INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Department of Mechanical Engineering

Date : Time : 3 hours Full Marks : 100 No. of students : 127

End-Sem. 2017 Sub.name: Applied Thermo-Fluids-I Sub.No.: ME~~40701~~ 41001

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All questions in Part-A and Part-B are compulsory. Wherever necessary, make suitable assumptions and state them clearly

Part-A (Internal Combustion Engines)
For air, R=0.287 kJ/kg-K

1. A 5.6-liter V8 engine with a compression ratio of 10.2:1 is equipped with cylinder cutout, which converts it to a 2.8-liter four-cylinder engine at low load requirements. The engine operates on an Otto cycle using gasoline, and with eight cylinders at 1800 RPM, it has an AF = 14.9, a volumetric efficiency of 57%, a combustion efficiency of 91%, and a mechanical efficiency of 92%. If cylinder cutout occurs, the engine speeds up to produce the same brake power output. Using only four cylinders at this condition, the engine has an AF = 14.2, a volumetric efficiency of 66% and a combustion efficiency of 99%, but a mechanical efficiency of only 90%. Ambient temperature and pressure are 27^{0}C and 101 kPa respectively. Heating value of fuel is 43 MJ/kg of fuel. Take γ = 1.35.

Calculate:

a. *Indicated thermal efficiency (%).*
b. *Percent reduction in fuel consumption operating on four cylinders to produce same brake power output.*
c. *Engine speed needed to produce same power output using only four cylinders.*

2+4+4=10

2. A six-cylinder, 3.6-liter SI engine is designed to have a maximum speed of 6000RPM. At this speed, the volumetric efficiency of the engine is 0.92. The engine will be equipped with a two-barrel carburetor, one barrel for low speeds and both barrel for high speeds. Gasoline density can be considered to be 750 kg/m^3. Ambient temperature and pressure are 27^{0}C and 101 kPa respectively. The AF ratio is 15.2. For air, ratio of specific heats is 1.4.

Calculate:

1. Throat diameter for the carburetor for maximum air flow. Discharge coefficient for the venture is 0.94.
2. Calculate the fuel capillary tube diameter if the tip of the jet is 1.5 cm above the fuel level in the float chamber. The discharge coefficient is 0.74 for the capillary nozzle.

7+6=13

3. Explain with proper graph:
   a. What do you understand by a fuel classified as **53-85-107^{0}C**,
   b. Variation of bsfc and brake power as a function of equivalence ratio,
   c. What is ignition delay? Plot it on a temperature time diagram with proper labeling.
   d. Explain the knocking phenomenon. Plot the pressure variation during knocking phenomenon.

3+3+3+3=12

4. An ideal air-standard diesel cycle with air as the working fluid has a compression ratio **18**. At the beginning of the compression process, the pressure, volume and the temperature are **101 kPa**, **500 cc** and **27^{0}C** respectively. The total heat addition during the combustion process is **1800 kJ/kg**. Take $\gamma = 1.35$.

   Calculate:

   a. The pressure and temperature at the end of compression process, at the end of the heat addition process, and at the end of the expansion process.
   b. The work done during compression, constant pressure heat addition and expansion processes (kJ).
   c. The cut-off ratio.
   d. Net work output (kJ), mep (kPa). (6+6+1+2 = 15)

Part-B (Refrigeration & Air conditioning)

Data required may be obtained from the graph and tables provided.

5. What length of capillary tube (ID=1.63 mm) will drop the pressure of saturated liquid refrigerant 22 at 40°C to the saturation temperature of 39°C. The flow rate is 0.010 kg/s

   The equation for the viscosity [Pa.s] dependence on temperature t [°C] is as follows.

   $\mu_f = 2.367 \times 10^{-4} - 1.715 \times 10^{-6}\, t + 8.869 \times 10^{-9}\, t^2$

   $\mu_g = 11.945 \times 10^{-6} + 50.06 \times 10^{-9}\, t + 0.2560 \times 10^{-9}\, t^2$

   The equation for friction factor f dependence on Reynolds number Re is as follows

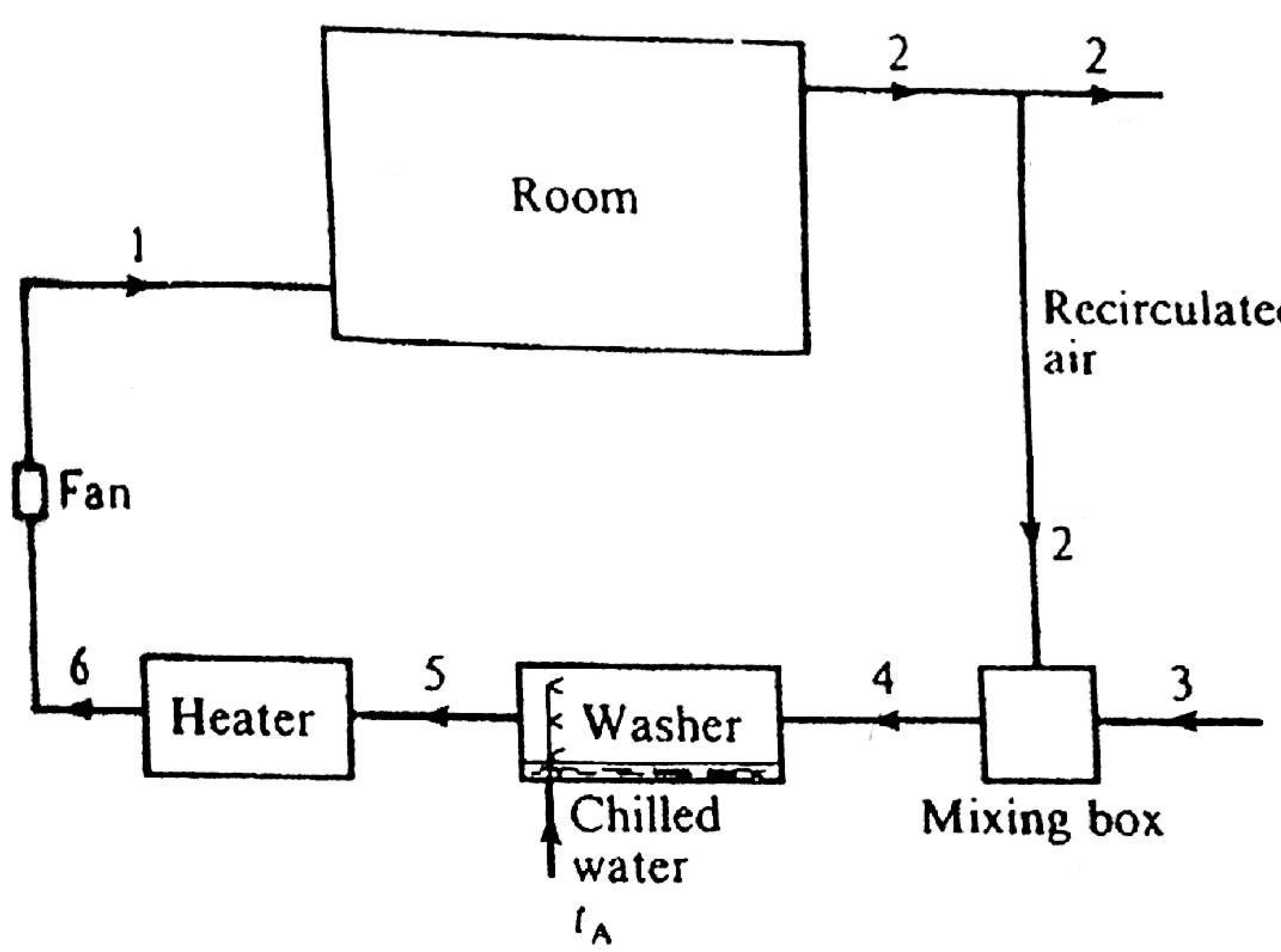
   $f = 0.33 / Re^{0.25}$

6. Air at 1°C dry bulb temperature and 80% relative humidity mixes adiabatically with air at 18°C dry bulb temperature and 40% relative humidity in the ratio of 1 to 3 by volume at 101.325kPa. Calculate the temperature and relative humidity of the mixture. Write the procedure to calculate the relative humidity if the pressure of the mixture is increased to 120kPa keeping the temperature same.

6+6=12

7. An air-conditioning plant is designed to maintain a room at a condition of 20°C dry bulb temperature and 0.0079 specific humidity when the outside condition is 30°C dry bulb temperature and 40% relative humidity. The heat gains are 18kW (sensible) and 3.6 kW (latent). The supply air contains one-third outside air by mass and the supply temperature is set to be 15°C dry bulb temperature.

The plant consists of a mixing chamber for fresh and recirculated air, an air washer with chilled spray water with an efficiency of 80%, and after heater and supply fan as shown in the diagram



Neglecting temperature changes in fan and ducting,

(i) show the points on the psycrometric chart

(ii) calculate the mass flow rate of supply air necessary

(iii) calculate the specific humidity of supply air

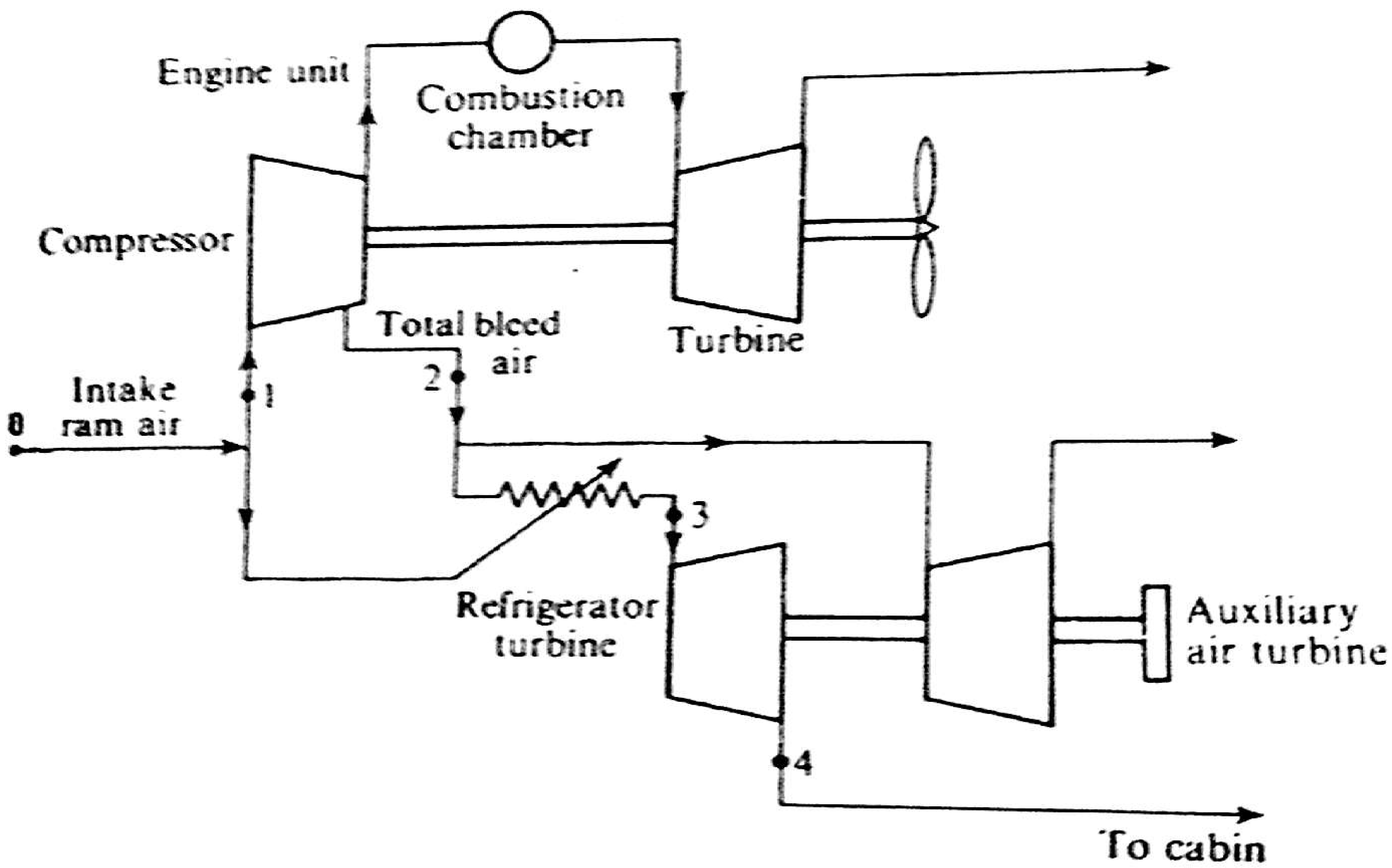
(iv) calculate the cooling duty of the washer

(v) calculate the heating duty of the after heater

3 x 5=15

8. In an air-cooling system of a jet aircraft, air is bled from the engine compressor at 3 bar, and is cooled in a heat exchanger to 105°C. It is expanded to 0.69 bar in an air turbine, the isentropic efficiency of the process being 85%. The air is then delivered to the cabin and leaves the air craft at 27°C. Draw the thermodynamic cycle as a T-s diagram. Calculate the temperature at which the air enters the cabin and the mass flow rate of air required for a refrigerating effect of 4 kW. If the air turbine is used to help drive the auxiliaries, calculate its contribution in power supply in kW.

For air, $c_p = 1.005$ kJ/kg.K, $c_p / c_v = 1.4$



3+4+4=11

Barometric pressure = 101.325 kPa
Enthalpy, kJ/kg of dry air
Saturation temperature, °C
Specific volume, m³ per kg dry air
Humidity ratio, kg moisture per kg dry air
Wet-bulb temperature, °C
Relative humidity
Dry-bulb temperature, °C
Enthalpy, kJ/kg of dry air

Table A-6 Refrigerant 22: properties of liquid and saturated vapor[6]

		Enthalpy, kJ/kg		Entropy, kJ/kg • K		Specific volume, L/kg	
t, °C	P, kPa	h_f	h_g	s_f	s_g	v_f	v_g
-60	37.48	134.763	379.114	0.73254	1.87886	0.68208	537.152
-55	49.47	139.830	381.529	0.75599	1.86389	0.68856	414.827
-50	64.39	144.959	383.921	0.77919	1.85000	0.69526	324.557
-45	82.71	150.153	386.282	0.80216	1.83708	0.70219	256.990
-40	104.95	155.414	388.609	0.82490	1.82504	0.70936	205.745
-35	131.68	160.742	390.896	0.84743	1.81380	0.71680	166.400
-30	163.48	166.140	393.138	0.86976	1.80329	0.72452	135.844
-28	177.76	168.318	394.021	0.87864	1.79927	0.72769	125.563
-26	192.99	170.507	394.896	0.88748	1.79535	0.73092	116.214
-24	209.22	172.708	395.762	0.89630	1.79152	0.73420	107.701
-22	226.48	174.919	396.619	0.90509	1.78779	0.73753	99.9362
-20	244.83	177.142	397.467	0.91386	1.78415	0.74091	92.8432
-18	264.29	179.376	398.305	0.92259	1.78059	0.74436	86.3546
-16	284.93	181.622	399.133	0.93129	1.77711	0.74786	80.4103
-14	306.78	183.878	399.951	0.93997	1.77371	0.75143	74.9572
-12	329.89	186.147	400.759	0.94862	1.77039	0.75506	69.9478
-10	354.30	188.426	401.555	0.95725	1.76713	0.75876	65.3399
-9	367.01	189.571	401.949	0.96155	1.76553	0.76063	63.1746
-8	380.06	190.718	402.341	0.06585	1.76394	0.76253	61.0958
-7	393.47	191.868	402.729	0.97014	1.76237	0.76444	59.0996
-6	407.23	193.021	403.114	0.97442	1.76082	0.76636	57.1820
-5	421.35	194.176	403.496	0.97870	1.75928	0.76831	55.3394
-4	435.84	195.335	403.876	0.98297	1.75775	0.77028	53.5682
-3	450.70	196.497	404.252	0.98724	1.75624	0.77226	51.8653
-2	465.94	197.662	404.626	0.99150	1.75475	0.77427	50.2274
-1	481.57	198.828	404.994	0.99575	1.75326	0.77629	48.6517
0	497.59	200.000	405.361	1.00000	1.75279	0.77834	47.1354
1	514.01	201.174	405.724	1.00424	1.75034	0.78041	45.6757
2	530.83	202.351	406.084	1.00848	1.74889	0.78249	44.2702
3	548.06	203.530	406.440	1.01271	1.74746	0.78460	42.9166
4	565.71	204.713	406.793	1.01694	1.74604	0.78673	41.6124
5	583.78	205.899	407.143	1.02116	1.74463	0.78889	40.3556
6	602.28	207.089	407.489	1.02537	1.74324	0.79107	39.1441
7	621.22	208.281	407.831	1.02958	1.74185	0.79327	37.9759
8	640.59	209.477	408.169	1.03379	1.74047	0.79549	36.8493
9	660.42	210.675	408.504	1.03799	1.73911	0.79775	35.7624
10	680.70	211.877	408.835	1.04218	1.73775	0.80002	34.7136
11	701.44	213.083	409.162	1.04637	1.73640	0.80232	33.7013
12	722.65	214.291	409.485	1.05056	1.73506	0.80465	32.7239
13	744.33	215.503	409.804	1.05474	1.73373	0.80701	31.7801
14	766.50	216.719	410.119	1.05892	1.73241	0.80939	30.8683
15	789.15	217.937	410.430	1.06309	1.73109	0.81180	29.9874
16	812.29	219.160	410.736	1.06726	1.72978	0.81424	29.1361
17	835.93	220.386	411.038	1.07142	1.72848	0.81671	28.3131
18	860.08	221.615	411.336	1.07559	1.72719	0.81922	27.5173
19	884.75	222.848	411.629	1.07974	1.72590	0.82175	26.7477
20	909.93	224.084	411.918	1.08390	1.72462	0.82431	26.0032

Table A-6 (continued)

		Enthalpy, kJ/kg		Entropy, kJ/kg • K		Specific volume, L/kg	
t, °C	P, kPa	h_f	h_g	s_f	s_g	v_f	v_g
21	935.64	225.324	412.202	1.08805	1.72334	0.82691	25.2829
22	961.89	226.568	412.481	1.09220	1.72206	0.82954	24.5857
23	988.67	227.816	412.755	1.09634	1.72080	0.83221	23.9107
24	1016.0	229.068	413.025	1.10048	1.71953	0.83491	23.2572
25	1043.9	230.324	413.289	1.10462	1.71827	0.83765	22.6242
26	1072.3	231.583	413.548	1.10876	1.71701	0.84043	22.0111
27	1101.4	232.847	413.802	1.11290	1.71576	0.84324	21.4169
28	1130.9	234.115	414.050	1.11703	1.71450	0.84610	20.8411
29	1161.1	235.387	414.293	1.12116	1.71325	0.84899	20.2829
30	1191.9	236.664	414.530	1.12530	1.71200	0.85193	19.7417
31	1223.2	237.944	414.762	1.12943	1.71075	0.85491	19.2168
32	1255.2	239.230	414.987	1.13355	1.70950	0.85793	18.7076
33	1287.8	240.520	415.207	1.13768	1.70826	0.86101	18.2135
34	1321.0	241.814	415.420	1.14181	1.70701	0.86412	17.7341
35	1354.8	243.114	415.627	1.14594	1.70576	0.86729	17.2686
36	1389.2	244.418	415.828	1.15007	1.70450	0.87051	16.8168
37	1424.3	245.727	416.021	1.15420	1.70325	0.87378	16.3779
38	1460.1	247.041	416.208	1.15833	1.70199	0.87710	15.9517
39	1496.5	248.361	416.388	1.16246	1.70073	0.88048	15.5375
40	1533.5	249.686	416.561	1.16659	1.69946	0.88392	15.1351
41	1571.2	251.016	416.726	1.17073	1.69819	0.88741	14.7439
42	1609.6	252.352	416.883	1.17486	1.69692	0.89097	14.3636
43	1648.7	253.694	417.033	1.17900	1.69564	0.89459	13.9938
44	1688.5	255.042	417.174	1.18315	1.69435	0.89828	13.6341
45	1729.0	256.396	417.308	1.18730	1.69305	0.90203	13.2841
46	1770.2	257.756	417.432	1.19145	1.69174	0.90586	12.9436
47	1812.1	259.123	417.548	1.19560	1.69043	0.90976	12.6122
48	1854.8	260.497	417.655	1.19977	1.68911	0.91374	12.2895
49	1898.2	261.877	417.752	1.20393	1.68777	0.91779	11.9753
50	1942.3	263.264	417.838	1.20811	1.68643	0.92193	11.6693
52	2032.8	266.062	417.983	1.21648	1.68370	0.93047	11.0806
54	2126.5	268.891	418.083	1.22489	1.68091	0.93939	10.5214
56	2223.2	271.754	418.137	1.23333	1.67805	0.94872	9.98952
58	2323.2	274.654	418.141	1.24183	1.67511	0.95850	9.48319
60	2426.6	277.594	418.089	1.25038	1.67208	0.96878	9.00062
62	2533.3	280.577	417.978	1.25899	1.66895	0.97960	8.54016
64	2643.5	283.607	417.802	1.26768	1.66570	0.99104	8.10023
66	2757.3	286.690	417.553	1.27647	1.66231	1.00317	7.67934
68	2874.7	289.832	417.226	1.28535	1.65876	1.01608	7.27605
70	2995.9	293.038	416.809	1.29436	1.65504	1.02987	6.88899
75	3316.1	301.399	415.299	1.31758	1.64472	1.06916	5.98334
80	3662.3	310.424	412.898	1.34223	1.63239	1.11810	5.14862
85	4036.8	320.505	409.101	1.36936	1.61673	1.18328	4.35815
90	4442.5	332.616	402.653	1.40155	1.59440	1.28230	3.56440
95	4883.5	351.767	386.708	1.45222	1.54712	1.52064	2.55133