(24)

THE INSTITUTION OF ENGINEERS, SRI LANKA

IESL ENGINEERING COURSE

PART I EXAMINATION – MARCH / APRIL 2006

105 THERMODYNAMICS

Answer any **FIVE (05) questions.** Time allowed : **Three (03) hrs**

- All questions carry equal marks.
- Tables of Thermodynamic & transport properties of fluids, and, R-134a tables are provided

Q1. (a) State the First law of thermodynamics.

(b) A piston -cylinder assembly initially having a volume of $0.01m^3$ receives saturated R-134a vapour at 16°C. The substance is compressed until its pressure and temperature reaches to 9bar and 60°C. During the compression process, the system loses 0.44kJ of heat to the surroundings.

(I) Show the compression process on a P-v diagram
(II) Calculate the compression work required

Q2. 0.01kg of an ideal gas occupies a volume of $0.002m^3$ at a pressure of 286.4kPa and temperature of 30°. Then this gas is allowed to expand until its volume becomes four times the initial volume. At this state, the pressure of the gas is measured as 101kPa. Show the process on a P-v diagram and determine;

(I) The molar mass of gas
(II) Final temperature of gas
(III) Change of entropy during the process (assuming C_p=1.005kJ/kgK)

Q3. (a) Write the Steady flow energy equation and apply it to an adiabatic nozzle. State any assumptions you make.

(b) Steam at 8bar and 200°C enters an insulated nozzle at a velocity of 50m/s and exits at a pressure of 1.5bar and 600m/s. Determine the quality of steam at nozzle outlet.

Q4. (a) State the Second law of thermodynamics for a heat engine and a heat pump.

(b) A Carnot heat pump delivers 72000kJ/h of heat to a house to maintain the interior at 23°C. On a day where the outside temperature drops to -3°C, determine;

(I) COP of the heat pump
(II) Power consumed by the compressor

(c) On a particular warm day, this machine is to be used to freeze food. If the freezer temperature is -3°C and the ambient air temperature is 23° determine the COP of the plant.

Q5. A steam power plant operates on Rankine cycle principle. The inlet conditions of the the turbine are 35bar and 300°C, while the condenser pressure is maintained at 0.1ba expansion process in the turbine is having an isentropic efficiency of 0.85. Show the cycle T-s diagram and determine;

(I) Feed pump work
(II) Energy supplied at boiler per kg of steam generation
(III) Dryness fraction of steam entering the condenser
(IV) Thermal efficiency of the cycle
(V) Mass flow rate of cooling water if it enters the condenser at 25°C and leaves at 50°C.

Q6. (a) State five important characteristics expected from a refrigerant.

(b) A cold room of a supermarket is served by a vapour compression refrigeration system. The evaporator operates at a pressure of 1.32bar and the condenser at a pressure of 8.83bar. The vapour leaving the evaporator is superheated by 10°C. The degree of subcool at the condenser outlet is 5°C. The compression process can be treated as ideal.

(I) Illustrate the cycle on a P-h diagram
(II) Using the R-134a tables provided, calculate;
  (i) Cooling capacity
  (ii) Compressor work
  (iii) Coefficient of performance (COP)

Q7. An air standard Otto cycle operates with a compression ratio of 8:1. The initial conditions for the cycle are 0.95bar and 17°C. At the beginning of the compression stroke, the cylinder volume is 2.20 litre, and 3.60kJ of energy is added as heat transfer during the constant volume heating process. Show the cycle on P-v diagram. Taking C_v=0.716kJ/kgK, determine;

(I) Pressure and temperature at the end of each process
(II) Cycle thermal efficiency
(III) Mean effective pressure (MEP)

Q8. An ideal Diesel cycle operates on 1kg of standard air with an initial pressure of 0.98bar and 35^0C. The pressure at the end of compression is 33bar, and, the cut-off is at 6% of the stroke after TDC. Show the cycle on P-v diagram. If γ = 1.4 and C_p=1.005kJ/kgK calculate;

(I) Pressure and temperature at all state points
(II) Heat supplied
(III) Thermal efficiency
(IV) Mean effective pressure

Table A-16 Properties of saturated refrigerant 134a (CF_4H_2): Temperature

(v, m³/kg; u, kJ/kg; h, kJ/kg; s, kJ/kg·K)

Temp., °C T	Press., bars P	Specific Volume		Internal Energy		Enthalpy			Ent	
		Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	S Vapor s_g
−40	0.5164	0.7055	0.3569	−0.04	204.45	0.00	222.88	222.88	0.0000	0.9560
−36	0.6332	0.7113	0.2947	4.68	206.73	4.73	220.67	225.40	0.0201	09506
−32	0.7704	0.7172	0.2451	9.47	209.01	9.52	218.37	227.90	0.0401	0.9456
−28	0.9305	0.7233	0.2052	14.31	211.29	14.37	216.01	230.38	0.0600	0.9411
−26	1.0199	0.7265	0.1882	16.75	212.43	16.82	214.80	231.62	0.0699	0.9390
−24	1.1160	0.7296	0.1728	19.21	213.57	19.29	213.57	232.85	0.0798	0.9370
−22	1.2192	0.7328	0.1590	21.68	214.70	21.77	212.32	234.08	0.0897	0.9351
−20	1.3299	0.7361	0.1464	24.17	215.84	24.26	211.05	235.31	0.0996	0.9332
−18	1.4483	0.7395	0.1350	26.67	216.97	26.77	209.76	236.53	0.1094	0.9315
−16	1.5748	0.7428	0.1247	29.18	218.10	29.30	208.45	237.74	0.1192	0.9298
−12	1.8540	0.7498	0.1068	34.25	220.36	34.39	205.77	240.15	0.1388	0.9267
−8	2.1704	0.7569	0.0919	39.38	222.60	39.54	203.00	242.54	0.1583	0.9239
−4	2.5274	0.7644	0.0794	44.56	224.84	44.75	200.15	244.90	0.1777	0.9213
0	2.9282	0.7721	0.0689	49.79	227.06	50.02	197.21	247.23	0.1970	0.9190
4	3.3765	0.7801	0.0600	55.08	229.27	55.35	194.19	249.53	0.2162	0.9169
8	3.8756	0.7884	0.0525	60.43	231.46	60.73	191.07	251.80	0.2354	0.9150
12	4.4294	0.7971	0.0460	65.83	233.63	66.18	187.85	254.03	0.2545	0.9132
16	5.0416	0.8062	0.0405	71.29	235.78	71.69	184.52	256.22	0.2735	0.9116
20	5.7160	0.8157	0.0358	76.80	237.91	77.26	181.09	258.36	0.2924	0.9102
24	6.4566	0.8257	0.0317	82.37	240.01	82.90	177.55	260.45	0.3113	0.9089
26	6.8530	0.8309	0.0298	85.18	241.05	85.75	175.73	261.48	0.3208	0.9082
28	7.2675	0.8362	0.0281	88.00	242.08	88.61	173.89	262.50	0.3302	0.9076
30	7.7006	0.8417	0.0265	90.84	243.10	91.49	172.00	263.50	0.3396	0.9070
32	8.1528	0.8473	0.0250	93.70	244.12	94.39	170.09	264.48	0.3490	0.9064
34	8.6247	0.8530	0.0236	96.58	245.12	97.31	168.14	265.45	0.3584	0.9058
36	9.1168	0.8590	0.0223	99.47	246.11	100.25	166.15	266.40	0.3678	0.9053
38	9.6298	0.8651	0.0210	102.38	247.09	103.21	164.12	267.33	0.3772	0.9047
40	10.164	0.8714	0.0199	105.30	248.06	106.19	162.05	268.24	0.3866	0.9041
42	10.720	0.8780	0.0188	108.25	249.02	109.19	159.04	269.14	0.3960	0.9035
44	11.299	0.8847	0.0177	111.22	249.96	112.22	157.79	270.01	0.4054	0.9030
48	12.526	0.8989	0.0159	117.22	251.79	118.35	153.33	271.68	0.4243	0.9017
52	13.851	0.9142	0.0142	123.31	253.55	124.58	148.66	273.24	0.4432	0.9004
56	15.278	0.9308	0.0127	129.51	255.23	130.93	143.75	274.68	0.4622	0.8990
60	16.813	0.9488	0.0114	135.82	256.81	137.42	138.57	275.99	0.4814	0.8973
70	21.162	1.0027	0.0086	152.22	260.15	154.34	124.08	278.43	0.5302	0.8918
80	26.324	1.0766	0.0064	169.88	262.14	172.71	106.41	279.12	0.5814	0.8827
90	32.435	1.1949	0.0046	189.82	261.34	193.69	82.63	276.32	0.6380	0.8655
100	39.742	1.5443	0.0027	218.60	248.49	224.74	34.40	259.13	0.7196	0.8117

Table A-18 Properties of superheated refrigerant 134a (CF_4H_2)

(T, °C; v, m³/kg; u, kJ/kg; h, kJ/kg; s, kJ/kg·K)

T	v	u	h	s	v	u	h	s
	0.6 bar (0.060 MPa) (T_{sat} = −37.07°C)				1.0 bar (0.10 MPa) (T_{sat} = −26.43°C)			
Sat.	0.31003	206.12	224.72	0.9520	0.19170	212.18	231.35	0.9395
−20	0.33536	217.86	237.98	1.0062	0.19770	216.77	236.54	0.9602
−10	0.34992	224.97	245.96	1.0371	0.20686	224.01	244.70	0.9918
0	0.36433	232.24	254.10	1.0675	0.21587	231.41	252.99	1.0227
10	0.37861	239.69	262.41	1.0973	0.22473	238.96	261.43	1.0531
20	0.39279	247.32	270.89	1.1267	0.23349	246.67	270.02	1.0829
30	0.40688	255.12	279.53	1.1557	0.24216	254.54	278.76	1.1122
40	0.42091	263.10	288.35	1.1844	0.25076	262.58	287.66	1.1411
50	0.43487	271.25	297.34	1.2126	0.25930	270.79	296.72	1.1696
60	0.44879	279.58	306.51	1.2405	0.26779	279.16	305.94	1.1977
70	0.46266	288.08	315.84	1.2681	0.27623	287.70	315.32	1.2254
80	0.47650	296.75	325.34	1.2954	0.28464	296.40	324.87	1.2528
90	0.49031					305.27	334.57	1.2799

PTO

properties of R134a

Saturation values							Superheat			
							10 K		20 K	
t_s	p_s	v_s	h_f	h_g	s_f	s_g	h	s	h	s
(°C)	(bar)	(m³/kg)	(kJ/kg)		(kJ/kg K)		(kJ/kg)	(kJ/kg K)	(kJ/kg)	(kJ/kg K)
−45	0.3908	0.458	42.67	268.49	0.7716	1.7613	276.73	1.7973	284.89	1.8288
−40	0.5188	0.356	48.94	271.40	0.7987	1.7528	279.77	1.7895	288.12	1.8231
−35	0.6612	0.279	55.22	274.30	0.8253	1.7452	283.02	1.7818	291.59	1.8156
−30	0.8436	0.222	61.52	277.21	0.8514	1.7385	286.23	1.7752	295.02	1.8092
−25	1.0638	0.178	67.83	280.12	0.8771	1.7325	289.44	1.7694	298.44	1.8036
−20	1.3271	0.145	74.18	283.03	0.9023	1.7273	292.62	1.7645	301.84	1.7989
−15	1.6389	0.118	80.56	285.94	0.9272	1.7228	295.81	1.7603	305.24	1.7948
−10	2.0051	0.098	86.98	288.86	0.9517	1.7189	299.00	1.7567	308.64	1.7914
−5	2.4371	0.081	93.46	291.77	0.9760	1.7155	302.18	1.7536	312.05	1.7884
0	2.9252	0.068	100.00	294.69	1.0000	1.7128	305.36	1.7511	315.44	1.7861
5	3.4920	0.058	106.61	297.60	1.0238	1.7105	308.55	1.7491	318.84	1.7842
10	4.1390	0.049	113.29	300.50	1.0475	1.7086	311.71	1.7475	322.23	1.7828
15	4.8734	0.042	120.06	303.38	1.0709	1.7071	314.86	1.7463	325.59	1.7817
20	5.7024	0.036	126.92	306.22	1.0943	1.7060	317.97	1.7454	328.93	1.7809
25	6.6337	0.031	133.89	309.03	1.1176	1.7051	321.08	1.7448	332.25	1.7804
30	7.6752	0.027	140.96	311.79	1.1408	1.7044	324.12	1.7444	335.52	1.7802
35	8.8351	0.023	148.15	314.47	1.1641	1.7038	327.11	1.7442	338.75	1.7801
40	10.1219	0.020	155.47	317.07	1.1873	1.7033	330.03	1.7440	341.91	1.7802
45	11.5447	0.017	162.93	319.54	1.2105	1.7028	332.87	1.7440	345.04	1.7804
55	14.8368	0.013	178.33	324.04	1.2572	1.7012	338.01	1.7432	350.74	1.7803
65	18.7960	0.010	194.53	327.62	1.3047	1.6983	342.73	1.7424	356.19	1.7805