SCHOOL OF MECHANICAL ENGINEERING
Faculty of Engineering

SEMM2413/SKMM2413 THERMODYNAMICS
TEST 1

1hour 30min

QUESTION 1 (*10 marks*)

a) Identify which of the following are extensive properties and which are intensive properties: (i) volume, m^3, (ii) internal energy, kJ, (iii) temperature, K, (iv) pressure, bar, (v) density, kg/m^3, and (vi) specific enthalpy, kJ/kg.

(3 marks)

b) i) A frictionless piston-cylinder device contains a gas as shown in Figure 1a. The piston has a mass of 8 kg and diameter of 15 cm. The local atmospheric pressure is 760 mmHg. Calculate the pressure of the gas in kPa. Take the density of mercury 13600 kg/m^3 and gravitational acceleration 9.81 m/s^2

ii) By placing some weights on the piston as shown in Figure 1b, the pressure of the gas in part (i) above is increased by 10%. Determine the mass of the weights required, in kg, for this pressure increment.

(7 marks)

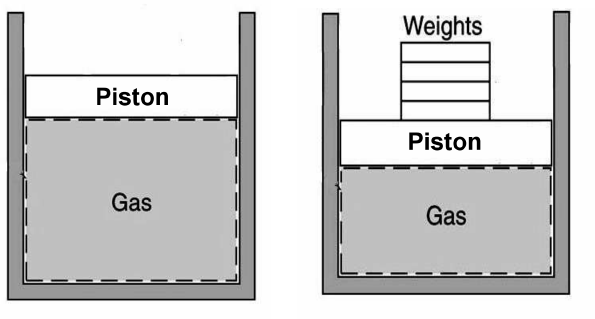

Figure 1a Figure 1b

QUESTION 2 *(20 marks)*

a) Draw the table and fill in the blanks for properties of water (H_2O) by using the property tables attached. Show your calculation clearly. Show and label all states on a single P-*v* diagram with respect to saturation lines.

State	T (°C)	P (kPa)	Quality, *x*	*v* (m^3/kg)	*h* (kJ/kg)	Phase
1	110		0.8			
2		150				Saturated vapor
3		300			3069.6	
4	80	5000				

(10 marks)

b) A rigid tank is filled with 5 kg of water initially at 100 kPa and specific enthalpy of 2100 kJ/kg. Then, the water is heated at constant volume until the pressure reaches 400 kPa. Determine the
   i) quality of the water at the initial state,
   ii) mass of the saturated liquid in the mixture at the initial state (kg),
   iii) volume of the saturated liquid in the mixture at the initial state (m^3),
   iv) final temperature (^oC).
   Show the process on a T-*υ* diagram.

(10 marks)

QUESTION 3 *(10 marks)*

a) A piston-cylinder device contains 0.5 m^3 of oxygen gas at 275 kPa and 300°C. Oxygen gas is now allowed to cool at constant pressure until the temperature drops to 90°C. Using gas constant, R of 0.2598 kJ/kgK, determine the change of the volume of the system during this process. Show and label the process on a P-V diagram.

(6 marks)

b) A rigid tank contains air at 250°C and 200 kPa pressure. The air is cooled such that the air reaches a final equilibrium state at 60°C. Determine the final pressure of the air. The gas constant, R, for air is 0.287 kJ/kgK. Show and label the process on a P-V diagram.

(4 marks)

Table A-4 Saturated Water
Temperature Table

Saturated water—Temperature table

		Specific volume, m^3/kg		*Internal energy,* kJ/kg			*Enthalpy,* kJ/kg			*Entropy,* kJ/kg·K		
Temp., T °C	Sat. press., P_{sat} kPa	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
75	38.597	0.001026	4.1291	313.99	2161.3	2475.3	314.03	2320.6	2634.6	1.0158	6.6655	7.6812
80	47.416	0.001029	3.4053	334.97	2146.6	2481.6	335.02	2308.0	2643.0	1.0756	6.5355	7.6111
85	57.868	0.001032	2.8261	355.96	2131.9	2487.8	356.02	2295.3	2651.4	1.1346	6.4089	7.5435
90	70.183	0.001036	2.3593	376.97	2117.0	2494.0	377.04	2282.5	2659.6	1.1929	6.2853	7.4782
95	84.609	0.001040	1.9808	398.00	2102.0	2500.1	398.09	2269.6	2667.6	1.2504	6.1647	7.4151
100	101.42	0.001043	1.6720	419.06	2087.0	2506.0	419.17	2256.4	2675.6	1.3072	6.0470	7.3542
105	120.90	0.001047	1.4186	440.15	2071.8	2511.9	440.28	2243.1	2683.4	1.3634	5.9319	7.2952
110	143.38	0.001052	1.2094	461.27	2056.4	2517.7	461.42	2229.7	2691.1	1.4188	5.8193	7.2382
115	169.18	0.001056	1.0360	482.42	2040.9	2523.3	482.59	2216.0	2698.6	1.4737	5.7092	7.1829
120	198.67	0.001060	0.89133	503.60	2025.3	2528.9	503.81	2202.1	2706.0	1.5279	5.6013	7.1292

Table A-5 Saturated Water
Pressure Table

Saturated water—Pressure table

		Specific volume, m^3/kg		*Internal energy,* kJ/kg			*Enthalpy,* kJ/kg			*Entropy,* kJ/kg·K		
Press., P kPa	Sat. temp., T_{sat} °C	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
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
450	147.90	0.001088	0.41392	622.65	1934.5	2557.1	623.14	2120.3	2743.4	1.8205	5.0356	6.8561
500	151.83	0.001093	0.37483	639.54	1921.2	2560.7	640.09	2108.0	2748.1	1.8604	4.9603	6.8207
550	155.46	0.001097	0.34261	655.16	1908.8	2563.9	655.77	2096.6	2752.4	1.8970	4.8916	6.7886
600	158.83	0.001101	0.31560	669.72	1897.1	2566.8	670.38	2085.8	2756.2	1.9308	4.8285	6.7593
650	161.98	0.001104	0.29260	683.37	1886.1	2569.4	684.08	2075.5	2759.6	1.9623	4.7699	6.7322
4000	250.35	0.001252	0.049779	1082.4	1519.3	2601.7	1087.4	1713.5	2800.8	2.7966	3.2731	6.0696
5000	263.94	0.001286	0.039448	1148.1	1448.9	2597.0	1154.5	1639.7	2794.2	2.9207	3.0530	5.9737
6000	275.59	0.001319	0.032449	1205.8	1384.1	2589.9	1213.8	1570.9	2784.6	3.0275	2.8627	5.8902

Table A-6 Superheated Water

Superheated water

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 = 0.20 MPa (120.21°C)				P = 0.30 MPa (133.52°C)				P = 0.40 MPa (143.61°C)			
Sat.	0.88578	2529.1	2706.3	7.1270	0.60582	2543.2	2724.9	6.9917	0.46242	2553.1	2738.1	6.8955
150	0.95986	2577.1	2769.1	7.2810	0.63402	2571.0	2761.2	7.0792	0.47088	2564.4	2752.8	6.9306
200	1.08049	2654.6	2870.7	7.5081	0.71643	2651.0	2865.9	7.3132	0.53434	2647.2	2860.9	7.1723
250	1.19890	2731.4	2971.2	7.7100	0.79645	2728.9	2967.9	7.5180	0.59520	2726.4	2964.5	7.3804
300	1.31623	2808.8	3072.1	7.8941	0.87535	2807.0	3069.6	7.7037	0.65489	2805.1	3067.1	7.5677
400	1.54934	2967.2	3277.0	8.2236	1.03155	2966.0	3275.5	8.0347	0.77265	2964.9	3273.9	7.9003
500	1.78142	3131.4	3487.7	8.5153	1.18672	3130.6	3486.6	8.3271	0.88936	3129.8	3485.5	8.1933
600	2.01302	3302.2	3704.8	8.7793	1.34139	3301.6	3704.0	8.5915	1.00558	3301.0	3703.3	8.4580
700	2.24434	3479.9	3928.8	9.0221	1.49580	3479.5	3928.2	8.8345	1.12152	3479.0	3927.6	8.7012
800	2.47550	3664.7	4159.8	9.2479	1.65004	3664.3	4159.3	9.0605	1.23730	3663.9	4158.9	8.9274
900	2.70656	3856.3	4397.7	9.4598	1.80417	3856.0	4397.3	9.2725	1.35298	3855.7	4396.9	9.1394
1000	2.93755	4054.8	4642.3	9.6599	1.95824	4054.5	4642.0	9.4726	1.46859	4054.3	4641.7	9.3396
1100	3.16848	4259.6	4893.3	9.8497	2.11226	4259.4	4893.1	9.6624	1.58414	4259.2	4892.9	9.5295
1200	3.39938	4470.5	5150.4	10.0304	2.26624	4470.3	5150.2	9.8431	1.69966	4470.2	5150.0	9.7102
1300	3.63026	4687.1	5413.1	10.2029	2.42019	4686.9	5413.0	10.0157	1.81516	4686.7	5412.8	9.8828

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a) i) $V (m^3)$ - Extensive
ii) $V (kJ)$ - Extensive
iii) $T (K)$ - Intensive
iv) $P (bar)$ - Intensive
v) $\rho (kg/m^3)$ - Intensive
vi) $h (kJ/kg)$ - Intensive

b) i) $P_1 = P_g + P_{atm}$

$P_{g_1} = \frac{F}{A} = \frac{mg}{A}$

$A = \frac{\pi d^2}{4} = \frac{\pi (15\times10^{-2})^2}{4}$

$= 0.01767 m^3$

$P_{g_1} = \frac{8 \times 9.81}{0.01767} \times \frac{1}{10^3}$

$= 4.4414 kPa$

$P_{atm} = \rho g h$

$= \frac{13600 \times 9.81}{10^3} \times \frac{760}{10^3}$

$= 101.396 kPa$

$P_1 = 4.4414 + 101.396$

$= 105.84 kPa$

ii) $P_2 = 1.1 P_1$

$= 1.1 \times 105.84$

$= 116.424 kPa$

$P_2 = P_p + P_{atm} + P_m$

$= P_1 + P_m$

$P_m = P_2 - P_1$

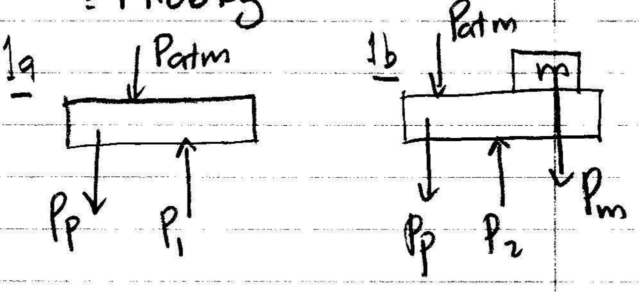
$= 116.2 - 105.84$

$= 10.58 kPa$

$P_m = \frac{m_m g}{A}$; $m_m = \frac{P_m A}{g}$

$m_m = \frac{10.58\times10^{-3} \times 0.01767}{9.81}$

$= 19.06 kg$



Q2) $T_1 = 110°C$, $x_1 = 0.8$, $0 < x < 1$ ∴ mixt

$P_1 = P_{sat} @ 110°C = 143.38 kPa$

$v = v_f + x(v_g - v_f)$

$= 0.001052 + 0.8(1.2094 - 0.001052)$

$= 0.9682 m^3/kg$

$h = h_f + x h_{fg}$

$= 461.42 + 0.8(2229.7)$

$= 2245.18 kJ/kg$

2) $T = T_{sat} @ 150 kPa = 111.35°C$

$x = 1.0$

$v = v_g @ 150 kPa = 1.1594 m^3/kg$

$h = h_g @ 150 kPa = 2693.1 kJ/kg$

3) $P = 300 kPa$, $h = 3096.6 kJ/kg$

$h > h_g @ 300 kPa$ ∴ s.h.v.

$T = 300°C$, $v = 0.87535 m^3/kg$

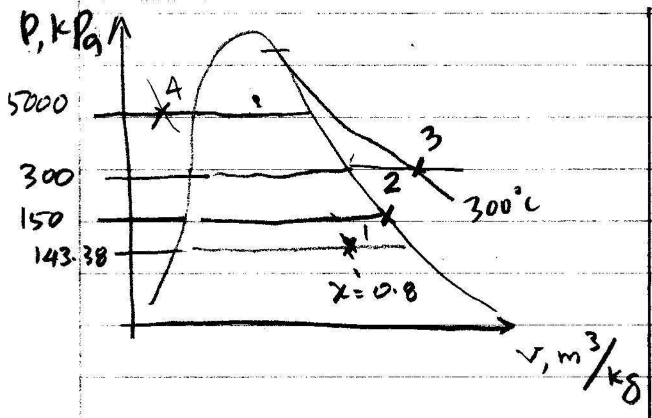
$x = -$

4) $T = 80°C$, $P = 5000 kPa$

$T < T_{sat} @ 5000 kPa$ ∴ c.l.

$x = -$, $v = v_f @ 80°C = 0.001029 m^3/kg$

$h = h_f @ 80°C = 335.02 kJ/kg$



b) H_2O

①		②
m=5kg, P_1=100kPa	Heating → v=c	P_2=400kPa

$h_1 = 2100$ kJ/kg

State 1 : $P_1 = 100$ kPa , $h_1 = 2100$ kJ/kg

At 100kPa, $h_{f_1} < h_1 < h_{g_1}$

∴ mixture

$$x_1 = \frac{h_1 - h_{f_1}}{h_{fg_1}} = \frac{2100 - 417.51}{2257.5} = 0.7453$$

State 2 : $P_2 = 400$ kPa

$v_2 = v_1$

$$v_1 = v_{f_1} + x_1(v_{g_1} - v_{f_1}) = 0.001043 + 0.7453(1.6941 - 0.001043) = 1.26288 \text{ m}^3/\text{kg}$$

At 400kPa , $v_2 > v_{g_2}$

∴ s.h.v.

i) $x_1 = 0.7453$

ii) $m_{f_1} = m - m_{g_1}$

$x_1 = \frac{m_{g_1}}{m}$, $m_{g_1} = x_1 m$

$m_{g_1} = 0.7453 \times 5 = 3.7265$ kg

$m_{f_1} = 5 - 3.7265 = 1.2735$ kg

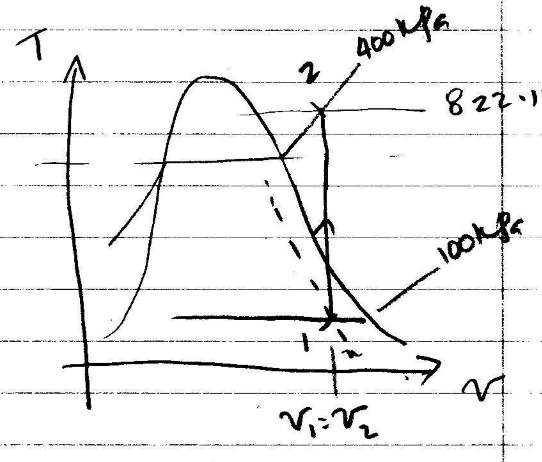
iii) $V_{f_1} = m_{f_1} \times v_{f_1} = 1.2735 \times 0.001043 = 1.3283 \times 10^{-3}$ m³.

iv) At 400kPa

T°C	v, m³/kg
800	1.23730
T_2	1.26288
900	1.35298

$$\frac{T_2 - 800}{900 - 800} = \frac{1.26288 - 1.23730}{1.35298 - 1.23730}$$

$T_2 = 822.11$°C



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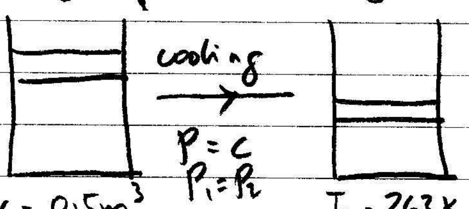
a) IG - O_2



$V_1 = 0.5 m^3$ $\quad T_2 = 363 K$

$P_1 = 275 kPa$ $\quad R = 0.2598 \frac{kJ}{kg.K}$

$T_1 = 573 K$

$\Delta V = V_1 - V_2$

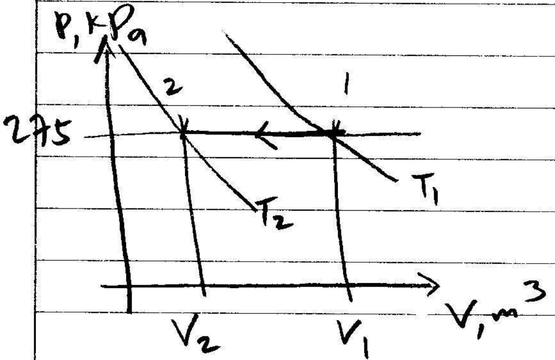
$\frac{P_2 V_2}{T_2} = \frac{P_1 V_1}{T_1}$, $V_2 = V_1 \frac{T_2}{T_1}$

$V_2 = 0.5 \times \frac{363}{573}$

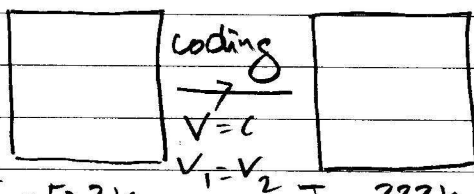
$= 0.3168 m^3$

$\Delta V = 0.5 - 0.3168$

$= 0.1832 m^3$



b) IG - Air



$T_1 = 523 K$ $\quad T_2 = 333 K$

$P_1 = 200 kPa$

$\frac{P_2 V_2}{T_2} = \frac{P_1 V_1}{T_1}$

$P_2 = \frac{P_1 T_2}{T_1}$

$= 200 \times \frac{333}{523}$

$= 127.34 kPa$