1. Methane $CH4_{(g)}$ is burned with air. Assuming that the molal ratio of N_2 to O_2 in air is 3.76. (A) Please calculate the theoretical air-fuel ratio on a mole basis. (4%) (B) When $CH4_{(g)}$ is burned with 200 percent theoretical air, please determine the molal analysis of the products (4%) and the partial pressure of the water vapor if the pressure is 0.1 MPa. (2%)

2. A small gas turbine uses $C_3H_{8(l)}$ for fuel and 200 percent theoretical air. The air and fuel enter at 25°C, 0.1MPa and the products of combustion leave at 1000°C, 0.1 MPa. (A) Please determine the enthalpies of reactants and combustion products (10%) (B) The output work from the engine per kmol of fuel (5%). Assume complete combustion and adiabatic, and use following notations to answer the above two questions. The enthalpies of formation (in kJ/kmol) of $C_3H_{8(g)}$, $CO_{2(g)}$, $H_2O_{(g)}$ are $\overline{h^o_{f,C_3H_{8(g)}}}$, $\overline{h^o_{f,CO_{2(g)}}}$ and $\overline{h^o_{f,H_2O_{(g)}}}$, respectively. The specific heats at constant pressure (in kJ/kmol-K) of $C_3H_{8(g)}$, $O_{2(g)}$, $N_{2(g)}$, $CO_{2(g)}$ and $H_2O_{(g)}$ are $C_{p,C_3H_{8(g)}}$, $C_{p,O_{2(g)}}$, $C_{p,N_{2(g)}}$, $C_{p,CO_{2(g)}}$, and $C_{p,H_2O_{(g)}}$, respectively.

3. A heat pump heats a house in the winter and then reverses to cool it in the summer. The interior temperature should be 20°C in the winter and 27°C in the summer. Heat transfer through the walls and ceiling is estimated to be 2500 kJ per hour per degree temperature difference between the inside and outside.
If the winter outside temperature is 0°C, what is the minimum power required to drive the heat pump? (10%)

4. A mass of 1 kg of air contained in a cylinder at 1.5 MPa, 1000 K, expands in a reversible isothermal process to volume 10 times larger. Please Calculate
   (a) The heat transfer during the process. (10%) (The gas constant R of air is 0.287 kJ/kg · K)
   (b) The change of entropy of the air. (5%)

5. Air in a piston cylinder device is cooled from an initial pressure and temperature of 8.0 MPa and 700 °C to a final temperature of 300 °C.
   (a) If the process is isobaric, using ideal gas properties of air table, find the heat transfer (kJ/kg) and work (kJ/kg) done by the piston/cylinder assembly. (20%)
   (b) If the process is polytropic with n=1.3, assuming ideal gas, find the final pressure. (5%)

Gas constant of air, $R = 0.287$ kJ/kg-K

Idea gas properties of air are given:

T(K)	h (kJ/kg)	u (kJ/kg)	s (kJ/kgK)
840	866.08	624.95	2.77170
860	888.27	641.40	2.79783
880	910.56	657.95	2.82344
900	932.93	674.58	2.84856
920	955.38	691.28	2.87324
940	977.92	708.08	2.89748
960	1000.55	725.02	2.92128
980	1023.25	741.98	2.94468
1000	1046.04	758.94	2.96770
1020	1068.89	776.10	2.99034
1040	1091.85	793.36	3.01260
1060	1114.86	810.62	3.03449

6.
   (a) A detailed analysis for the performance of a reciprocating internal combustion engine would take into account many features. To simplify these complexities, an air-standard analysis is often used for elementary thermodynamic analyses of internal combustion engines. Write down the major assumptions made in the air-standard analysis? (5%)
   (b) The pressure-specific volume (p-v) diagram of an air-standard cycle is shown in Fig. 1. Sketch the cycle on T-s coordinates. (5%)

(c) For a particular cycle described by Fig. 1, if the compression ratio during the isentropic compression is 10 (v1/v2 = 10), p1 = 100 kPa, T1 = 200 K., and the constant volume heat addition per unit mass, $\frac{Q_{23}}{m}$, of air is 573.9 kJ/kg, determine the net work, in kJ per kg of air. The properties for air modeled as an ideal gas are shown in the attached table. (5%)

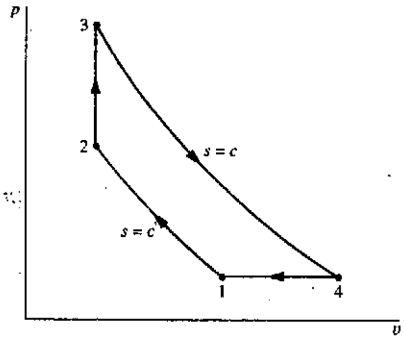

Fig. 1

Table A-22E **Ideal Gas Properties of Air**

T(°R), h and u(Btu/lb), $s°$(Btu/lb · °R)

				when $\Delta s = 0$[1]						when $\Delta s = 0$	
T	h	u	$s°$	p_r	v_r	T	h	u	$s°$	p_r	v_r
[redacted]											
460	109.90	78.36	0.56235	0.7913	215.33	1080	260.97	186.93	0.76964	16.28	24.58
480	114.69	81.77	0.57255	0.9182	193.65	1120	271.03	194.25	0.77880	18.60	22.30
500	119.48	85.20	0.58233	1.0590	174.90	1160	281.14	201.63	0.78767	21.18	20.29
520	124.27	88.62	0.59172	1.2147	158.58	1200	291.30	209.05	0.79628	24.01	18.51
537	128.34	91.53	0.59945	1.3593	146.34	1240	301.52	216.53	0.80466	27.13	16.93
[redacted]											
640	153.09	109.21	0.64159	2.514	94.30	1480	363.89	262.44	0.85062	53.04	10.34
660	157.92	112.67	0.64902	2.801	87.27	1520	374.47	270.26	0.85767	58.78	9.578
680	162.73	116.12	0.65621	3.111	80.96	1560	385.08	278.13	0.86456	65.00	8.890
700	167.56	119.58	0.66321	3.446	75.25	1600	395.74	286.06	0.87130	71.73	8.263
720	172.39	123.04	0.67002	3.806	70.07	1650	409.13	296.03	0.87954	80.89	7.556
[redacted]											
840	201.56	143.98	0.70747	6.573	47.34	1950	490.88	357.20	0.92504	157.1	4.598
860	206.46	147.50	0.71323	7.149	44.57	2000	504.71	367.61	0.93205	174.0	4.258
880	211.35	151.02	0.71886	7.761	42.01	2050	518.61	378.08	0.93891	192.3	3.949
900	216.26	154.57	0.72438	8.411	39.64	2100	532.55	388.60	0.94564	212.1	3.667
920	221.18	158.12	0.72979	9.102	37.44	2150	546.54	399.17	0.95222	233.5	3.410

1. p_r and v_r data for use with Eqs. 6.41 and 6.42, respectively.

Table A-22E **(Continued)**

T(°R), h and u(Btu/lb), $s°$(Btu/lb · °R)

				when $\Delta s = 0$[1]						when $\Delta s = 0$	
T	h	u	$s°$	p_r	v_r	T	h	u	$s°$	p_r	v_r
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2450	631.48	463.54	0.98919	400.5	2.266	3950	1073.2	802.43	1.12955	3103	.4715
2500	645.78	474.40	0.99497	435.7	2.125	4000	1088.3	814.06	1.13334	3280	.4518
2550	660.12	485.31	1.00064	473.3	1.996	4050	1103.4	825.72	1.13709	3464	.4331
2600	674.49	496.26	1.00623	513.5	1.876	4100	1118.5	837.40	1.14079	3656	.4154
2650	688.90	507.25	1.01172	556.3	1.765	4150	1133.6	849.09	1.14446	3858	.3985
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2950	776.05	573.84	1.04288	876.4	1.247	4700	1300.9	978.73	1.18232	6701	.2598
3000	790.68	585.04	1.04779	941.4	1.180	4800	1331.5	1002.5	1.18876	7362	.2415
3050	805.34	596.28	1.05264	1011	1.118	4900	1362.2	1026.3	1.19508	8073	.2248
3100	820.03	607.53	1.05741	1083	1.060	5000	1392.9	1050.1	1.20129	8837	.2096
3150	834.75	618.82	1.06212	1161	1.006	5100	1423.6	1074.0	1.20738	9658	.1956
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
3450	923.52	687.04	1.08904	1719	0.7436						
3500	938.40	698.48	1.09332	1829	0.7087						
3550	953.30	709.95	1.09755	1946	0.6759						
3600	968.21	721.44	1.10172	2068	0.6449						
3650	983.15	732.95	1.10584	2196	0.6157						

7.

(a) Using appropriate thermodynamic relations, show that the following relationship (Clapeyron equation): $\left(\dfrac{dp}{dT}\right)_{sat} = \dfrac{h_g - h_f}{T(v_g - v_f)}$ is satisfied when a change in phase from saturated liquid to saturated vapor at fixed temperature occurs. (5%)

(b) If a substance, the saturation pressure-temperature curve is described by $\ln p_{sat} = A - B/T$, where A and B are constants. Show that $h_{fg} = \dfrac{p_{sat} v_{fg} B}{T}$, where $h_{fg} = h_g - h_f$ and $v_{fg} = v_g - v_f$. (5%)