B.E. CHEMICAL ENGINEERING FIRST YEAR FIRST SEMESTER – 2018

FUNDAMENTALS OF CHEMICAL ENGINEERING

Time : Three hours | Full Marks : 100

(50 marks for each part)

Use separate answer scripts for each part

PART I

Answer any two questions
Assume any missing data

1(a) The heat transfer coefficient for forced convection in straight tubes is expressed by

Where h = heat transfer coefficient, Btu/(hr)(ft²)(°F); C_p =heat capacity of the gas, Btu/(lb)(°F); G is the mass velocity, lb/(ft²)(sec); D = internal diameter of the pipe, inch.
Transform the equation in a new form wherein h, C_p, G and D are in SI unit. (12)

1(b) The heat transfer coefficient, h depends on the tube diameter (D), the mass average velocity (G; kg/m².s), the heat capacity (C_p), viscosity (μ; kg/m.s) and the thermal conductivity of the fluid, k . Find the dimensionless form of governing equation using Buckingham pi theorem. (13)

2(a) The diffusivity, D (cm²/s) of a gas varies with temperature T(K) according to Arrhenius equation

$$D = D_o \exp\left(-\frac{E}{RT}\right)$$

Where, D_o is the pre-exponential factor; E is the activation energy of diffusion and R = 1.987 cal/(mol.K)
Diffusivity of SO_2 in a fluorosilicone tube was measured at several temperatures with following result

T(K)	D (cm²/s)x10⁶
347.0	1.34
374.2	2.50
396.2	4.55
420.7	8.52
447.7	14.07

(i) What are the units of D_o and E?
(ii) Determine the magnitude of D_o and E (10)

2(b) Derive the expression relating the average molecular weight of a mixture to the mass fraction and molecular weight of the components (5)

2(c) An aqueous solution of 35% H_2SO_4 has a specific gravity of 1.2563. Determine the volume of this solution that would contain 195 kg of H_2SO_4. (5)

2(d) Write short notes on one of the following (i) Cox chart (b) Crystallization (5)

3(a) The vapor pressure of two components water and acetic acid are given by

$$\log_{10}(\text{mm Hg}) = 8.07131 - \frac{1730.63}{233.426 + t(^{\circ}C)}$$

$$\log_{10}(\text{mm Hg}) = 8.26735 - \frac{2258.222}{300.97 + t(^{\circ}C)}$$

Find the equilibrium pressure and vapor phase mole fraction at T = 110 °C and liquid phase mole fraction of acetic acid = 0.4. (10)

3(b) Water is present in nitrogen at 30 °C and 1000 mm Hg. Determine the absolute humidity of water if the relative humidity is 70%. (5)

3(c) Determine latent heat of vaporization of water at 40 °C (5)

3(d) Discuss the different methods for cooling of liquids (5)

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Part-II

Use separate answer scripts for each part.

Time: Three hours *Full marks: 100*
(50 marks for each part)

Answer any five questions. All questions carry equal marks. Assume any missing data.

1 A continuous belt moving vertically through a bath of viscous liquid drags a layer of liquid, of thickness h, along with it. The volume flow rate of liquid, Q, is assumed to depend on the viscosity μ, density ρ, acceleration due to gravity g, the thickness h, and V, where V is the belt speed. Use Buckingham Pi theorem to predict the form of dependence of Q on the other variables

10

2 The Arrhenius equation which relates the rate of reaction with temperature is as follows

$$k = Ae^{-E/RT}$$

In investigating a certain chemical reaction, following data were obtained.

T(K)	k (sec^{-1})
373	1.05×10^{-16}
380	1.07×10^{-15}
392	9.30×10^{-15}
402	6.95×10^{-14}

Evaluate E and A using a semilogarithmic graph paper. $R = 8.314\ JK^{-1}mol^{-1}$

10

3 (a) What is an invariant system? Give an example

(b) Consider the vapor-liquid equilibrium of a benzene-toluene mixture at 80°C and 750mm Hg. Find the composition of the liquid mixture. Which is the more volatile component? The valor pressure of benzene and toluene are given by

Benzene: $\log_{10}(\text{mm Hg}) = 6.906 - \frac{1211}{T(°C)+220.8}$

Toluene: $\log_{10}(\text{mm Hg}) = 6.9533 - \frac{1343.9}{T(°C)+219.38}$

2+8

4 (a) Name two important dimensionless numbers in chemical engineering with their significance.

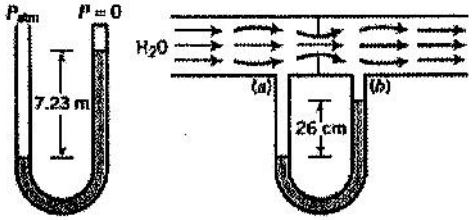
(b) What is dew point ?

(c) The absolute humidity and dry bulb temperature of air is 0.010kg/kg dry air and 25°C respectively. Use psychrometric chart to obtain the relative humidity, degree of superheat and the wet bulb temperature. Estimate the

amount of water in $100m^3$ of air at these conditions.

3+2+5

5 A fluid of unknown density is used in two manometers- one sealed end, the other across an orifice in a water pipeline. The readings shown here are obtained on a day when barometric pressure is 756 mm Hg. What is the pressure drop from point (a) to point (b) in N/m^2, mm Hg and psi?



10

6 (a) Write a short note on liquid-liquid extraction.

(b) A mixture of 80% H_2 and 20% N_2 (molar basis) is contained in a tank at 700 atm and -157°C. Estimate the specific volume of the mixture in L/mol. Use generalized compressibility chart. Critical temperatures for H_2 and N_2 are 33K and 126.2K and critical pressures for H_2 and N_2 are 12.8 atm and 33.5 atm.

2+8

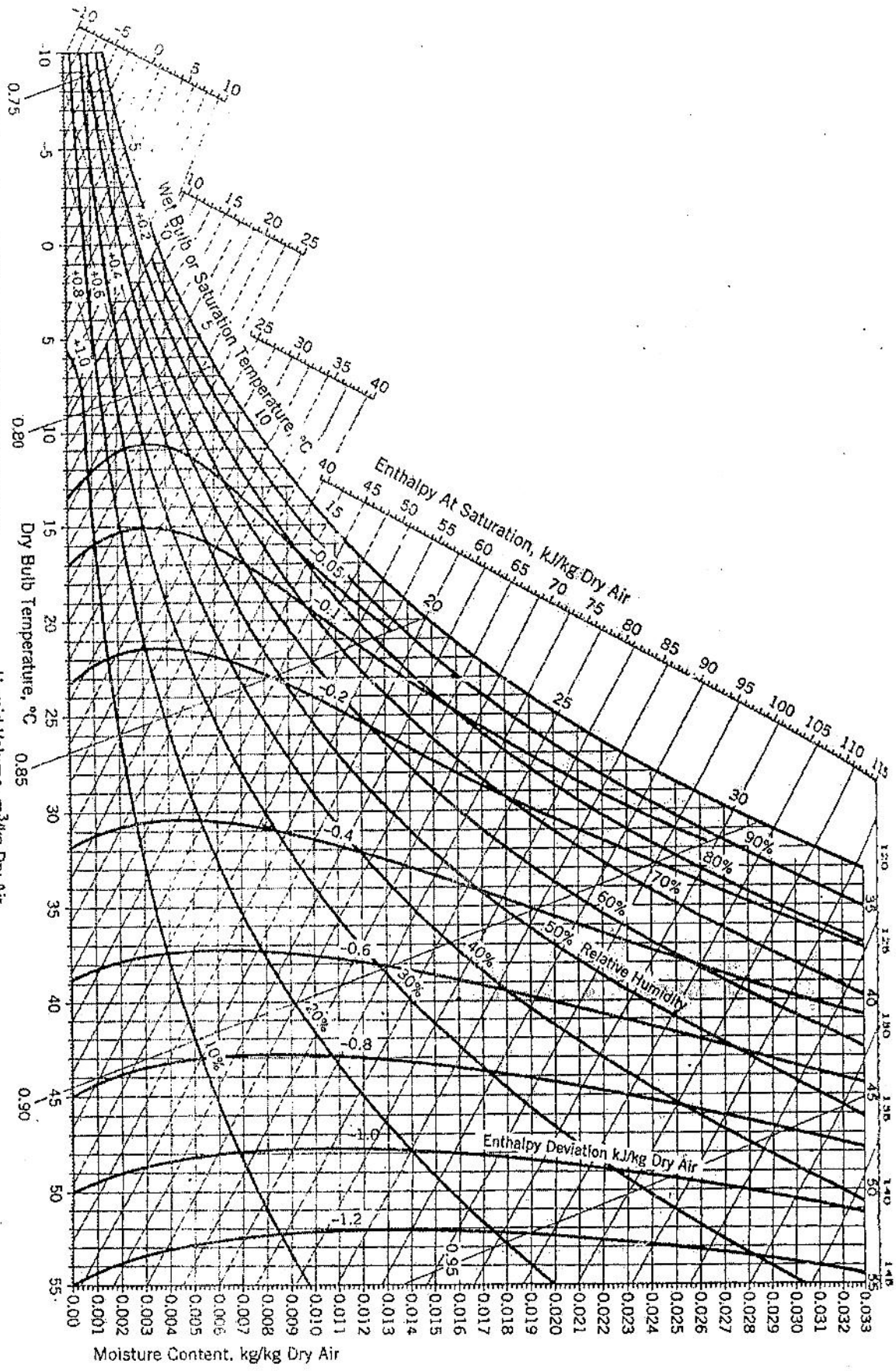


Figure 8.4-1 Psychrometric chart—SI units. Reference states: H_2O (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier Corporation.)

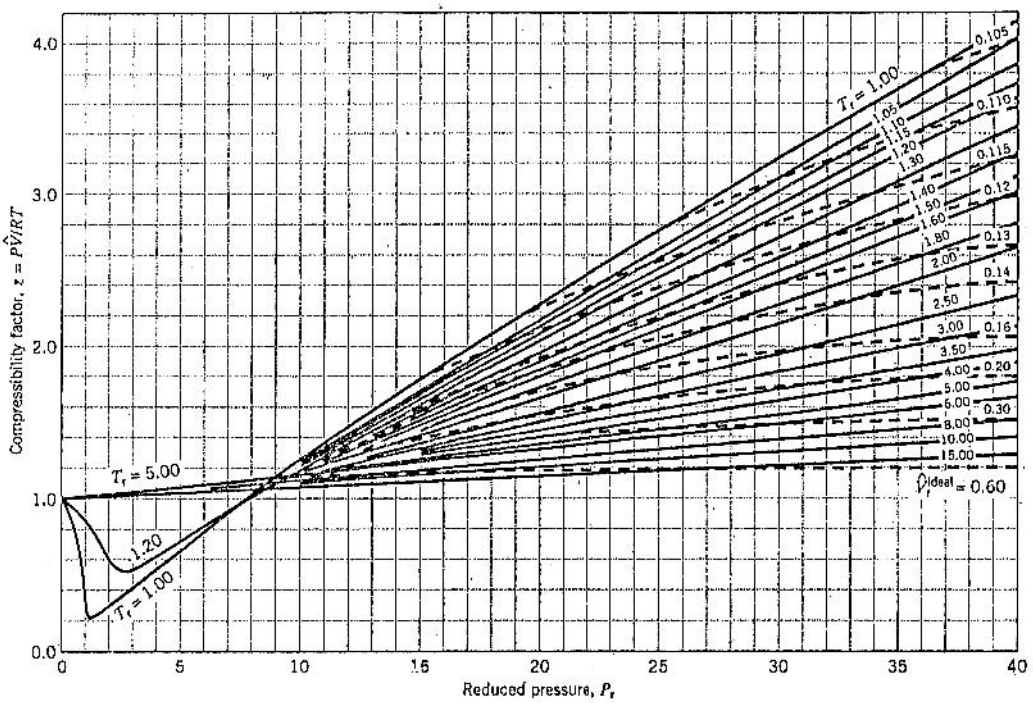


Figure 5.4-4 Generalized compressibility chart, high pressures. (From D. M. Himmelblau, *Basic Principles and Calculations in Chemical Engineering*, 3rd Edition, copyright © 1974, p. 177. Reprinted by permission of Prentice Hall, Inc., Englewood Cliffs, NJ.)