00251

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	:	2016/17
Date	:	24th November 2017
Time	:	14.00 hrs. - 17.00 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 a total of **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 Pages 5, 6 and 7 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, C_v = 0.718 kJ /kg.K , R = 0.287 kJ /kg.K , γ = 1.4

Section A

Q1. (a) Show from the first principles that, for a perfect gas with constant specific heat capacities expanding polytropically (i.e. according to the law pv^n = constant) in a non-flow process, the change of entropy can be expressed with usual notation, by the following equation.

$$s_2 - s_1 = \frac{n-\gamma}{\gamma-1}\frac{R}{n} \ln\frac{p_2}{p_1}$$

(b) Gaseous methane is compressed polytropically by a piston from 25°C and 0.80 bar to a pressure of 5.0 bar. Assuming an index of compression of 1.2, calculate the change of entropy and work done, per unit mass of the gas. The relative molecular mass of methane is 16 and $\gamma = 1.30$.

Q2. (a) Sketch the ***P***(pressure)-***V***(volume) and ***T***(Temperature)-***S***(entropy) diagrams of an air standard diesel cycle and explain the processes.

(b) In an air standard Diesel cycle, the compression ratio is 16, and at the beginning of isentropic compression, the temperature is 15°C and the pressure is 0.1MPa. Heat is added until the temperature at the end of the constant pressure process is 1480°C. Calculate the following.

(i) Cut off ratio,

(ii) Heat supplied per kg of air,
(iii) 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 at a temperature of 15°C passes through a heat exchanger at a velocity of 30 m/s where its temperature is raised to 800°C. It then enters a turbine with the same velocity of 30 m/s and expands until the temperature falls to 650°C. On leaving the turbine, the air is taken at a velocity of 60 m/s to a nozzle where it expands until the temperature falls to 500°C. If the air flow rate is 2 kg/s, calculate the following.

(i) Rate of heat transfer to the air in the heat exchanger,

(ii) Power output from the turbine assuming no heat loss, and

(iii) Velocity at exit from the nozzle, assuming no heat loss.

Take the enthalpy of air as $h = c_p t$, where c_p is the specific heat equal to 1.005kJ/kg K and t is the temperature.

Q4. Steam at 20 bar, 360°C is expanded in a steam turbine to 0.08 bar. It then enters a condenser, where it is condensed to saturated liquid water. A pump feeds back the water into the boiler.

(a) Assuming ideal processes, find per kg of steam the net work and the cycle efficiency.
(b) If the turbine and the pump have 80% efficiency, find the percentage reduction in the net work and cycle efficiency.

Section B

Q5. (a) Define total force and centre of pressure of an inclined plane immersed in a fluid.
(b) A 3.6 m square gate provided in an oil tank is hinged at its top edge as shown in Fig.Q5. The tank contains gasoline (specific gravity = 0.7) up to a height of 1.8 m above the top edge of the gate. The space above the oil is subjected to a negative pressure of 8250 N/m^2. Determine the necessary vertical pull F to be applied at the lower edge to open the gate.

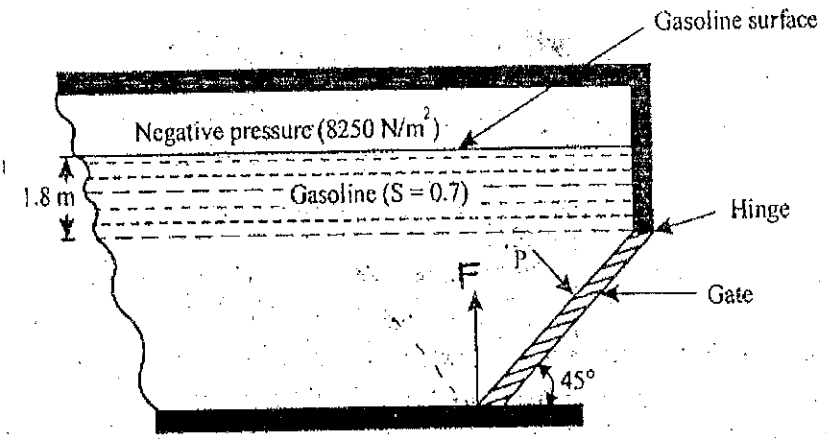


Fig.Q5

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.

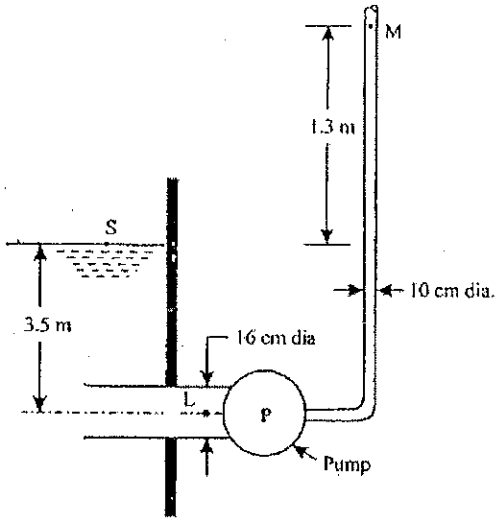


Fig.Q6

(b) Fig.Q6 shows a pump **P** pumping 72 litres/sec of water from a tank.

(i) What will be the pressures at points L and M when the pump delivers 12 kW of power to the flow? Neglect the losses in the system.

(ii) What will be the pressure at M if the losses up to the pump are negligible and the losses between the pump and the point M are equal to 1.8 times the velocity head?

Q7. (a) Show that from the basic principles with usual notations, the actual discharge (Q_{act}) of a horizontal venturi-meter shown in Fig. Q7 is given by;

$$Q_{act} = C_d \times \frac{A_1 A_2}{\sqrt{(A_1^2 - A_2^2}} \times \sqrt{2gh}$$

Where; A_1 = cross sectional area of the pipe at point 1,
A_2 = cross sectional area of the pipe at point 2(throat)
h = Differential head
C_d = co-efficient of venturi-meter

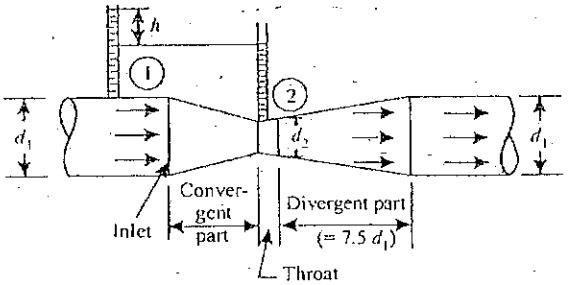


Fig.Q7

(b) A horizontal venturi-meter with inlet diameter 200 mm and throat diameter 100 mm is used to measure the flow of water. The pressure at inlet is 0.18 N/mm^2 and the vacuum pressure at the throat is 280 mm of mercury. Find the rate of flow. The co-efficient of venturi-meter(C_d) can be taken as 0.98.

Q8. (a) Write down the major and minor energy (head) losses in flow through pipes.

(b) Water is pumped at the rate of 0.02 m^3/s to an overhead tank using a pipe of 150 mm diameter and length of 300 m long. The pipe discharges water into the tank at a height of 15 m above the pump. If the friction factor is 0.0075 for the pipe, determine the following.

(i) Pressure developed by the pump on its delivery side, and

(ii) Power delivered to water by the pump.

Draw also the hydraulic gradient line from the pump to the tank. Assume that the first 285 m of the delivery pipe is horizontal and the rest is vertical.

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Saturated Water and Steam

T [°C]	p_s [bar]	v_g [m³/kg]	h_f [kJ/kg]	h_{fg} [kJ/kg]	h_g [kJ/kg]	s_f [kJ/kg K]	s_{fg} [kJ/kg K]	s_g [kJ/kg K]
0.01	0.006112	206.1	0*	2500.8	2500.8	0*	9.155	9.155
1	0.006566	192.6	4.2	2498.3	2502.5	0.015	9.113	9.128
2	0.007054	179.9	8.4	2495.9	2504.3	0.031	9.071	9.102
3	0.007575	168.2	12.6	2493.6	2506.2	0.046	9.030	9.076
4	0.008129	157.3	16.8	2491.3	2508.1	0.061	8.989	9.050
5	0.008719	147.1	21.0	2488.9	2509.9	0.076	8.948	9.024
6	0.009346	137.8	25.2	2486.6	2511.8	0.091	8.908	8.999
7	0.01001	129.1	29.4	2484.3	2513.7	0.106	8.868	8.974
8	0.01072	121.0	33.6	2481.9	2515.5	0.121	8.828	8.949
9	0.01147	113.4	37.8	2479.6	2517.4	0.136	8.788	8.924
10	0.01227	106.4	42.0	2477.2	2519.2	0.151	8.749	8.900
11	0.01312	99.90	46.2	2474.9	2521.1	0.166	8.710	8.876
12	0.01401	93.83	50.4	2472.5	2522.9	0.180	8.671	8.851
13	0.01497	88.17	54.6	2470.2	2524.8	0.195	8.633	8.828
14	0.01597	82.89	58.8	2467.8	2526.6	0.210	8.594	8.804
15	0.01704	77.97	62.9	2465.5	2528.4	0.224	8.556	8.780
16	0.01817	73.38	67.1	2463.1	2530.2	0.239	8.518	8.757
17	0.01936	69.09	71.3	2460.8	2532.1	0.253	8.481	8.734
18	0.02063	65.08	75.5	2458.4	2533.9	0.268	8.444	8.712
19	0.02196	61.34	79.7	2456.0	2535.7	0.282	8.407	8.689
20	0.02337	57.84	83.9	2453.7	2537.6	0.296	8.370	8.666
21	0.02486	54.56	88.0	2451.4	2539.4	0.310	8.334	8.644
22	0.02642	51.49	92.2	2449.0	2541.2	0.325	8.297	8.622
23	0.02808	48.62	96.4	2446.6	2543.0	0.339	8.261	8.600
24	0.02982	45.92	100.6	2444.2	2544.8	0.353	8.226	8.579
25	0.03166	43.40	104.8	2441.8	2546.6	0.367	8.190	8.557
26	0.03360	41.03	108.9	2439.5	2548.4	0.381	8.155	8.536
27	0.03564	38.81	113.1	2437.2	2550.3	0.395	8.120	8.515
28	0.03778	36.73	117.3	2434.8	2552.1	0.409	8.085	8.494
29	0.04004	34.77	121.5	2432.4	2553.9	0.423	8.050	8.473
30	0.04242	32.93	125.7	2430.0	2555.7	0.436	8.016	8.452
32	0.04754	29.57	134.0	2425.3	2559.3	0.464	7.948	8.412
34	0.05318	26.60	142.4	2420.5	2562.9	0.491	7.881	8.372
36	0.05940	23.97	150.7	2415.8	2566.5	0.518	7.814	8.332
38	0.06624	21.63	159.1	2411.0	2570.1	0.545	7.749	8.294
40	0.07375	19.55	167.5	2406.2	2573.7	0.572	7.684	8.256
42	0.08198	17.69	175.8	2401.4	2577.2	0.599	7.620	8.219
44	0.09100	16.03	184.2	2396.6	2580.8	0.625	7.557	8.182
46	0.1009	14.56	192.5	2391.8	2584.3	0.651	7.494	8.145
48	0.1116	13.23	200.9	2387.0	2587.9	0.678	7.433	8.111
50	0.1233	12.04	209.3	2382.1	2591.4	0.704	7.371	8.075
55	0.1574	9.578	230.2	2370.1	2600.3	0.768	7.223	7.991
60	0.1992	7.678	251.1	2357.9	2609.0	0.831	7.078	7.909
65	0.2501	6.201	272.0	2345.7	2617.7	0.893	6.937	7.830
70	0.3116	5.045	293.0	2333.3	2626.3	0.955	6.800	7.755
75	0.3855	4.133	313.9	2320.8	2634.7	1.015	6.666	7.681
80	0.4736	3.408	334.9	2308.3	2643.2	1.075	6.536	7.611
85	0.5780	2.828	355.9	2295.6	2651.5	1.134	6.410	7.544
90	0.7011	2.361	376.9	2282.8	2659.7	1.192	6.286	7.478
95	0.8453	1.982	398.0	2269.8	2667.8	1.250	6.166	7.416
100	1.01325	1.673	419.1	2256.7	2675.8	1.307	6.048	7.355

† u and s are chosen to be zero for saturated liquid at the triple point.

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/[m³/kg]			0.0295	0.0352	0.0399	0.0441	0.0481	0.0556
	u_g	2581	u/[kJ/kg]			2634	2772	2879	2978	3073	3260
	h_g	2772	h/[kJ/kg]			2841	3018	3158	3287	3410	3649
	s_g	5.814	s/[kJ/kg K]			5.934	6.231	6.448	6.632	6.796	7.088

*See footnote on p. 6.

Further Properties of Water and Steam

T [°C]	p_s [bar]	v_f 10^{-3}[m³/kg]	c_{pf} [kJ/kg K]	c_{pg}	μ_f 10^{-6}[kg/m s]	μ_g	k_f 10^{-3}[kW/m K]	k_g	$(Pr)_f$	$(Pr)_g$
0.01	0.006112	0.10002	4.210	1.86	1752	8.49	569	16.3	12.96	0.97
5	0.008719	0.10001	4.204	1.86	1501	8.66	578	16.7	10.92	0.96
10	0.01227	0.10003	4.193	1.86	1300	8.83	587	17.1	9.29	0.96
15	0.01704	0.10010	4.186	1.87	1136	9.00	595	17.5	7.99	0.96
20	0.02337	0.10018	4.183	1.87	1002	9.18	603	17.9	6.95	0.96
25	0.03166	0.10030	4.181	1.88	890	9.35	611	18.3	6.09	0.96
30	0.04242	0.10044	4.179	1.88	797	9.52	618	18.7	5.39	0.96
35	0.05622	0.10060	4.178	1.88	718	9.70	625	19.1	4.80	0.96
40	0.07375	0.10079	4.179	1.89	651	9.87	632	19.5	4.30	0.96
45	0.09582	0.10099	4.181	1.89	594	10.0	638	19.9	3.89	0.95
50	0.1233	0.1012	4.182	1.90	544	10.2	643	20.4	3.54	0.95
55	0.1574	0.1015	4.183	1.90	501	10.4	648	20.8	3.23	0.95
60	0.1992	0.1017	4.185	1.91	463	10.6	653	21.2	2.97	0.95
65	0.2501	0.1020	4.188	1.92	430	10.7	658	21.6	2.74	0.95
70	0.3116	0.1023	4.191	1.93	400	10.9	662	22.0	2.53	0.96
75	0.3855	0.1026	4.194	1.94	374	11.1	666	22.5	2.36	0.96
80	0.4736	0.1029	4.198	1.95	351	11.3	670	22.9	2.20	0.96
85	0.5780	0.1032	4.203	1.96	330	11.4	673	23.3	2.06	0.96
90	0.7011	0.1036	4.208	1.97	311	11.6	676	23.8	1.94	0.96
95	0.8453	0.1040	4.213	1.99	294	11.8	678	24.3	1.83	0.97
100	1.01325	0.1044	4.219	2.01	279	12.0	681	24.8	1.73	0.97
105	1.208	0.1048	4.226	2.03	265	12.2	683	25.3	1.64	0.98
110	1.433	0.1052	4.233	2.05	252	12.4	684	25.8	1.56	0.99
115	1.691	0.1056	4.240	2.07	241	12.6	686	26.3	1.49	0.99
120	1.985	0.1060	4.248	2.09	230	12.8	687	26.8	1.42	1.00
125	2.321	0.1065	4.26	2.12	220	13.0	687	27.3	1.36	1.01
130	2.701	0.1070	4.27	2.15	211	13.2	688	27.8	1.31	1.02
135	3.131	0.1075	4.28	2.18	203	13.4	688	28.3	1.26	1.03
140	3.614	0.1080	4.29	2.21	195	13.5	688	28.8	1.22	1.04
145	4.155	0.1085	4.30	2.25	188	13.7	687	29.4	1.18	1.05
150	4.760	0.1091	4.32	2.29	181	13.9	687	30.0	1.14	1.07
160	6.181	0.1102	4.35	2.38	169	14.2	684	31.3	1.07	1.09
170	7.920	0.1114	4.38	2.49	159	14.6	681	32.6	1.02	1.12
180	10.03	0.1128	4.42	2.62	149	15.0	676	34.1	0.97	1.15
190	12.55	0.1142	4.46	2.76	141	15.3	671	35.7	0.94	1.18
200	15.55	0.1157	4.51	2.91	134	15.7	665	37.5	0.91	1.22
210	19.08	0.1173	4.56	3.07	127	16.0	657	39.4	0.88	1.25
220	23.20	0.1190	4.63	3.25	121	16.3	648	41.5	0.86	1.28
230	27.98	0.1209	4.70	3.45	116	16.7	639	43.9	0.85	1.31
240	33.48	0.1229	4.78	3.68	111	17.1	628	46.5	0.84	1.35
250	39.78	0.1251	4.87	3.94	107	17.5	616	49.5	0.85	1.39
260	46.94	0.1276	4.98	4.22	103	17.9	603	52.8	0.85	1.43
270	55.05	0.1302	5.10	4.55	99	18.3	589	56.6	0.86	1.47
280	64.19	0.1332	5.24	4.98	96	18.8	574	61.0	0.88	1.53
290	74.45	0.1366	5.42	5.46	93	19.3	558	66.0	0.90	1.60
300	85.92	0.1404	5.65	6.18	90	19.8	541	72.0	0.94	1.70
320	112.9	0.1499								
340	146.1	0.1639								
360	186.7	0.1894								
370	210.5	0.2225								
374.15	221.2	0.317								

The values for saturated water can be used with good accuracy above saturation pressure. The values for saturated steam can be used with only moderate accuracy below saturation pressure at temperatures greater than 200 °C.