Problem Sheet 4: PROPERTIES OF STEAM

Problem sheet

1. It is desired to give a visual demonstration for the critical point. For this purpose a 10 liter rigid, transparent container is filled with wet steam at 100 kPa so that upon heating, it passes through the critical point. Determine (a) the amount (mass) of steam to be filled, (b) the ratio of vapor volume to liquid volume. Specific volume of water is 0.003155 m^3/kg.

   [*Ans: (a)3.17 kg, (b) 2.029*]
2. A vessel having a volume of 0.4 m^3 contains 2 kg of water and water vapor mixture in equilibrium at a pressure of 600 kPa. Calculate the volume and mass of the liquid and the vapor.
3. Suppose a close and rigid vessel is initially filled with saturated water and saturated vapor at 100 kPa. On transferring energy as heat the water is found to pass through the critical point. Determine the ratio of the volume of saturated vapor to the volume of saturated liquid with which the chamber was initially filled.
4. 4 kg of steam at x = 0.5 and p = 6 bar is heated so that it becomes a (a) 0.95 dry at constant pressure; (b) dry saturated at constant pressure; (c) superheated to 300 ^oC at 6 bar, (d) Superheated to 250 degree of superheat at 6 bar. Find the heat added in each case.
5. Find the state (quality and specific enthalpy) of steam when: (a) p = 6 bar, and h = 2690 kJ/kg; (b) p and υ= 0.2 m^3/kg; (c) p = 75 bar and t = 300 ^oC; (d) p = 230 bar and 700 ^oC.
6. A pressure cooker contains 1.5 kg of dry saturated steam at 5 bar. Find the quantity of dry saturated steam at 5 bar. Find the quantity of heat that must be rejected so as to reduce the quality to 60% dry. Determine the final steam condition.
7. 1 kg of steam at 16 bar and x = 0.7 is expanded isothermally to 3 bar. Determine the amount of heat transfer and work done during the process. Will the internal energy change during the process?
8. 3 kg of steam is expanded isntropically fronm 20 bar and 350 ^oC to 0.5 bar. Find the amount of work done if the expansion takes place in a (a) piston-cylinder arrangement, and (b) a steam turbine.
9. Steam expands from an initial state of 20 MPa and 550^o C to a final pressure of 5 kPa, and a quality of 90% dryness fraction. Determine (a) the change in enthalpy, and (b) change in entropy during the process.

   [*Ans: (a) -1074.9 kJ/kg, (b) 1.2666 kJ/kg*]
10. Wet steam with a specific entropy of 1.302 units undergoes a nonflow reversible process at a constant pressure of 27 bar. If the final specific entropy is 1.6393, determine (a) final condition of steam, (b) change in enthalpy, (c) change in internal energy, and (d) amount of heat transferred.
11. Find the quantity of heat required to generate 3 kg of steam at a pressure 7.5 bar from water at a temperature of 25^o C when (a) the dryness fraction of steam is 0.88, (b) when it is superheated at a constant pressure to 270^o C. For (b) also calculate the heat requirement by assuming a mean specific heat of saturated steam of 2.31 kJ/kg-K.

    [*Ans: (a) 7256.1 kJ, (b) 8708.8 kJ*]

12. A spherical shell of 40 cm radius contains steam at a pressure of 90 bar with 0.95 dryness fraction. The shell and its content are cooled until the pressure drops to 10 bar. Find the mass of the vessel contents and dryness fraction of steam after cooling. Do not neglect the volume of water present.

[*Ans: (a)13.7205 kg, (b) 0.1007*]

13. Determine the state of the steam at:

    a. p= 10 bar and $\upsilon = 0.185\ m^3/kg$.

    b. p= 15 bar and $t = 215^o$ C.

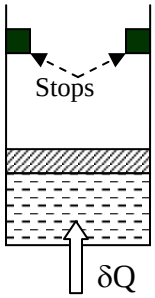
    c. p = 20 bar and h = 2721.42 kJ/kg (reference enthalpy taken at $t = 0^o$ C)

[*Ans: (a)x = 0.934, (b) superheat of 17.6^o C, (c) x = 0.959*]

14. A Sealed tube has a volume of 0.1 liters and contains a certain fraction of liquid and vapor (H_2O) in equilibrium at 0.1 MPa. The fraction of liquid and vapor is such that when the heated, steam will pass through the critical point. Calculate the heat transfer when steam is heated from the initial state of 0.1 MPa to the critical state.

[*Ans: $x_1 = 0.00125$*]

15. 5 kg of water at 15^oC is contained in a vertical cylinder by a frictionless piston of a mass such that the pressure of the water is 700 kPa (Refer to the figure). Heat is transferred slowly to the water, causing the piston to rise until it reaches the stops at which point the volume inside the cylinder is 0.5 m^3. More heat is transferred to the water until it exists as dry vapor. Find (a) the final pressure in the cylinder, (b) the heat transfer and work done during the process. (c) Show the process in T-s diagram.



[*Ans: (a)20 bar, (b) 13.033 MJ, (c)346.5 kJ*]

16. 5000 m^3/hr wet steam at $x = 0.95$ and $p = 10$ bar is to be supplied by a boiler for a processing plant. Calculate (a) the mass of steam supplied per hr., (b) the quantity of coal (calorific value 16000 kJ/kg) to be burned in a boiler (of 89 % efficiency) to generate the steam. Assume feed water temperature of 25 ^oC

[*Ans: (a)x = 27086 kg/hr, (b) 5440.5 kg/hr*]

17. A 0.085 m^3 drum contains saturated water and vapor at 334^o C. Find the mass water and steam present if half of the drum is filled with water.

[*Ans: m_{water}= 26.712 kg, m_{steam} = 3.524 kg*]

18. A piston cylinder arrangement is filled with wet steam of quality 0.8 at a pressure of 0.1 MPa. Heat is transferred at constant pressure till the temperature of the steam rises to 300^o C. Calculate the work done by steam and the heat transfer.

[*Ans: 128.36 kJ/kg, 850.44 kJ/kg*]