00146

The Open University of Sri Lanka
Faculty of Engineering Technology

Study Programme	:	Bachelor of Technology Honours in Engineering
Name of the Examination	:	Final Examination
Course Code and Title	**:**	**MEX3235 Thermo-Fluids**
Academic Year	:	2015/16
Date	:	19th November 2016
Time	:	13.30 hrs. - 16.30 hrs.
Duration	:	Three(3) hours

General instructions:

(i) Read all instructions carefully before answering the questions.
(ii) This question paper consists of five pages.
(iii) Answer any **five questions** selecting **at least two questions** from each **Section A and Section B.** All questions carry equal marks.
(iv) Required Tables of Thermodynamic and transport properties of Fluids are available on Page 4 and 5 of this question paper.
(v) You may use the following data wherever necessary.
Universal Gas constant R_0 = 8.314 kJ/kmol K
Data for Air as ideal gas:
C_p =1.005 kJ /kg.K, Cv = 0.718 kJ /kg.K , R = 0.287 kJ /kg.K , γ = 1.4

Section A

Q1. (a) State the first law of Thermodynamics.

(b) The internal energy of a certain substance is given by the following equation; $\boldsymbol{u = 3.56pv + 84}$ where *u* is given in *kJ/kg*, *p* is in *kPa* and *v* is in *m³/kg*.
A system composed of *3 kg* of this substance expands from an initial pressure of *500 kPa* and a volume of *0.22 m³* to a final pressure *100 kPa* in a process in which pressure and volume are related by $pv^{1.2}$ = constant.

(i) If the expansion is quasi-static, find heat transferred *(Q)*, internal energy change*(ΔU)*, and workdone *(W)* for the process.
(ii) In another process the same system expands according to the same pressure-volume relationship as in part (i), but the heat transfer in this case is 30 kJ. Find the work transfer for this process.
(iii) Explain the difference in work transfer in parts (i) and (ii).

Q2. (a) The cycle efficiency of an air standard Dual Cycle (η_{Dual}) is given by the following formula with usual notations;

$$\eta_{Dual} = 1 - \left(\frac{1}{r_k^{\gamma-1}}\right)\left\{\frac{r_p . r_c^{\gamma} - 1}{r_p - 1 + \gamma r_p\,(r_c - 1)}\right\}$$

Identify each term in the formula.

(b) An air standard dual cycle has a compression ratio of *16*, and compression begins at *1* bar, *50⁰C*. The maximum pressure is *70* bar. The heat transferred to air at constant pressure is equal to that at constant volume. Estimate the following.

(i) pressures and temperatures at the cardinal points of the cycle.
(ii) cycle efficiency, and
(iii) mean effective pressure of the cycle.

Q3. (a) Write the steady flow energy equation for open system flow process.

(b) Air flows steadily at the rate of *0.5 kg/s* through an air compressor, entering at *7 m/s* velocity, *100 kPa* pressure, and *0.95* m^3/kg volume, and leaving at *5 m/s*, *700 kPa*, and *0.19* m^3/kg. The internal energy of the air leaving is *90 kJ/kg* greater than that of the air entering. Cooling water in the compressor jackets absorbs heat from the air at the rate of *58 kW*.

(i) Compute the rate of shaft work input to the air in kW, and

(ii) Find the ratio of the inlet pipe diameter to outlet pipe diameter.

Q4. Steam at *0.8 MPa*, *250⁰C* and flowing at the rate of *1 kg/s* passes into a pipeline carrying wet steam at *0.8 MPa*, *0.95* dry. After adiabatic mixing the flow rate is *2.3 kg/s*. Determine the condition of steam after mixing.

The mixture is now expanded in a frictionless nozzle isentropically to a pressure of *0.4 MPa*. Determine the velocity of the steam leaving the nozzle. Neglect the velocity of steam in the pipeline.

Section B

Q5. (a) Define total force and centre of pressure of an inclined plane immersed in a fluid.

(b) Fig.Q5 shows a circular opening in the sloping wall of a reservoir closed by disc valve *0.9 m* diameter. The disc is hinged at H and a balancing weight W is just sufficient to hold the valve closed when the reservoir is empty. How much additional weight should be placed on the arm, *1.2 m* from the hinge in order that the valve shall remain closed until the water level is *0.72 m* above the center of the valve?

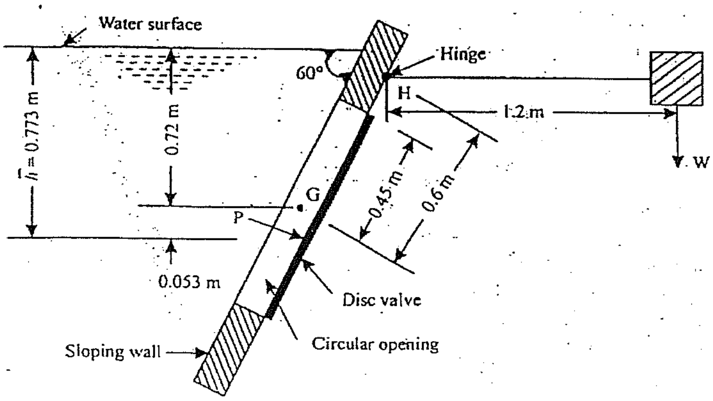

Fig.Q5

Q6. (a) Write down the Bernoulli's Equation for an ideal incompressible fluid flow and state the assumptions made in the derivation of the equation.

(b) A closed tank of a fire-engine is partly filled with water, the air space above being under pressure. A hose pipe of *6 cm* diameter connected to the tank discharges water in the tank on to a roof of a building *2.5 m* above the level of water. The friction losses are *45 cm* of water.
Determine the air pressure which must be maintained in the tank to deliver *20 litres/sec* on to the roof.

Q7. (a) Write down the major and minor energy (head) losses in a flow through pipes.

(b) A pipe of diameter *225 mm* is attached to a *150 mm* diameter pipe by means of a flange in such a manner that the axes of the two pipes are in a straight line. Water flows through the arrangement at the rate of $0.05\ m^3/s$. The pressure loss at the transition as indicated by differential gauge length on a water –mercury manometer connected between two pipes equals *35 mm*.
Calculate;
(i) loss of head due to contraction, and
(ii) co-efficient of contraction.

Q8. (a) Derive an expression for the volumetric flow rate of a fluid flowing through an orifice meter. Write down the advantages and disadvantages of using an orifice meter over a venturimeter.

(b) Water is flowing through a pipeline of *50 cm* diameter at 30^0C. An orifice is placed in the pipeline to measure the flow rate. Orifice diameter is *20 cm*. If the manometer reads *30 cm* of Hg, calculate the water flow rate and the velocity of the fluid through the pipe. (ρ_{water} at 30^0C = 987 kg/m^3, ρ_{Hg} = 13600 kg/m^3.)

Saturated Water and Steam

p [bar]	t_s [°C]	v_g [m³/kg]	u_f [kJ/kg]	u_g	h_f [kJ/kg]	h_{fg}	h_g	s_f [kJ/kg K]	s_{fg}	s_g
1.0	99.6	1.694	417	2506	417	2258	2675	1.303	6.056	7.359
1.1	102.3	1.549	429	2510	429	2251	2680	1.333	5.994	7.327
1.2	104.8	1.428	439	2512	439	2244	2683	1.361	5.937	7.298
1.3	107.1	1.325	449	2515	449	2238	2687	1.387	5.884	7.271
1.4	109.3	1.236	458	2517	458	2232	2690	1.411	5.835	7.246
1.5	111.4	1.159	467	2519	467	2226	2693	1.434	5.789	7.223
1.6	113.3	1.091	475	2521	475	2221	2696	1.455	5.747	7.202
1.7	115.2	1.031	483	2524	483	2216	2699	1.475	5.707	7.182
1.8	116.9	0.9774	491	2526	491	2211	2702	1.494	5.669	7.163
1.9	118.6	0.9292	498	2528	498	2206	2704	1.513	5.632	7.145
2.0	120.2	0.8856	505	2530	505	2202	2707	1.530	5.597	7.127
2.1	121.8	0.8461	511	2531	511	2198	2709	1.547	5.564	7.111
2.2	123.3	0.8100	518	2533	518	2193	2711	1.563	5.533	7.096
2.3	124.7	0.7770	524	2534	524	2189	2713	1.578	5.503	7.081
2.4	126.1	0.7466	530	2536	530	2185	2715	1.593	5.474	7.067
2.5	127.4	0.7186	535	2537	535	2182	2717	1.607	5.446	7.053
2.6	128.7	0.6927	541	2539	541	2178	2719	1.621	5.419	7.040
2.7	130.0	0.6686	546	2540	546	2174	2720	1.634	5.393	7.027
2.8	131.2	0.6462	551	2541	551	2171	2722	1.647	5.368	7.015
2.9	132.4	0.6253	556	2543	556	2168	2724	1.660	5.344	7.004
3.0	133.5	0.6057	561	2544	561	2164	2725	1.672	5.321	6.993
3.5	138.9	0.5241	584	2549	584	2148	2732	1.727	5.214	6.941
4.0	143.6	0.4623	605	2554	605	2134	2739	1.776	5.121	6.897
4.5	147.9	0.4139	623	2558	623	2121	2744	1.820	5.037	6.857
5.0	151.8	0.3748	639	2562	640	2109	2749	1.860	4.962	6.822
5.5	155.5	0.3427	655	2565	656	2097	2753	1.897	4.893	6.790
6	158.8	0.3156	669	2568	670	2087	2757	1.931	4.830	6.761
7	165.0	0.2728	696	2573	697	2067	2764	1.992	4.717	6.709
8	170.4	0.2403	720	2577	721	2048	2769	2.046	4.617	6.663
9	175.4	0.2149	742	2581	743	2031	2774	2.094	4.529	[illegible]
10	179.9	0.1944	762	2584	763	2015	2778	2.138	4.448	6.586
11	184.1	0.1774	780	2586	781	2000	2781	2.179	4.375	6.554
12	188.0	0.1632	797	2588	798	1986	2784	2.216	4.307	6.523
13	191.6	0.1512	813	2590	815	1972	2787	2.251	4.244	6.495
14	195.0	0.1408	828	2593	830	1960	2790	2.284	4.185	6.469
15	198.3	0.1317	843	2595	845	1947	2792	2.315	4.130	6.445
16	201.4	0.1237	857	2596	859	1935	2794	2.344	4.078	6.422
17	204.3	0.1167	870	2597	872	1923	2795	2.372	4.028	6.400
18	207.1	0.1104	883	2598	885	1912	2797	2.398	3.981	6.379
19	209.8	0.1047	895	2599	897	1901	2798	2.423	3.936	6.359
20	212.4	0.09957	907	2600	909	1890	2799	2.447	3.893	6.340
22	217.2	0.09069	928	2601	931	1870	2801	2.492	3.813	6.305
24	221.8	0.08323	949	2602	952	1850	2802	2.534	3.738	6.272
26	226.0	0.07689	969	2603	972	1831	2803	2.574	3.668	6.242
28	230.0	0.07142	988	2603	991	1812	2803	2.611	3.602	6.213
30	233.8	0.06665	1004	2603	1008	1795	2803	2.645	3.541	6.186
32	237.4	0.06246	1021	2603	1025	1778	2803	2.679	3.482	6.161
34	240.9	0.05875	1038	2603	1042	1761	2803	2.710	3.426	6.136
36	244.2	0.05544	1054	2602	1058	1744	2802	2.740	3.373	6.113
38	247.3	0.05246	1068	2602	1073	1729	2802	2.769	3.322	6.091
40	250.3	0.04977	1082	2602	1087	1714	2801	2.797	3.273	6.070

Superheated Steam

p/[bar] (t_s/[°C])			t/[°C]	200	250	300	350	400	450	500	600
5 (151.8)	v_g	0.3748	v	0.4252	0.4745	0.5226	0.5701	0.6172	0.6641	0.7108	0.8040
	u_g	2562	u	2644	2725	2804	2883	2963	3045	3129	3300
	h_g	2749	h	2857	2962	3065	3168	3272	3377	3484	3702
	s_g	6.822	s	7.060	7.271	7.460	7.633	7.793	7.944	8.087	8.351
6 (158.8)	v_g	0.3156	v	0.3522	0.3940	0.4344	0.4743	0.5136	0.5528	0.5919	0.6697
	u_g	2568	u	2640	2722	2801	2881	2962	3044	3128	3299
	h_g	2757	h	2851	2958	3062	3166	3270	3376	3483	3701
	s_g	6.761	s	6.968	7.182	7.373	7.546	7.707	7.858	8.001	8.267
7 (165.0)	v_g	0.2728	v	0.3001	0.3364	0.3714	0.4058	0.4397	0.4734	0.5069	0.5737
	u_g	2573	u	2636	2720	2800	2880	2961	3043	3127	3298
	h_g	2764	h	2846	2955	3060	3164	3269	3374	3482	3700
	s_g	6.709	s	6.888	7.106	7.298	7.473	7.634	7.786	7.929	8.195
8 (170.4)	v_g	0.2403	v	0.2610	0.2933	0.3242	0.3544	0.3842	0.4138	0.4432	0.5018
	u_g	2577	u	2631	2716	2798	2878	2960	3042	3126	3298
	h_g	2769	h	2840	2951	3057	3162	3267	3373	3481	3699
	s_g	6.663	s	6.817	7.040	7.233	7.409	7.571	7.723	7.866	8.132
9 (175.4)	v_g	0.2149	v	0.2305	0.2597	0.2874	0.3144	0.3410	0.3674	0.3937	0.4458
	u_g	2581	u	2628	2714	2796	2877	2959	3041	3126	3298
	h_g	2774	h	2835	2948	3055	3160	3266	3372	3480	3699
	s_g	6.623	s	6.753	6.980	7.176	7.352	7.515	7.667	7.811	8.077
10 (179.9)	v_g	0.1944	v	0.2061	0.2328	0.2580	0.2825	0.3065	0.3303	0.3540	0.4010
	u_g	2584	u	2623	2711	2794	2875	2957	3040	3124	3297
	h_g	2778	h	2829	2944	3052	3158	3264	3370	3478	3698
	s_g	6.586	s	6.695	6.926	7.124	7.301	7.464	7.617	7.761	8.028
15 (198.3)	v_g	0.1317	v	0.1324	0.1520	0.1697	0.1865	0.2029	0.2191	0.2351	0.2667
	u_g	2595	u	2597	2697	2784	2868	2952	3035	3120	3294
	h_g	2792	h	2796	2925	3039	3148	3256	3364	3473	3694
	s_g	6.445	s	6.452	6.711	6.919	7.102	7.268	7.423	7.569	7.838
20 (212.4)	v_g	0.0996	v		0.1115	0.1255	0.1386	0.1511	0.1634	0.1756	0.1995
	u_g	2600	u		2681	2774	2861	2946	3030	3116	3291
	h_g	2799	h		2904	3025	3138	3248	3357	3467	3690
	s_g	6.340	s		6.547	6.768	6.957	7.126	7.283	7.431	7.701
30 (233.8)	v_g	0.0666	v		0.0706	0.0812	0.0905	0.0993	0.1078	0.1161	0.1324
	u_g	2603	u		2646	2751	2845	2933	3020	3108	3285
	h_g	2803	h		2858	2995	3117	3231	3343	3456	3682
	s_g	6.186	s		6.289	6.541	6.744	6.921	7.082	7.233	7.507
40 (250.3)	v_g	0.0498	v			0.0588	0.0664	0.0733	0.0800	0.0864	0.0988
	u_g	2602	u			2728	2828	2921	3010	3099	3279
	h_g	2801	h			2963	3094	3214	3330	3445	3674
	s_g	6.070	s			6.364	6.584	6.769	6.935	7.089	7.368
50 (263.9)	v_g	0.0394	v			0.0453	0.0519	0.0578	0.0632	0.0685	0.0786
	u_g	2597	u			2700	2810	2907	3000	3090	3273
	h_g	2794	h			2927	3070	3196	3316	3433	3666
	s_g	5.973	s			6.212	6.451	6.646	6.818	6.975	7.258
60 (275.6)	v_g	0.0324	v			0.0362	0.0422	0.0473	0.0521	0.0566	0.0652
	u_g	2590	u			2670	2792	2893	2988	3081	3266
	h_g	2784	h			2887	3045	3177	3301	3421	3657
	s_g	5.890	s			6.071	6.336	6.541	6.719	6.879	7.166
70 (285.8)	v_g	0.0274	v			0.0295	0.0352	0.0399	0.0441	0.0481	0.0556
	u_g	2581	u			2634	2772	2879	2978	3073	3260
	h_g	2772	h			2841	3018	3158	3287	3410	3649
	s_g	5.814	s			5.934	6.231	6.448	6.632	6.796	7.088