國立清華大學 101 學年度碩士班考試入學試題

系所班組別：工程與系統科學系碩士班 乙組

考試科目（代碼）：熱力學（2602）

　　　*請在【答案卷、卡】作答

1. Explain

(a). Given the following process, Fig.1, please write down the coefficient performance value (γ) with function of $f(Q_{in}, Q_{out}, W_{cycle})$ and $f(Q_{out}, Q_{in})$ for heat pump cycle (4%).

(b). Given the following process, Fig.2, please write down the coefficient performance value (β) with function of $f(Q_{in}, Q_{out}, W_{cycle})$ and $f(Q_{out}, Q_{in})$ for refrigeration cycle (4%).

(c). What is the isentropic process (2%).

(d). If kinetic energy and potential energy can be neglected in a typical steady state and adiabatic process, which thermal properties would be keep at a constant value for throtting process (2%).

(e). Explain what is Carnot Vapor Cycle and draw T-S diagram of the Carnot Cycle, you are asked to mark the state 1, state 2, state 3, state 4, absorb heat Q_H from the high temperature reservoir T_H and dissipated heat Q_L to the low temperature reservoir T_L (6%).

(f). A power cycle is operating shown as the following figure 3, calculate the thermal efficiency if it is Carnot Cycle (2%).

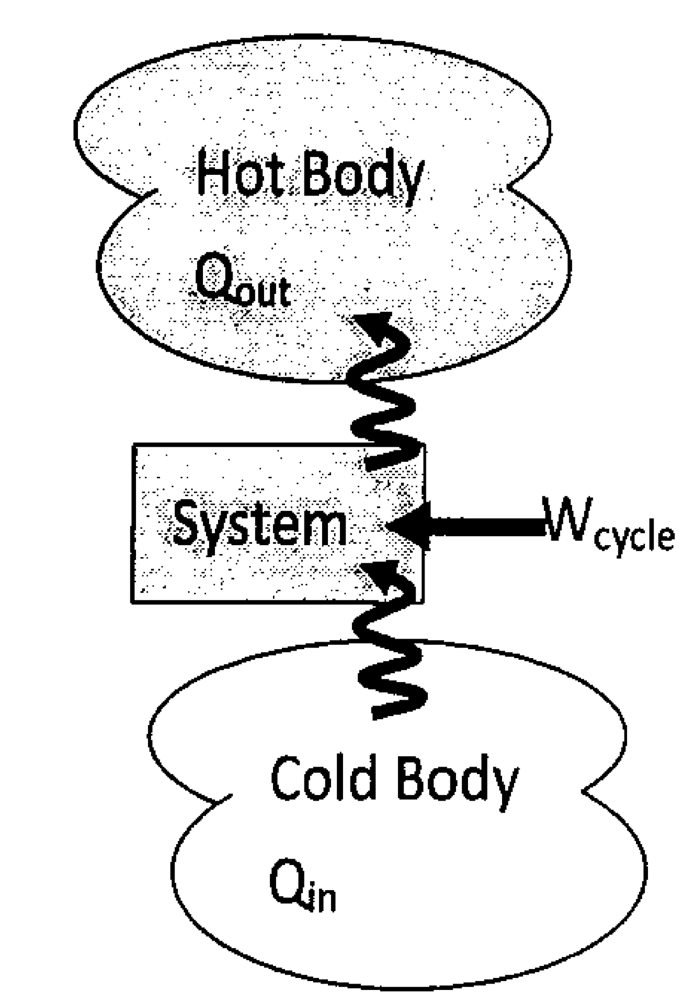


Fig. 1 heat pump cycle

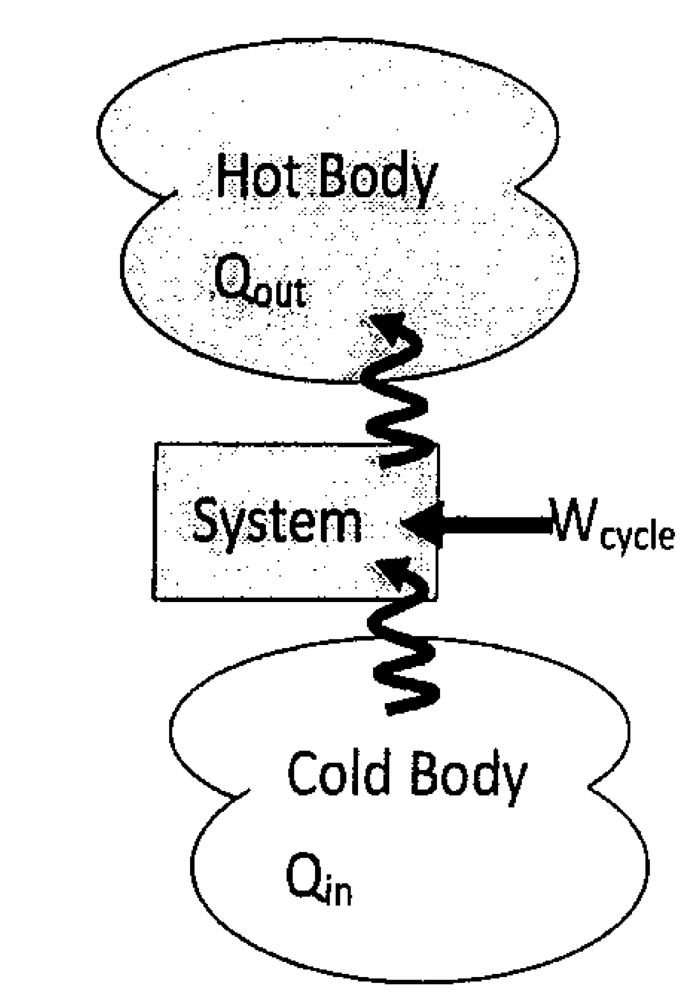


Fig. 2 refrigeration cycle

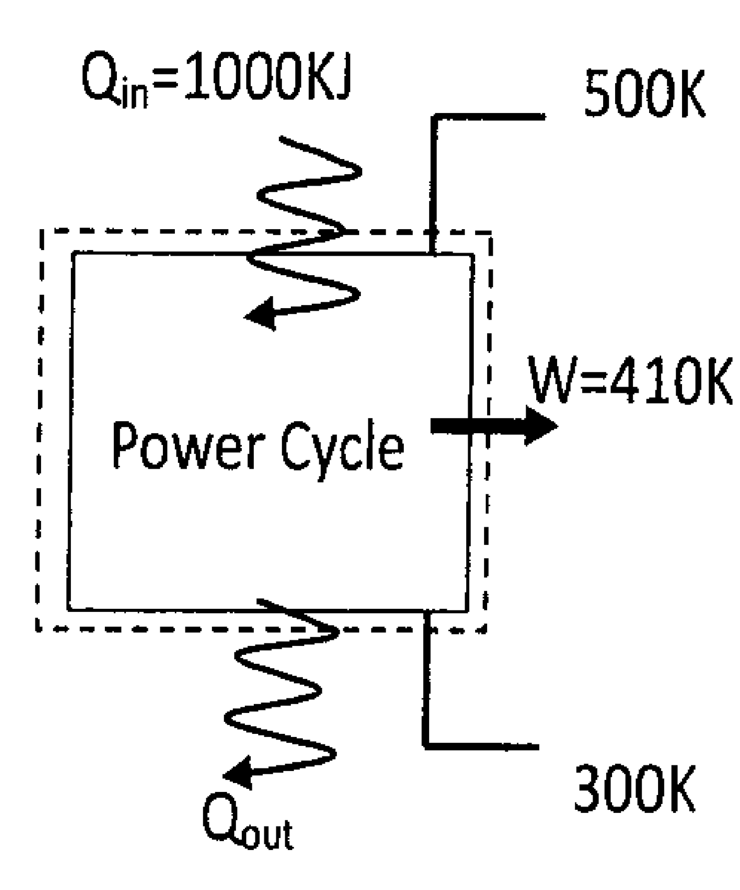


Fig. 3 Carnot Vapor Cycle

2. Given you the 1^{st}. law equation $dU=\delta Q-\delta W$. To simplify, assume it is ideal gas, how do you prove (a) Q is path function from the mathematic methods (10%) and how do prove (b) entropy is state function from the mathematic methods too [hint: $dS=(\delta Q/T)$] (10%)

3. (A) Try to evaluate the quality of the $\oint \frac{\delta Q_{irr}}{T}$ and $\oint \delta Q_{irr}$ is larger than zero or equal to zero or less than zero for :

   (1) Irreversible heat engine (2%)
   (2) Reversible heat pump (2%)
   (3) Irreversible heat pump (2%)
   (4) Reversible heat engine (2%)

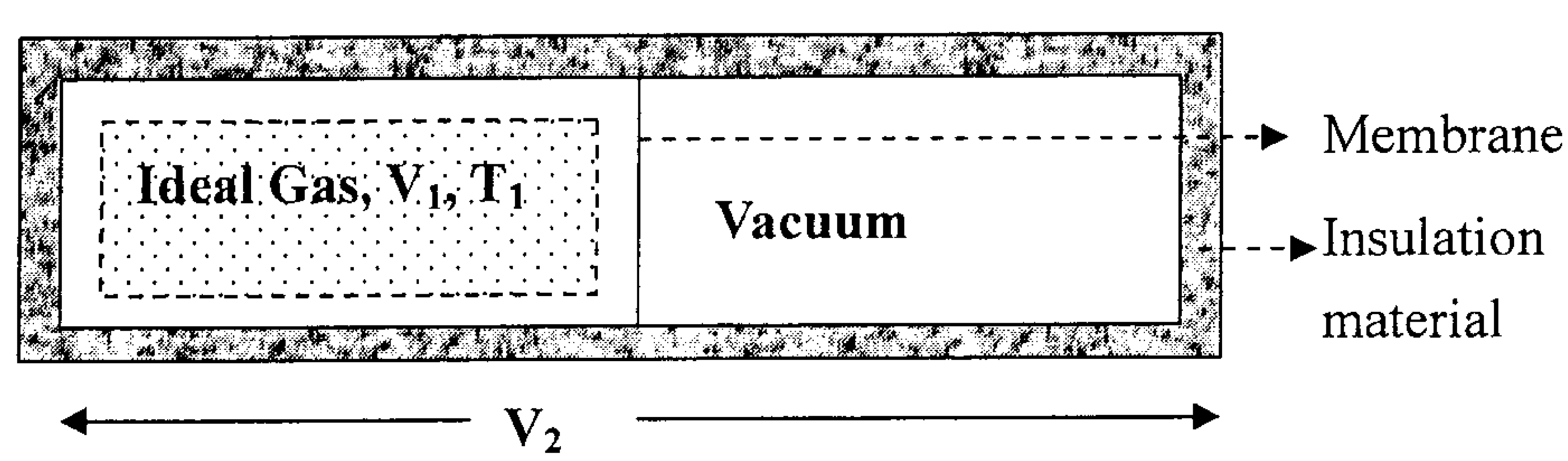
   (B) Explain what is heat engine (2%)

   (C) Explain what is heat pump (2%)

   (D) Try to derivate the relation between P(pressure), V(volume) and K when the system is closed, reversible, adiabatic and working fluid is ideal gas. (8%) where $k=C_p/C_v$, for ideal gas, $C_p=C_v+R$

4. In the following figure 1, shows a gas separated from vacuum by a membrane (state 1: V_1, T_1). The tank is fully isolated with fiber glass. Then let membrane rupture and the gas fill the entire volume, (state 2: V_2), all the friction loss can be neglected, gas can be assumed to be an ideal gas, no flow work:

   (a) Is there any mechanical work? If there is mechanical work, write down the work equation as function of (T, V_1, V_2), if there is no mechanical work, explain why? (2%)
   (b) What is the internal energy change? (3%)
   (c) What is the temperature T_2 at state 2? And why (5%)
   (d) What is the entropy change? (5%)
   (e) Draw the P-V diagram from state 1 to state2 (5%)



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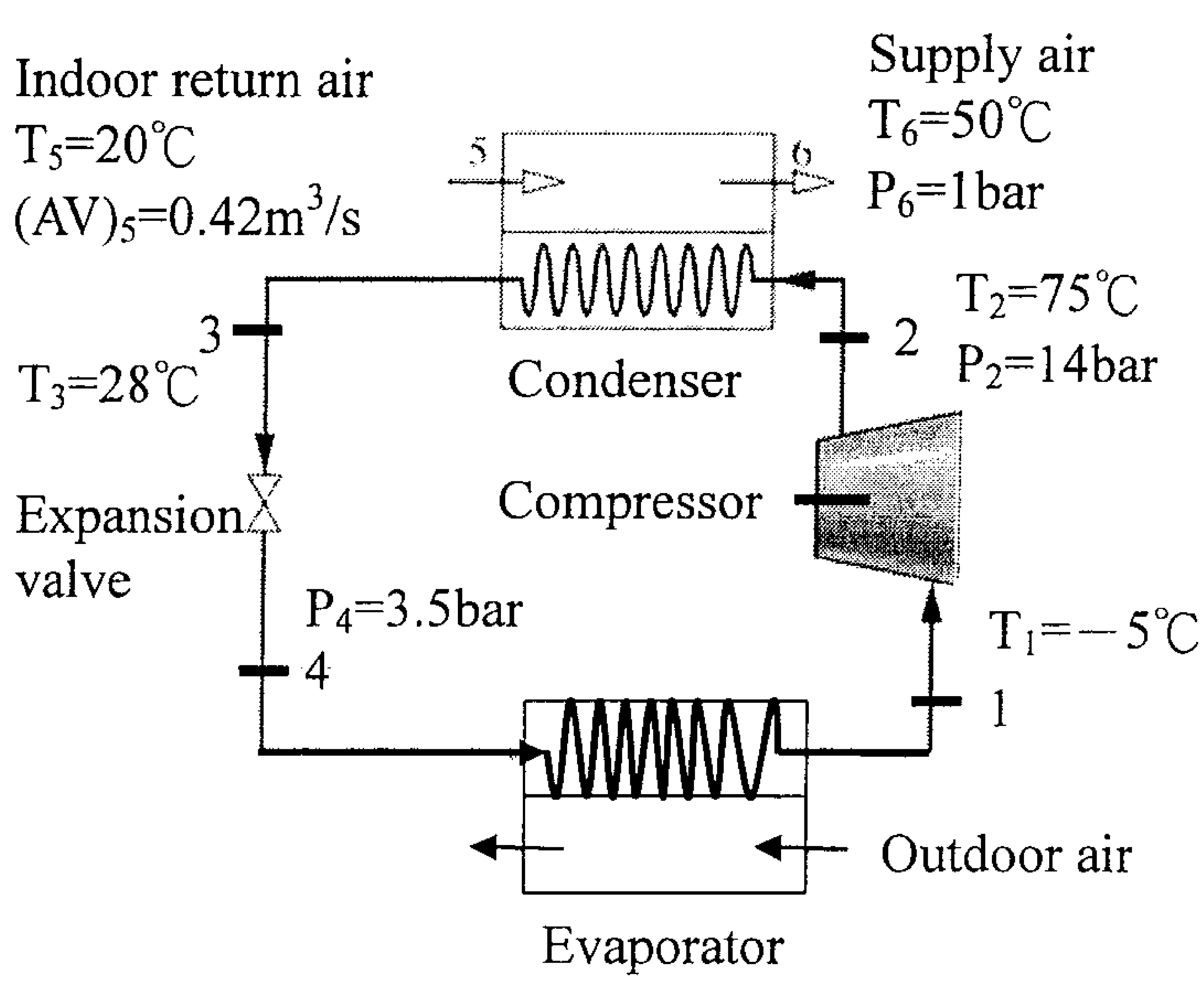
5. Components of a heat pump for supplying heated air to a dwelling are shown in the schematic below. At steady state, **Refrigerant 22** enters the compressor at -5°C, and is compressed adiabatically to 75°C, 14 bar. From the compressor, the refrigerant passes through the condenser, where it condenses to liquid at 28°C. Assume there is no friction loss on condenser or evaporator. The refrigerant expands through a throttling valve to 3.5 bar. Return air from the dwelling enters the condenser at 20°C with a volumetric flow rate of 0.42 m^3/s and exits at 50°C, 1 bar with a negligible change in pressure. Using the ideal gas model for the air and neglecting kinetic and potential energy effects, (a) Determine s_1, s_2, and s_3 in (KJ/Kg,K) (3%), h_1, h_2, and h_3 in (KJ/Kg) (3%) (b) Determine T_4 in (℃), h_4 in (KJ/Kg), s_4 in (KJ/Kg,K) and quality x_4 (4%) (c) Determine air mass flowrate (1%) and Refrigerant 22 mass flowrate (1%) in (Kg/s) (d) Determine the rates of entropy production, in kW/K, for control volumes enclosing **the condenser (1%)**, **compressor(1%)**, and **expansion valve(1%)**, respectively. (e) Determine the actual power for compressor in (KJ/Kg) (1%), the isentropic temperature at state 2, T_{2s} in (℃) (1%), the isentropic compressor work $W_{c,s}$ in (KJ/Kg) (2%) and the isentropic efficiency (1%). R=8.314 KJ/Kmole,K, $C_{p,air}$=1.005KJ/Kg,K, M_{air}= 28.97 Kg/Kmole, 1 bar= 10^5 N/m^2, 1 KJ=1000N-m, attached A is the **Refrigerant 22 table**



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Attached A: Refrigerant 22 table

R-22

TABLE A-7 Properties of Saturated Refrigerant 22 (Liquid–Vapor): Temperature Table

		Specific Volume m³/kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		
Temp. °C	Press. bar	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	Temp. °C
−60	0.3749	0.6833	0.5370	−21.57	203.67	−21.55	245.35	223.81	−0.0964	1.0547	−60
−50	0.6451	0.6966	0.3239	−10.89	207.70	−10.85	239.44	228.60	−0.0474	1.0256	−50
−45	0.8290	0.7037	0.2564	−5.50	209.70	−5.44	236.39	230.95	−0.0235	1.0126	−45
−40	1.0522	0.7109	0.2052	−0.07	211.68	0.00	233.27	233.27	0.0000	1.0005	−40
−36	1.2627	0.7169	0.1730	4.29	213.25	4.38	230.71	235.09	0.0186	0.9914	−36
−32	1.5049	0.7231	0.1468	8.68	214.80	8.79	228.10	236.89	0.0369	0.9828	−32
−30	1.6389	0.7262	0.1355	10.88	215.58	11.00	226.77	237.78	0.0460	0.9787	−30
−28	1.7819	0.7294	0.1252	13.09	216.34	13.22	225.43	238.66	0.0551	0.9746	−28
−26	1.9345	0.7327	0.1159	15.31	217.11	15.45	224.08	239.53	0.0641	0.9707	−26
−22	2.2698	0.7393	0.0997	19.76	218.62	19.92	221.32	241.24	0.0819	0.9631	−22
−20	2.4534	0.7427	0.0926	21.99	219.37	22.17	219.91	242.09	0.0908	0.9595	−20
−18	2.6482	0.7462	0.0861	24.23	220.11	24.43	218.49	242.92	0.0996	0.9559	−18
−16	2.8547	0.7497	0.0802	26.48	220.85	26.69	217.05	243.74	0.1084	0.9525	−16
−14	3.0733	0.7533	0.0748	28.73	221.58	28.97	215.59	244.56	0.1171	0.9490	−14
−12	3.3044	0.7569	0.0698	31.00	222.30	31.25	214.11	245.36	0.1258	0.9457	−12
−10	3.5485	0.7606	0.0652	33.27	223.02	33.54	212.62	246.15	0.1345	0.9424	−10
−8	3.8062	0.7644	0.0610	35.54	223.73	35.83	211.10	246.93	0.1431	0.9392	−8
−6	4.0777	0.7683	0.0571	37.83	224.43	38.14	209.56	247.70	0.1517	0.9361	−6
−4	4.3638	0.7722	0.0535	40.12	225.13	40.46	208.00	248.45	0.1602	0.9330	−4
−2	4.6647	0.7762	0.0501	42.42	225.82	42.78	206.41	249.20	0.1688	0.9300	−2
0	4.9811	0.7803	0.0470	44.73	226.50	45.12	204.81	249.92	0.1773	0.9271	0
2	5.3133	0.7844	0.0442	47.04	227.17	47.46	203.18	250.64	0.1857	0.9241	2
4	5.6619	0.7887	0.0415	49.37	227.83	49.82	201.52	251.34	0.1941	0.9213	4
6	6.0275	0.7930	0.0391	51.71	228.48	52.18	199.84	252.03	0.2025	0.9184	6
8	6.4105	0.7974	0.0368	54.05	229.13	54.56	198.14	252.70	0.2109	0.9157	8
10	6.8113	0.8020	0.0346	56.40	229.76	56.95	196.40	253.35	0.2193	0.9129	10
12	7.2307	0.8066	0.0326	58.77	230.38	59.35	194.64	253.99	0.2276	0.9102	12
16	8.1268	0.8162	0.0291	63.53	231.59	64.19	191.02	255.21	0.2442	0.9048	16
20	9.1030	0.8263	0.0259	68.33	232.76	69.09	187.28	256.37	0.2607	0.8996	20
24	10.164	0.8369	0.0232	73.19	233.87	74.04	183.40	257.44	0.2772	0.8944	24
28	11.313	0.8480	0.0208	78.09	234.92	79.05	179.37	258.43	0.2936	0.8893	28
32	12.556	0.8599	0.0186	83.06	235.91	84.14	175.18	259.32	0.3101	0.8842	32
36	13.897	0.8724	0.0168	88.08	236.83	89.29	170.82	260.11	0.3265	0.8790	36
40	15.341	0.8858	0.0151	93.18	237.66	94.53	166.25	260.79	0.3429	0.8738	40
45	17.298	0.9039	0.0132	99.65	238.59	101.21	160.24	261.46	0.3635	0.8672	45
50	19.433	0.9238	0.0116	106.26	239.34	108.06	153.84	261.90	0.3842	0.8603	50
60	24.281	0.9705	0.0089	120.00	240.24	122.35	139.61	261.96	0.4264	0.8455	60

Source: Tables A-7 through A-9 are calculated based on equations from A. Kamei and S. W. Beyerlein, "A Fundamental Equation for Chlorodifluoromethane (R-22)," *Fluid Phase Equilibria*, Vol. 80, No. 11, 1992, pp. 71–86.

Attached A: Refrigerant 22 table

TABLE A-9 *(Continued)*

p = 12.0 bar = 1.20 MPa (T_{sat} = 30.25°C)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
Sat.	0.01955	235.48	258.94	0.8864
40	0.02083	242.63	267.62	0.9146
50	0.02204	249.69	276.14	0.9413
60	0.02319	256.60	284.43	0.9666
70	0.02428	263.44	292.58	0.9907
80	0.02534	270.25	300.66	1.0139
90	0.02636	277.07	308.70	1.0363
100	0.02736	283.90	316.73	1.0582
110	0.02834	290.77	324.78	1.0794
120	0.02930	297.69	332.85	1.1002
130	0.03024	304.65	340.95	1.1205
140	0.03118	311.68	349.09	1.1405
150	0.03210	318.77	357.29	1.1601
160	0.03301	325.92	365.54	1.1793
170	0.03392	333.14	373.84	1.1983

p = 14.0 bar = 1.40 MPa (T_{sat} = 36.29°C)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
Sat.	0.01662	236.89	260.16	0.8786
40	0.01708	239.78	263.70	0.8900
50	0.01823	247.29	272.81	0.9186
60	0.01929	254.52	281.53	0.9452
70	0.02029	261.60	290.01	0.9703
80	0.02125	268.60	298.34	0.9942
90	0.02217	275.56	306.60	1.0172
100	0.02306	282.52	314.80	1.0395
110	0.02393	289.49	323.00	1.0612
120	0.02478	296.50	331.19	1.0823
130	0.02562	303.55	339.41	1.1029
140	0.02644	310.64	347.65	1.1231
150	0.02725	317.79	355.94	1.1429
160	0.02805	324.99	364.26	1.1624
170	0.02884	332.26	372.64	1.1815

p = 16.0 bar = 1.60 MPa (T_{sat} = 41.73°C)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
Sat.	0.01440	238.00	261.04	0.8715
50	0.01533	244.66	269.18	0.8971
60	0.01634	252.29	278.43	0.9252
70	0.01728	259.65	287.30	0.9515
80	0.01817	266.86	295.93	0.9762
90	0.01901	274.00	304.42	0.9999
100	0.01983	281.09	312.82	1.0228
110	0.02062	288.18	321.17	1.0448
120	0.02139	295.28	329.51	1.0663
130	0.02214	302.41	337.84	1.0872
140	0.02288	309.58	346.19	1.1077
150	0.02361	316.79	354.56	1.1277
160	0.02432	324.05	362.97	1.1473
170	0.02503	331.37	371.42	1.1666

p = 18.0 bar = 1.80 MPa (T_{sat} = 46.69°C)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
Sat.	0.01265	238.86	261.64	0.8649
50	0.01301	241.72	265.14	0.8758
60	0.01401	249.86	275.09	0.9061
70	0.01492	257.57	284.43	0.9337
80	0.01576	265.04	293.40	0.9595
90	0.01655	272.37	302.16	0.9839
100	0.01731	279.62	310.77	1.0073
110	0.01804	286.83	319.30	1.0299
120	0.01874	294.04	327.78	1.0517
130	0.01943	301.26	336.24	1.0730
140	0.02011	308.50	344.70	1.0937
150	0.02077	315.78	353.17	1.1139
160	0.02142	323.10	361.66	1.1338
170	0.02207	330.47	370.19	1.1532

p = 20.0 bar = 2.00 MPa (T_{sat} = 51.26°C)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
Sat.	0.01124	239.51	261.98	0.8586
60	0.01212	247.20	271.43	0.8873
70	0.01300	255.35	281.36	0.9167
80	0.01381	263.12	290.74	0.9436
90	0.01457	270.67	299.80	0.9689
100	0.01528	278.09	308.65	0.9929
110	0.01596	285.44	317.37	1.0160
120	0.01663	292.76	326.01	1.0383
130	0.01727	300.08	334.61	1.0598
140	0.01789	307.40	343.19	1.0808
150	0.01850	314.75	351.76	1.1013
160	0.01910	322.14	360.34	1.1214
170	0.01969	329.56	368.95	1.1410
180	0.02027	337.03	377.58	1.1603

p = 24.0 bar = 2.4 MPa (T_{sat} = 59.46°C)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
Sat.	0.00907	240.22	261.99	0.8463
60	0.00913	240.78	262.68	0.8484
70	0.01006	250.30	274.43	0.8831
80	0.01085	258.89	284.93	0.9133
90	0.01156	267.01	294.75	0.9407
100	0.01222	274.85	304.18	0.9663
110	0.01284	282.53	313.35	0.9906
120	0.01343	290.11	322.35	1.0137
130	0.01400	297.64	331.25	1.0361
140	0.01456	305.14	340.08	1.0577
150	0.01509	312.64	348.87	1.0787
160	0.01562	320.16	357.64	1.0992
170	0.01613	327.70	366.41	1.1192
180	0.01663	335.27	375.20	1.1388

R-22

Attached A: Refrigerant 22 table

TABLE A-9 (*Continued*)

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
	p = 3.5 bar = 0.35 MPa (T_{sat} = −10.39°C)				p = 4.0 bar = 0.40 MPa (T_{sat} = −6.56°C)			
Sat.	0.06605	222.88	246.00	0.9431	0.05812	224.24	247.48	0.9370
−10	0.06619	223.10	246.27	0.9441				
−5	0.06789	225.99	249.75	0.9572	0.05860	225.16	248.60	0.9411
0	0.06956	228.86	253.21	0.9700	0.06011	228.09	252.14	0.9542
5	0.07121	231.74	256.67	0.9825	0.06160	231.02	225.66	0.9670
10	0.07284	234.63	260.12	0.9948	0.06306	233.95	259.18	0.9795
15	0.07444	237.52	263.57	1.0069	0.06450	236.89	262.69	0.9918
20	0.07603	240.42	267.03	1.0188	0.06592	239.83	266.19	1.0039
25	0.07760	243.34	270.50	1.0305	0.06733	242.77	269.71	1.0158
30	0.07916	246.27	273.97	1.0421	0.06872	245.73	273.22	1.0274
35	0.08070	249.22	227.46	1.0535	0.07010	248.71	276.75	1.0390
40	0.08224	252.18	280.97	1.0648	0.07146	251.70	280.28	1.0504
45	0.08376	255.17	284.48	1.0759	0.07282	254.70	283.83	1.0616