Prince of Songkla University
Faculty of Engineering

Final Examination — **Semester 1/2552**

3 October 2009 — **Time 13:30-16:30**

216-231 ENGINEERING THERMODYNAMIC I — **Room: R300**

Directions

- A4 paper is allowed and can be written two sides of the A4 paper.
- All types of calculator are permitted.
- Attempt all 5 questions.
- The exam paper has 9 pages.

Juntakan Taweekun
Instructor

Problem	Marks	
1	15	
2	15	
3	15	
4	15	
5	15	
Total	75	

Name ____________________

ID ____________________

Name ____ ID ________________________

Question 1 (15 points)

A rigid tank is divided into two equal parts by a partition. Initially, one side of the tank contains 5 kg of water at 200 kPa and 25 °C, and the other side is evacuated. The partition is then removed, and the water expands into the entire tank. The water is allowed to exchange heat with its surroundings until the temperature in the tank returns to the initial value of 25 °C. Determine

a) the volume of the tank
b) the final pressure
c) the heat transfer for this process

Name ____ ID ________________________

Question 2 (15 points)

A mass of 15 kg of air in a piston-cylinder device is heated from 25 °C to 77 °C by passing current through a resistance heater inside the cylinder. The pressure inside the cylinder is held constant at 300 kPa during the process, and a heat loss of 60 kJ occurs. Determine the electric energy supplied in kWh.

Name ____ ID ______________________

Question 3 (15 points)

A heat pump with a COP of 2.55 supplies energy to a house at a rate of 68,500 kJ/h. Determine

a) The electric power drawn by the heat pump (in unit of kW)
b) The rate of heat absorption from the outside air (in unit of kW)

Name ______________________________________ ID ____________________

Question 4 (15 points)

A carnot heat engine receives heat from a reservoir at 927 °C at a rate of 740 kJ/min and rejects the waste heat to the ambient air at 27 °C. The entire work output of the heat engine is used to drive a refrigerator that removes heat from the refrigerated space at -7 °C and transfers it to the same ambient air at 27 °C . Determine

a) the maximum rate of heat removal from the refrigerated space
b) the total rate of heat rejection to the ambient air

Name ____ ID ____________________

Question 5 (15 points)

The efficiency of cooking appliance affects the internal heat gain from them since an inefficient appliance consumes a greater amount of energy for the same task, and the excess energy consumed shows up as heat in the living space. The efficiency of open burners is determined to be 75 percent for electric units and 35 percent for gas units. Consider a 2 kW electric burner at a location where the unit costs of electricity and natural gas are 4 Baht/kWh and 24.5 Baht/therm, respectively. Determine the rate of energy consumption by the burner and the unit cost of utilized energy for both electric and gas burners. (Use 1 therm = 29.3 kWh)

TABLE A.1 Thermodynamic Properties of Steam

TABLE A.1.1 Saturated Steam: Temperature Table

Temp. Sat. °C	Press. Sat. kPa	Specific Volume m^3/kg Sat. Liquid v_f	Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Evap. u_{fg}	Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Entropy $kJ/kg\ K$ Sat. Liquid s_f	Evap. s_{fg}	Sat. Vapor s_g
0.01	0.6113	0.001000	206.14	.00	2375.3	2375.3	.01	2501.3	2501.4	.0000	9.1562	9.1562
5	0.8721	0.001000	147.12	20.97	2361.3	2382.3	20.98	2489.6	2510.6	.0761	8.9496	9.0257
10	1.2276	0.001000	106.38	42.00	2347.2	2389.2	42.01	2477.7	2519.8	.1510	8.7498	8.9008
15	1.7051	0.001001	77.93	62.99	2333.1	2396.1	62.99	2465.9	2528.9	.2245	8.5569	8.7814
20	2.339	0.001002	57.79	83.95	2319.0	2402.9	83.96	2454.1	2538.1	.2966	8.3706	8.6672
25	3.169	0.001003	43.36	104.88	2304.9	2409.8	104.89	2442.3	2547.2	.3674	8.1905	8.5580
30	4.246	0.001004	32.89	125.78	2290.8	2416.6	125.79	2430.5	2556.3	.4369	8.0164	8.4533
35	5.628	0.001006	25.22	146.67	2276.7	2423.4	146.68	2418.6	2565.3	.5053	7.8478	8.3531
40	7.384	0.001008	19.52	167.56	2262.6	2430.1	167.57	2406.7	2574.3	.5725	7.6845	8.2570
45	9.593	0.001010	15.26	188.44	2248.4	2436.8	188.45	2394.8	2583.2	.6387	7.5261	8.1648
50	12.349	0.001012	12.03	209.32	2234.2	2443.5	209.33	2382.7	2592.1	.7038	7.3725	8.0763
55	15.758	0.001015	9.568	230.21	2219.9	2450.1	230.23	2370.7	2600.9	.7679	7.2234	7.9913
60	19.940	0.001017	7.671	251.11	2205.5	2456.6	251.13	2358.5	2609.6	.8312	7.0784	7.9096
65	25.03	0.001020	6.197	272.02	2191.1	2463.1	272.06	2346.2	2618.3	.8935	6.9375	7.8310
70	31.19	0.001023	5.042	292.95	2176.6	2469.6	292.98	2333.8	2626.8	.9549	6.8004	7.7553
75	38.58	0.001026	4.131	313.90	2162.0	2475.9	313.93	2321.4	2635.3	1.0155	6.6669	7.6824
80	47.39	0.001029	3.407	334.86	2147.4	2482.2	334.91	2308.8	2643.7	1.0753	6.5369	7.6122
85	57.83	0.001033	2.828	355.84	2132.6	2488.4	355.90	2296.0	2651.9	1.1343	6.4102	7.5445
90	70.14	0.001036	2.361	376.85	2117.7	2494.5	376.92	2283.2	2660.1	1.1925	6.2866	7.4791
95	84.55	0.001040	1.982	397.88	2102.7	2500.6	397.96	2270.2	2668.1	1.2500	6.1659	7.4159
100	101.35	0.001044	1.6729	418.94	2087.6	2506.5	419.04	2257.0	2676.1	1.3069	6.0480	7.3549
105	120.82	0.001048	1.4194	440.02	2072.3	2512.4	440.15	2243.7	2683.8	1.3630	5.9328	7.2958
110	143.27	0.001052	1.2102	461.14	2057.0	2518.1	461.30	2230.2	2691.5	1.4185	5.8202	7.2387
115	169.06	0.001056	1.0366	482.30	2041.4	2523.7	482.48	2216.5	2699.0	1.4734	5.7100	7.1833
120	198.53	0.001060	0.8919	503.50	2025.8	2529.3	503.71	2202.6	2706.3	1.5276	5.6020	7.1296
125	232.1	0.001065	0.7706	524.74	2009.9	2534.6	524.99	2188.5	2713.5	1.5813	5.4962	7.0775
130	270.1	0.001070	0.6685	546.02	1993.9	2539.9	546.31	2174.2	2720.5	1.6344	5.3925	7.0269
135	313.0	0.001075	0.5822	567.35	1977.7	2545.0	567.69	2159.6	2727.3	1.6870	5.2907	6.9777

TABLE A.1.4 Compressed Liquid

T	v	u	h	s	v	u	h	s	v	u	h	s
	P = 5 MPa (263.99)				P = 10 MPa (311.06)				P = 15 MPa (342.24)			
Sat.	.0012859	1147.8	1154.2	2.9202	.0014524	1393.0	1407.6	3.3596	.0016581	1585.6	1610.5	3.6848
0	.0009977	.04	5.04	.0001	.0009952	.09	10.04	.0002	.0009928	.15	15.05	.0004
20	.0009995	83.65	88.65	.2956	.0009972	83.36	93.33	.2945	.0009950	83.06	97.99	.2934
40	.0010056	166.95	171.97	.5705	.0010034	166.35	176.38	.5686	.0010013	165.76	180.78	.5666
60	.0010149	250.23	255.30	.8285	.0010127	249.36	259.49	.8258	.0010105	248.51	263.67	.8232
80	.0010268	333.72	338.85	1.0720	.0010245	332.59	342.83	1.0688	.0010222	331.48	346.81	1.0656
100	.0010410	417.52	422.72	1.3030	.0010385	416.12	426.50	1.2992	.0010361	414.74	430.28	1.2955
120	.0010576	501.80	507.09	1.5233	.0010549	500.08	510.64	1.5189	.0010522	498.40	514.19	1.5145
140	.0010768	586.76	592.15	1.7343	.0010737	584.68	595.42	1.7292	.0010707	582.66	598.72	1.7242
160	.0010988	672.62	678.12	1.9375	.0010953	670.13	681.08	1.9317	.0010918	667.71	684.09	1.9260
180	.0011240	759.63	765.25	2.1341	.0011199	756.65	767.84	2.1275	.0011159	753.76	770.50	2.1210
200	.0011530	848.1	853.9	2.3255	.0011480	844.5	856.0	2.3178	.0011433	841.0	858.2	2.3104
220	.0011866	938.4	944.4	2.5128	.0011805	934.1	945.9	2.5039	.0011748	929.9	947.5	2.4953
240	.0012264	1031.4	1037.5	2.6979	.0012187	1026.0	1038.1	2.6872	.0012114	1020.8	1039.0	2.6771
260	.0012749	1127.9	1134.3	2.8830	.0012645	1121.1	1133.7	2.8699	.0012550	1114.6	1133.4	2.8576
280					.0013216	1220.9	1234.1	3.0548	.0013084	1212.5	1232.1	3.0393
300					.0013972	1328.4	1342.3	3.2469	.0013770	1316.6	1337.3	3.2260
320									.0014724	1431.1	1453.2	3.4247
340									.0016311	1567.5	1591.9	3.6546

T	P=20 MPa(365.81)				P=30 MPa				P=50 MPa			
Sat.	.002036	1785.6	1826.3	4.0139								
0	.0009904	.19	20.01	.0004	.0009856	.25	29.82	.0001	.0009766	.20	49.03	-.0014
20	.0009928	82.77	102.62	.2923	.0009886	82.17	111.84	.2899	.0009804	81.00	130.02	.2848
40	.0009992	165.17	185.16	.5646	.0009951	164.04	193.89	.5607	.0009872	161.86	211.21	.5527
60	.0010084	247.68	267.85	.8206	.0010042	246.06	276.19	.8154	.0009962	242.98	292.79	.8052
80	.0010199	330.40	350.80	1.0624	.0010156	328.30	358.77	1.0561	.0010073	324.34	374.70	1.0440
100	.0010337	413.39	434.06	1.2917	.0010290	410.78	441.66	1.2844	.0010201	405.88	456.89	1.2703
120	.0010496	496.76	517.76	1.5102	.0010445	493.59	524.93	1.5018	.0010348	487.65	539.39	1.4857
140	.0010678	580.69	602.04	1.7193	.0010621	576.88	608.75	1.7098	.0010515	569.77	622.35	1.6915
160	.0010885	665.35	687.12	1.9204	.0010821	660.82	693.28	1.9096	.0010703	652.41	705.92	1.8891
180	.0011120	750.95	773.20	2.1147	.0011047	745.59	778.73	2.1024	.0010912	735.69	790.25	2.0794
200	.0011388	837.7	860.5	2.3031	.0011302	831.4	865.3	2.2893	.0011146	819.7	875.5	2.2634
220	.0011693	925.9	949.3	2.4870	.0011590	918.3	953.1	2.4711	.0011408	904.7	961.7	2.4419
240	.0012046	1016.0	1040.0	2.6674	.0011920	1006.9	1042.6	2.6490	.0011702	990.7	1049.2	2.6158
260	.0012462	1108.6	1133.5	2.8459	.0012303	1097.4	1134.3	2.8243	.0012034	1078.1	1138.2	2.7860
280	.0012965	1204.7	1230.6	3.0248	.0012755	1190.7	1229.0	2.9986	.0012415	1167.2	1229.3	2.9537
300	.0013596	1306.1	1333.3	3.2071	.0013304	1287.9	1327.8	3.1741	.0012860	1258.7	1323.0	3.1200
320	.0014437	1415.7	1444.6	3.3979	.0013997	1390.7	1432.7	3.3539	.0013388	1353.3	1420.2	3.2868
340	.0015684	1539.7	1571.0	3.6075	.0014920	1501.7	1546.5	3.5426	.0014032	1452.0	1522.1	3.4557
360	.0018226	1702.8	1739.3	3.8772	.0016265	1626.6	1675.4	3.7494	.0014838	1556.0	1630.2	3.6291
380					.0018691	1781.4	1837.5	4.0012	.0015884	1667.2	1746.6	3.8101

TABLE A.18 Properties of Air at Atmospheric Pressure [a]

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/m^3	c_p kJ/kg °C	$\mu \times 10^6$ kg/m s	$\nu \times 10^4$ m^2/s	k W/m °C	$\alpha \times 10^4$ m^2/s	Pr
100	3.6010	1.0266	6.924	0.01923	0.009246	0.02501	0.770
150	2.3675	1.0099	10.283	0.04343	0.013735	0.05745	0.753
200	1.7684	1.0061	13.289	0.07490	0.018090	0.10165	0.739
250	1.4128	1.0053	15.990	0.11310	0.022270	0.15675	0.722
300	1.1774	1.0057	18.462	0.15690	0.026240	0.22160	0.708
350	0.9980	1.0090	20.750	0.20760	0.030030	0.29830	0.697
400	0.8826	1.0140	22.860	0.25900	0.033650	0.37600	0.689
450	0.7833	1.0207	24.840	0.31710	0.037070	0.42220	0.683
500	0.7048	1.0295	26.710	0.37900	0.040380	0.55640	0.680
550	0.6423	1.0392	28.480	0.44340	0.043600	0.65320	0.680
600	0.5879	1.0551	30.180	0.51340	0.046590	0.75120	0.680
650	0.5430	1.0635	31.770	0.58510	0.04953	0.85780	0.682
700	0.5030	1.0752	33.320	0.66250	0.05230	0.96720	0.684
750	0.4709	1.0856	34.810	0.73910	0.055090	1.07740	0.686
800	0.4405	1.0978	36.250	0.82290	0.057790	1.19510	0.689
850	0.4149	1.1095	37.650	0.90750	0.060280	1.30970	0.692
900	0.3925	1.1212	38.990	0.99300	0.062790	1.42710	0.696
950	0.3716	1.1321	40.230	1.08200	0.065250	1.55100	0.699
1000	0.3524	1.1417	41.520	1.17800	0.067520	1.67790	0.702
1100	0.3204	1.1600	44.400	1.38600	0.073200	1.96900	0.704
1200	0.2947	1.1790	46.900	1.59100	0.078200	2.25100	0.707
1300	0.2707	1.1970	49.300	1.82100	0.083700	2.58300	0.705
1400	0.2515	1.2140	51.700	2.05500	0.089100	2.92000	0.705
1500	0.2355	1.2300	54.000	2.29100	0.094600	3.26200	0.705
1600	0.2211	1.2480	56.300	2.54500	0.100000	3.60900	0.705
1700	0.2082	1.2670	58.500	2.80500	0.105000	3.97700	0.705
1800	0.1970	1.2870	60.700	3.08100	0.111000	4.37900	0.704
1900	0.1858	1.3090	62.900	3.38500	0.117000	4.81100	0.704
2000	0.1762	1.3380	65.000	3.69000	0.124000	5.26000	0.702
2100	0.1682	1.3720	67.200	3.99600	0.131000	5.71500	0.700
2200	0.1602	1.4190	69.300	4.32600	0.139000	6.12000	0.707
2300	0.1518	1.4820	71.400	4.64000	0.149000	6.54000	0.710
2400	0.1458	1.5740	73.500	5.04000	0.161000	7.02000	0.718
2500	0.1394	1.6880	75.700	5.43500	0.175000	7.44100	0.730

[a] From *Natl. Bur. Stand. (U.S.) Circ.* 564, 1955.