PRINCE OF SONGKLA UNIVERSITY

FACULTY OF ENGINEERING

Midterm Examination Semester I **Academic year : 2005**

Date : December 13, 2005 **Time : 9.00 – 12.00 น.**

Subject : 230 – 392 Basic Chemical Engineering II **Room : R 300**

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1) All notes and books are allowed.

2) There are total 4 questions.

Question	Points value	Score
1	25	
2	25	
3	25	
4	25	
Total	100	

Name.............................   Student ID.........................

1. A straight rectangular fin has a length of 30 mm and a thickness of 2 mm. The thermal conductivity is 50 $W/m^{o}C$. The fin is exposed to an convection environment at $20^{o}C$ and h= 400 $W/m^{2o}C$. Calculate the maximum possible heat loss for the base temperature of 160 ^{o}C. What is the actual heat loss for this base temperature?

Name.............................   Student ID.........................

2. A condenser is to be designed to condense 10,000 kg/h of refrigerant (CCl_2F_2) at 35 ^{o}C .A square of 25 by 25 array of 12- mm diameter tubes is to be used, with water flow inside the tubes maintaining the wall temperature at 30 ^{o}C. Calculate the length of the tubes. H_{fg} = 130 kJ/kg at 38 ^{o}C.

Name............................ Student ID........................

3. Water at the rate of 0.8 kg/s at 93 °C is forced through a 5-cm-ID copper tube at a suitable velocity. The wall thickness is 0.8 mm. Air at 15 °C and atmospheric pressure is forced over the outside of the tube at a velocity of 15 m/s in a direction normal to the axis of the tube. What is the heat loss per meter of length of the tube?

Name............................   Student ID.........................

4. A shell and tubes heat exchanger operates with two shell passés and four tubes passes. The shell fluid is ethylene glycol, which enters at 120 ^{o}C and leaves at 60 ^{o}C with the flow rate of 50 kg/h. Water flows in the tubes, entering at 40 ^{o}C and leaving at 80 ^{o}C . The overall heat transfer coefficient for this arrangement is 800 W/m^{2} ^{o}C. Calculate the flow rate of water required and the area of the heat exchanger.

Table A-4 Properties of Saturated Liquids† *(continued)*

T, °C	ρ, kg/m³	c_p, kJ/kg·°C	ν, m²/s	k, W/m·°C	α, m²/s	Pr	β, K⁻¹
			Dichlorodifluoromethane (Freon), CCl_2F_2				
−50	1 546.75	0.8750	0.310×10^{-6}	0.067	0.501×10^{-7}	6.2	2.63×10^{-3}
−40	1 518.71	0.8847	0.279	0.069	0.514	5.4	
−30	1 489.56	0.8956	0.253	0.069	0.526	4.8	
−20	1 460.57	0.9073	0.235	0.071	0.539	4.4	
−10	1 429.49	0.9203	0.221	0.073	0.550	4.0	
0	1 397.45	0.9345	0.214×10^{-6}	0.073	0.557×10^{-7}	3.8	
10	1 364.30	0.9496	0.203	0.073	0.560	3.6	
20	1 330.18	0.9659	0.198	0.073	0.560	3.5	
30	1 295.10	0.9835	0.194	0.071	0.560	3.5	
40	1 257.13	1.0019	0.191	0.069	0.555	3.5	
50	1 215.96	1.0216	0.190	0.067	0.545	3.5	
			Glycerin, $C_3H_5(OH)_3$				
0	1 276.03	2.261	0.00831	0.282	0.983×10^{-7}	84.7×10^3	
10	1 270.11	2.319	0.00300	0.284	0.965	31.0	
20	1 264.02	2.386	0.00118	0.286	0.947	12.5	0.50×10^{-3}
30	1 258.09	2.445	0.00050	0.286	0.929	5.38	
40	1 252.01	2.512	0.00022	0.286	0.914	2.45	
50	1 244.96	2.583	0.00015	0.287	0.893	1.63	
			Ethylene glycol, $C_2H_4(OH)_2$				
0	1 130.75	2.294	57.53×10^{-6}	0.242	0.934×10^{-7}	615	
20	1 116.65	2.382	19.18	0.249	0.939	204	0.65×10^{-3}
40	1 101.43	2.474	8.69	0.256	0.939	93	
60	1 087.66	2.562	4.75	0.260	0.932	51	
80	1 077.56	2.650	2.98	0.261	0.921	32.4	
100	1 058.50	2.742	2.03	0.263	0.908	22.4	
			Engine oil (unused)				
0	899.12	1.796	0.00428	0.147	0.911×10^{-7}	47,100	
20	888.23	1.880	0.00090	0.145	0.872	10,400	0.70×10^{-3}
40	876.05	1.964	0.00024	0.144	0.834	2,870	
60	864.04	2.047	0.839×10^{-4}	0.140	0.800	1,050	
80	852.02	2.131	0.375	0.138	0.769	490	
100	840.01	2.219	0.203	0.137	0.738	276	
120	828.96	2.307	0.124	0.135	0.710	175	
140	816.94	2.395	0.080	0.133	0.686	116	
160	805.89	2.483	0.056	0.132	0.663	84	

Table A-5 Properties of Air at Atmospheric Pressure†

The values of μ, k, c_p, and Pr are not strongly pressure-dependent and may be used over a fairly wide range of pressures.

T, K	ρ kg/m³	c_p, kJ/kg°C	μ, kg/ms × 10⁵	ν, m²/s × 10⁶	k, W/m°C	α, m²/s × 10⁴	Pr
100	3.6010	1.0266	0.6924	1.923	0.009246	0.02501	0.770
150	2.3675	1.0099	1.0283	4.343	0.013735	0.05745	0.753
200	1.7684	1.0061	1.3289	7.490	0.01809	0.10165	0.739
250	1.4128	1.0053	1.5990	11.31	0.02227	0.15675	0.722
300	1.1774	1.0057	1.8462	15.69	0.02624	0.22160	0.708
350	0.9980	1.0090	2.075	20.76	0.03003	0.2983	0.697
400	0.8826	1.0140	2.286	25.90	0.03365	0.3760	0.689
450	0.7833	1.0207	2.484	31.71	0.03707	0.4222	0.683
500	0.7048	1.0295	2.671	37.90	0.04038	0.5564	0.680
550	0.6423	1.0392	2.848	44.34	0.04360	0.6532	0.680
600	0.5879	1.0551	3.018	51.34	0.04659	0.7512	0.680
650	0.5430	1.0635	3.177	58.51	0.04953	0.8578	0.682
700	0.5030	1.0752	3.332	66.25	0.05230	0.9672	0.684
750	0.4709	1.0856	3.481	73.91	0.05509	1.0774	0.686
800	0.4405	1.0978	3.625	82.29	0.05779	1.1951	0.689
850	0.4149	1.1095	3.765	90.75	0.06028	1.3097	0.692
900	0.3925	1.1212	3.899	99.3	0.06279	1.4271	0.696
950	0.3716	1.1321	4.023	108.2	0.06525	1.5510	0.699
1000	0.3524	1.1417	4.152	117.8	0.06752	1.6779	0.702
1100	0.3204	1.160	4.44	138.6	0.0732	1.969	0.704
1200	0.2947	1.179	4.69	159.1	0.0782	2.251	0.707
1300	0.2707	1.197	4.93	182.1	0.0837	2.583	0.705
1400	0.2515	1.214	5.17	205.5	0.0891	2.920	0.705
1500	0.2355	1.230	5.40	229.1	0.0946	3.262	0.705
1600	0.2211	1.248	5.63	254.5	0.100	3.609	0.705
1700	0.2082	1.267	5.85	280.5	0.105	3.977	0.705
1800	0.1970	1.287	6.07	308.1	0.111	4.379	0.704
1900	0.1858	1.309	6.29	338.5	0.117	4.811	0.704
2000	0.1762	1.338	6.50	369.0	0.124	5.260	0.702
2100	0.1682	1.372	6.72	399.6	0.131	5.715	0.700
2200	0.1602	1.419	6.93	432.6	0.139	6.120	0.707
2300	0.1538	1.482	7.14	464.0	0.149	6.540	0.710
2400	0.1458	1.574	7.35	504.0	0.161	7.020	0.718
2500	0.1394	1.688	7.57	543.5	0.175	7.441	0.730

†From *Natl. Bur. Stand. (U.S.) Circ.* 564, 1955.

Table A-9 Properties of Water (Saturated Liquid)†

Note: $Gr_x Pr = \left(\frac{g\beta\rho^2 c_p}{\mu k}\right) x^3 \Delta T$

°C	c_p, kJ/kg°C	ρ, kg/m³	μ, kg/ms	k, W/m°C	Pr	$\frac{g\beta\rho^2 c_p}{\mu k}$, 1/m³°C
0	4.225	999.8	1.79×10^{-3}	0.566	13.25	
4.44	4.208	999.8	1.55	0.575	11.35	1.91×10^{9}
10	4.195	999.2	1.31	0.585	9.40	6.34×10^{9}
15.56	4.186	998.6	1.12	0.595	7.88	1.08×10^{10}
21.11	4.179	997.4	9.8×10^{-4}	0.604	6.78	1.46×10^{10}
26.67	4.179	995.8	8.6	0.614	5.85	1.91×10^{10}
32.22	4.174	994.9	7.65	0.623	5.12	2.48×10^{10}
37.78	4.174	993.0	6.82	0.630	4.53	3.3×10^{10}
43.33	4.174	990.6	6.16	0.637	4.04	4.19×10^{10}
48.89	4.174	988.8	5.62	0.644	3.64	4.89×10^{10}
54.44	4.179	985.7	5.13	0.649	3.30	5.66×10^{10}
60	4.179	983.3	4.71	0.654	3.01	6.48×10^{10}
65.55	4.183	980.3	4.3	0.659	2.73	7.62×10^{10}
71.11	4.186	977.3	4.01	0.665	2.53	8.84×10^{10}
76.67	4.191	973.7	3.72	0.668	2.33	9.85×10^{10}
82.22	4.195	970.2	3.47	0.673	2.16	1.09×10^{11}
87.78	4.199	966.7	3.27	0.675	2.03	
93.33	4.204	963.2	3.06	0.678	1.90	
104.4	4.216	955.1	2.67	0.684	1.66	
115.6	4.229	946.7	2.44	0.685	1.51	
126.7	4.250	937.2	2.19	0.685	1.36	
137.8	4.271	928.1	1.98	0.685	1.24	
148.9	4.296	918.0	1.86	0.684	1.17	
176.7	4.371	890.4	1.57	0.677	1.02	
204.4	4.467	859.4	1.36	0.665	1.00	
232.2	4.585	825.7	1.20	0.646	0.85	
260	4.731	785.2	1.07	0.616	0.83	
287.7	5.024	735.5	9.51×10^{-5}			
315.6	5.703	678.7	8.68			

†Adapted from A. I. Brown and S. M. Marco, "Introduction to Heat Transfer," 3d ed., McGraw-Hill Book Company, New York, 1958.