UNIVERSITY OF GHANA

B.Sc ENGINEERING SECOND SEMESTER EXAMINATION: 2015/2016
SCHOOL OF ENGINEERING SCIENCES
FPEN 304: ENGINEERING AND DESIGN OF FOOD PROCESSES II (3 Credits)

INSTRUCTIONS

ANSWER FOUR QUESTIONS

PROVIDED: P-H DIAGRAM FOR FREON-12, STEAM TABLES, GRAPH SHEET

TIME ALLOWED: TWO (2) HOURS

1. A Freon (R-12) vapour-compression refrigeration system is operating under saturated conditions. The following data were obtained: condenser pressure, 900 kPa; temperature of evaporator is -10°C. This refrigeration system is being used to maintain a controlled-temperature chamber at -7 C. The walls of the chamber provide an overall resistance to conductive heat transfer equivalent to 0.5 m^2 °C/W. The convective heat transfer coefficient on the outside wall/ceiling is 2.5 W/m^2 °C and on the inside wall/ceiling is 10 W/m^2 °C. The outside ambient temperature is 40 °C. The total wall and ceiling area is 100 m^2. Ignore any heat gain from the floor.
   a) Chart the path of the refrigerant on the given p-H diagram
   b) Calculate the flow rate of refrigerant for the above system.
   c) Calculate the power requirements (kW) of the compressor operating to maintain the above conditions.

2. a) Give two limitations of the Plank's method for freezing time determination.

   b) Name two types of direct-contact freezing devices

   c) A fabricated food, in the form of small spherical pellets, is to be frozen in an air-blast freezer. The air-blast freezer is operating with air at -45°C. The initial product temperature is 25°C. The pellets have a diameter of 5 cm, the density of the products is 980 kg/m^3. The initial freezing temperature is -2.5°C. The moisture content of the food product is 80%. The thermal conductivity of the frozen product is 1.9 W/(m °C). The convective heat transfer coefficient is 50 W/(m °C). (Latent heat of fusion of water: 333.2 kJ/kg).

   Calculate the freezing time

3. a) Give five features that differentiate sterilization from pasteurization

The temperature of the slowest heating location for a liquid food in a can is as follows:

Time (min)	Temp (°C)
0	75
1	105
2	125
3	140
4	135
5	120
6	100

b) Plot the process curve and identify the major segments

c) The thermal process is being applied to a microbial population with D_{121} of 1.0 min and z=10°C. Calculate the lethality (F_{121}) for the thermal process.

4. Orange juice is being concentrated in a natural-circulation single effect evaporator. At steady-state conditions, dilute juice is the feed introduced at a rate of 0.60 kg/s. The concentration of the dilute juice is 10% total solids. The juice is concentrated to 80% total solids. The specific heats of dilute apple juice and concentrate are 4.5 and 2.6 kJ/(kg °C), respectively. The steam pressure is measured to be 316.3 kPa. The inlet feed temperature is 45.0°C. The product inside the evaporator boils at 60.0°C. The overall heat-transfer coefficient is assumed to be 955 W/(m^2 °C). Assume a boiling-point elevation of 3°C. Calculate

a) The mass flow rate of concentrated product
b) Steam requirements
c) Steam economy, and
d) Heat-transfer area.

5. A spray drier with a 5 m diameter and 10 m height is used to dry skim milk to a final moisture content of 5%. The air entering the drier is 120°C, is heated from ambient air at 25°C and 75% relative humidity and flows co-currently with the product droplets (and particles) through the system. The skim milk enters the drier at 45°C with 90.5% moisture content and the exit temperature is 55°C. The specific heat of product solids is 2.0 kJ/kg.K. The heated air leaves the system at 5°C above the product temperature. Air flow rate is 1000 m^3/min.

a) Determine the production rate for the system; kg of 5% moisture content product per unit time
b) The temperature and % RH of air leaving the drier
c) The thermal energy for heating the air entering the drier

(R=8.314 kPa.m^3/kg mol.K)

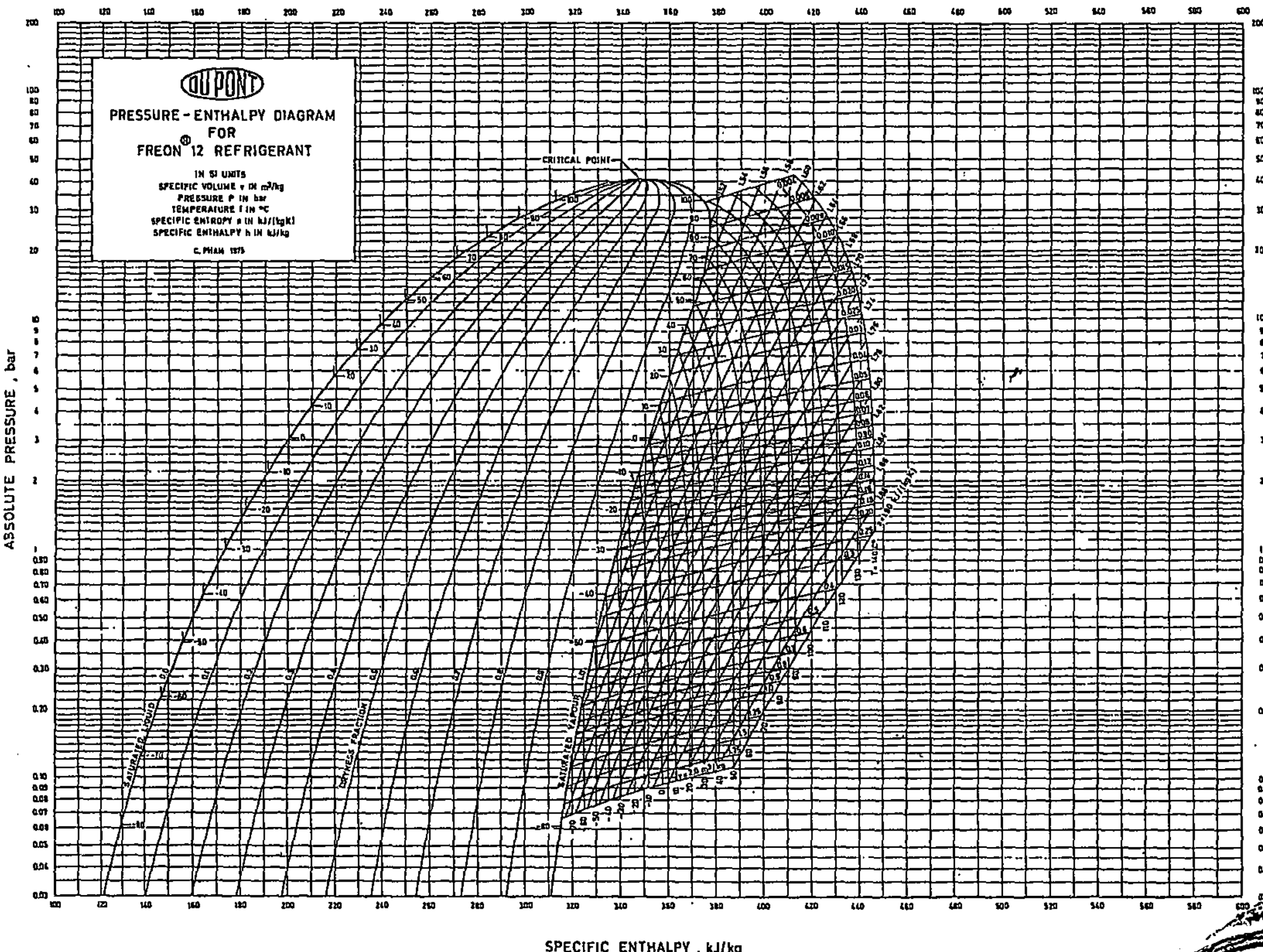


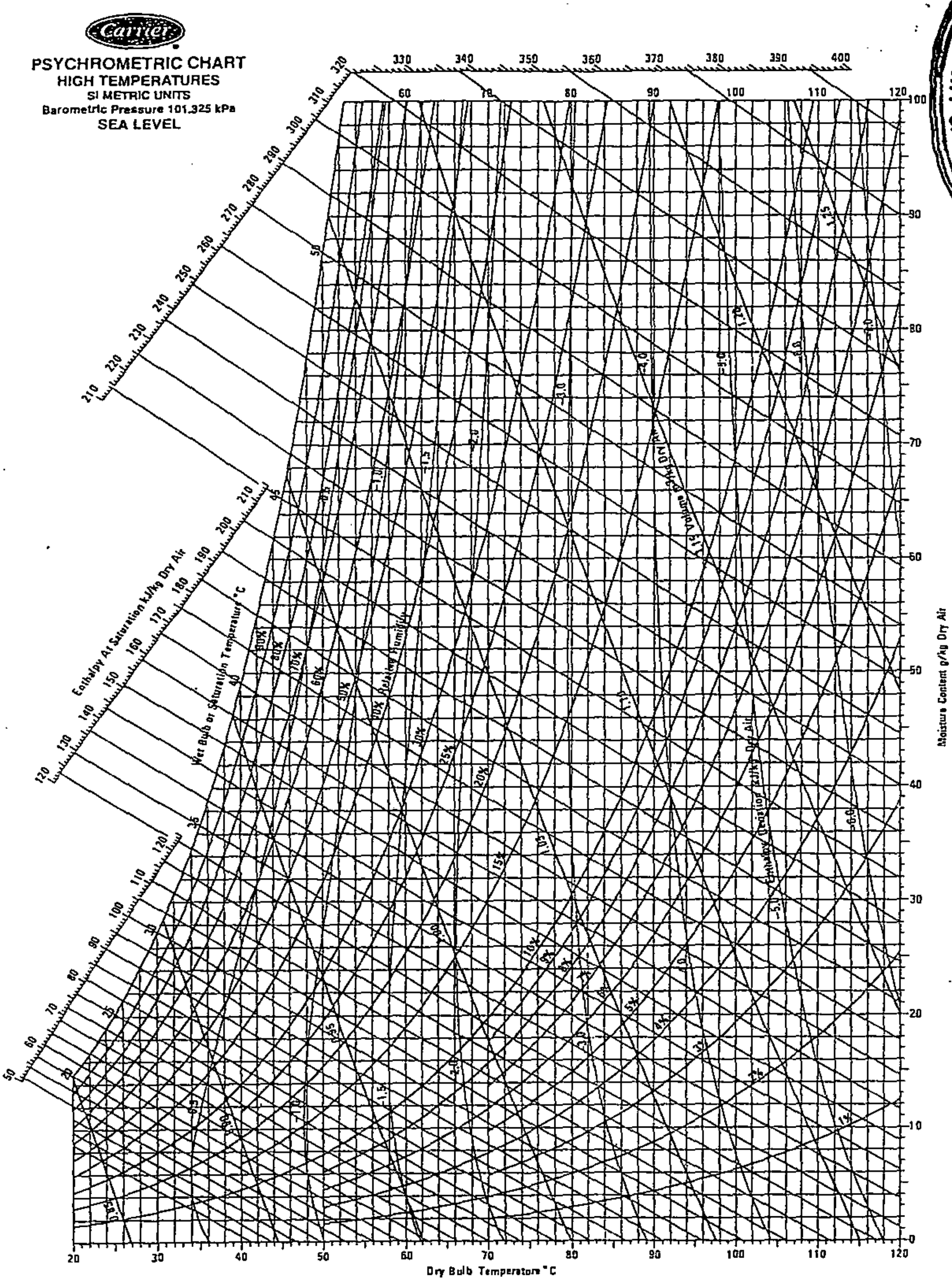
Fig. A.6.1 Pressure–enthalpy diagram for Refrigerant 12. (Reproduced by permission of Du Pont de Nemours International S.A.)

Table A-2 Properties of Saturated Steam

Temperature (°C)	Vapor pressure (kPa)	Specific volume (m^3/kg)		Enthalpy (kJ/kg)		Entropy (kJ/[kg K])	
		Liquid	Saturated vapor	Liquid (H_c)	Saturated vapor (H_v)	Liquid	Saturated vapor
0.01	0.6113	0.0010002	206.136	0.00	2501.4	0.0000	9.1562
3	0.7577	0.0010001	168.132	12.57	2506.9	0.0457	9.0773
6	0.9349	0.0010001	137.734	25.20	2512.4	0.0912	9.0003
9	1.1477	0.0010003	113.386	37.80	2517.9	0.1362	8.9253
12	1.4022	0.0010005	93.784	50.41	2523.4	0.1806	8.8524
15	1.7051	0.0010009	77.926	62.99	2528.9	0.2245	8.7814
18	2.0640	0.0010014	65.038	75.58	2534.4	0.2679	8.7123
21	2.487	0.0010020	54.514	88.14	2539.9	0.3109	8.6450
24	2.985	0.0010027	45.883	100.70	2545.4	0.3534	8.5794
27	3.567	0.0010035	38.774	113.25	2550.8	0.3954	8.5156
30	4.246	0.0010043	32.894	125.79	2556.3	0.4369	8.4533
33	5.034	0.0010053	28.011	138.33	2561.7	0.4781	8.3927
36	5.947	0.0010063	23.940	150.86	2567.1	0.5188	8.3336
40	7.384	0.0010078	19.523	167.57	2574.3	0.5725	8.2570
45	9.593	0.0010099	15.258	188.45	2583.2	0.6387	8.1648
50	12.349	0.0010121	12.032	209.33	2592.1	0.7038	8.0763
55	15.758	0.0010146	9.568	230.23	2600.9	0.7679	7.9913
60	19.940	0.0010172	7.671	251.13	2609.6	0.8312	7.9096
65	25.03	0.0010199	6.197	272.06	2618.3	0.8935	7.8310
70	31.19	0.0010228	5.042	292.98	2626.8	0.9549	7.7553
75	38.58	0.0010259	4.131	313.93	2635.3	1.0155	7.6824
80	47.39	0.0010291	3.407	334.91	2643.7	1.0753	7.6122
85	57.83	0.0010325	2.828	355.90	2651.9	1.1343	7.5445
90	70.14	0.0010360	2.361	376.92	2660.1	1.1925	7.4791
95	84.55	0.0010397	1.9819	397.96	2668.1	1.2500	7.4159
100	101.35	0.0010435	1.6729	419.04	2676.1	1.3069	7.3549
105	120.82	0.0010475	1.4194	440.15	2683.8	1.3630	7.2958
110	143.27	0.0010516	1.2102	461.30	2691.5	1.4185	7.2387
115	169.06	0.0010559	1.0366	482.48	2699.0	1.4734	7.1833
120	198.53	0.0010603	0.8919	503.71	2706.3	1.5276	7.1296
125	232.1	0.0010649	0.7706	524.99	2713.5	1.5813	7.0775
130	270.1	0.0010697	0.6685	546.31	2720.5	1.6344	7.0269
135	313.0	0.0010746	0.5822	567.69	2727.3	1.6870	6.9777
140	316.3	0.0010797	0.5089	589.13	2733.9	1.7391	6.9299
145	415.4	0.0010850	0.4463	610.63	2740.3	1.7907	6.8833
150	475.8	0.0010905	0.3928	632.20	2746.5	1.8418	6.8379
155	543.1	0.0010961	0.3468	653.84	2752.4	1.8925	6.7935
160	617.8	0.0011020	0.3071	675.55	2758.1	1.9427	6.7502
165	700.5	0.0011080	0.2727	697.34	2763.5	1.9925	6.7078
170	791.7	0.0011143	0.2428	719.21	2768.7	2.0419	6.6663
175	892.0	0.0011207	0.2168	741.17	2773.6	2.0909	6.6256
180	1002.1	0.0011274	0.19405	763.22	2778.2	2.1396	6.5857
190	1254.4	0.0011414	0.15654	807.62	2786.4	2.2359	6.5079
200	1553.8	0.0011565	0.12736	852.45	2793.2	2.3309	6.4323
225	2548	0.0011992	0.07849	966.78	2803.3	2.5639	6.2503
250	3973	0.0012512	0.05013	1085.36	2801.5	2.7927	6.0730
275	5942	0.0013168	0.03279	1210.07	2785.0	3.0208	5.8938
300	8581	0.0010436	0.02167	1344.0	2749.0	3.2534	5.7045

Source: Abridged from Keenan *et al.* (1969).

A.5 Psychrometric Charts



A.5.1 Psychrometric chart for high temperature range.