.422	18.536
	21	18.650	18.765	18.880	18.996	19.113	19.231	19.349	19.468	19.587	19.707
	22	19.827	19.948	20.070	20.193	20.316	20.440	20.565	20.690	20.815	20.941
	23	21.068	21.196	21.324	21.453	21.583	21.714	21.845	21.977	22.110	22.243
	24	22.377	22.512	22.648	22.785	22.922	23.060	23.198	23.337	23.476	23.616

[a]From R. H. Perry and C. H. Chilton, Eds., *Chemical Engineers' Handbook*, 5th Edition, McGraw-Hill, New York, 1973, Tables 3-3 and 3-5. Reprinted by permission of McGraw-Hill Book Co.

(*continued*)

Table (Continued)

T(°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
25	23.756	23.897	24.039	24.182	24.326	24.471	24.617	24.764	24.912	25.060
26	25.209	25.359	25.509	25.660	25.812	25.964	26.117	26.271	26.426	26.582
27	26.739	26.897	27.055	27.214	27.374	27.535	27.696	27.858	28.021	28.185
28	28.349	28.514	28.680	28.847	29.015	29.184	29.354	29.525	29.697	29.870
29	30.043	30.217	30.392	30.568	30.745	30.923	31.102	31.281	31.461	31.642
30	31.824	32.007	32.191	32.376	32.561	32.747	32.934	33.122	33.312	33.503
31	33.695	33.888	34.082	34.276	34.471	34.667	34.864	35.062	35.261	35.462
32	35.663	35.865	36.068	36.272	36.477	36.683	36.891	37.099	37.308	37.518
33	37.729	37.942	38.155	38.369	33.584	38.801	38.018	39.237	39.457	39.677
34	39.898	40.121	40.344	40.569	40.796	41.023	41.251	41.480	41.710	41.942
35	42.175	42.409	42.644	42.880	43.117	43.355	43.595	43.836	44.078	44.320
36	44.563	44.808	45.054	45.301	45.549	45.799	46.050	46.302	46.556	46.811
37	47.067	47.324	47.582	47.841	48.102	48.364	48.627	48.891	49.157	49.424
38	49.692	49.961	50.231	50.502	50.774	51.048	51.323	51.600	51.879	52.160
39	52.442	52.725	53.009	53.294	53.580	53.867	54.156	54.446	54.737	55.030
40	55.324	55.61	55.91	56.21	56.51	56.81	57.11	57.41	57.72	58.03
41	58.34	58.65	58.96	59.27	59.58	59.90	60.22	60.54	60.86	61.18
42	61.50	61.82	62.14	62.47	62.80	63.13	63.46	63.79	64.12	64.46
43	64.80	65.14	65.48	65.82	66.16	66.51	66.86	67.21	67.56	67.91
44	68.26	68.61	68.97	69.33	69.69	70.05	70.41	70.77	71.14	71.51
45	71.88	72.25	72.62	72.99	73.36	73.74	74.12	74.50	74.88	75.26
46	75.65	76.04	76.43	76.82	77.21	77.60	78.00	78.40	78.80	79.20
47	79.60	80.00	80.41	80.82	81.23	81.64	82.05	82.46	82.87	83.29
48	83.71	84.13	84.56	84.99	85.42	85.85	86.28	86.71	87.14	87.58
49	88.02	88.46	88.90	89.34	89.79	90.24	90.69	91.14	91.59	92.05

T(°C)	0	1	2	3	4	5	6	7	8	9
50	92.51	97.20	102.09	107.20	112.51	118.04	123.80	129.82	136.08	142.60
60	149.38	156.43	163.77	171.38	179.31	187.54	196.09	204.96	214.17	223.73
70	233.7	243.9	254.6	265.7	277.2	289.1	301.4	314.1	327.3	341.0
80	355.1	369.7	384.9	400.6	416.8	433.6	450.9	468.7	487.1	506.1

T(°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
90	525.76	527.76	529.77	531.78	533.80	535.82	537.86	539.90	541.95	544.00
91	546.05	548.11	550.18	552.26	554.35	556.44	558.53	560.64	562.75	564.87
92	566.99	569.12	571.26	573.40	575.55	577.71	579.87	582.04	584.22	586.41
93	588.60	590.80	593.00	595.21	597.43	599.66	601.89	604.13	606.38	608.64
94	610.90	613.17	615.44	617.72	620.01	622.31	624.61	626.92	629.24	631.57
95	633.90	636.24	938.59	640.94	643.30	645.67	648.05	650.43	652.82	655.22
96	657.62	660.03	662.45	664.88	667.31	669.75	672.20	674.66	677.12	679.69
97	682.07	684.55	687.04	689.54	692.05	694.57	697.10	699.63	702.17	704.71
98	707.27	709.83	712.40	714.98	717.56	720.15	722.75	725.36	727.98	730.61
99	733.24	735.88	738.53	741.18	743.85	746.52	749.20	751.89	754.58	757.29
100	760.00	762.72	765.45	768.19	770.93	773.68	776.44	779.22	782.00	784.78
101	787.57	790.37	793.18	796.00	798.82	801.66	804.50	807.35	810.21	813.08

...3/-

Common Engineering Conversion Factors

Length	Volume
1 ft = 12 in = 0.3048 m, 1 yard = 3 ft 1 mi = 5280 ft = 1609.344 m 1 nautical mile (nmi) = 6076 ft	1 ft^3 = 0.028317 m^3 = 7.481 gal. 1 bbl = 42 U.S. gal 1 U.S. gal = 231 in^3 = 3.7853 L = 4 qt = 0.833 Imp. gal. 1 L = 0.001 m^3 = 0.035315 ft^3 = 0.2642 U.S. gal
Mass	**Density**
1 slug = 32.174 lb_m = 14.594 kg 1 lb_m = 0.4536 kg = 7000 grains	1 slug/ft^3 = 515.38 kg/m^3, 1 g/cm^3 = 1000 kg/m^3 1 lb_m/ft^3 = 16.0185 kg/m^3, 1 lb_m/in^3 = 27.68 g/cm^3
Acceleration & Area	**Velocity**
1 ft/s^2 = 0.3048 m/s^2 1 ft^2 = 0.092903 m^2	1 ft/s = 0.3048 m/s, 1 knot = 1 nmi/h = 1.6878 ft/s 1 mi/h = 1.4666666 ft/s (fps) = 0.44704 m/s
Mass Flow & Mass Flux	**Volume Flow**
1 slug/s = 14.594 kg/s. 1 lb_m/s = 0.4536 kg/s 1 kg/m^2-s = 0.2046 lb_m/ft^2-s = 0.00636 slug/ft^2-s	1 gal/min = 0.002228 ft^3/s = 0.06309 L/s 1 million gal/day = 1.5472 ft^3/s = 0.04381 m^3/s
Pressure	**Force and Surface Tension**
1 lb_f/ft^3 = 47.88 Pa, 1 torr = 1 mm Hg 1 psi = 144 psf, 1 bar = 10^5 Pa 1 atm = 2116.2 psf = 14.696 psi = 101, 325 Pa = 29.9 in. Hg = 33.9 ft H_2O	1 lb_f = 4.448222 N = 16 oz, 1 dyne = 1 g-cm/s^2 = 10^{-5} N 1 kg_f = 2.2046 lb_f = 9.80665 N 1 U.S. (short) ton = 2000 lb_f, 1 N = 0.2248 lb_f 1 N/m = 0.0685 lb_f/ft
Power	**Energy and Specific Energy**
1 hp = 550 (ft-lb_f)/s = 745.7 W 1 (ft-lb_f)/s = 1.3558 W 1 Watt = 3.4123 Btu/h = 0.00134 hp	1 ft-lb_f = 1.35582 J, 1 hp-h = 2544.5 Btu 1 Btu = 252 cal = 1055.056 J = 778.17 ft-lb_f 1 cal = 4.1855 J, 1 ft-lb_f/lb_m = 2.9890 J/kg
Specific Weight	**Heat Flux**
1 lb_f/ft^3 = 157.09 N/m^3	1 W/m^2 = 0.3171 Btu/(h-ft^2)
Viscosity	**Kinematic Viscosity**
1 slug/(ft-s) = 47.88 kg/(m-s) = 478.8 poise (p) 1 p=1 g/(cm-s)=0.1 kg/(m-s)=0.002088 slug/(ft-s)	1 ft^2/h = 2.506 .10^{-5} m^2/s, 1 ft^2/s = 0.092903 m^2/s 1 stoke (st) = 1 cm^2/s = 0.0001 m^2/s = 0.001076 ft^2/s
Temperature Scale Readings	
°F = (9/5)°C + 32 °C = (5/9) (°F – 32) °R = °F + 459.69 °K = °C + 273.16	
Specific Heat or Gas Constant*	**Thermal Conductivity***
1 (ft-lb_f)/(slug-°R) = 0.16723 (N-m) (kg-K) 1 Btu/(lb-°R) = 4186.8 J/(kg-K)	1 cal/(s-cm-°C) = 242 Btu/(h-ft-°R) 1 Btu/(h-ft-°R) = 1.7307 W/(m-K)

* Note that the intervals in absolute (Kelvin) and °C are equal. Also, 1 °R = 1 °F.

Latent heat: 1 J/kg = 4.2995 x 10-4 Btu/lb_m = 10.76 lb_f-ft/slug = 0.3345 lb_f– ft/lb_m, 1 Btu/lb_m = 2325.9 J/kg.

Heat transfer coefficient: 1 Btu/(h-ft^2-°F) = 5.6782 W/(m^2 - °C).

Heat generation rate: 1 W/m^3 = 0.09665 Btu/(h-ft^3)

Heat transfer per unit length: 1 W/m = 1.0403 Btu/(h-ft)

Mass transfer coefficient: 1 m/s = 11.811 ft/h, 1 lbmol/(h-ft^2) = 0013562 kgmol/(s-m^2)