

國立成功大學

111學年度碩士班招生考試試題

編 號： 66

系 所： 機械工程學系

科 目： 熱力學

日 期： 0219

節 次： 第 2 節

備 註： 可使用計算機

※ 考生請注意：本試題可使用計算機。請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

1. (20%) A well-insulated tank contains 25 kg of Refrigerant 134a initially at 300 kPa with a quality of 80%. The pressure is maintained by nitrogen gas acting against a piston as shown in Figure 1. The valve opens and carries 134a at 1 MPa and 120°C from the supply line to the tank. The pressure of nitrogen in the tank is maintained as 300 kPa when the piston expands. The valve is closed when all the liquid has vaporized. Determine the amount of refrigerant admitted to the tank. Please use Table 1 to evaluate the properties of 134a.

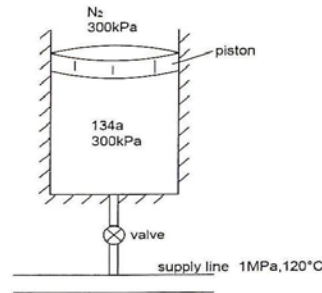


Figure 1

2. (30%) By injecting liquid water (0.3 kg/s) into superheated steam, the desuperheater shown in Figure 2 has a saturated vapor steam at its exit. Steady-state operating data are provided in Table 2. The heat transfer, potential energy, and kinetic energy are negligible.

- (1). (10%) Locate state 1, 2, and 3 on a sketch of the T-S diagram.
- (2). (20%) Determine the rate of entropy generation within the desuperheater (kW/K)

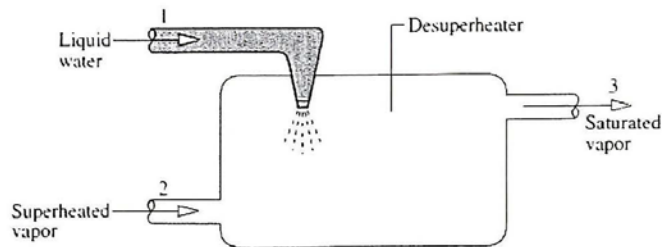


Figure 2

3. (35%) Consider isentropic flow of an ideal gas with constant k .
- (1) (20%) Show that $\frac{T^*}{T_0} = \frac{2}{k+1}$ and $\frac{p^*}{p_0} = \left(\frac{2}{k+1}\right)^{k/(k-1)}$ where T^* and p^* are the temperature and pressure, respectively, at the state where Mach number is unity, and T_0 and p_0 are the temperature and pressure, respectively, at the stagnation state.
- (Hint: $T_0 = T + \left(\frac{v^2}{2c_p}\right)$, $c_p = \frac{kR}{k-1}$ and $c = \sqrt{kRT}$)
- (2) (5%) Air enters a converging nozzle with negligible velocity at a pressure of 1.0 MPa and a temperature of 360 K; back pressure at the exit is 500 kPa. For isentropic flow of an ideal gas with $k = 1.4$, check whether the flow is choked in the nozzle using the results of part (1).
- (3) (10%) If the exit area of the nozzle in part (2) is 0.001 m^2 , determine the mass flow rate, in kg/s, and the exit Mach number.
4. (15%) Ammonia with a mass flow rate of 5 kg/min is the working fluid within an ideal vapor-compression refrigeration cycle. Saturated vapor enters the compressor and saturated liquid exits the condenser. The evaporator temperature is -10°C and the condenser pressure is 10 bar. Please use Table 3 to evaluate the required properties.
- (1) (5%) Sketch the processes of the cycle on a T-s diagram. Enumerate the state points and clearly indicate the corresponding location of each state point on the cycle block diagram.
- (2) (5%) Determine the COP of the cycle.
- (3) (5%) Evaluate the refrigeration capacity of the refrigeration cycle.

Table 1

Properties of Saturated Refrigerant 134a (Liquid-Vapor): Pressure Table

Press. bar	Temp. °C	Specific Volume m ³ /kg		Internal Energy kJ/kg		Enthalpy kJ/kg		
		Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g
2.0	-10.09	0.7532	0.0993	36.69	221.43	36.84	204.46	241.30
2.4	-5.37	0.7618	0.0834	42.77	224.07	42.95	201.14	244.09
2.8	-1.23	0.7697	0.0719	48.18	226.38	48.39	198.13	246.52
3.2	2.48	0.7770	0.0632	53.06	228.43	53.31	195.35	248.66
3.6	5.84	0.7839	0.0564	57.54	230.28	57.82	192.76	250.58

Properties of Superheated Refrigerant 134a Vapor

T °C	v m ³ /kg	u kJ/kg	h kJ/kg	s kJ/kg · K
$p = 10.0 \text{ bar} = 1.00 \text{ MPa}$ ($T_{\text{sat}} = 39.39^\circ\text{C}$)				
80	0.02538	287.82	313.20	1.0405
90	0.02649	297.53	324.01	1.0707
100	0.02755	307.27	334.82	1.1000
110	0.02858	317.06	345.65	1.1286
120	0.02959	326.93	356.52	1.1567
130	0.03058	336.88	367.46	1.1841
140	0.03154	346.92	378.46	1.2111

Table 2

State	p (MPa)	T (°C)	v (m ³ /kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg · K)
1	2	38	1.0065×10^{-3}	166.5	168.3	0.5658
2	2	320	0.1308	2807.9	3069.5	6.8452
3	1.5	Sat. Vap.	1.159	2519.7	2693.6	7.2233

Table 3

Properties of Saturated Ammonia (Liquid-Vapor): Temperature Table

Pressure Conversions: 1 bar = 0.1 MPa = 10 ⁵ kPa		Specific Volume m ³ /kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		Temp. °C
Temp. °C	Press. bar	Sat. Liquid v _f × 10 ³	Sat. Vapor v _g	Sat. Liquid u _f	Sat. Vapor u _g	Sat. Liquid h _f	Evap. h _{fg}	Sat. Vapor h _g	Sat. Liquid s _f	Sat. Vapor s _g	
-50	0.4086	1.4245	2.6255	-43.94	1264.99	-43.88	1416.20	1372.32	-0.1922	6.1543	-50
-45	0.5453	1.4367	2.0060	-22.03	1271.19	-21.95	1402.52	1380.57	-0.0951	6.0523	-45
-40	0.7174	1.4493	1.5524	-0.10	1277.20	0.00	1388.56	1388.56	0.0000	5.9557	-40
-36	0.8850	1.4597	1.2757	17.47	1281.87	17.60	1377.17	1394.77	0.0747	5.8819	-36
-32	1.0832	1.4703	1.0561	35.09	1286.41	35.25	1365.55	1400.81	0.1484	5.8111	-32
-30	1.1950	1.4757	0.9634	43.93	1288.63	44.10	1359.65	1403.75	0.1849	5.7767	-30
-28	1.3159	1.4812	0.8803	52.78	1290.82	52.97	1353.68	1406.66	0.2212	5.7430	-28
-26	1.4465	1.4867	0.8056	61.65	1292.97	61.86	1347.65	1409.51	0.2572	5.7100	-26
-22	1.7390	1.4980	0.6780	79.46	1297.18	79.72	1335.36	1415.08	0.3287	5.6457	-22
-20	1.9019	1.5038	0.6233	88.40	1299.23	88.68	1329.10	1417.79	0.3642	5.6144	-20
-18	2.0769	1.5096	0.5739	97.36	1301.25	97.68	1322.77	1420.45	0.3994	5.5837	-18
-16	2.2644	1.5155	0.5291	106.36	1303.23	106.70	1316.35	1423.05	0.4346	5.5536	-16
-14	2.4652	1.5215	0.4885	115.37	1305.17	115.75	1309.86	1425.61	0.4695	5.5239	-14
-12	2.6798	1.5276	0.4516	124.42	1307.08	124.83	1303.28	1428.11	0.5043	5.4948	-12
-10	2.9089	1.5338	0.4180	133.50	1308.95	133.94	1296.61	1430.55	0.5389	5.4662	-10
-8	3.1532	1.5400	0.3874	142.60	1310.78	143.09	1289.86	1432.95	0.5734	5.4380	-8
-6	3.4134	1.5464	0.3595	151.74	1312.57	152.26	1283.02	1435.28	0.6077	5.4103	-6
-4	3.6901	1.5528	0.3340	160.88	1314.32	161.46	1276.10	1437.56	0.6418	5.3831	-4
-2	3.9842	1.5594	0.3106	170.07	1316.04	170.69	1269.08	1439.78	0.6759	5.3562	-2
0	4.2962	1.5660	0.2892	179.29	1317.71	179.96	1261.97	1441.94	0.7097	5.3298	0
2	4.6270	1.5727	0.2695	188.53	1319.34	189.26	1254.77	1444.03	0.7435	5.3038	2
4	4.9773	1.5796	0.2514	197.80	1320.92	198.59	1247.48	1446.07	0.7770	5.2781	4
6	5.3479	1.5866	0.2348	207.10	1322.47	207.95	1240.09	1448.04	0.8105	5.2529	6
8	5.7395	1.5936	0.2195	216.42	1323.96	217.34	1232.61	1449.94	0.8438	5.2279	8
10	6.1529	1.6008	0.2054	225.77	1325.42	226.75	1225.03	1451.78	0.8769	5.2033	10
12	6.5890	1.6081	0.1923	235.14	1326.82	236.20	1217.35	1453.55	0.9099	5.1791	12
16	7.5324	1.6231	0.1691	253.95	1329.48	255.18	1201.70	1456.87	0.9755	5.1314	16
20	8.5762	1.6386	0.1492	272.86	1331.94	274.26	1185.64	1459.90	1.0404	5.0849	20
24	9.7274	1.6547	0.1320	291.84	1334.19	293.45	1169.16	1462.61	1.1048	5.0394	24
28	10.993	1.6714	0.1172	310.92	1336.20	312.75	1152.24	1465.00	1.1686	4.9948	28
32	12.380	1.6887	0.1043	330.07	1337.97	332.17	1134.87	1467.03	1.2319	4.9509	32
36	13.896	1.7068	0.0930	349.32	1339.47	351.69	1117.00	1468.70	1.2946	4.9078	36
40	15.549	1.7256	0.0831	368.67	1340.70	371.35	1098.62	1469.97	1.3569	4.8652	40
45	17.819	1.7503	0.0725	393.01	1341.81	396.13	1074.84	1470.96	1.4341	4.8125	45
50	20.331	1.7765	0.0634	417.56	1342.42	421.17	1050.09	1471.26	1.5109	4.7604	50

$u_f = (\text{table value})/1000$

Table 3 (continued)

Properties of Saturated Ammonia (Liquid-Vapor): Pressure Table

Pressure Conversions: 1 bar = 0.1 MPa = 10 ² kPa		Specific Volume m ³ /kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		Press. bar
Press. bar	Temp. °C	Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Sat. Vapor s_g	
0.40	-50.36	1.4236	2.6795	-45.52	1264.54	-45.46	1417.18	1371.72	-0.1992	6.1618	0.40
0.50	-46.53	1.4330	2.1752	-28.73	1269.31	-28.66	1406.73	1378.07	-0.1245	6.0829	0.50
0.60	-43.28	1.4410	1.8345	-14.51	1273.27	-14.42	1397.76	1383.34	-0.0622	6.0186	0.60
0.70	-40.46	1.4482	1.5884	-2.11	1276.66	-2.01	1389.85	1387.84	-0.0086	5.9643	0.70
0.80	-37.94	1.4546	1.4020	8.93	1279.61	9.04	1382.73	1391.78	0.0386	5.9174	0.80
0.90	-35.67	1.4605	1.2559	18.91	1282.24	19.04	1376.23	1395.27	0.0808	5.8760	0.90
1.00	-33.60	1.4660	1.1381	28.03	1284.61	28.18	1370.23	1398.41	0.1191	5.8391	1.00
1.25	-29.07	1.4782	0.9237	48.03	1289.65	48.22	1356.89	1405.11	0.2018	5.7610	1.25
1.50	-25.22	1.4889	0.7787	65.10	1293.80	65.32	1345.28	1410.61	0.2712	5.6973	1.50
1.75	-21.86	1.4984	0.6740	80.08	1297.33	80.35	1334.92	1415.27	0.3312	5.6435	1.75
2.00	-18.86	1.5071	0.5946	93.50	1300.39	93.80	1325.51	1419.31	0.3843	5.5969	2.00
2.25	-16.15	1.5151	0.5323	105.68	1303.08	106.03	1316.83	1422.86	0.4319	5.5558	2.25
2.50	-13.67	1.5225	0.4821	116.88	1305.49	117.26	1308.76	1426.03	0.4753	5.5190	2.50
2.75	-11.37	1.5295	0.4408	127.26	1307.67	127.68	1301.20	1428.88	0.5152	5.4858	2.75
3.00	-9.24	1.5361	0.4061	136.96	1309.65	137.42	1294.05	1431.47	0.5520	5.4554	3.00
3.25	-7.24	1.5424	0.3765	146.06	1311.46	146.57	1287.27	1433.84	0.5864	5.4275	3.25
3.50	-5.36	1.5484	0.3511	154.66	1313.14	155.20	1280.81	1436.01	0.6186	5.4016	3.50
3.75	-3.58	1.5542	0.3289	162.80	1314.68	163.38	1274.64	1438.03	0.6489	5.3774	3.75
4.00	-1.90	1.5597	0.3094	170.55	1316.12	171.18	1268.71	1439.89	0.6776	5.3548	4.00
4.25	-0.29	1.5650	0.2921	177.96	1317.47	178.62	1263.01	1441.63	0.7048	5.3336	4.25
4.50	1.25	1.5702	0.2767	185.04	1318.73	185.75	1257.50	1443.25	0.7308	5.3135	4.50
4.75	2.72	1.5752	0.2629	191.84	1319.91	192.59	1252.18	1444.77	0.7555	5.2946	4.75
5.00	4.13	1.5800	0.2503	198.39	1321.02	199.18	1247.02	1446.19	0.7791	5.2765	5.00
5.25	5.48	1.5847	0.2390	204.69	1322.07	205.52	1242.01	1447.53	0.8018	5.2594	5.25
5.50	6.79	1.5893	0.2286	210.78	1323.06	211.65	1237.15	1448.80	0.8236	5.2430	5.50
5.75	8.05	1.5938	0.2191	216.66	1324.00	217.58	1232.41	1449.99	0.8446	5.2273	5.75
6.00	9.27	1.5982	0.2104	222.37	1324.89	223.32	1227.79	1451.12	0.8649	5.2122	6.00
7.00	13.79	1.6148	0.1815	243.56	1328.04	244.69	1210.38	1455.07	0.9394	5.1576	7.00
8.00	17.84	1.6302	0.1596	262.64	1330.64	263.95	1194.36	1458.30	1.0054	5.1099	8.00
9.00	21.52	1.6446	0.1424	280.05	1332.82	281.53	1179.44	1460.97	1.0649	5.0675	9.00
10.00	24.89	1.6584	0.1285	296.10	1334.66	297.76	1165.42	1463.18	1.1191	5.0294	10.00
12.00	30.94	1.6841	0.1075	324.99	1337.52	327.01	1139.52	1466.53	1.2152	4.9625	12.00
14.00	36.26	1.7080	0.0923	350.58	1339.56	352.97	1115.82	1468.79	1.2987	4.9050	14.00
16.00	41.03	1.7306	0.0808	373.69	1340.97	376.46	1093.77	1470.23	1.3729	4.8542	16.00
18.00	45.38	1.7522	0.0717	394.85	1341.88	398.00	1073.01	1471.01	1.4399	4.8086	18.00
20.00	49.37	1.7731	0.0644	414.44	1342.37	417.99	1053.27	1471.26	1.5012	4.7670	20.00

$v_f = (\text{table value})/1000$