ESO 201A/202

MID SEM EXAM 2 hours 60 marks September 17, 2014

Name: **Roll No:**

1. *Please write your name and roll number on the Question Paper as well as on the booklet provided for rough work.*
2. *Please write your final answers in the boxes provided with each question and* ***RETURN the question paper ONLY****.*

Q 1. (*6 marks*) A rigid container contains **5 kg** of superheated water vapor at 4 MPa and 300 ℃. It is cooled by a constant volume (isochoric/isometric) process until the pressure in the container drops to 1 MPa. Answer the following:

(a)	Quality of steam at the end of the cooling process =	29.88	%	(2marks)
(b)	Internal energy (U) of steam at the end of the cooling process =	6.528	MJ	(2marks)
(c)	Amount of heat transformed from the container, Q_{out} =	7.103	MJ	(2marks)

Q 2. (*8 marks*)

(a) Consider superheated water vapor at 4 MPa and 680 K. Let v be the specific volume of this vapor. Answer the following:

(i)	v as obtained from steam tables by linear interpolation =	0.10856	m^3/kg	(2marks)
(ii)	v as obtained from generalized compressibility chart =	0.0745	m^3/kg	(2marks)

(b) A 1 m^3 vessel contains 40 kg of air at a pressure of 4 MPa. Answer the following:

(i)	Temperature as obtained from ideal gas equation =	348.5	K	(1marks)
(ii)	Temperature as obtained from van der Waals equation =	352.3	K	(3marks)

Q 3. (*4 marks*) Properties of saturated liquid water at 100 ℃ are :

$P_{sat} = 101.42\ kPa,\ v_f = 0.001043\ m^3/kg\ ,u_f = 419.06\ kJ/kg$. Using only this data, answer the following (round-off your answer to 2 decimal places):

(a)	Enthalpy of saturated liquid water at 100 ℃ =	419.17	kJ/kg	(2marks)
(b)	If liquid water is assumed to be incompressible the enthalpy of compressed (subcooled) liquid water at 100 ℃ and 10 MPa =	429.49	kJ/kg	(2marks)

Q 4. (*8 marks*) Consider a 50 L $(0.05\ m^3)$ evacuated rigid bottle that is surrounded by the atmosphere at 100 kPa and 300 K. A valve at the neck of the bottle is opened and air is allowed to flow slowly into the bottle. When the pressure in the bottle reaches 100 kPa, the valve is closed. At this point, the temperature of the air in the bottle is measured to be 400 K. Answer the following:

(a) Amount of air that has entered into the bottle = 0.043554 kg (2marks)

(b) Heat transfer through the wall of the bottle to the atmosphere during the filling process = 0.623 kJ (3marks)

Now the bottle as filled above is left to cool to atmospheric temperature of 300 K. Answer the following:

(c) Heat transfer through the wall of the bottle to the atmosphere during the cooling process = 3.127 kJ (2marks)

(d) Final pressure of the air in the bottle = 75 kPa (1mark)

Q 5. (*4 marks*) 0.1 m^3 of the saturated liquid water at 800 kPa is expanded isothermally in a closed system until its quality is 80 %. Answer the following:

(a) Volume at the end of the expansion process = 17.265 m^3 (2marks)

(b) Total work produced by this expansion = 13.73 MJ (2marks)

Q 6. (*5 marks*) A piston-cylinder device contains 0.1 kg of air at 2 MPa and 600 K. The air is expanded isothermally to 500 kPa. Considering air as an ideal gas, answer the following:

(a) Work done by the gas = 23.87 kJ (2marks)

(b) Heat transferred to the gas = 23.87 kJ (2marks)

(c) Change in the internal energy of the gas = 0 kJ (1mark)

Q 7. (*6 marks*) Refrigerant *134a* enters the capillary tube of a refrigerator as saturated liquid at 1 MPa and is throttled to a pressure of 0.14 MPa. Answer the following:

(a) Quality of the refrigerant at the final state = 37.8 % (3marks)

(b) Temperature drop during the throttling process = 58.14 °C (1mark)

The wet refrigerant as obtained above at the end of the throttling process is sent to the evaporator section of the refrigerator. Answer the following:

(c) Heat absorbed by the refrigerant until it becomes saturated vapor = 131.84 kJ/kg (2marks)

Q 8. (*7 marks*) Air enters an adiabatic nozzle steadily at 300 $kPa, 500\ K$ and $40\ m/s$ and leaves at 100 kPa and 200 m/s. The inlet area of the nozzle is 100 cm^2. Assuming air to be an ideal gas with constant specific heats, answer the following:

(a)	The mass flow of air through the nozzle =	0.8362	kg/s	(2marks)
(b)	Temperature of the air at the nozzle exit =	480.9	K	(3marks)
(c)	Exit area of the nozzle =	57.7	cm^2	(2marks)

Q 9. (*6 marks*)

(a) Steam enters a steady flow adiabatic turbine with a mass flow rate of 10 kg/s at 4 MPa and 500 °C and leaves as saturated vapor at 10 kPa. Neglecting $\Delta(KE + PE)$, answer the following:

Power produced by the turbine =	8.621	MW	(2marks)

(b) An adiabatic air compressor compresses 20 L/s (0.02 m^3/s) of air at 100 kPa and 300 K to 1000 kPa and 575 K. Neglecting $\Delta(KE + PE)$ and assuming air to be an ideal gas with constant specific heats, answer the following:

(i)	Mass flow rate of air through the compressor =	0.02323	kg/s	(2marks)
(ii)	Power required to drive the compressor =	6.42	kW	(2marks)

Q 10. (*6 marks*) A rigid tank is filled with 100 kg of saturated liquid water at 1 MPa. A valve at the bottom of the tank is opened and 95 kg liquid water is withdrawn from the tank. During this process, heat is transferred to water in the tank such that the temperature in the tank remains constant. Answer the following:

(a)	Quality of water-steam mixture at the end of the above process =	11.08	%	(3marks)
(b)	The amount of heat transferred to the tank in the above process =	1.115	MJ	(3marks)

For air:

$$R = 0.287 kJ/kg.K, \quad c_p = 1.005 kJ/kg.K, \quad c_v = 0.718\ kJ/kg.K.$$

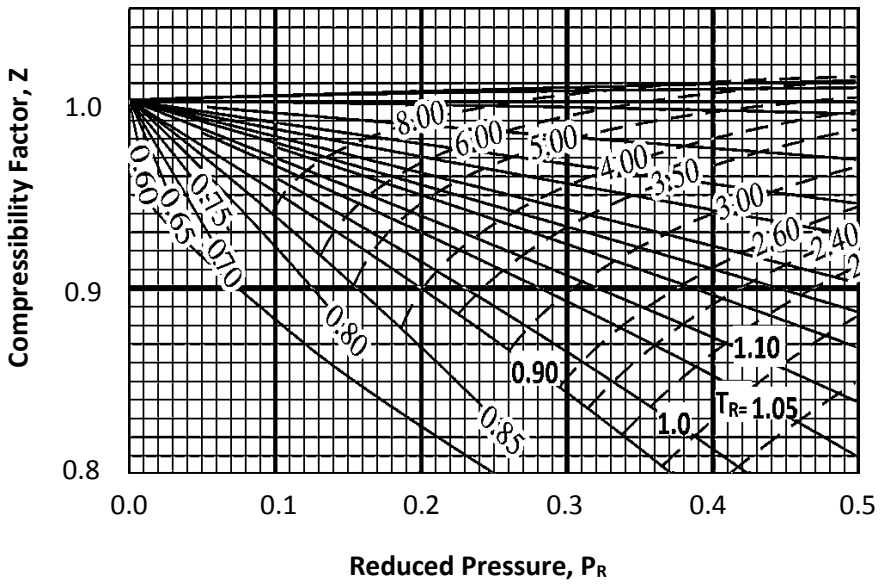
For water vapor:

$$R = 0.4615\ kJ/kg.K, \quad T_{cr} = 647.1\ K, \quad P_{cr} = 22.06\ MPa.$$

van der Waals equation:

$$\left(P + \frac{a}{v^2}\right)(v - b) = RT$$

For air $a = 162\ Pa.m^6/kg^2, \quad b = 0.00126\ m^3/kg.$



Superheated water vapor

T °C	*v* m³/kg	*u* kJ/kg	*h* kJ/kg	*s* kJ/kg · K
	P = 4.0 MPa (250.35°C)			
Sat.	0.04978	2601.7	2800.8	6.0696
275	0.05461	2668.9	2887.3	6.2312
300	0.05887	2726.2	2961.7	6.3639
350	0.06647	2827.4	3093.3	6.5843
400	0.07343	2920.8	3214.5	6.7714
450	0.08004	3011.0	3331.2	6.9386
500	0.08644	3100.3	3446.0	7.0922
600	0.09886	3279.4	3674.9	7.3706
700	0.11098	3462.4	3906.3	7.6214
800	0.12292	3650.6	4142.3	7.8523
900	0.13476	3844.8	4383.9	8.0675
1000	0.14653	4045.1	4631.2	8.2698
1100	0.15824	4251.4	4884.4	8.4612
1200	0.16992	4463.5	5143.2	8.6430
1300	0.18157	4680.9	5407.2	8.8164

Saturated water -- Pressure Table

		Specific volume, m³/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
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	2405.3	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
800	170.41	0.001115	0.24035	719.97	1856.1	2576.0	720.87	2047.5	2768.3	2.0457	4.6160	6.6616
850	172.94	0.001118	0.22690	731.00	1846.9	2577.9	731.95	2038.8	2770.8	2.0705	4.5705	6.6409
900	175.35	0.001121	0.21489	741.55	1838.1	2579.6	742.56	2030.5	2773.0	2.0941	4.5273	6.6213
950	177.66	0.001124	0.20411	751.67	1829.6	2581.3	752.74	2022.4	2775.2	2.1166	4.4862	6.6027
1000	179.88	0.001127	0.19436	761.39	1821.4	2582.8	762.51	2014.6	2777.1	2.1381	4.4470	6.5850

Saturated refrigerant -134a Pressure Table

		Specific volume, m³/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
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
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
1000	39.37	0.0008700	0.020313	106.45	144.23	250.68	107.32	163.67	270.99	0.39189	0.52368	0.91558
1200	46.29	0.0008934	0.016715	116.70	137.11	253.81	117.77	156.10	273.87	0.42441	0.48863	0.91303
1400	52.40	0.0009166	0.014107	125.94	130.43	256.37	127.22	148.90	276.12	0.45315	0.45734	0.91050