First Semester Examination
2022/2023 Academic Session

February 2023

EME 431 – Refrigeration and Air Conditioning
(Penyejukan & Penyamanan Udara)

Duration: 2 hours
(Masa: 2 jam)

Please check that this examination paper consists of TEN (10) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEPULUH (10) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: Answer ALL **FOUR (4)** questions.

*[**Arahan**: Jawab **EMPAT (4)** soalan]*

...2/-

1. (a) Identify the refrigerants and fill up the blank boxes.

ASHRAE Number	Chemical Name	Molecular Formula	Type
	Trichlorotetrafluoropropane	$C_3HF_4Cl_3$	Halocarbon
R600a	Isobutane	$CH(CH_3)_2CH_3$	
	1,2-Difluoroethane	$C_2H_4F_2$	Halocarbon
	Chlorofluoromethane	CH_2FCl	Halocarbon
R401A	R-22/152a/124	53±2% $CHClF_2$ 13+0.5,-1.5% $C_2H_4F_2$ 34±1% C_2HF_4Cl	
R704	Helium	He	

(30 marks)

(b) As an engineer, you are assigned to design a refrigeration system using vapour compression cycle with refrigerant R717 that able to cool down to -15°C. The system will be installed at a place with the outdoor temperature at 12°C in spring, 45°C in summer, 25°C in fall and 6°C in winter.

(i) What is the maximum required pressure at the evaporator and minimum required pressure at the condenser of the refrigeration system in order to fulfil the design requirements?

(10 marks)

If the energy consumption by the compressor during summer is 25 kW, and the compressor efficiency is 90%, calculate:

(ii) refrigerating effect,

(10 marks)

(iii) refrigerant mass flow rate,

(30 marks)

(iv) refrigerating capacity, and

(10 marks)

(v) Coefficient of Performance (COP) of the system.

(10 marks)

...3/-

2. (a) An air cooler has the efficiency of 80%, and the given ambient conditions are 33°C and 67% of relative humidity, calculate:

(i) Output air temperature, and
(ii) Output air relative humidity

(30 marks)

(b) A frozen food factory is equipped with a vapour absorption refrigeration system, the generator, condenser, evaporator, and absorber of the refrigeration system operate at the temperatures of 110°C, 40°C, -15°C and 30°C, respectively. The mass flow rate at the pump is 0.2 kg/s. Calculate:

(i) The absorbent concentration at absorber and generator

(10 marks)

(ii) Both mass flow rates from the generator

(20 marks)

(iii) Cooling capacity of the system

(10 marks)

(iv) Energy input to the system

(20 marks)

(v) COP of the system

(10 marks)

3. (a) Describe briefly with the aid of schematic diagram, the main components of typical central air conditioning system in Malaysia.

(30 marks)

(b) A multipurpose hall of 7 m height as shown in Figure Q3b, is proposed to be built at USM to accommodate 500 peoples. Assume ambient temperature to be 32°C and hall temperature to be 25°C. The south wall is a double-layer glass with no shading. Coefficient of overall heat transfer for walls/roof is U= 0.64W/m^2K and lighting requirement is 20 W/m^2 of floor area (18W Fluorescent lamps). You MUST consider suitable equipment (Personal Computer, projector, etc.) in the hall. Use the data in Table Q3 for your calculations and make all the necessary assumptions. Calculate the peak gained heat and SHF in the hall.

(70 marks)

...4/-

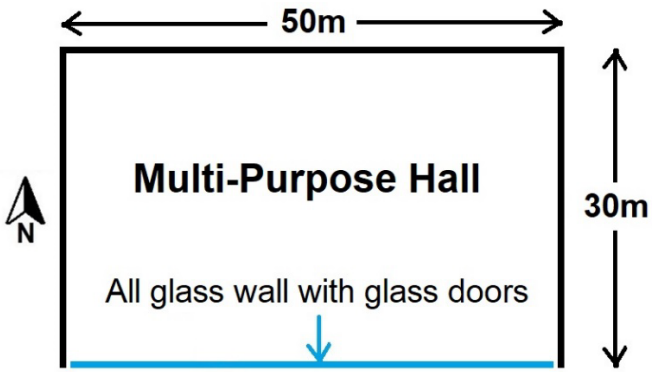

Figure Q3b

Table Q3b

$CLTD_C$

Daily Temperature Range	Design Temperature, °C												MSHGF (W/m^2)
	29		32			35			38		41	43	
	L	M	L	M	H	L	M	H	M	H	M	H	
North	4	2	7	4	2	10	7	4	10	7	10	13	347
NE and NW	8	5	11	8	5	13	11	8	13	11	13	16	637
East and West	10	7	13	10	7	16	13	10	16	13	16	18	618
SE and SW	9	6	12	9	6	14	12	9	14	12	14	17	230
South	6	3	9	6	3	12	9	6	12	9	12	14	120
Roofs	23	21	26	23	21	28	26	23	28	26	28	31	830

Shading Coefficients and U-Factors for Windows

	Inside Shade					
	None		Drapery, Venetian Blind, or Translucent Roller Shade		Opaque Roller Shade	
Glass Type	SC	*U*	SC	*U*	SC	*U*
Single	1.00	5.91	0.50	4.60	0.38	4.60
Double	0.88	3.46	0.45	3.12	0.36	3.12
Heat-absorbing	0.58	2.56	0.37	2.50	0.33	2.50
Triple	0.80	2.50	0.44	2.27	0.36	2.27

Note: *U* is in $W/(m^2 \cdot K)$.

4. [a] Describe briefly the reducing trunk duct system and provide **ONE (1)** advantage and disadvantage.

(30 marks)

...5/-

(b) An air conditioning system is designed to maintain temperature of 25ºC and relative humidity of 50% in a room. The outside air is at a temperature of 32ºC and relative humidity of 80%. The cooling load of the room is 15 kW sensible heat gain and 3 kW latent heat gain. The fresh air supply is 20% by mass. Temperature of the cold air to the room is 15ºC. Assume that the cooling coil efficiency is 80% and neglect the effect of the fan.

(i) Plot the process on the provided psychrometric chart and submit the chart with your answer sheets.

(10 marks)

Calculate:

(ii) Actual flow rate of air supply to the room
(iii) Refrigeration capacity of the cooling coil in ton refrigeration (TR)
(iv) Heating capacity of the re-heater

(60 marks)

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Appendix A – Ammonia Properties Tables

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

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

Temp. °C	Press. bar	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Specific Volume m^3/kg Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Internal Energy kJ/kg Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Enthalpy kJ/kg Evap. h_{fg}	Enthalpy kJ/kg Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Entropy kJ/kg · K Sat. Vapor s_g	Temp. °C
−50	0.4086	1.4245	2.6265	−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

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 = 5.5 bar = 0.55 MPa (T_{sat} = 6.79°C)				p = 6.0 bar = 0.60 MPa (T_{sat} = 9.27°C)			
Sat.	0.22861	1323.06	1448.80	5.2430	0.21038	1324.89	1451.12	5.2122
10	0.23227	1329.88	1457.63	5.2743	0.21115	1326.47	1453.16	5.2195
20	0.24335	1350.50	1484.34	5.3671	0.22155	1347.62	1480.55	5.3145
30	0.25403	1370.35	1510.07	5.4534	0.23152	1367.90	1506.81	5.4026
40	0.26441	1389.64	1535.07	5.5345	0.24118	1387.52	1532.23	5.4851
50	0.27454	1408.53	1559.53	5.6114	0.25059	1406.67	1557.03	5.5631
60	0.28449	1427.13	1583.60	5.6848	0.25981	1425.49	1581.38	5.6373
80	0.30398	1463.85	1631.04	5.8230	0.27783	1462.52	1629.22	5.7768
100	0.32307	1500.36	1678.05	5.9525	0.29546	1499.25	1676.52	5.9071
120	0.34190	1537.02	1725.07	6.0753	0.31281	1536.07	1723.76	6.0304
140	0.36054	1574.07	1772.37	6.1926	0.32997	1573.24	1771.22	6.1481
160	0.37903	1611.66	1820.13	6.3055	0.34699	1610.92	1819.12	6.2613
180	0.39742	1649.88	1868.46	6.4146	0.36390	1649.22	1867.56	6.3707
200	0.41571	1688.79	1917.43	6.5203	0.38071	1688.20	1916.63	6.4766

	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 7.0 bar = 0.70 MPa (T_{sat} = 13.79°C)			
Sat.	0.18148	1328.04	1455.07	5.1576
20	0.18721	1341.72	1472.77	5.2186
30	0.19610	1362.88	1500.15	5.3104
40	0.20464	1383.20	1526.45	5.3958
50	0.21293	1402.90	1551.95	5.4760
60	0.22101	1422.16	1576.87	5.5519
80	0.23674	1459.85	1625.56	5.6939
100	0.25205	1497.02	1673.46	5.8258
120	0.26709	1534.16	1721.12	5.9502
140	0.28193	1571.57	1768.92	6.0688
160	0.29663	1609.44	1817.08	6.1826
180	0.31121	1647.90	1865.75	6.2925
200	0.32571	1687.02	1915.01	6.3988

	v	u	h	s
	p = 8.0 bar = 0.80 MPa (T_{sat} = 17.84°C)			
Sat.	0.15958	1330.64	1458.30	5.1099
20	0.16138	1335.59	1464.70	5.1318
30	0.16948	1357.71	1493.29	5.2277
40	0.17720	1378.77	1520.53	5.3161
50	0.18465	1399.05	1546.77	5.3986
60	0.19189	1418.77	1572.28	5.4763
80	0.20590	1457.14	1621.86	5.6209
100	0.21949	1494.77	1670.37	5.7545
120	0.23280	1532.24	1718.48	5.8801
140	0.24590	1569.89	1766.61	5.9995
160	0.25886	1607.96	1815.04	6.1140
180	0.27170	1646.57	1863.94	6.2243
200	0.28445	1685.83	1913.39	6.3311

	v	u	h	s
	p = 9.0 bar = 0.90 MPa (T_{sat} = 21.52°C)			
Sat.	0.14239	1332.82	1460.97	5.0675
30	0.14872	1352.36	1486.20	5.1520
40	0.15582	1374.21	1514.45	5.2436
50	0.16263	1395.11	1541.47	5.3286
60	0.16922	1415.32	1567.61	5.4083
80	0.18191	1454.39	1618.11	5.5555
100	0.19416	1492.50	1667.24	5.6908
120	0.20612	1530.30	1715.81	5.8176
140	0.21788	1568.20	1764.29	5.9379
160	0.22948	1606.46	1813.00	6.0530
180	0.24097	1645.24	1862.12	6.1639
200	0.25237	1684.64	1911.77	6.2711

	v	u	h	s
	p = 10.0 bar = 1.00 MPa (T_{sat} = 24.89°C)			
	0.12852	1334.66	1463.18	5.0294
	0.13206	1346.82	1478.88	5.0816
	0.13868	1369.52	1508.20	5.1768
	0.14499	1391.07	1536.06	5.2644
	0.15106	1411.79	1562.86	5.3460
	0.16270	1451.60	1614.31	5.4960
	0.17389	1490.20	1664.10	5.6332
	0.18478	1528.35	1713.13	5.7612
	0.19545	1566.51	1761.96	5.8823
	0.20598	1604.97	1810.94	5.9981
	0.21638	1643.91	1860.29	6.1095
	0.22670	1683.44	1910.14	6.2171

	v	u	h	s
	p = 12.0 bar = 1.20 MPa (T_{sat} = 30.94°C)			
Sat.	0.10751	1337.52	1466.53	4.9625
40	0.11287	1359.73	1495.18	5.0553
60	0.12378	1404.54	1553.07	5.2347
80	0.13387	1445.91	1606.56	5.3906
100	0.14347	1485.55	1657.71	5.5315
120	0.15275	1524.41	1707.71	5.6620
140	0.16181	1563.09	1757.26	5.7850
160	0.17072	1601.95	1806.81	5.9021
180	0.17950	1641.23	1856.63	6.0145
200	0.18819	1681.05	1906.87	6.1230
220	0.19680	1721.50	1957.66	6.2282
240	0.20534	1762.63	2009.04	6.3303
260	0.21382	1804.48	2061.06	6.4297
280	0.22225	1847.04	2113.74	6.5267

	v	u	h	s
	p = 14.0 bar = 1.40 MPa (T_{sat} = 36.26°C)			
	0.09231	1339.56	1468.79	4.9050
	0.09432	1349.29	1481.33	4.9453
	0.10423	1396.97	1542.89	5.1360
	0.11324	1440.06	1598.59	5.2984
	0.12172	1480.79	1651.20	5.4433
	0.12986	1520.41	1702.21	5.5765
	0.13777	1559.63	1752.52	5.7013
	0.14552	1598.92	1802.65	5.8198
	0.15315	1638.53	1852.94	5.9333
	0.16068	1678.64	1903.59	6.0427
	0.16813	1719.35	1954.73	6.1485
	0.17551	1760.72	2006.43	6.2513
	0.18283	1802.78	2058.75	6.3513
	0.19010	1845.55	2111.69	6.4488

	v	u	h	s
	p = 16.0 bar = 1.60 MPa (T_{sat} = 41.03°C)			
Sat.	0.08079	1340.97	1470.23	4.8542
60	0.08951	1389.06	1532.28	5.0461
80	0.09774	1434.02	1590.40	5.2156
100	0.10539	1475.93	1644.56	5.3648
120	0.11268	1516.34	1696.64	5.5008
140	0.11974	1556.14	1747.72	5.6276
160	0.12663	1595.85	1798.45	5.7475
180	0.13339	1635.81	1849.23	5.8621
200	0.14005	1676.21	1900.29	5.9723
220	0.14663	1717.18	1951.79	6.0789
240	0.15314	1758.79	2003.81	6.1823
260	0.15959	1801.07	2056.42	6.2829
280	0.16599	1844.05	2109.64	6.3809

	v	u	h	s
	p = 18.0 bar = 1.80 MPa (T_{sat} = 45.38°C)			
Sat.	0.07174	1341.88	1471.01	4.8086
60	0.07801	1380.77	1521.19	4.9627
80	0.08565	1427.79	1581.97	5.1399
100	0.09267	1470.97	1637.78	5.2937
120	0.09931	1512.22	1690.98	5.4326
140	0.10570	1552.61	1742.88	5.5614
160	0.11192	1592.76	1794.23	5.6828
180	0.11801	1633.08	1845.50	5.7985
200	0.12400	1673.78	1896.98	5.9096
220	0.12991	1715.00	1948.83	6.0170
240	0.13574	1756.85	2001.18	6.1210
260	0.14152	1799.35	2054.08	6.2222
280	0.14724	1842.55	2107.58	6.3207

	v	u	h	s
	p = 20.0 bar = 2.00 MPa (T_{sat} = 49.37°C)			
Sat.	0.06445	1342.37	1471.26	4.7670
60	0.06875	1372.05	1509.54	4.8838
80	0.07596	1421.36	1573.27	5.0696
100	0.08248	1465.89	1630.86	5.2283
120	0.08861	1508.03	1685.24	5.3703
140	0.09447	1549.03	1737.98	5.5012
160	0.10016	1589.65	1789.97	5.6241
180	0.10571	1630.32	1841.74	5.7409
200	0.11116	1671.33	1893.64	5.8530
220	0.11652	1712.82	1945.87	5.9611
240	0.12182	1754.90	1998.54	6.0658
260	0.12706	1797.63	2051.74	6.1675
280	0.13224	1841.03	2105.50	6.2665

Appendix B – Psychrometric Chart

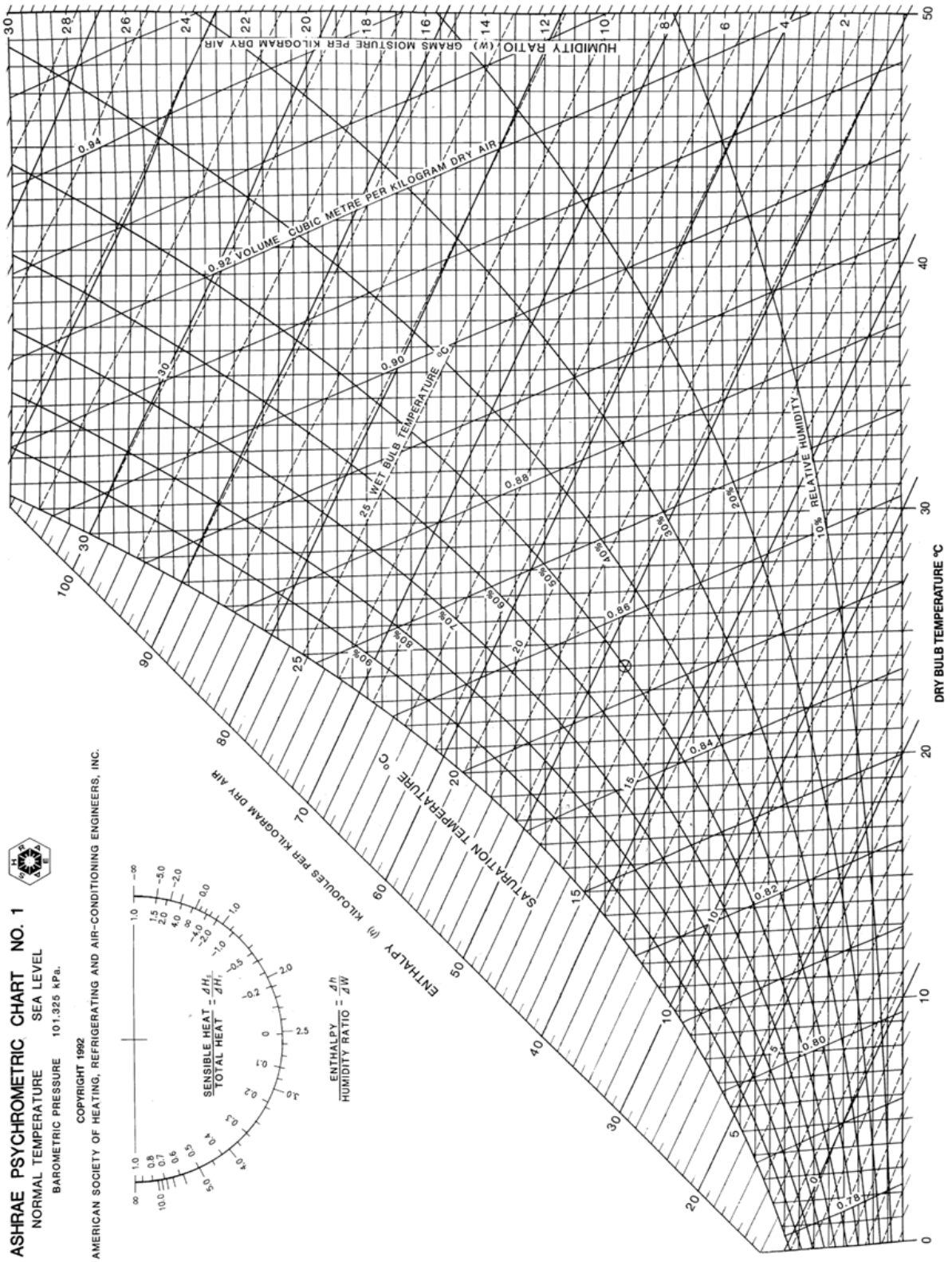
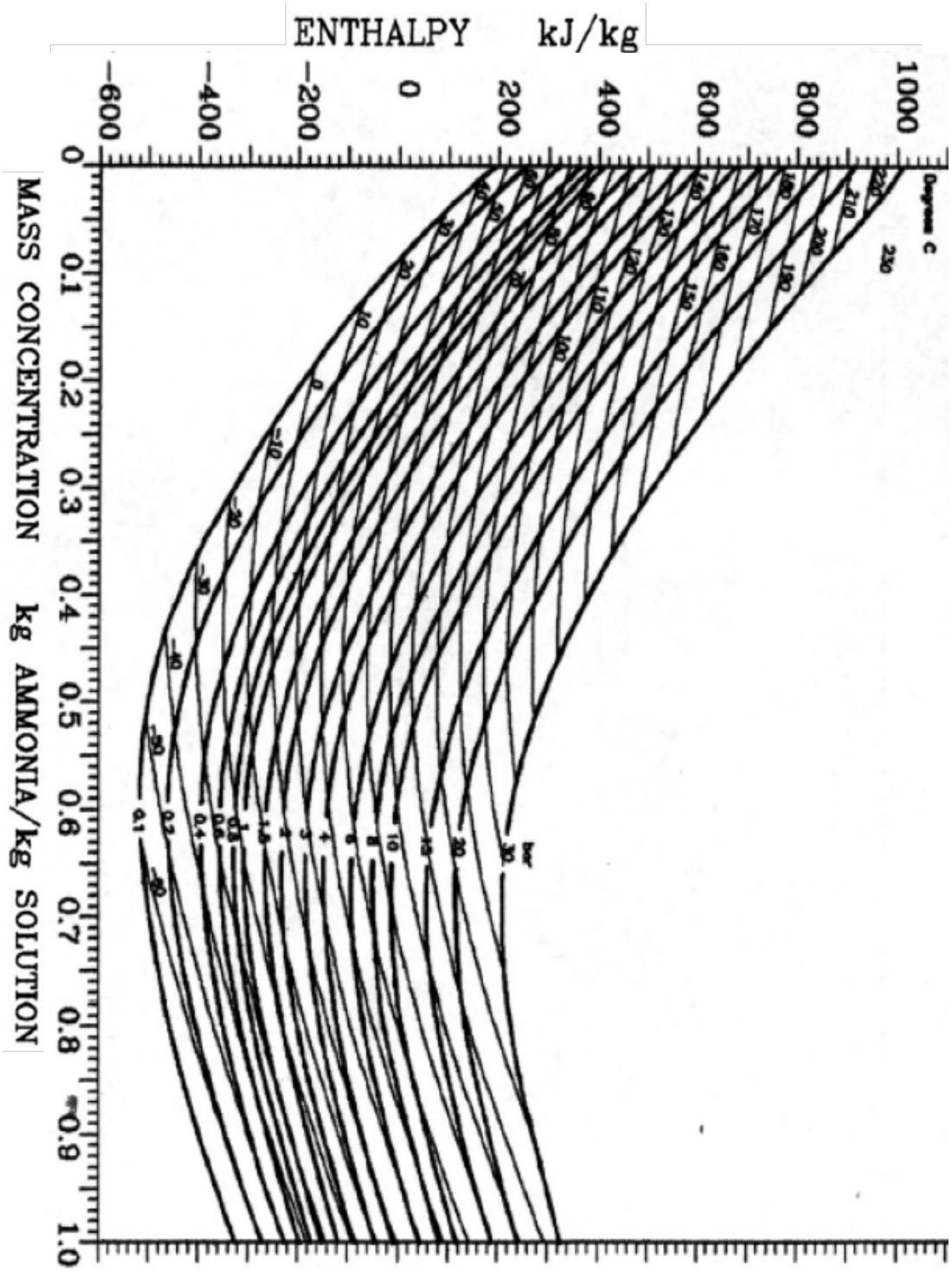


Fig. 1 ASHRAE Psychrometric Chart No. 1

Appendix C – Enthalpy Concentration for Ammonia Water Solution



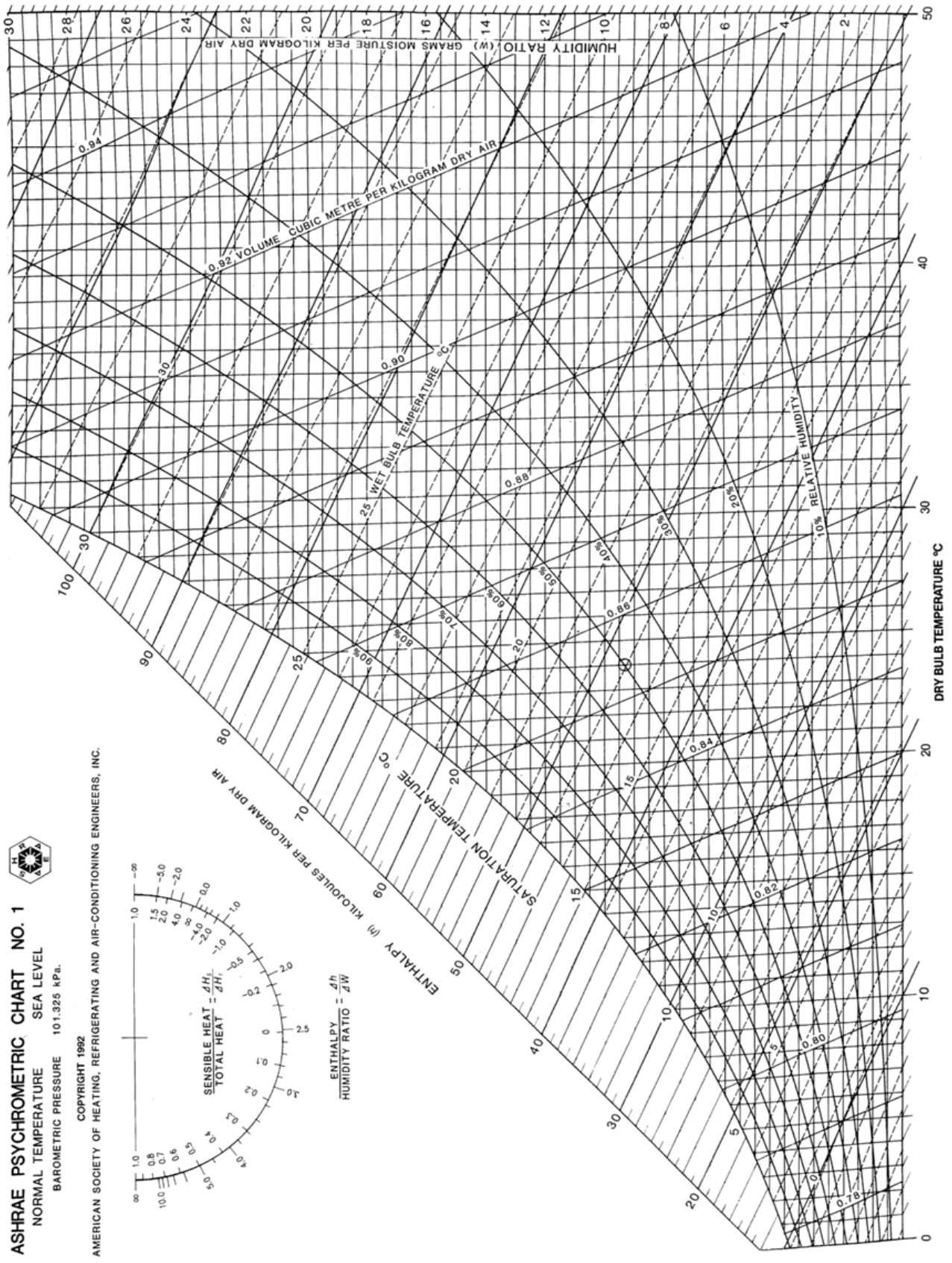


Fig. 1 ASHRAE Psychrometric Chart No. 1