



SME 4433 – REFRIGERATION & AIR-CONDITIONING

TEST #1

3/0

Name: MOHD REZA FADHLAN B. DAUD

Matrix No.: SX060677MMJ04

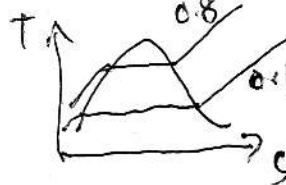
Important: Attached this question paper together with your answer sheets.Question 1Refrigerator is a *cyclic* device. Describe briefly the following:

- What does it mean by "cyclic device"?
- What is the main function of this device?

Close System
 absorb heat & maintain the
 Temp. (5 marks)

Question 2

Sketch the *actual* vapor compression refrigeration cycle on a temperature-entropy (*T-s*) diagram. List the differences between this actual cycle and the corresponding *ideal* vapor compression cycle. Show them clearly on the sketch of the actual cycle.



(10 marks)

Question 3

Refrigerant-134a enters the compressor of a refrigerator at a pressure of 0.1 MPa, temperature of -10°C and leaves the compressor at a pressure of 0.8 MPa. The refrigerant is then cooled in a condenser, where it exits at a pressure of 0.7 MPa and temperature of 22°C . The refrigerant then flows through a throttle valve, in which it is throttled to a pressure of 0.06 MPa. Heat transfer and pressure drops in the piping lines connecting the various components can be neglected. Sketch the cycle on a *pressure-enthalpy* (*p-h*) diagram and show all the state points clearly. If the *isentropic efficiency* of the compressor is 94% and the refrigerant flows at a rate of 0.08 kg/s, determine the:

- temperature of the refrigerant leaving the compressor, $^{\circ}\text{C}$;
- rate of heat *rejected* in the condenser, kW;
- refrigeration capacity, ton;
- coefficient of performance of the refrigerator.

333.53 kW

(25 marks)

Saturated refrigerant-134a—Temperature table (Continued)

Temp., T , °C	Specific volume, m^3/kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, $kJ/kg \cdot K$			
	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
20	572.07	0.0008161	0.035969	78.86	162.16	241.02	79.32	182.27	261.59	0.30063	0.62172	0.92234
22	608.27	0.0008210	0.033828	81.64	160.42	242.06	82.14	180.49	262.64	0.31011	0.61149	0.92160
24	646.18	0.0008261	0.031834	84.44	158.65	243.10	84.98	178.69	263.67	0.31958	0.60130	0.92088
26	685.84	0.0008313	0.029976	87.26	156.87	244.12	87.83	176.85	264.68	0.32903	0.59115	0.92018
28	727.31	0.0008366	0.028242	90.09	155.05	245.14	90.69	174.99	265.68	0.33846	0.58102	0.91948

Superheated refrigerant-134a

T °C	v m^3/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m^3/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m^3/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
P = 0.06 MPa ($T_{sat} = -36.95^\circ C$)				P = 0.10 MPa ($T_{sat} = -26.37^\circ C$)				P = 0.14 MPa ($T_{sat} = -18.77^\circ C$)				
Sat.	0.31121	209.12	227.79	0.9644	0.19254	215.19	234.44	0.9518	0.14014	219.54	239.16	0.9446
-20	0.33608	220.60	240.76	1.0174	0.19841	219.66	239.50	0.9721				
-10	0.35048	227.55	248.58	1.0477	0.20743	226.75	247.49	1.0030	0.14605	225.91	246.36	0.9724
0	0.36476	234.66	256.54	1.0774	0.21630	233.95	255.58	1.0332	0.15263	233.23	254.60	1.0031
10	0.37893	241.92	264.66	1.1066	0.22506	241.30	263.81	1.0628	0.15908	240.66	262.93	1.0331
20	0.39302	249.35	272.94	1.1353	0.23373	248.79	272.17	1.0918	0.16544	248.22	271.38	1.0624
30	0.40705	256.95	281.37	1.1636	0.24233	256.44	280.68	1.1203	0.17172	255.93	279.97	1.0912
40	0.42102	264.71	289.97	1.1915	0.25088	264.25	289.34	1.1484	0.17794	263.79	288.70	1.1195
50	0.43495	272.64	298.74	1.2191	0.25937	272.22	298.16	1.1762	0.18412	271.79	297.57	1.1474
60	0.44883	280.73	307.66	1.2463	0.26783	280.35	307.13	1.2035	0.19025	279.96	306.59	1.1749
70	0.46269	288.99	316.75	1.2732	0.27626	288.64	316.26	1.2305	0.19635	288.28	315.77	1.2020
80	0.47651	297.41	326.00	1.2997	0.28465	297.08	325.55	1.2572	0.20242	296.75	325.09	1.2288
90	0.49032	306.00	335.42	1.3260	0.29303	305.69	334.99	1.2836	0.20847	305.38	334.57	1.2553
100	0.50410	314.74	344.99	1.3520	0.30138	314.46	344.60	1.3096	0.21449	314.17	344.20	1.2814

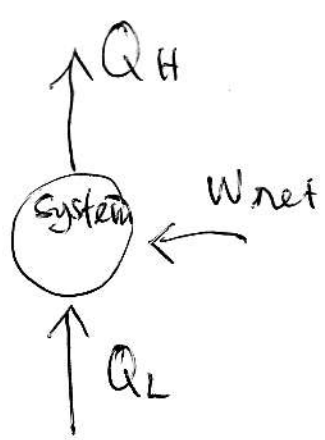
Superheated refrigerant-134a (Continued)

T °C	v m^3/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m^3/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m^3/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
P = 0.50 MPa ($T_{sat} = 15.71^\circ C$)				P = 0.60 MPa ($T_{sat} = 21.55^\circ C$)				P = 0.70 MPa ($T_{sat} = 26.69^\circ C$)				
Sat.	0.041118	238.75	259.30	0.9240	0.034295	241.83	262.40	0.9218	0.029361	244.48	265.03	0.9199
20	0.042115	242.40	263.46	0.9383								
30	0.044338	250.84	273.01	0.9703	0.035984	249.22	270.81	0.9499	0.029966	247.48	268.45	0.9313
40	0.046456	259.26	282.48	1.0011	0.037865	257.86	280.58	0.9816	0.031696	256.39	278.57	0.9641
50	0.048499	267.72	291.96	1.0309	0.039659	266.48	290.28	1.0121	0.033322	265.20	288.53	0.9954
60	0.050485	276.25	301.50	1.0599	0.041389	275.15	299.98	1.0417	0.034875	274.01	298.42	1.0256
70	0.052427	284.89	311.10	1.0883	0.043069	283.89	309.73	1.0705	0.036373	282.87	308.33	1.0549
80	0.054331	293.64	320.80	1.1162	0.044710	292.73	319.55	1.0987	0.037829	291.80	318.28	1.0835
90	0.056205	302.51	330.61	1.1436	0.046318	301.67	329.46	1.1264	0.039250	300.82	328.29	1.1114
100	0.058053	311.50	340.53	1.1705	0.047900	310.73	339.47	1.1536	0.040642	309.95	338.40	1.1389
110	0.059880	320.63	350.57	1.1971	0.049458	319.91	349.59	1.1803	0.042010	319.19	348.60	1.1658
120	0.061687	329.89	360.73	1.2233	0.050997	329.23	359.82	1.2067	0.043358	328.55	358.90	1.1924
130	0.063479	339.29	371.03	1.2491	0.052519	338.67	370.18	1.2327	0.044688	338.04	369.32	1.2186
140	0.065256	348.83	381.46	1.2747	0.054027	348.25	380.66	1.2584	0.046004	347.66	379.86	1.2444
150	0.067021	358.51	392.02	1.2999	0.055522	357.96	391.27	1.2838	0.047306	357.41	390.52	1.2699
160	0.068775	368.33	402.72	1.3249	0.057006	367.81	402.01	1.3088	0.048597	367.29	401.31	1.2951
P = 0.80 MPa ($T_{sat} = 31.31^\circ C$)				P = 0.90 MPa ($T_{sat} = 35.51^\circ C$)				P = 1.00 MPa ($T_{sat} = 39.37^\circ C$)				
Sat.	0.025621	246.79	267.29	0.9183	0.022683	248.85	269.26	0.9169	0.020313	250.68	270.99	0.9156
40	0.027035	254.82	276.45	0.9480	0.023375	253.13	274.17	0.9327	0.020406	251.30	271.71	0.9179
50	0.028547	263.86	286.69	0.9802	0.024809	262.44	284.77	0.9660	0.021796	260.94	282.74	0.9525
60	0.029973	272.83	296.81	1.0110	0.026146	271.60	295.13	0.9976	0.023068	270.32	293.38	0.9850
70	0.031340	281.81	306.88	1.0408	0.027413	280.72	305.39	1.0280	0.024261	279.59	303.85	1.0160
80	0.032659	290.84	316.97	1.0698	0.028630	289.86	315.63	1.0574	0.025398	288.86	314.25	1.0458
90	0.033941	299.95	327.10	1.0981	0.029806	299.06	325.89	1.0860	0.026492	298.15	324.64	1.0748
100	0.035193	309.15	337.30	1.1258	0.030951	308.34	336.19	1.1140	0.027552	307.51	335.06	1.1031
110	0.036420	318.45	347.59	1.1530	0.032068	317.70	346.56	1.1414	0.028584	316.94	345.53	1.1308
120	0.037625	327.87	357.97	1.1798	0.033164	327.18	357.02	1.1684	0.029592	326.47	356.06	1.1580
130	0.038813	337.40	368.45	1.2061	0.034241	336.76	367.58	1.1949	0.030581	336.11	366.69	1.1846
140	0.039985	347.06	379.05	1.2321	0.035302	346.46	378.23	1.2210	0.031554	345.85	377.40	1.2109
150	0.041143	356.85	389.76	1.2577	0.036349	356.28	389.00	1.2467	0.032512	355.71	388.22	1.2368
160	0.042290	366.76	400.59	1.2830	0.037384	366.23	399.88	1.2721	0.033457	365.70	399.15	1.2623
170	0.043427	376.81	411.55	1.3080	0.038408	376.31	410.88	1.2972	0.034392	375.81	410.20	1.2875
180	0.044554	386.99	422.64	1.3327	0.039423	386.52	422.00	1.3221	0.035317	386.04	421.36	1.3124

Q1. a) Cyclic device for refrigeration is liquid will process in close system and recycle within part of refrigerator. Main part of refrigerator is:

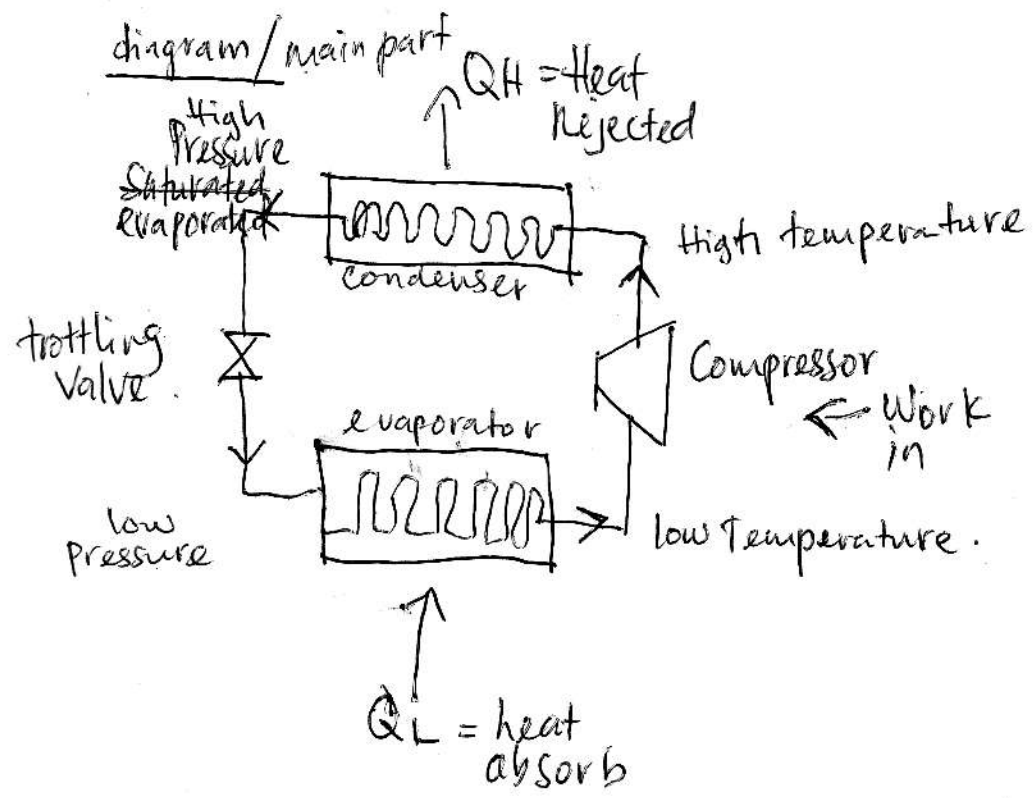
- i) Condenser
- ii) Compressor
- iii) evaporator
- iv) throttle valve
- v) Liquid (Refrigerant).

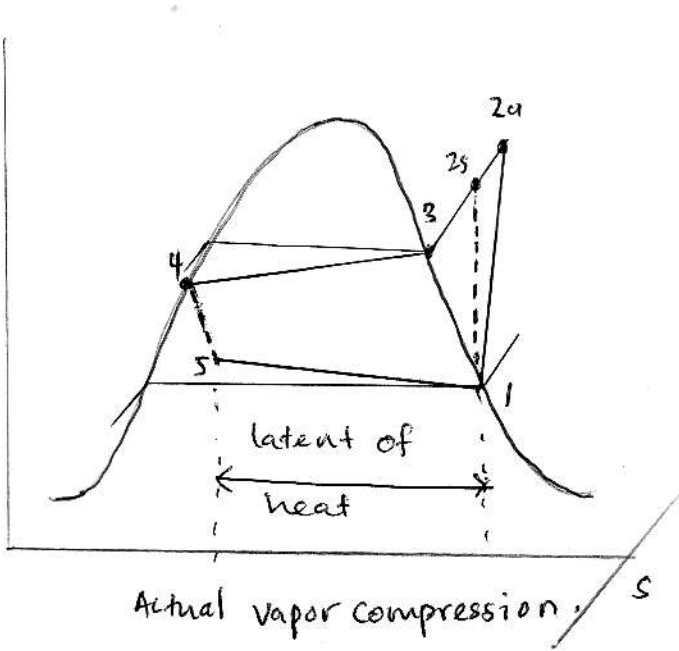
b) Main Function



- i) To absorb heat and from hot area and rejected to warm/hot area.
- ii) To maintain the temperature at cold area.
- iii) Maintain the humidity of air.

diagram/main part





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Actual Vapor

ideal vapor

1-2 process have a isentropic efficiency of compressor - Not an isentropic process

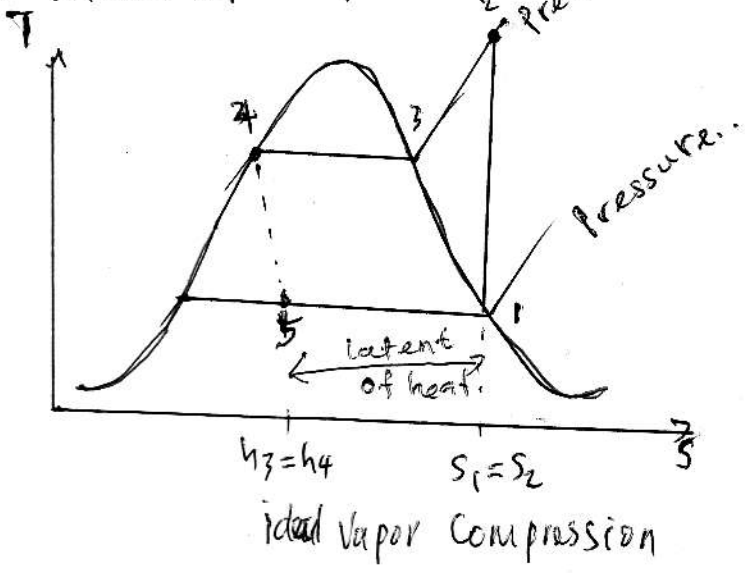
1-2 is a isentropic process (adiabatic process).

State 4
Pressure drop at outlet of condenser

State 4
pressure maintain at outlet of main. ~~evapo~~ condenser.

State 5
Pressure input evaporator is higher than output of evaporator
*Process of heat increase because of latent of heat increase

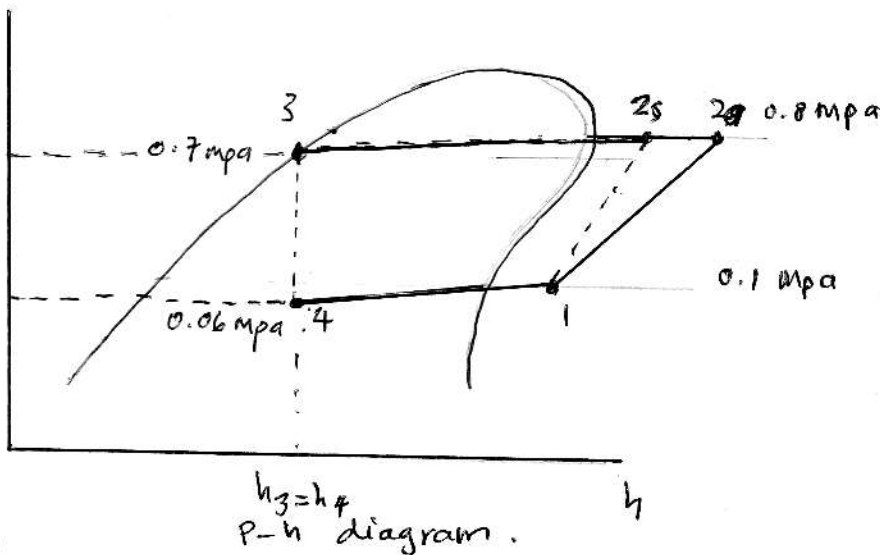
State 5
Assuming inlet and outlet of evaporator pressure is same value.
*low on latent of heat.



$h_3 = h_4$ $s_1 = s_2$

ideal Vapor Compression

P



State 1

$$h_1 = h_g @ P = 0.1 \text{ MPa}, T = -10^\circ\text{C}$$

$$h_1 = 247.49 \text{ kJ/kg}$$

$$s_1 = s_g = 1.0030 \text{ kJ/kg}\cdot\text{k}$$

State 2s

$$s_1 = s_2 = 1.0030 \text{ kJ/kg}\cdot\text{k} \quad \text{② Pressure } 0.8 \text{ MPa.}$$

Temp(T_2) between 50°C and 60°C .

T	h	s
50	286.69	0.9802
T_2	h_2	1.0030
60	296.81	1.0110

$$h_2 = 286.69 + (296.81 - 286.69) \left(\frac{1.0030 - 0.9802}{1.0110 - 0.9802} \right)$$

$$h_2 = 294.18 \text{ kJ/kg}$$

$$T_2 = 50 + (60 - 50) \left(\frac{1.0030 - 0.9802}{1.0110 - 0.9802} \right)$$

$$T_2 = 57.4^\circ\text{C}$$

State 3

hf at $T = 22^\circ\text{C}$ and $P = 0.7 \text{ MPa}$.

$$h_f = h_3 = 82.14 \text{ kJ/kg}\cdot\text{k}$$

State 4

$$h_3 = h_4 = 82.14 \text{ kJ/kg}\cdot\text{k}$$

State 2a

$$\eta_{vis,c} = \frac{h_{2s} - h_1}{h_{2a} - h_1}$$

$$h_{2a} = \frac{h_{2s} - h_1}{\eta_{vis,c}} + h_1$$

$$h_{2a} = \frac{294.18 - 247.49}{0.94} + 247.49$$

$$h_{2a} = 297.16 \text{ kJ/kg}$$

Temp, state 2a
between 60°C and 70°C .

- a) Temp of Refrigerant leaving the compressor.
~~57.4°C Finding at state 2 process.~~
- b) Heat Rejected.

T	h
60	296.81
T _{2a}	297.16
70	306.88

$$\frac{T_{2a} - 60}{70 - 60} = \frac{297.16 - 296.81}{306.88 - 296.81}$$

$$T_{2a} = 60.35^\circ\text{C}$$

- a) Temp. Ref leave the compressor
 60.35°C Finding at state 2a

b) $Q_H = \dot{m}(h_{2a} - h_3)$
 $= 0.08(297.16 - 82.14)$
 $= 17.20 \text{ kW}$

c) $Q_L = \dot{m}(h_1 - h_4)$
 $= 0.08(247.49 - 82.14)$
 $= 13.228 \text{ kW}$ where 1 ton = 333.53 kW
 $= 0.03966 \text{ ton of Capacity.}$

d) $COP_R = \frac{W_{net}}{Q_{in}} = \frac{Q_L}{W_{net}}$

$$COP_R = \frac{\dot{m}(h_{2a} - h_1)}{\dot{m}(h_1 - h_4)}$$

$$COP_R = \frac{0.08(297.16 - 82.14)}{0.08(247.49 - 82.14)}$$

~~$COP_R = 1.300$~~

$$COP_R = \frac{\dot{m}(h_1 - h_4)}{\dot{m}(h_{2a} - h_1)}$$

$$= \frac{247.49 - 82.14}{297.16 - 247.49}$$

$$COP_R = 3.33$$

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