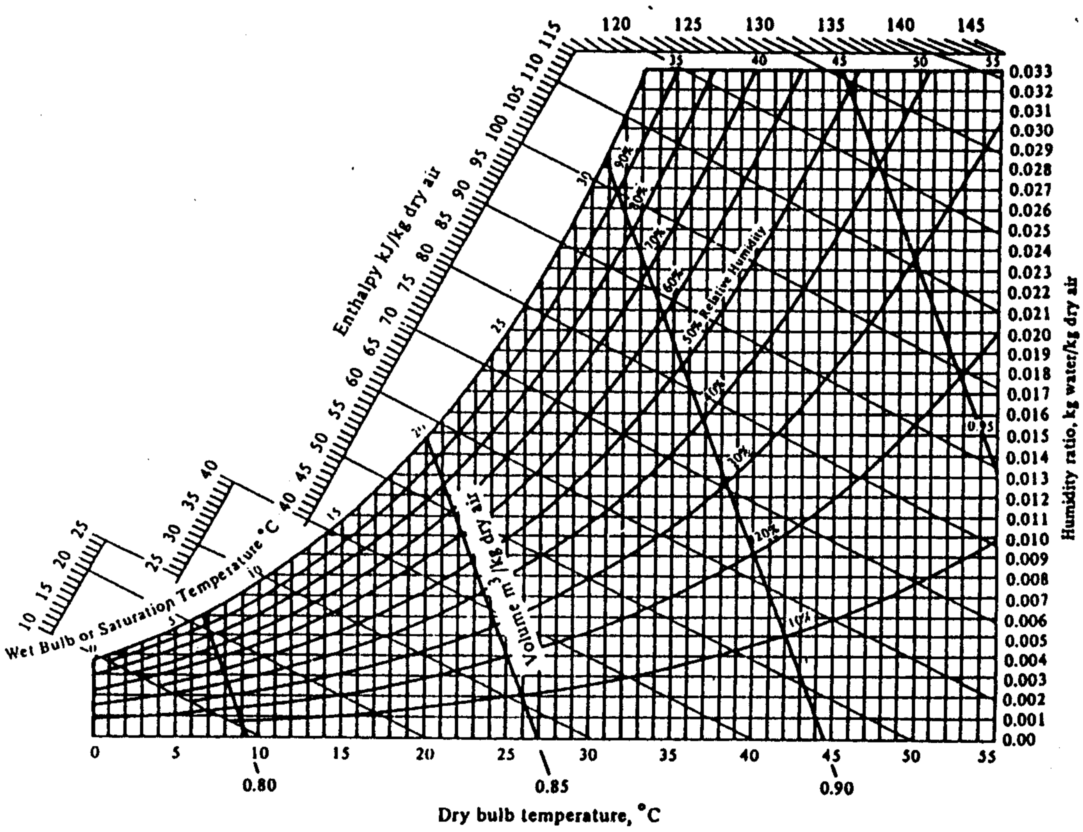
1. Write the irreversibility associated with a change of state for a closed system
(1) in terms of the entropy change
(2) in terms of the availability
(3) and describe the relationship between the entropy change and availability. (20%)

2. Describe the Joule-Thompson coefficient and the inversion temperature. (10%)

3. A steady-flow heating and humidification process is used to provide moist air at a dry bulb temperature of 25 °C with a relative humidity of 45 percent. Outdoor air at 5 °C dry bulb and 90 percent relative humidity enters the heating section at a rate of 60 m^3/min and its dry bulb temperature is increased to 24 °C. Steam is then sprayed into the air in the humidifier section so that the desired exit conditions are achieved. Determine the heat-transfer rate required in the heating section. Suppose the steam added in the humidifier section at a pressure of 1 atm. Assume the processes occur at a constant total pressure of 1 atm. (Using the psychrometric chart) (20%)



Psychrometric chart for 1 atm total pressure (101.3 kPa).

Air, H_2O

4. Explain the following terms (16%)
(a) system and control volume
(b) thermodynamic equilibrium
(c) work and heat
(d) triple point

5. The mass rate of flow into a steam turbine is 1.5 kg/s, and the heat transfer from the turbine is 8.5 kW. The following data are known for the steam entering and leaving the turbine.

	Inlet Conditions	Exit Conditions
Pressure	2.0 MPa	0.1 MPa
Temperature	350 °C	
Quality		100%
Velocity	50 m/s	200 m/s
Elevation above reference point	6 m	3 m
enthalpy	3137.0 kJ/kg	2675.5 kJ/kg
$g = 9.08066\ m/s^2$		

Determine the power output of the turbine. (10%)

6. A steel bar is heated up to a high temperature and then is cooled down in the air. How will you obtain when you analyze this process based on (1) thermodynamics (2) heat transfer? (8%)

7. (1) Derive the following expression of the Joule-Thomson coefficient, μ_J. (16%)

$$\mu_J = \left(\frac{\partial T}{\partial p}\right)_h = \frac{1}{c_p}\left[T\left(\frac{\partial v}{\partial T}\right)_p - v\right]$$

(2) For a gas obeying the van der Waals equation of state,

$$p = \frac{RT}{v-b} - \frac{a}{v^2}$$

Derive the expression of μ_J for this gas.

(3) Show that μ_J is zero for the ideal gas.

(4) Show that the equation of the inversion curve is

$$p = \frac{a}{bv}\left(2 - \frac{3b}{v}\right)$$