Question Paper

Exam Date & Time: 03-May-2019 (02:00 PM - 05:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

Chemical Engg.Thermodynamics - I [ICHM 122 - S2]

Marks: 100 **Duration: 180 mins.**

A

Answer 5 out of 8 questions.

1) Mercury has a density of 13.69×10^3 kg/m^3 in the liquid state and 14.193×10^3 kg/m^3 in the solid state, both measured at the melting point of 234.33 K at 1 bar. If the heat of fusion of mercury is 9.7876 kJ/kg, what is the melting point of mercury at 10 bar? (10)

A)

B) For the vaporization of water, derive the Clausius - Clapeyron equation. (10)

2) For an ideal gas, prove that (12)

A) $$C_P - C_V = \frac{\beta^2 TV}{K}$$

B) The molar volume of an organic liquid at 300 K and 1 bar is 0.1 m^3/mol and its coefficient of expansion is 1.25×10^{-3} K^{-1}. What would be the change in entropy if the pressure is increased to 20 bar at 300 K? (8)

3) A vapour compression refrigeration system with ammonia as the working fluid is to operate between 266 K and 300 K. Determine the COP, if a temperature approach of 5 K is necessary in the evaporator and condenser and the efficiency of the compressor is 75%. Enthalpy of saturated vapour at 261 K = 652 kJ/kg and the enthalpy of superheated vapour entering the condenser = 758 kJ/kg, enthalpy of saturated liquid at 305 K = 159 kJ/kg. (8)

A)

B) The compression ratio in an air-standard Otto cycle is 8. The temperature and pressure at the beginning of the compression stroke are 290 K and 100 kPa. Heat transferred per cycle is 450 kJ/kg of air. The specific heat of air are C_P = 1.005 kJ/kg K and C_V = 0.718 kJ/kg K. Determine the pressure and temperature of air at the end of each process. (12)

4) A) Describe the important properties that should be considered for choosing a refrigerant in refrigeration process. (10)

B) Heat is transferred to 10 kg of air which is initially at 100 kPa and 300 K until its temperature reaches 600 K. Determine the change in internal energy, the change in enthalpy, the heat supplied and the work done in the constant pressure processes. Assume that air is an ideal gas for which the P-V-T relationship is PV = nRT. Take C_P =29.099 kJ/kmol K and C_V =20.785 kJ/kmol K. (10)

5) A) A heat pump is used to maintain the temperature inside a building at 295 K by pumping heat from the outside air at 275 K. The unit has an overall efficiency of 25%. The pump is driven electrically and the electric power is generated by the combustion of certain fuel gas. The heat of combustion of the fuel is 890.9 kJ/mol. It is estimated that only 33% of the heat of combustion of the fuel is converted into electricity. Determine the amount of fuel burned for delivering 1000 MJ of heat to the building. (10)

B) A 40 kg steel casting (C_P = 0.5 kJ kg^{-1} K^{-1}) at a temperature of 450°C is quenched in 150 kg of oil (C_P = 2.5 kJ kg^{-1} K^{-1}) at 25°C. If there are no heat losses, what is the change in entropy of (i) the casting, (ii) the oil, and (iii) both considered together? (10)

6) A) Electrolysis of water is given by the following reaction (10)

$$H_2O \rightarrow H_2 + \frac{1}{2}O_2$$

Process takes place at P = 1 atm & T = 298 K. The change in enthalpy required for this phase change is 286 kJ/mol. Determine the change in internal energy of the system during the process.
Data:

$$S_{H_2O} = 70\frac{J}{K} \quad S_{H_2} = 131\frac{J}{K} \quad S_{O_2} = 205\frac{J}{K}$$

B) Obtain expression to relate vander Waal's constant 'a' and 'b' in terms of critical properties. (10)

7) A) Twenty kilograms of air is compressed from 1 bar, 300 K to 5 bar in a single stage compressor. The process is polytropic with (20)

n = 1.25. The specific heat of air at constant pressure in kJ/kmol K is:

$$C_p = 27.4528 + 6.1839 \times 10^{-3} T - 8.9932 \times 10^{-7} T^2$$

Determine the amount of heat transferred to the surroundings.

8) The P-V-T behaviour of nitrogen is represented by the ideal gas (14)

A) equation PV = nRT. Where n is the number of moles of the gas and R is the ideal gas constant. The heat capacity of the gas is C_P =29.1 kJ/kmol K and C_V =20.8 kJ/kmol K. The gas initially at 10 bar and 280 K is undergoing a change of state to the final condition of 1 bar and 340 K. Determine the change in internal energy and change in enthalpy.

B) A steam turbine using steam at 1368 kPa and 645 K and (6) discharging saturated steam at 137 kPa is used to generate power for certain chemical plant. The turbine acts adiabatically and the feed and discharge velocities may be considered equal. Determine the theoretical horsepower developed by the turbine if it uses 1650 kg steam per hour. From the steam tables, enthalpy of superheated steam at 1368 kPa and 645 K is 3200 kJ/kg and enthalpy of saturated steam at 137 kPa is 2690 kJ/kg.

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