BACHELOR OF CHEMICAL ENGINEERING EXAMINATION, 2025

(3rd Year, 1st Semester)

SEPARATION PROCESSES I

Time : Three hours | (50 Marks for each Part) | Full Marks : 100

Use separate answer scripts for each Part

Assume any missing data

Answer __10 marks from Q.No. 1__ and __40 marks from Q. No. 2__

PART: I

Q.No.	CO	Question	Marks
1.	1 & 3	**a)** Show that if internal diffusion of moisture controls for long time, rate of drying is proportional to moisture content and inversely proportional to thickness of solid bed; independent of gas velocity and its humidity.	5
		b) An induced draft cooling tower is rated to cool 1500 gpm (gallon per min) of water from 40°C to 29°C. The total dissolved solids (TDS) concentration must not exceed 900 ppm. The TDS of makeup water is 300 ppm. About 0.1% of the water is lost by "drift" from the tower and leakages in the circulation system. Calculate blow down and makeup water rate. Consider, Evaporation loss = (water flow rate, gpm)x(cooling range, °F)x(0.0008) in gpm. 1 gpm equals 3.79 LPM (liters per minute)	5
		c) Show that $H_{tOG} = H_{tG} + \left(\frac{1}{A}\right) H_{tL}$ where; H_{tOG}: Height of overall gas-phase transfer unit H_{tG}: Height of individual gas-phase transfer unit H_{tL}: Height of individual liquid-phase transfer unit $\frac{1}{A}$: Stripping factor	5
		d) "Tray Efficiency" is a measure of the relationship between the theoretical number of stages and the actual number of stages in tray column. Explain it with the help of different types of tray efficiency terms.	5
		e) Write an expression for the overall mass transfer coefficient during gas separation using membranes. Write a feed side mass transfer	5

[Turn over

		coefficient, a membrane diffusion profile and product side concentration profile.	
2.	2 & 4	**a)** Gas, from a petroleum distillation column, has its concentration of H_2S reduced from 0.03 kmol H_2S/kmol of inert hydrocarbon gas to 1% of this value by scrubbing with a triethanolamine-water solvent in a countercurrent packed tower, operating at 300K and at atmospheric pressure. The equilibrium relation for the solution may be taken as $Y_e = 2X$. The solvent enters the tower free of H_2S and leaves containing 0.013 kmol of H_2S/kmol of solvent. If the flow of inert gas is 0.015 kmol/s-m^{2}of tower cross section, calculate: i) the height of the column necessary, and ii) the number of transfer units, N_{OG} required. The overall mass transfer coefficient for absorption may be taken as 0.04 kmol/s-m^3(unit mole fraction driving force).	20
		b) A recently installed induced draft cooling tower was guaranteed by the manufacturer to cool 0.1262 m^3/s of 43°C water to 30°C when the available air has a wet bulb temperature 24°C. A test on the tower, when operated at full fan capacity , provided the following data: Inlet water, 46°C Outlet water 25.6°C Inlet air, 24°C dry bulb, 15.6° C wet bulb temperature Outlet air, 37.6 °C, essentially saturated i) what is the fan capacity (m^3/s) at operating condition ii) can the tower be expected to meet the guarantee conditions? Note that to do so, Nt_{OG} in the test must be at least equal the guarantee value if Ht_{OG} is unchanged.	20
		c) Coca-Cola bottles are made out of plastic. The contents diffuse at a slow rate through the walls of the container and out into the air and result in some losses. It has been suggested to coat the inner wall of the container to reduce the losses. With a coating thickness of 25 μm	5

and diffusion coefficient in the coating of $1x10^{-9}$ m^2/s, what would be the benefit to the manufacturer? Assume a thickness of 1.5 mm for the plastic container as $1x10^{-6}$ m^2/s.

d) Consider absorption of the solute C from a carrier gas A using the solvent B. The gas phase mass transfer coefficient is $k_G = 0.05$ kmol/m2hr.kPa. At a particular section of the absorber, the mole fraction of C in the bulk gas is 0.15 and total pressure is 120kPa. The bulk liquid concentration is 0.045 mole fraction, local flux is known to be 0.08 kmol/m2.hr. 10

i) calculate the interfacial concentration of the solute and the fraction of the total resistance lying in the gas phase.

ii) if the gas phase mass transfer coefficient increases by 50% but all other parameters remain the same, what would be the fractional increase in the molar flux of the solute?

The equilibrium solubility of gas is linear $y = 2.5x$ for $y \leq 0.15$.

e) A filter cake is dried for 5hrs from an initial moisture content of 30% to 10% (wet basis). Calculate the time required to dry the filter cake from 30% to 6% (wet basis). 15

Equilibrium moisture content: 4% in dry basis

Critical moisture content: 14% on dry basis

Assume that the rate of drying in the falling rate period is directly proportional to the free moisture content.

If the air velocity were increased to 4 m/s from0.75 m/s , what would be the anticipated saving in time if surface evaporation is controlling?

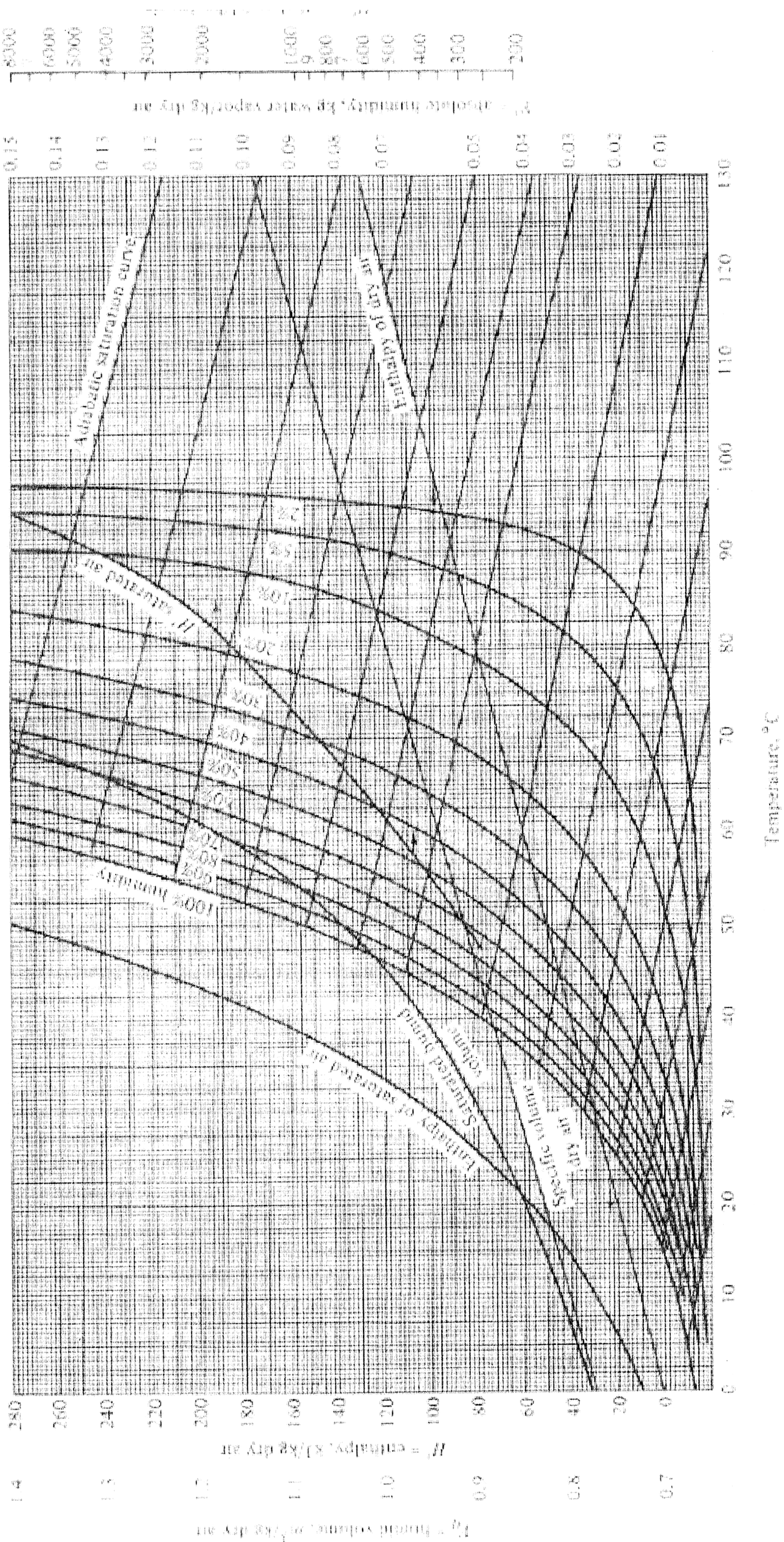
Given: $N_c \propto h \propto G^{0.8}$ for $parallel\ flow$

$N_c \propto h \propto G^{0.37}$ for $perpendicular\ flow$

Where G = gas velocity x density

f) The overhead condenser in distillation tower requires 20 kg/s of cooling water removing 270 watts of heat. The water will leave the 25

		condenser at 45°C. It is cooled to an induced draft cooling tower. The entering air is at 24°C wet-bulb temperature and 30°C dry bulb temperature. The water need to be cooled to within 7°C of the inlet air wet bulb temperature. An air/water (v) ratio of 1.25 times the minimum is used. The make-up water will come from a well at 10°C, hardness 500 ppm dissolved solids. The circulating water should not exceed 200 ppm hardness. In the tower packing, Kyaρ = 0.9 kg/m^3-s. This is for gas rate of 2 kg/m^2s and a liquid rate at 2.7 kg/m^2s. Compute the dimensions of the packed section and make-up water rate.	


Temperature, °C
H' = enthalpy, kJ/kg dry air
Adiabatic saturation curve
Enthalpy of dry air
100% humidity
H' saturated air
Enthalpy of saturated air
Saturated humid volume
Specific volume dry air

Ex/Che/PC/B/T/311/2025

B.E. CHEMICAL ENGINEERING THIRD YEAR FIRST SEMESTER EXAM 2025
3rd Year, 1st Semester

SEPARATION PROCESSES - I

Time: 3 Hours | Full Marks: 100

Part II (50 Marks)

Answer Question No. 5 and any Five (5) from the rest

1. *Mass Transfer at the Interphase [CO1]* **[3+3+2=8]**

a. Define an Overall Mass Transfer Coefficient. Why do we use the overall mass transfer coefficients to elucidate interphase mass transfer?
b. Explain 'Two Resistance Theory' with the help of a diagram.
c. What modification could be used in the mass transfer equation when the gas phase is highly soluble in the liquid phase?

2. *Humidification [CO3]* **[4+4=8]**

Refer to the psychrometric chart and answer the following. A sample of air parcel has a dry bulb temperature of 28°C and an absolute humidity of 0.007 kg of water/kg bone dry air.

a. Describe the process by which this sample of air be dehumidified to an absolute humidity of 0.004 kg of water/kg bone dry air with dry bulb temperature remaining at 28°C.
b. If it is desired to humidify the original air sample to an absolute humidity of 0.021 kg of water/kg bone dry air with dry bulb temperature remaining at 28°C, describe the practical process adopted through a sketch on the psychrometric chart?

3. *Drying [CO3]* **[8]**

Drying of a food product is carried out in an insulated tray. The drying air has a partial pressure of water equal to 2360 Pa and a wet-bulb temperature of 30°C. The product has a drying surface of 0.05 m^2/kg drying solid. The material has a critical moisture content of 0.12 (dry basis) and negligible equilibrium moisture content. The drying rate in the falling rate period is proportional to the moisture content. The mass transfer coefficient is 5.34×10^{-4} kg/m^2. h. Pa. Vapor pressure of water at 30°C =4232 Pa. Calculate:

a. Drying rate in the constant rate period in kg/m^2. h.

[Turn over

b. The time required in hour to dry the material from a moisture content of 0.22 to 0.06 (both on dry basis).

4. *Mass Transfer at the Interphase [CO2]* **[8]**

A bubble of pure oxygen, originally d_1 cm in diameter is injected into a stirred vessel of oxygen-free water at 25°C. After t minutes, the bubble has shrunk to a diameter of d_2 cm. Assuming no resistance to mass transfer in the gas phase, considering the bubble as your system, find out the liquid phase mass transfer coefficient. You may assume that the ideal gas law is valid for obtaining gas phase concentration of oxygen. Assume additional variables, if necessary.

5. *Humidification [CO2 + CO4]* **[10]**

With respect to the design of cooling towers, give the physical significance of the following terms (a diagram may be used for the explanation): $\int_{H_1'}^{H_2'} \frac{dH'}{H_i'-H'}$; $\frac{G_S}{k_y'\bar{a}}$. How these terms are evaluated? Here: G_S is the mass flux of air (dry basis); $k_y'\bar{a}$ is the individual volumetric gas phase mass transfer coefficient; H_i' is the interfacial enthalpy at saturation of the air-water system at any temperature where a tie-line meets the equilibrium curve; H' is the enthalpy of the unsaturated air-water system at any temperature where the tie-line meets the operating line; H_1', H_2' are the enthalpies of unsaturated air at the entry and exit respectively.

6. *Absorption [CO3]* **[8]**

An effluent gas containing 12% benzene is to be scrubbed in a packed column continuously, operating in counter-current manner using an oil at 43°C and 1 atm pressure in a manner such that the exit gas contains only 1% benzene and the exit gas flow rate is 1200 kg/hr.m^2, Determine the minimum mass velocity of the oil. The equilibrium relationship for the system is given by: $y = 0.263x$ where x and y are expressed in mole fraction units.

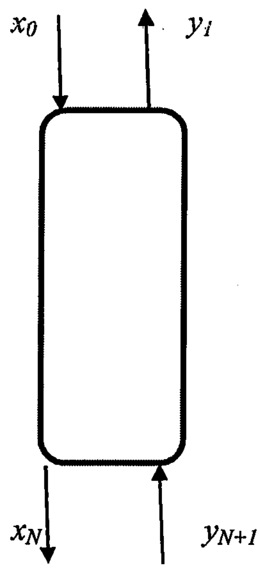
7. *Mass Transfer at the Interphase [CO2 + CO3]* **[8]**

Air bubbles having diameters of d mm are stirred in a vessel containing water at 37°C. The diffusion coefficient ofoxygen in water is $D_{O_2-H_2O}$ cm^2 /s. Estimate the mass transfer coefficient. If the solubility of oxygen at 37°C is s mol/cm^3, calculate the maximum flux of oxygen going into the vessel. Assume: ρ_L = density of water in g/cm^3; ρ_G = density of oxygen in g/cm^3; g = acceleration due to gravity cm/s^2; μ_{O_2} = viscosity of water in g/cm s.

8. *Stripping [CO2 + CO4]* **[8]**

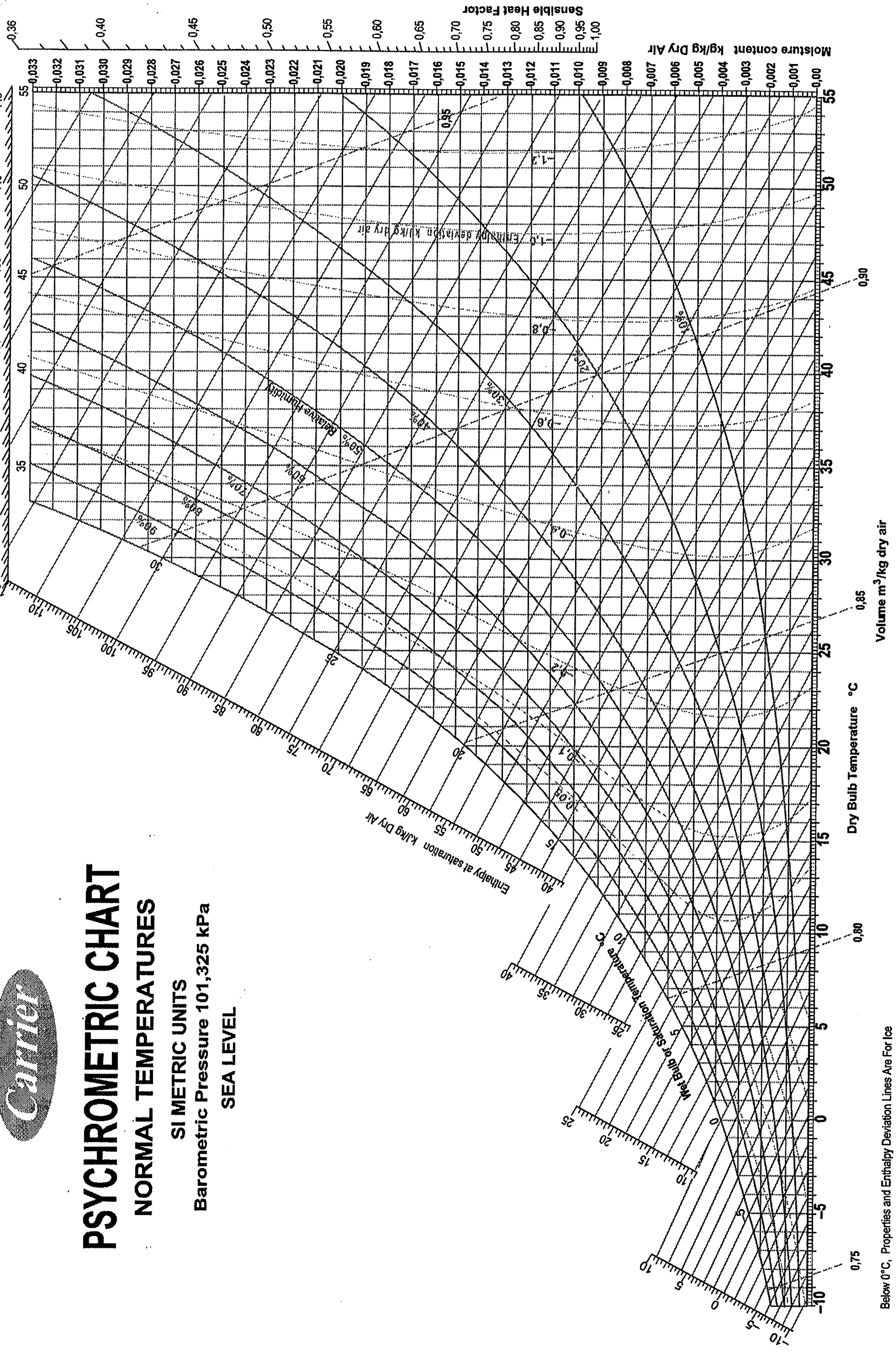
A countercurrent multistage stripper, as shown in the Figure below, is used to remove an impurity from a cream using pure steam. 100 kg/h of liquid cream containing 20 ppm of impurity, by weight, is fed to the stripper. It is desired to reduce the concentration of impurity in the cream to 1 ppm. Assume that the liquid cream does not evaporate, and the steam does not condense. The equilibrium relation is $y=10x$, where y and x are the ppm of impurity in the steam and the cream respectively.

a. Indicate schematically on a x-y plot the equilibrium line and operating line for minimum steam flow rate.
b. Determine the minimum flowrate of steam required.
c. If the rate of steam input to the stripper is 1.5 times the minimum, determine the required integral no. of theoretical stages.



9. *Answer in short: [CO1 + CO4]* **[2x4=8]**

a. Significance of Blowdown in context to the operation of a cooling tower.
b. How will NTU change with a change in the type of packing when inlet conditions to a packed absorber are maintained the same.
c. Two disadvantages of HETP.
d. Air with dry and wet bulb temperatures of t_{d1} and t_{w1} respectively is passed through a heater and then through an adiabatic cooler and exits with dry and wet bulb temperatures of t_{d2} and t_{w2} respectively. Draw a valid relationship between all four temperatures.


Carrier
PSYCHROMETRIC CHART
NORMAL TEMPERATURES
SI METRIC UNITS
Barometric Pressure 101,325 kPa
SEA LEVEL
Sensible Heat Factor
Moisture content kg/kg Dry Air
Dry Bulb Temperature °C
Volume m³/kg dry air
Enthalpy at saturation kJ/kg Dry Air
Wet Bulb or Saturation Temperature °C
Relative Humidity
Enthalpy deviation kJ/kg dry air
Below 0°C, Properties and Enthalpy Deviation Lines Are For Ice