ELIZADE UNIVERSITY, ILARA-MOKIN,
ONDO STATE, NIGERIA
DEPARTMENT OF MECHANICAL ENGINEERING

SECOND SEMESTER EXAMINATIONS

2017/2018 ACADEMIC SESSION

HOD'S SIGNATURE

COURSE: MEE302 – Thermodynamics

CLASS: 300 Level Mechanical & Automotive Engineering

TIME ALLOWED: 2 hours 30 minutes

INSTRUCTIONS: Attempt any four questions

Date: July/August, 2018

Question 1

(a) Which is higher between the back work ratio of gas turbine and steam turbine engines? Explain **(5 marks)**

(b) A gas-turbine power plant operating on an Ideal Brayton cycle has a pressure ratio, r_p, of 8. The gas temperature is 300 K at the compressor inlet and 1300 K at the turbine inlet. Utilizing the air-standard assumptions determine the gas temperature at the exits of (i) the compressor, (ii) the turbine (iii) the back work ratio, and (iv) the thermal efficiency **(10 marks)**

Question 2

(a) Explain briefly the methods by which increase in the efficiency of a Rankine cycle can be achieved. **(6 marks)**

(b) Consider a steam power plant operating on the simple ideal Rankine cycle. Steam enters the turbine at a 3 MPa and 350 $°C$ and is condensed in the condenser at a pressure of 75 kPa. Determine the

(i) thermal efficiency of this cycle.

(ii) back work ratio and

(iii)thermal efficiency of a Carnot cycle operating between the same limits **(9 marks)**

Question 3

(a) Why is the Reversed Carnot cycle executed within the saturation dome not a realistic model for refrigeration cycle? **(6 marks)**

(b) A refrigerator uses refrigerant-134a as the working fluid and operates on an ideal vapour-compression refrigeration cycle between 0.14 and 0.8 MPa. If the mass flow rate of the refrigerant is 0.05 kg/s, determine the

(i) rate of heat removal from the refrigerated space,

(ii) power input to the compressor,

(iii)rate of heat rejection to the environment, and the

(iv)COP of the refrigeration **(9 marks)**

Question 4

(a) Mention the **two critical factors** to be considered in refrigerant selection and any other **two factors** **(6 marks)**

(b) A room $5\ m \times 5\ m \times 3\ m$ room contains air at 25 °C and 100 kPa at a relative humidity of 75 percent. Take $c_p = 1.005\ kJ/kg$, $R_a = 0.287\ kPa.m^3/kg.K$, $R_v = 0.4615\ kPa.m^3/kg.K$ Determine the

(i) partial pressure of dry air

(ii) specific humidity

(iii)enthalpy per unit mass of the dry air

(iv)masses of the dry air and water vapour in the room **(9 marks)**

Question 5

(a) On a hot afternoon, the outer surface of a glass of iced-water "sweats". How can you explain this sweating? **(6 marks)**

(b) A simple ideal Brayton cycle with air as the working fluid has a pressure ratio of 10. The air enters the compressor at 295 K and the turbine at 1240 K. Accounting for the variation of specific heats with temperature, determine the

(i) air temperature at the compressor exit,

(ii) back work ratio, and

(iii)thermal efficiency. **(9 marks)**

Question 6

(a) List **four** other types of refrigeration systems other than the vapour-compression refrigeration and mention **two refrigerants** **(6 marks)**

(b) A gas-turbine power plant operating on an has a pressure ratio, r_p, of 8. The gas temperature is 300 K at the compressor inlet and 1300 K at the turbine inlet. Taking the compressor efficiency to be 80% and turbine efficiency to be 85% for the cycle, Determine the

(i) back work ratio

(ii) thermal efficiency

(iii)turbine exit temperature **(9 marks)**

SELECTED RELEVANT FORMULAS

1. $\frac{P_{r_2}}{P_{r_1}} = \frac{P_2}{P_1}$
2. $\eta_C = \frac{w_s}{w_a}$
3. $\eta_T = \frac{w_a}{w_s}$
4. $\eta_{th} = \frac{w_{net}}{q_{in}}$ or $\eta_{th} = 1 - \frac{q_{out}}{q_{in}}$
5. $(q_{in} - q_{out}) + (w_{in} - w_{out}) = h_e - h_i$
6. $w_{pump,in} = v(P_2 - P_1)$
7. $\dot{w} = \dot{m}(\Delta h)$
8. $\phi = \frac{P_v}{P_g}$
9. $\omega = \frac{0.622P_v}{P - P_v}$
10. $P = P_a + P_v$
11. $COP_R = \frac{Q_L}{W_{in}}$
12. $COP_{R,Carnot} = \frac{1}{(T_H/T_L)-1}$

TABLE A–17

Ideal-gas properties of air

T K	h kJ/kg	P_r	u kJ/kg	v_r	s° kJ/kg·K
290	290.16	1.2311	206.91	676.1	1.668802
295	295.17	1.3068	210.89	647.9	1.685115
298	298.18	1.3543	212.64	631.9	1.695028
300	300.19	1.3860	214.07	621.2	1.702703
305	305.22	1.4686	217.67	596.0	1.718665
310	310.24	1.5546	221.25	572.3	1.734598
315	315.27	1.6442	224.85	549.8	1.751036
320	320.29	1.7375	228.42	528.6	1.766690
325	325.31	1.8345	232.02	508.4	1.782149
330	330.34	1.9352	235.61	489.4	1.797783
340	340.42	2.149	242.82	454.1	1.827790
350	350.49	2.379	250.02	422.2	1.857708
360	360.58	2.626	257.24	393.4	1.888543
370	370.67	2.892	264.46	367.2	1.91313
380	380.77	3.176	271.69	343.4	1.940001
390	390.88	3.481	278.93	321.5	1.966133
400	400.98	3.806	286.16	301.6	1.991194
410	411.12	4.153	293.43	283.3	2.016699
420	421.26	4.522	300.69	266.6	2.041142
430	431.43	4.915	307.99	251.1	2.065533
440	441.61	5.332	315.30	236.8	2.088870
450	451.80	5.775	322.62	223.6	2.11161
460	462.02	6.245	329.97	211.4	2.13407
470	472.24	6.742	337.32	200.1	2.156604
480	482.49	7.268	344.70	189.5	2.17760
490	492.74	7.824	352.08	179.7	2.19876
500	503.02	8.411	359.49	170.6	2.21952
510	513.32	9.031	366.92	162.1	2.23993
520	523.63	9.684	374.36	154.1	2.25997
530	533.98	10.37	381.84	146.7	2.27967
540	544.35	11.10	389.34	139.7	2.29906
550	555.74	11.86	396.86	133.1	2.31809
560	565.17	12.66	404.42	127.0	2.33685
570	575.59	13.50	411.97	121.2	2.35531

T K	h kJ/kg	P_r	u kJ/kg	v_r	s° kJ/kg·K
680	691.82	25.85	496.62	75.50	2.541.75
690	702.52	27.29	504.45	72.56	2.55731
700	713.27	28.80	512.33	69.76	2.57277
710	724.04	30.38	520.23	67.07	2.588810
720	734.82	32.02	528.14	64.53	2.603719
730	745.62	33.72	536.07	62.13	2.618603
740	756.44	35.50	544.02	59.82	2.633280
750	767.29	37.35	551.99	57.63	2.647737
760	778.18	39.27	560.01	55.54	2.661.76
780	800.03	43.35	576.12	51.64	2.69013
800	821.95	47.75	592.30	48.08	2.717787
820	843.98	52.59	608.59	44.84	2.745504
840	866.08	57.60	624.95	41.85	2.771.70
860	888.27	63.09	641.40	39.12	2.797783
880	910.56	68.98	657.95	36.61	2.823344
900	932.93	75.29	674.58	34.31	2.848856
920	955.38	82.05	691.28	32.18	2.873214
940	977.92	89.28	708.08	30.22	2.897488
960	1000.55	97.00	725.02	28.40	2.921128
980	1023.25	105.2	741.98	26.73	2.946868
1000	1046.04	114.0	758.94	25.17	2.967.70
1020	1068.89	123.4	776.10	23.72	2.990234
1040	1091.85	133.3	793.36	23.29	3.012960
1060	1114.86	143.9	810.62	21.14	3.034489
1080	1137.89	155.2	827.88	19.98	3.056208
1100	1161.07	167.1	845.33	18.896	3.077732
1120	1184.28	179.7	862.79	17.886	3.098825
1140	1207.57	193.1	880.35	16.946	3.119883
1160	1230.92	207.2	897.91	16.064	3.13916
1180	1254.34	222.2	915.57	15.241	3.159916
1200	1277.79	238.0	933.33	14.470	3.179888
1220	1301.31	254.7	951.09	13.747	3.199834
1240	1324.93	272.3	968.95	13.069	3.219751

TABLE A–17

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298	298.18	1.3543	212.64	631.9	1.69528
300	300.19	1.3860	214.07	621.2	1.70203
305	305.22	1.4686	217.67	596.0	1.71865
310	310.24	1.5546	221.25	572.3	1.73498
315	315.27	1.6442	224.85	549.8	1.75106
320	320.29	1.7375	228.42	528.6	1.76690
325	325.31	1.8345	232.02	508.4	1.78249
330	330.34	1.9352	235.61	489.4	1.79783
340	340.42	2.149	242.82	454.1	1.82790
350	350.49	2.379	250.02	422.2	1.85708
360	360.58	2.626	257.24	393.4	1.88543
370	370.67	2.892	264.46	367.2	1.91313
380	380.77	3.176	271.69	343.4	1.94001
390	390.88	3.481	278.93	321.5	1.96633
400	400.98	3.806	286.16	301.6	1.99194
410	411.12	4.153	293.43	283.3	2.01699
420	421.26	4.522	300.69	266.6	2.04142
430	431.43	4.915	307.99	251.1	2.06533
440	441.61	5.332	315.30	236.8	2.08870
450	451.80	5.775	322.62	223.6	2.11161
460	462.02	6.245	329.97	211.4	2.13407
470	472.24	6.742	337.32	200.1	2.15604
480	482.49	7.268	344.70	189.5	2.17760
490	492.74	7.824	352.08	179.7	2.19876
500	503.02	8.411	359.49	170.6	2.21952
510	513.32	9.031	366.92	162.1	2.23993
520	523.63	9.684	374.36	154.1	2.25997
530	533.98	10.37	381.84	146.7	2.27967
540	544.35	11.10	389.34	139.7	2.29906
550	555.74	11.86	396.86	133.1	2.31809
560	565.17	12.66	404.42	127.0	2.33685
570	575.59	13.50	411.97	121.2	2.35531
680	691.82	25.85	496.62	75.50	2.54175
690	702.52	27.29	504.45	72.56	2.55731
700	713.27	28.80	512.33	69.76	2.57277
710	724.04	30.38	520.23	67.07	2.58810
720	734.82	32.02	528.14	64.53	2.60319
730	745.62	33.72	536.07	62.13	2.61803
740	756.44	35.50	544.02	59.82	2.63280
750	767.29	37.35	551.99	57.63	2.64737
760	778.18	39.27	560.01	55.54	2.66176
780	800.03	43.35	576.12	51.64	2.69013
800	821.95	47.75	592.30	48.08	2.71787
820	843.98	52.59	608.59	44.84	2.74504
840	866.08	57.60	624.95	41.85	2.77170
860	888.27	63.09	641.40	39.12	2.79783
880	910.56	68.98	657.95	36.61	2.82344
900	932.93	75.29	674.58	34.31	2.84856
920	955.38	82.05	691.28	32.18	2.87324
940	977.92	89.28	708.08	30.22	2.89748
960	1000.55	97.00	725.02	28.40	2.92128
980	1023.25	105.2	741.98	26.73	2.94468
1000	1046.04	114.0	758.94	25.17	2.96770
1020	1068.89	123.4	776.10	23.72	2.99034
1040	1091.85	133.3	793.36	23.29	3.01260
1060	1114.86	143.9	810.62	21.14	3.03449
1080	1137.89	155.2	827.88	19.98	3.05608
1100	1161.07	167.1	845.33	18.896	3.07732
1120	1184.28	179.7	862.79	17.886	3.09825
1140	1207.57	193.1	880.35	16.946	3.11883
1160	1230.92	207.2	897.91	16.064	3.13916
1180	1254.34	222.2	915.57	15.241	3.15916
1200	1277.79	238.0	933.33	14.470	3.17888
1220	1301.31	254.7	951.09	13.747	3.19834
1240	1324.93	272.3	968.95	13.069	3.21751

TABLE A–5

Saturated water—Pressure table

Press., P kPa	Sat. temp., T_{sat} °C	Specific volume, m³/kg: Sat. liquid, v_f	Specific volume, m³/kg: Sat. vapor, v_g	Internal energy, kJ/kg: Sat. liquid, u_f	Internal energy, kJ/kg: Evap., u_{fg}	Internal energy, kJ/kg: Sat. vapor, u_g	Enthalpy, kJ/kg: Sat. liquid, h_f	Enthalpy, kJ/kg: Evap., h_{fg}	Enthalpy, kJ/kg: Sat. vapor, h_g	Entropy, kJ/kg·K: Sat. liquid, s_f	Entropy, kJ/kg·K: Evap., s_{fg}	Entropy, kJ/kg·K: Sat. vapor, s_g
1.0	6.97	0.001000	129.19	29.302	2355.2	2384.5	29.303	2484.4	2513.7	0.1059	8.8690	8.9749
1.5	13.02	0.001001	87.964	54.686	2338.1	2392.8	54.688	2470.1	2524.7	0.1956	8.6314	8.8270
2.0	17.50	0.001001	66.990	73.431	2325.5	2398.9	73.433	2459.5	2532.9	0.2606	8.4621	8.7227
2.5	21.08	0.001002	54.242	88.422	2315.4	2403.8	88.424	2451.0	2539.4	0.3118	8.3302	8.6421
3.0	24.08	0.001003	45.654	100.98	2306.9	2407.9	100.98	2443.9	2544.8	0.3543	8.2222	8.5765
4.0	28.96	0.001004	34.791	121.39	2293.1	2414.5	121.39	2432.3	2553.7	0.4224	8.0510	8.4734
5.0	32.87	0.001005	28.185	137.75	2282.1	2419.8	137.75	2423.0	2560.7	0.4762	7.9176	8.3938
7.5	40.29	0.001008	19.233	168.74	2261.1	2429.8	168.75	2406.3	2574.0	0.5763	7.6738	8.2501
10	45.81	0.001010	14.670	191.79	2245.4	2437.2	191.81	2392.1	2583.9	0.6492	7.4996	8.1488
15	53.97	0.001014	10.020	225.93	2222.1	2448.0	225.94	2372.3	2598.3	0.7549	7.2522	8.0071
20	60.06	0.001017	7.6481	251.40	2204.6	2456.0	251.42	2357.5	2608.9	0.8320	7.0752	7.9073
25	64.96	0.001020	6.2034	271.93	2190.4	2462.4	271.96	2345.5	2617.5	0.8932	6.9370	7.8302
30	69.09	0.001022	5.2287	289.24	2178.5	2467.7	289.27	2335.3	2624.6	0.9441	6.8234	7.7675
40	75.86	0.001026	3.9933	317.58	2158.8	2476.3	317.62	2318.4	2636.1	1.0261	6.6430	7.6691
50	81.32	0.001030	3.2403	340.49	2142.7	2483.2	340.54	2304.7	2645.2	1.0912	6.5019	7.5931
75	91.76	0.001037	2.2172	384.36	2111.8	2496.1	384.44	2278.0	2662.4	1.2132	6.2426	7.4558
100	99.61	0.001043	1.6941	417.40	2088.2	2505.6	417.51	2257.5	2675.0	1.3028	6.0562	7.3589
101.325	99.97	0.001043	1.6734	418.95	2087.0	2506.0	419.06	2256.5	2675.6	1.3069	6.0476	7.3545
125	105.97	0.001048	1.3750	444.23	2068.8	2513.0	444.36	2240.6	2684.9	1.3741	5.9100	7.2841
150	111.35	0.001053	1.1594	466.97	2052.3	2519.2	467.13	2226.0	2693.1	1.4337	5.7894	7.2231
175	116.04	0.001057	1.0037	486.82	2037.7	2524.5	487.01	2213.1	2700.2	1.4850	5.6865	7.1716
200	120.21	0.001061	0.88578	504.50	2024.6	2529.1	504.71	2201.6	2706.3	1.5302	5.5968	7.1270
225	123.97	0.001064	0.79329	520.47	2012.7	2533.2	520.71	2191.0	2711.7	1.5706	5.5171	7.0877
250	127.41	0.001067	0.71873	535.08	2001.8	2536.8	535.35	2181.2	2716.5	1.6072	5.4453	7.0525
275	130.58	0.001070	0.65732	548.57	1991.6	2540.1	548.86	2172.0	2720.9	1.6408	5.3800	7.0207
300	133.52	0.001073	0.60582	561.11	1982.1	2543.2	561.43	2163.5	2724.9	1.6717	5.3200	6.9917
325	136.27	0.001076	0.56199	572.84	1973.1	2545.9	573.19	2155.4	2728.6	1.7005	5.2645	6.9650
350	138.86	0.001079	0.52422	583.89	1964.6	2548.5	584.26	2147.7	2732.0	1.7274	5.2128	6.9402
375	141.30	0.001081	0.49133	594.32	1956.6	2550.9	594.73	2140.4	2735.1	1.7526	5.1645	6.9171
400	143.61	0.001084	0.46242	604.22	1948.9	2553.1	604.66	2133.4	2738.1	1.7765	5.1191	6.8955

TABLE A–6

Superheated water (*Concluded*)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg-K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg-K
	P = 2.50 MPa (223.95°C)				P = 3.00 MPa (233.85°C)			
Sat.	0.07995	2602.1	2801.9	6.2558	0.06667	2603.2	2803.2	6.1856
225	0.08026	2604.8	2805.5	6.2629				
250	0.08705	2663.3	2880.9	6.4107	0.07063	2644.7	2856.5	6.2893
300	0.09894	2762.2	3009.6	6.6459	0.08118	2750.8	2994.3	6.5412
350	0.10979	2852.5	3127.0	6.8424	0.09056	2844.4	3116.1	6.7450
400	0.12012	2939.8	3240.1	7.0170	0.09938	2933.6	3231.7	6.9235
450	0.13015	3026.2	3351.6	7.1768	0.10789	3021.2	3344.9	7.0856
500	0.13999	3112.8	3462.8	7.3254	0.11620	3108.6	3457.2	7.2359
600	0.15931	3288.5	3686.8	7.5979	0.13245	3285.5	3682.8	7.5103
700	0.17835	3469.3	3915.2	7.8455	0.14841	3467.0	3912.2	7.7590
800	0.19722	3656.2	4149.2	8.0744	0.16420	3654.3	4146.9	7.9885
900	0.21597	3849.4	4389.3	8.2882	0.17988	3847.9	4387.5	8.2028
1000	0.23466	4049.0	4635.6	8.4897	0.19549	4047.7	4634.2	8.4045
1100	0.25330	4254.7	4887.9	8.6804	0.21105	4253.6	4886.7	8.5955
1200	0.27190	4466.3	5146.0	8.8618	0.22658	4465.3	5145.1	8.7771
1300	0.29048	4683.4	5409.5	9.0349	0.24207	4682.6	5408.8	8.9502

Saturated refrigerant-134a—Pressure table

Press., P kPa	Sat. temp., T_{sat} °C	Specific volume, m³/kg: Sat. liquid, v_f	Specific volume, m³/kg: Sat. vapor, v_g	Internal energy, kJ/kg: Sat. liquid, u_f	Internal energy, kJ/kg: Evap., u_{fg}	Internal energy, kJ/kg: Sat. vapor, u_g	Enthalpy, kJ/kg: Sat. liquid, h_f	Enthalpy, kJ/kg: Evap., h_{fg}	Enthalpy, kJ/kg: Sat. vapor, h_g	Entropy, kJ/kg·K: Sat. liquid, s_f	Entropy, kJ/kg·K: Evap., s_{fg}	Entropy, kJ/kg·K: Sat. vapor, s_g
120	−22.32	0.0007324	0.16212	22.40	195.11	217.51	22.49	214.48	236.97	0.09275	0.85503	0.94779
140	−18.77	0.0007383	0.14014	26.98	192.57	219.54	27.08	212.08	239.16	0.11087	0.83368	0.94456
160	−15.60	0.0007437	0.12348	31.09	190.27	221.35	31.21	209.90	241.11	0.12693	0.81496	0.94190
180	−12.73	0.0007487	0.11041	34.83	188.16	222.99	34.97	207.90	242.86	0.14139	0.79826	0.93965
200	−10.09	0.0007533	0.099867	38.28	186.21	224.48	38.43	206.03	244.46	0.15457	0.78316	0.93773
700	26.69	0.0008331	0.029361	88.24	156.24	244.48	88.82	176.21	265.03	0.33230	0.58763	0.91994
750	29.06	0.0008395	0.027371	91.59	154.08	245.67	92.22	173.98	266.20	0.34345	0.57567	0.91912
800	31.31	0.0008458	0.025621	94.79	152.00	246.79	95.47	171.82	267.29	0.35404	0.56431	0.91835
850	33.45	0.0008520	0.024069	97.87	149.98	247.85	98.60	169.71	268.31	0.36413	0.55349	0.91762
900	35.51	0.0008580	0.022683	100.83	148.01	248.85	101.61	167.66	269.26	0.37377	0.54315	0.91692
950	37.48	0.0008641	0.021438	103.69	146.10	249.79	104.51	165.64	270.15	0.38301	0.53323	0.91624

Superheated refrigerant-134a (*Continued*)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K
	P = 0.80 MPa (T_{sat} = 31.31°C)				P = 0.90 MPa (T_{sat} = 35.51°C)				P = 1.00 MPa (T_{sat} = 39.37°C)			
Sat.	0.025621	246.79	267.29	0.9183	0.022683	248.85	269.26	0.9169	0.020313	250.68	270.99	0.9156
40	0.027035	254.82	276.45	0.9480	0.023375	253.13	274.17	0.9327	0.020406	251.30	271.71	0.9179
50	0.028547	263.86	286.69	0.9802	0.024809	262.44	284.77	0.9660	0.021796	260.94	282.74	0.9525
60	0.029973	272.83	296.81	1.0110	0.026146	271.60	295.13	0.9976	0.023068	270.32	293.38	0.9850

Saturated water—Temperature table

Temp., T °C	Sat. press., P_{sat} kPa	Specific volume, m³/kg: Sat. liquid, v_f	Specific volume, m³/kg: Sat. vapor, v_g	Internal energy, kJ/kg: Sat. liquid, u_f	Internal energy, kJ/kg: Evap., u_{fg}	Internal energy, kJ/kg: Sat. vapor, u_g	Enthalpy, kJ/kg: Sat. liquid, h_f	Enthalpy, kJ/kg: Evap., h_{fg}	Enthalpy, kJ/kg: Sat. vapor, h_g	Entropy, kJ/kg·K: Sat. liquid, s_f	Entropy, kJ/kg·K: Evap., s_{fg}	Entropy, kJ/kg·K: Sat. vapor, s_g
0.01	0.6117	0.001000	206.00	0.000	2374.9	2374.9	0.001	2500.9	2500.9	0.0000	9.1556	9.1556
5	0.8725	0.001000	147.03	21.019	2360.8	2381.8	21.020	2489.1	2510.1	0.0763	8.9487	9.0249
10	1.2281	0.001000	106.32	42.020	2346.6	2388.7	42.022	2477.2	2519.2	0.1511	8.7488	8.8999
15	1.7057	0.001001	77.885	62.980	2332.5	2395.5	62.982	2465.4	2528.3	0.2245	8.5559	8.7803
20	2.3392	0.001002	57.762	83.913	2318.4	2402.3	83.915	2453.5	2537.4	0.2965	8.3696	8.6661
25	3.1698	0.001003	43.340	104.83	2304.3	2409.1	104.83	2441.7	2546.5	0.3672	8.1895	8.5567
30	4.2469	0.001004	32.879	125.73	2290.2	2415.9	125.74	2429.8	2555.6	0.4368	8.0152	8.4520