Name: _____ Student ID _____

Prince of Songkla University
Faculty of Engineering

Final Exam: Semester I **Academic Year: 2009 – 10**
Date: September 29, 2009 **Time: 1:30 – 4:30 PM**
Subject: 230-301 – Basic Chemical Engineering I **Room: R200**

Part I: Energy Balance

Instructions: There are a total of 2 problems. You have 60 minutes to work on them. The points for each problem are not distributed evenly. Place your name and the student ID number on every page. This is a CLOSED BOOK exam. Students are allowed to use only a pen or pencil, a calculator, and a pocket or talking dictionary. No notes are allowed in the exam. No exams are allowed to leave the room.

Points Distribution (For Grader Only)		
Problem	Points Value	Score
1	25	
2	25	
Total	50	

Exam prepared by
Ram Yamsaengsung
September 22, 2009

PLEASE CHECK TO MAKE SURE THAT YOU HAVE 6 PAGES OF THE EXAM AND TWO SHEETS FROM THE STEAM TABLE BEFORE BEGINNING

GOOD LUCK!!!

Final Exam Part I

1. Ammonia is burned in air with a resulting flue gas having an Orsat analysis of 6.5% O_2 and 93.5% N_2. Determine the following if the NH_3 flow rate is 28.7 m^3/min at 45°C and 125.6 kPa. **(25 points)**

   (a) The m^3 of air required at 25°C and 100.0 kPa used per m^3 of ammonia used. **(5 points)**
   (b) The percent excess air used. **(5 points)**
   (c) The m^3 of actual air at 25°C and 100.0 kPa. **(5 points)**
   (d) The amount of heat that must be removed (kJ) in order to cool the water vapor produced from 100°C to liquid water at 20°C. Assume the exiting water vapor is at 101.3 kPa. **(10 points)**

Conversions: 1Btu = 1.055 kJ 1 lb = 0.454 kg
1 atm = 14.696 psia

Constants: R = 82.06 (cm^3-atm/g mol-K) = 8.314 (kPa-m^3/kg mol-K)

Equations:

$$PV = nRT$$

$$P_i = \left(\frac{n_i}{n_{tot}}\right)P_{tot}$$

$$\Delta E = Q + W - \Delta[(H + K + P)]$$

$$\Delta H = n\int_{T1}^{T2} C_p dT = n(h_2 - h_1)$$

$$\Delta \hat{H}^0_{rxn} = \sum \Delta \hat{H}^0_{f\ products} - \sum \Delta \hat{H}^0_{f\ reactants}$$

$$\Delta H_i = n_i\left[\int_{25}^{T_i} C_{pi} dT + \Delta \hat{H}^0_{fi} + \Delta \hat{H}_{phase\ change}\right]$$

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2. In a pasteurization process, steam is used to raise the temperature of the orange juice from 25°C to 73°C. If 2500 kg/hr of orange juice is fed into the heat exchanger, determine the following: **(25 Points Total)**

   (a) Determine the amount of heat gained by the orange juice in kJ/hr. **(10 points)**
   (b) Determine the amount of saturated steam (in **kg/hr**) required if the steam enters as saturated vapor at 1 atm and leaves as 25% saturated liquid. **(15 points)**

The Cp of the orange juice is 4.00 kJ/kg °C.

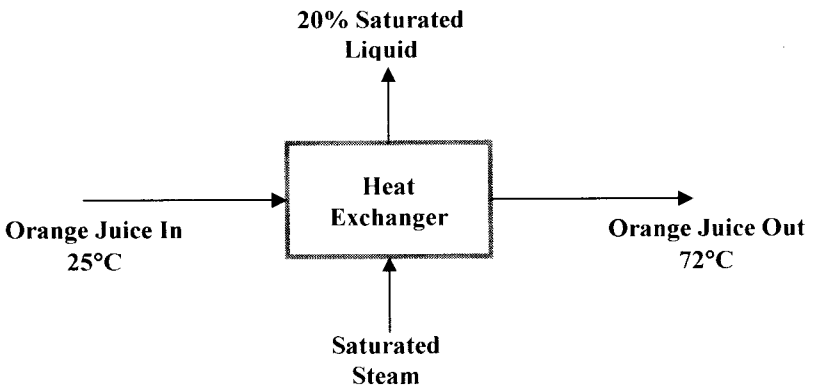

Table 3. Superheated Steam — *Continued*

Abs Press. Lb/Sq In. (Sat. Temp)		Sat. Water	Sat. Steam	Temperature — Degrees Fahrenheit 750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1400	1500
11000	v			0.0245	0.0267	0.0296	0.0335	0.0386	0.0443	0.0503	0.0562	0.0620	0.0676	0.0727	0.0776	0.0868	0.0952
	h			779.5	846.9	917.5	992.1	1069.9	1146.3	1215.9	1280.2	1339.7	1394.4	1444.6	1491.5	1578.7	1660.6
	s			0.9196	0.9742	1.0292	1.0851	1.1412	1.1945	1.2414	1.2833	1.3209	1.3544	1.3842	1.4112	1.4595	1.5023
11500	v			0.0243	0.0263	0.0290	0.0325	0.0370	0.0423	0.0478	0.0534	0.0588	0.0641	0.0691	0.0739	0.0827	0.0909
	h			777.7	843.8	912.4	984.5	1059.8	1134.9	1204.3	1268.7	1328.8	1384.4	1435.5	1483.2	1571.8	1654.7
	s			0.9163	0.9698	1.0232	1.0772	1.1316	1.1840	1.2308	1.2727	1.3107	1.3446	1.3750	1.4025	1.4515	1.4949
12000	v			0.0241	0.0260	0.0284	0.0317	0.0357	0.0405	0.0456	0.0508	0.0560	0.0610	0.0659	0.0704	0.0790	0.0869
	h			776.1	841.0	907.9	977.8	1050.9	1124.5	1193.7	1258.0	1318.5	1374.7	1426.6	1475.1	1564.9	1648.8
	s			0.9131	0.9657	1.0177	1.0701	1.1229	1.1742	1.2209	1.2627	1.3010	1.3353	1.3662	1.3941	1.4438	1.4877
12500	v			0.0238	0.0256	0.0279	0.0309	0.0346	0.0390	0.0437	0.0486	0.0535	0.0583	0.0629	0.0673	0.0756	0.0832
	h			774.7	838.6	903.9	971.9	1043.1	1115.2	1184.1	1247.9	1308.8	1365.4	1418.0	1467.2	1558.2	1643.1
	s			0.9101	0.9618	1.0127	1.0637	1.1151	1.1653	1.2117	1.2534	1.2918	1.3264	1.3576	1.3860	1.4363	1.4808
13000	v			0.0236	0.0253	0.0275	0.0302	0.0336	0.0376	0.0420	0.0466	0.0512	0.0558	0.0602	0.0645	0.0725	0.0799
	h			773.5	836.3	900.4	966.8	1036.2	1106.7	1174.8	1238.5	1299.6	1356.5	1409.6	1459.4	1551.6	1637.4
	s			0.9073	0.9582	1.0080	1.0578	1.1079	1.1571	1.2030	1.2445	1.2831	1.3179	1.3494	1.3781	1.4291	1.4741
13500	v			0.0235	0.0251	0.0271	0.0297	0.0328	0.0364	0.0405	0.0448	0.0492	0.0535	0.0577	0.0619	0.0696	0.0768
	h			772.3	834.4	897.2	962.2	1030.0	1099.1	1166.3	1229.7	1291.0	1348.1	1401.5	1451.8	1545.2	1631.9
	s			0.9045	0.9548	1.0037	1.0524	1.1014	1.1495	1.1948	1.2361	1.2749	1.3098	1.3415	1.3705	1.4221	1.4675
14000	v			0.0233	0.0248	0.0267	0.0291	0.0320	0.0354	0.0392	0.0432	0.0474	0.0515	0.0555	0.0595	0.0670	0.0740
	h			771.3	832.6	894.3	958.0	1024.5	1092.3	1158.5	1221.4	1283.0	1340.2	1393.8	1444.4	1538.8	1626.5
	s			0.9019	0.9515	0.9996	1.0473	1.0953	1.1426	1.1872	1.2282	1.2671	1.3021	1.3339	1.3631	1.4153	1.4612
14500	v			0.0231	0.0246	0.0264	0.0287	0.0314	0.0345	0.0380	0.0418	0.0458	0.0496	0.0534	0.0573	0.0646	0.0714
	h			770.4	831.0	891.7	954.3	1019.6	1086.2	1151.4	1213.8	1275.4	1332.9	1386.4	1437.3	1532.6	1621.1
	s			0.8994	0.9484	0.9957	1.0426	1.0897	1.1362	1.1801	1.2208	1.2597	1.2949	1.3266	1.3560	1.4087	1.4551
15000	v			0.0230	0.0244	0.0261	0.0282	0.0308	0.0337	0.0369	0.0405	0.0443	0.0479	0.0516	0.0552	0.0624	0.0690
	h			769.6	829.5	889.3	950.9	1015.1	1080.6	1144.9	1206.8	1268.1	1326.0	1379.4	1430.3	1526.4	1615.9
	s			0.8970	0.9455	0.9920	1.0382	1.0846	1.1302	1.1735	1.2139	1.2525	1.2880	1.3197	1.3491	1.4022	1.4491
15500	v			0.0228	0.0242	0.0258	0.0278	0.0302	0.0329	0.0360	0.0393	0.0429	0.0464	0.0499	0.0534	0.0603	0.0668
	h			768.9	828.2	887.2	947.8	1011.1	1075.7	1139.0	1200.3	1261.1	1319.6	1372.8	1423.6	1520.4	1610.8
	s			0.8946	0.9427	0.9886	1.0340	1.0797	1.1247	1.1674	1.2073	1.2457	1.2815	1.3131	1.3424	1.3959	1.4433

Sh = superheat, F
v = specific volume, cu ft per lb
h = enthalpy, Btu per lb
s = entropy, Btu per R per lb

SYSTÈME INTERNATIONAL (SI METRIC) UNITS

Table 1. Saturated Steam and Saturated Water: Temperature Table

Temp °C T	Press kPa P	Volume, m³/kg Water v_f	Volume, m³/kg Steam v_g	Enthalpy, kJ/kg Water h_f	Enthalpy, kJ/kg Evap. h_{fg}	Enthalpy, kJ/kg Steam h_g	Entropy, kJ/kg K Water s_f	Entropy, kJ/kg K Evap. s_{fg}	Entropy, kJ/kg K Steam s_g	Temp °C T
0	0.6108	0.0010002	206.31	−0.04	2501.6	2501.6	−0.0002	9.1579	9.1577	0
0.01	0.6112	0.0010002	206.16	0.00	2501.6	2501.6	0.0000	9.1575	9.1575	0.01
5	0.8718	0.0010000	147.16	21.01	2489.7	2510.7	0.0762	8.9507	9.0269	5
10	1.2270	0.0010003	106.43	41.99	2477.9	2519.9	0.1510	8.7510	8.9020	10
15	1.7040	0.0010008	77.98	62.94	2466.1	2529.0	0.2243	8.5582	8.7825	15
20	2.377	0.0010017	57.84	83.86	2454.3	2538.2	0.2963	8.3721	8.6684	20
25	3.166	0.0010029	43.40	104.77	2442.5	2547.3	0.3670	8.1922	8.5592	25
30	4.241	0.0010043	32.93	125.66	2430.7	2556.4	0.4365	8.0181	8.4546	30
35	5.622	0.0010060	25.25	146.56	2418.8	2565.4	0.5049	7.8494	8.3543	35
40	7.375	0.0010078	19.546	167.45	2406.9	2574.4	0.5721	7.6861	8.2583	40
45	9.582	0.0010098	15.276	188.35	2394.9	2583.3	0.6383	7.5277	8.1661	45
50	12.335	0.0010121	12.046	209.26	2382.9	2592.2	0.7035	7.3741	8.0776	50
55	15.741	0.0010145	9.579	230.17	2370.8	2601.0	0.7677	7.2248	7.9925	55
60	19.920	0.0010171	7.679	251.09	2358.6	2609.7	0.8310	7.0798	7.9108	60
65	25.010	0.0010199	6.202	272.03	2346.3	2618.3	0.8933	6.9388	7.8322	65
70	31.16	0.0010228	5.046	292.97	2334.0	2626.9	0.9548	6.8017	7.7565	70
75	38.55	0.0010259	4.134	313.93	2321.5	2635.4	1.0154	6.6681	7.6835	75
80	47.36	0.0010292	3.409	334.92	2308.8	2643.8	1.0753	6.5380	7.6132	80
85	57.80	0.0010326	2.829	355.91	2296.1	2652.0	1.1343	6.4111	7.5454	85
90	70.11	0.0010361	2.3613	376.94	2283.2	2660.1	1.1925	6.2873	7.4799	90
95	84.53	0.0010398	1.9822	397.99	2270.2	2668.2	1.2501	6.1665	7.4166	95
100	101.33	0.0010437	1.6730	419.06	2256.9	2676.0	1.3069	6.0485	7.3554	100
105	120.80	0.0010477	1.4183	440.17	2243.6	2683.7	1.3630	5.9331	7.2962	105
110	143.27	0.0010519	1.2099	461.32	2230.0	2691.3	1.4185	5.8203	7.2388	110
115	169.06	0.0010562	1.0363	482.50	2216.2	2698.7	1.4733	5.7099	7.1832	115
120	198.54	0.0010606	0.8915	503.72	2202.2	2708.0	1.5276	5.6017	7.1293	120
125	232.1	0.0010652	0.7702	524.99	2188.0	2713.0	1.5813	5.4957	7.0769	125
130	270.1	0.0010700	0.6681	546.31	2173.6	2719.9	1.6344	5.3917	7.0261	130
135	313.1	0.0010750	0.5818	567.68	2158.9	2726.6	1.6869	5.2897	6.9766	135
140	361.4	0.0010801	0.5085	589.10	2144.0	2733.1	1.7390	5.1894	6.9284	140
145	415.5	0.0010853	0.4460	610.59	2128.7	2739.3	1.7906	5.0910	6.8815	145
150	476.0	0.0010908	0.3924	632.15	2113.2	2745.4	1.8416	4.9941	6.8358	150
155	543.3	0.0010984	0.3464	653.77	2097.4	2751.2	1.8923	4.8989	6.7911	155
160	618.1	0.0011022	0.3068	675.47	2081.3	2756.7	1.9425	4.8050	6.7475	160
165	700.8	0.0011082	0.2724	697.25	2064.8	2762.0	1.9923	4.7126	6.7048	165
170	792.0	0.0011145	0.2426	719.12	2047.9	2767.1	2.0416	4.6214	6.6630	170
175	892.4	0.0011209	0.21654	741.07	2030.7	2771.8	2.0906	4.5314	6.6221	175
180	1002.7	0.0011275	0.19380	763.12	2013.2	2776.3	2.1393	4.4426	6.5819	180
185	1123.3	0.0011344	0.17386	785.26	1995.2	2780.4	2.1876	4.3548	6.5424	185
190	1255.1	0.0011415	0.15632	807.52	1976.7	2784.3	2.2356	4.2680	6.5036	190

LE C.1 (*cont.*)

Absolute pressure		*Specific volume*			*Enthalpy*		
Lb/in.² p	In. Hg 32°F	Sat. Liquid v_f	Evap. v_{fg}	Sat. Vapor v_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g
3.198	6.511	0.01631	111.88	111.90	111.88	1011.3	1123.2
3.363	6.847	0.01632	106.72	106.74	113.88	1010.2	1124.1
3.536	7.199	0.01633	101.82	101.84	115.87	1009.0	1124.9
3.716	7.566	0.01634	97.18	97.20	117.87	1007.8	1125.7
3.904	7.948	0.01635	92.79	92.81	119.87	1006.7	1126.6
4.100	8.348	0.01636	88.62	88.64	121.87	1005.5	1127.4
4.305	8.765	0.01637	84.66	84.68	123.87	1004.4	1128.3
4.518	9.199	0.01638	80.90	80.92	125.87	1003.2	1129.1
4.739	9.649	0.01639	77.37	77.39	127.87	1002.0	1129.9
4.970	10.12	0.01640	74.00	74.02	129.88	1000.8	1130.7
5.210	10.61	0.01642	70.79	70.81	131.88	999.7	1131.6
5.460	11.12	0.01643	67.76	67.78	133.88	998.5	1132.4
5.720	11.65	0.01644	64.87	64.89	135.88	997.3	1133.2
5.990	12.20	0.01645	62.12	62.14	137.89	996.1	1134.0
6.272	12.77	0.01646	59.50	59.52	139.89	995.0	1134.9
6.565	13.37	0.01647	57.01	57.03	141.89	993.8	1135.7
6.869	13.99	0.01648	56.64	54.66	143.90	992.6	1136.5
7.184	14.63	0.01650	52.39	52.41	145.90	991.4	1137.3
7.510	15.29	0.01651	50.26	50.28	147.91	990.2	1138.1
7.849	15.98	0.01652	48.22	48.24	149.92	989.0	1138.9
8.201	16.70	0.01653	46.28	46.30	151.92	987.8	1139.7
8.566	17.44	0.01654	44.43	44.45	153.93	986.6	1140.5
8.944	18.21	0.01656	42.67	42.69	155.94	985.3	1141.3
9.336	19.01	0.01657	40.99	41.01	157.95	984.1	1142.1
9.744	19.84	0.01658	39.38	39.40	159.95	982.8	1142.8
10.168	20.70	0.01659	37.84	37.86	161.96	981.5	1143.5
10.605	21.59	0.01661	36.38	36.40	163.97	980.3	1144.3
11.057	22.51	0.01662	34.98	35.00	165.98	979.0	1145.0
11.525	23.46	0.01663	33.65	33.67	167.99	977.8	1145.8
12.010	24.45	0.01665	32.37	32.39	170.01	976.6	1146.6
12.512	25.47	0.01666	31.15	31.17	172.02	975.3	1147.3
13.031	26.53	0.01667	29.99	30.01	174.03	974.1	1148.1
13.568	27.62	0.01669	28.88	28.90	176.04	972.8	1148.8
14.123	28.75	0.01670	27.81	27.83	178.06	971.5	1149.6
14.696	29.92	0.01672	26.81	26.83	180.07	970.3	1150.4
15.591		0.01674	25.35	25.37	186.10	968.3	1151.4
17.188		0.01677	23.14	23.16	188.14	965.2	1153.3
18.915		0.01681	21.15	21.17	193.18	961.9	1155.1

TABLE C.1 (*cont.*)

Absolute pressure			*Specific volume*			*Enthalpy*		
Temp. Fahr. t	Lb/in.² p	In. Hg 32°F	Sat. Liquid v_f	Evap. v_{fg}	Sat. Vapor v_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g
230	20.78		0.01684	19.371	19.388	198.22	958.7	1156.9
235	22.80		0.01688	17.761	17.778	203.28	955.3	1158.6
240	24.97		0.01692	16.307	16.324	208.34	952.1	1160.4
245	27.31		0.01696	15.010	15.027	213.41	948.7	1162.1
250	29.82		0.01700	13.824	13.841	218.48	945.3	1163.8
255	32.53		0.01704	12.735	12.752	223.56	942.0	1165.6
260	35.43		0.01708	11.754	11.771	228.65	938.6	1167.3
265	38.54		0.01713	10.861	10.878	233.74	935.3	1169.0
270	41.85		0.01717	10.053	10.070	238.84	931.8	1170.6
275	45.40		0.01721	9.313	9.330	243.94	928.2	1172.1
280	49.20		0.01726	8.634	8.651	249.06	924.6	1173.7
285	53.25		0.01731	8.015	8.032	254.18	921.0	1175.2
290	57.55		0.01735	7.448	7.465	259.31	917.4	1176.7
295	62.13		0.01740	6.931	6.948	264.45	913.7	1178.2
300	67.01		0.01745	6.454	6.471	269.60	910.1	1179.7
305	72.18		0.01750	6.014	6.032	274.76	906.3	1181.1
310	77.68		0.01755	5.610	5.628	279.92	902.6	1182.5
315	83.50		0.01760	5.239	5.257	285.10	898.8	1183.9
320	89.65		0.01765	4.897	4.915	290.29	895.0	1185.3
325	96.16		0.01771	4.583	4.601	295.49	891.1	1186.6
330	103.03		0.01776	4.292	4.310	300.69	887.1	1187.8
335	110.31		0.01782	4.021	4.039	305.91	883.2	1189.1
340	117.99		0.01788	3.771	3.789	311.14	879.2	1190.3
345	126.10		0.01793	3.539	3.557	316.38	875.1	1191.5
350	134.62		0.01799	3.324	3.342	321.64	871.0	1192.6
355	143.58		0.01805	3.126	3.144	326.91	866.8	1193.7
360	153.01		0.01811	2.940	2.958	332.19	862.5	1194.7
365	162.93		0.01817	2.768	2.786	337.48	858.2	1195.7
370	173.33		0.01823	2.607	2.625	342.79	853.8	1196.6
375	184.23		0.01830	2.458	2.476	348.11	849.4	1197.5
380	195.70		0.01836	2.318	2.336	353.45	844.9	1198.4
385	207.71		0.01843	2.189	2.207	358.80	840.4	1199.2
390	220.29		0.01850	2.064	2.083	364.17	835.7	1199.9
395	233.47		0.01857	1.9512	1.9698	369.56	831.0	1200.6
400	247.25		0.01864	1.8446	1.8632	374.97	826.2	1201.2
405	261.67		0.01871	1.7445	1.7632	380.40	821.4	1201.8
410	276.72		0.01878	1.6508	1.6696	385.83	816.6	1202.4

v = specific volume, ft_3/lb. h = enthalpy, Btu/lb.