INSTITUTION OF ENGINEERS SRI LANKA

ENGINEERING THERMODYNAMICS

2009 –MAY

Date : 05/05/2009 **Time : 3 Hours**

Answer any of Five Questions **All Questions Carry Equal Marks**

Q1.

A reversible air- standard cycle consists of 3 sequential non-flow processes as follows

1-2 Constant pressure heating

2-3 Constant Volume cooling

3-4 Adiabatic Compression

a) Sketch the cycle on p-v and T-s diagrams, in usual notations
b) Establish an expression for the cycle thermal efficiency, in terms of temperatures at states 1 and 3, that is T_1 and T_3 and the specific heat ratio of the gas γ.
c) Given that T_1 is 500K and $V_2=3V_1$, Calculate the cycle efficiency and the specific work output. (Assume that $\gamma = 1.4$ and specific heat capacity at constant pressure is 1.005 kJ/kg.K for the gas)

Q2.

An ideal diesel cycle using air as the working fluid has a volume compression ratio of 18:1 and a fuel cutoff ratio of 2:1. The intake conditions are 1 bar, 300K, and 0.1MPa.Using air standard assumptions, determine:

I. Draw P-v and T-s diagrams
II. The temperature and pressure at each state point
III. The cycle thermal efficiency

Q3.

An ideal air standard Otto cycle has a volume compression ratio of 8:1. At the beginning of the compression stroke the air is at 100 kPa and temperature 27^{0}C, and 1500kJ/kg of heat is added to the cycle during the constant-volume heat addition process. Considering the cold air standard assumptions determine, Take C_V=0.72kJ/Kg K and $\gamma = 1.4$

I. Pressure and temperature at all state points
II. The specific work output
III. The thermal efficiency of the cycle

Q4.

a) State the second law of thermodynamics?
b) An inventor claims to have developed a heat engine which receives 950 kJ of heat from a source at 400K and produces 300kJ of net work while rejecting the waste heat to sink at 293K. Is this claim reasonable?
c) An air conditioning system maintains the inside temperature of room at 20^{0}C when the outside temperature is 35^{0}C. If the air conditioning system draws 5kW of power for its operation, determine the maximum rate of heat removal that it can provide from the house.

Q5.

a) Write the steady flow energy equation.
b) Write four steady flow devices and states a key characteristic for each of such devices.
c) Fluid flows through a steady- open system at the rate of 3kg/s. At the system inlet, the pressure velocity and internal energy are 5 atm, 150 m/s and 2000 kJ/kg, respectively, and the specific volume is 0.4 m^3/kg. The fluid leaves the system with 1.2 atm, 80m/s, an internal energy of 1300 KJ/kg and specific volume of 1.1 m^3/ kg.The fluid losses 25 kJ/kg through heat transfer during the process, Determine the power output of the system, neglecting the change in potential energy

Q6.

a) Explain why it is desirable for a vapour entering the compressor of a refrigerator to be superheated

b) A refrigeration plant using refrigerant-134a works between saturation temperature limits of -40 ^{0}C and -30 ^{0}C.The refrigerant enters the throttle valve as an under cooled liquid at 25^{0}C and enters the compressor as a saturated vapour.

   I. Sketch the cycle on T-s and p-h diagrams.

   II. Assuming that the isentropic efficiency of the compressor is 0.85, calculate the coefficient of performance of the plant.

Q7.

A steam power plant is operates on the basis of a Rankine-cycle. The superheated steam enters the steam turbine at 60 bar and 500^{0}C. The power output is 25 MW. Condensation occurs at 2 bar.

During day-time operation the condenser waste heat is used for process heating in a nearby factory. During the night time the waste heat is utilized in a Rankine cycle which uses R-12 as the working fluid. This cycle operates at an upper saturation temperature of 80^{0}C with no superheat. Condensation of the cycle occurs at 10^{0}C.

Assume:

I. No heat losses
II. No Feed pump work
III. The turbines of both cycles have 100% isentropic efficiency

Calculate following and find out **the thermal efficiency** of power plant

a) The mass flow rate of steam power cycle

b) The condenser waste heat of steam power cycle.

c) Mass flow rate of R-12 power cycle

Q8.

a) State the first law of thermodynamics

b) 0.5 kg of N_2 gas T 100 kPa and 40^0C is contains in a cylinder. The piston is moved compressing N_2 until the pressure becomes 1 MPa and temperature becomes 160^0C.The work done during the process is 30 kJ. Calculate the heat transfer from the N_2 to the surrounding. Use C_V for N_2 to as 0.75kJ/kgK.

c) Air enters a compressor at 0.1 MPa and 25^0C having volume of $1.8m^3/kg$ and compressed to 0.5 MPa isothermally. Determine during the process:

I. Work done
II. Change in internal energy
III. Amount of heat transfer

TABLE A-22 Ideal Gas Properties of Air

T(K), h and u(kJ/kg), s°(kJ/kg·K)

T	h	p_r	u	v_r	s°	T	h	p_r	u	v_r	s°
200	199.97	0.3363	142.56	1707.	1.29559	450	451.80	5.775	322.62	223.6	[illegible]
210	209.97	0.3987	149.69	1512.	1.34444	460	462.02	6.245	329.97	211.4	2.134[illegible]
220	219.97	0.4690	156.82	1346.	1.39105	470	472.24	6.742	337.32	200.1	2.15604
230	230.02	0.5477	164.00	1205.	1.43557	480	482.49	7.268	344.70	189.5	2.17760
240	240.02	0.6355	171.13	1084.	1.47824	490	492.74	7.824	352.08	179.7	2.19876
250	250.05	0.7329	178.28	979.	1.51917	500	503.02	8.411	359.49	170.6	2.21952
260	260.09	0.8405	185.45	887.8	1.55848	510	513.32	9.031	366.92	162.1	2.23993
270	270.11	0.9590	192.60	808.0	1.59634	520	523.63	9.684	374.36	154.1	2.25997
280	280.13	1.0889	199.75	738.0	1.63279	530	533.98	10.37	381.84	146.7	2.27967
285	285.14	1.1584	203.33	706.1	1.65055	540	544.35	11.10	389.34	139.7	2.29906
290	290.16	1.2311	206.91	676.1	1.66802	550	554.74	11.86	396.86	133.1	2.31809
295	295.17	1.3068	210.49	647.9	1.68515	560	565.17	12.66	404.42	127.0	2.33685
300	300.19	1.3860	214.07	621.2	1.70203	570	575.59	13.50	411.97	121.2	2.35531
305	305.22	1.4686	217.67	596.0	1.71865	580	586.04	14.38	419.55	115.7	2.37348
310	310.24	1.5546	221.25	572.3	1.73498	590	596.52	15.31	427.15	110.6	2.39140
315	315.27	1.6442	224.85	549.8	1.75106	600	607.02	16.28	434.78	105.8	2.40902
320	320.29	1.7375	228.42	528.6	1.76690	610	617.53	17.30	442.42	101.2	2.42644
325	325.31	1.8345	232.02	508.4	1.78249	620	628.07	18.36	450.09	96.92	2.44356
330	330.34	1.9352	235.61	489.4	1.79783	630	638.63	19.84	457.78	92.84	2.46048
340	340.42	2.149	242.82	454.1	1.82790	640	649.22	20.64	465.50	88.99	2.47716
350	350.49	2.379	250.02	422.2	1.85708	650	659.84	21.86	473.25	85.34	2.49364
360	360.58	2.626	257.24	393.4	1.88543	660	670.47	23.13	481.01	81.89	2.50985
370	370.67	2.892	264.46	367.2	1.91313	670	681.14	24.46	488.81	78.61	2.52589
380	380.77	3.176	271.69	343.4	1.94001	680	691.82	25.85	496.62	75.50	2.54175
390	390.88	3.481	278.93	321.5	1.96633	690	702.52	27.29	504.45	72.56	2.55731
400	400.98	3.806	286.16	301.6	1.99194	700	713.27	28.80	512.33	69.76	2.57277
410	411.12	4.153	293.43	283.3	2.01699	710	724.04	30.38	520.23	67.07	2.58810
420	421.26	4.522	300.69	266.6	2.04142	720	734.82	32.02	528.14	64.53	2.60319
430	431.43	4.915	307.99	251.1	2.06533	730	745.62	33.72	536.07	62.13	2.61803
440	441.61	5.332	315.30	236.8	2.08870	740	756.44	35.50	544.02	59.82	2.63280

TABLE A-22 *(Continued)*

T(K), h and u(kJ/kg), $s°$(kJ/kg·K)

T	h	p_r	u	v_r	$s°$	T	h	p_r	u	v_r	$s°$
750	767.29	37.35	551.99	57.63	2.64737	1300	1395.97	330.9	1022.82	11.275	3.27345
760	778.18	39.27	560.01	55.54	2.66176	1320	1419.76	352.5	1040.88	10.747	3.29160
770	789.11	41.31	568.07	53.39	2.67595	1340	1443.60	375.3	1058.94	10.247	3.30959
780	800.03	43.35	576.12	51.64	2.69013	1360	1467.49	399.1	1077.10	9.780	3.32724
790	810.99	45.55	584.21	49.86	2.70400	1380	1491.44	424.2	1095.26	9.337	3.34474
800	821.95	47.75	592.30	48.08	2.71787	1400	1515.42	450.5	1113.52	8.919	3.36200
820	843.98	52.59	608.59	44.84	2.74504	1420	1539.44	478.0	1131.77	8.526	3.37901
840	866.08	57.60	624.95	41.85	2.77170	1440	1563.51	506.9	1150.13	8.153	3.39586
860	888.27	63.09	641.40	39.12	2.79783	1460	1587.63	537.1	1168.49	7.801	3.41247
880	910.56	68.98	657.95	36.61	2.82344	1480	1611.79	568.8	1186.95	7.468	3.42892
900	932.93	75.29	674.58	34.31	2.84856	1500	1635.97	601.9	1205.41	7.152	3.44516
920	955.38	82.05	691.28	32.18	2.87324	1520	1660.23	636.5	1223.87	6.854	3.46120
940	977.92	89.28	708.08	30.22	2.89748	1540	1684.51	672.8	1242.43	6.569	3.47712
960	1000.55	97.00	725.02	28.40	2.92128	1560	1708.82	710.5	1260.99	6.301	3.49276
980	1023.25	105.2	741.98	26.73	2.94468	1580	1733.17	750.0	1279.65	6.046	3.50829
1000	1046.04	114.0	758.94	25.17	2.96770	1600	1757.57	791.2	1298.30	5.804	3.52364
1020	1068.89	123.4	776.10	23.72	2.99034	1620	1782.00	834.1	1316.96	5.574	3.53879
1040	1091.85	133.3	793.36	22.39	3.01260	1640	1806.46	878.9	1335.72	5.355	3.55381
1060	1114.86	143.9	810.62	21.14	3.03449	1660	1830.96	925.6	1354.48	5.147	3.56867
1080	1137.89	155.2	827.88	19.98	3.05608	1680	1855.50	974.2	1373.24	4.949	3.58335
1100	1161.07	167.1	845.33	18.896	3.07732	1700	1880.1	1025	1392.7	4.761	3.5979
1120	1184.28	179.7	862.79	17.886	3.09825	1750	1941.6	1161	1439.8	4.328	3.6336
1140	1207.57	193.1	880.35	16.946	3.11883	1800	2003.3	1310	1487.2	3.944	3.6684
1160	1230.92	207.2	897.91	16.064	3.13916	1850	2065.3	1475	1534.9	3.601	3.7023
1180	1254.34	222.2	915.57	15.241	3.15916	1900	2127.4	1655	1582.6	3.295	3.7354
1200	1277.79	238.0	933.33	14.470	3.17888	1950	2189.7	1852	1630.6	3.022	3.7677
1220	1301.31	254.7	951.09	13.747	3.19834	2000	2252.1	2068	1678.7	2.776	3.7994
1240	1324.93	272.3	968.95	13.069	3.21751	2050	2314.6	2303	1726.8	2.555	3.8303
1260	1348.55	290.8	986.90	12.435	3.23638	2100	2377.4	2559	1775.3	2.356	3.8605
1280	1372.24	310.4	1004.76	11.835	3.25510	2150	2440.3	2837	1823.8	2.175	3.8901
						2200	2503.2	3138	1872.4	2.012	3.9191
						2250	2566.4	3464	1921.3	1.864	3.9474