Engineering Thermodynamics

Tutorial-2 **Work, Properties of pure substances**

1. Fill out the following table for water
   a. p=500 kPa, T= 20 C. find v, x (b) p=500 kPa, v=0.2 m3/kg. Find T, x (c) p=1400 kPa, T=200. Find v, x (d) T=300, x=0.8. Find v, p.
2. Give the phase for the following states.
   a. T=275 C, p=5 MPa b. T=-2 C, p=100 kPa.
3. Determine the phase or phases in a system consisting of H_2O at the following conditions and sketch p – v and T – v diagrams showing the location of each state. (a) p = 5 bar, T = 151.9°C. (b) p = 5 bar, T = 200°C. (c) T = 200°C, p = 2.5 MPa. (d) T = 160°C, p = 4.8 bar. (e) T = 212°C, p = 1 bar.
4. A sealed rigid vessel has volume of 1 m^3 and contains 2 kg of water at 100 °C. The vessel is now heated. If a safety pressure valve is installed, at what pressure should the valve be set to have a maximum temperature of 200 °C?
5. You want a pot of water to boil at 105 ^oC. How heavy a lid should you put on the 15 cm diameter pot when Patm = 101 kPa? 35.85 kg
6. Two tanks are connected as shown in Fig, both containing water. Tank A is at 200 kPa, v = 0.5 m^3/kg, V_A = 1 m^3 and tank B contains 3.5 kg at 0.5 MPa, 400 °C. The valve is now opened and the two come to a uniform state. Find the final specific volume. 0.5746 m^3/kg
7. Saturated water vapor at 200 kPa is in a constant pressure piston cylinder. At this state the piston is 0.1 m from the cylinder bottom. How much is this distance and the temperature if the water is cooled to occupy half the original volume?x_2=0.4994
8. Determine the quality of two phase liquid mixture of H_2O at 20 ^oC with a specific value of 20 m^3/kg. 0.3461
9. Water vapour is heated in a closed rigid tank from saturated vapour at 160 ^oC to a final temperature of 400 ^oC. determine the initial and final pressures, in bar, and sketch the processes on T-v and p-v diagrams. 617.7, 998.4 kPa
10. A 1 m^3 rigid tank has air at 1500 kPa and ambient 300 K connected by a valve to a piston cylinder. The piston of area 0.1 m^2 requires 250 kPa below it to float. The valve is opened and the piston moves slowly 2 m up and the valve is closed. During the process air temperature remains at 300 K. What is the final pressure in the tank? 1450 kPa
11. A piston/cylinder arrangement is loaded with a linear spring and the outside atmosphere. It contains water at 5 MPa, 400°C with the volume being 0.1 m^3. If the piston is at the bottom, the spring exerts a force such that P_{lift} = 200 kPa. The system now cools until the pressure reaches 1200 kPa. Find the mass of water, the final state (T_2, v_2) and plot the P–v diagram for the process. x_2=0.06724
12. A cylinder/piston arrangement contains water at 105°C, 85% quality with a volume of 1 L. The system is heated, causing the piston to rise and encounter a linear spring as shown in Fig. At this point the volume is 1.5 L, piston diameter is 150 mm, and the spring constant is 100 N/mm. The heating continues, so the piston compresses the spring. What is the cylinder temperature when the pressure reaches 200 kPa? 641.6 ^oC
13. A cylinder is fitted with a 10-cm-diameter piston that is restrained by a linear spring (force proportional to distance). The spring force constant is 80 kN/m and the piston initially rests on the stops, with a cylinder volume of 1 L. The valve to the air line is opened and the piston begins to rise when the cylinder pressure is 150 kPa. When the valve is closed, the cylinder volume is 1.5 L and the temperature is 80°C. What mass of air is inside the cylinder? 0.01182 kg
14. A piston/cylinder contains 1 kg water at 20 ^oC with volume 0.1 m^3. By mistake someone locks the piston preventing it from moving while we heat the water to saturated vapor. Find the final temperature, volume and the process work.212.2 ^oC, 0.1 m^3
15. A piston cylinder contains 1 kg of liquid water at 20 ^oC and 300 kPa. There is a linear spring mounted on the piston such that when the water is heated the pressure reaches 3 MPa with a volume of 0.1 m^3. A.

Find the final temperature. B. Plot the process in a P-v diagram. C. Find the work in the process. 403.64 C, 163.34 kJ

16. A piston/cylinder arrangement shown in Fig. initially contains air at 150 kPa, 400°C. The setup is allowed to cool to the ambient temperature of 20°C. a. Is the piston resting on the stops in the final state? What is the final pressure in the cylinder? b. What is the specific work done by the air during this process? -96.57 kJ/kg
17. A piston/cylinder contains 1 kg of liquid water at 20°C and 300 kPa. Initially the piston floats, with a maximum enclosed volume of 0.002 m^3 if the piston touches the stops. Now heat is added so a final pressure of 600 kPa is reached. Find the final volume and the work in the process. 0.3 kJ
18. Two kilograms of water is contained in a piston/cylinder with a massless piston loaded with a linear spring and the outside atmosphere. Initially the spring force is zero and $P_1 = P_0 = 100$ kPa with a volume of 0.2 m^3. If the piston just hits the upper stops the volume is 0.8 m3 and T = 600°C. Heat is now added until the pressure reaches 1.2 MPa. Find the final temperature, show the P – v diagram and find the work done during the process. 770 ^oC, 330.3 kJ
19. Two springs with same spring constant are installed in a massless piston/cylinder with the outside air at 100 kPa. If the piston is at the bottom, both springs are relaxed and the second spring comes in contact with the piston at V = 2 m^3. The cylinder contains ammonia initially at −2 °C, x = 0.13, V = 1 m^3, which is then heated until the pressure finally reaches 1200 kPa. At what pressure will the piston touch the second spring? Find the final temperature and the total work done by the ammonia. (need data for ammonia: can be taken from the appendix of the text books or use EES) 1348.7 kJ
20. A system consisting of 2 kg of ammonia undergoes a power cycle composed of the following processes. Process 1-2: constant volume from p_1=10 bar, x_1=0.6 to saturated vapour. Process 2-3: constant temperature to $p_3=p_1$, Q_{23}=228 kJ, process 3-1: constant pressure. Sketch the cycle on p-v and T-v diagrams. (Need data for ammonia: can be taken from the appendix of the text books or use EES).
21. A bottle with a volume of 0.1 m_3 contains butane with a quality of 75% and a temperature of 300 K. Estimate the total butane mass in the bottle using the generalized compressibility chart.
22. A mass of 2 kg of acetylene is in a 0.045 m^3 rigid container at a pressure of 4.3 MPa. Use the generalized charts to estimate the temperature.
23. A 500-L tank stores 100 kg of nitrogen gas at 150 K. To design the tank the pressure must be estimated and three different methods are suggested. Which is the most accurate, and how different in percent are the other two? (a) Ideal gas (b) Generalized compressibility chart

Additional Problems:

24. Saturated (liquid + vapor) ammonia at 60 °C is contained in a rigid steel tank. It is used in an experiment, where it should pass through the critical point when the system is heated. What should the initial mass fraction of liquid be?

25. A sealed rigid vessel of 2 m^3 contains a saturated mixture of liquid and vapor R-134a at 10°C. If it is heated to 50°C, the liquid phase disappears. Find the pressure at 50°C and the initial mass of the liquid.

26. Consider two tanks, A and B, connected by a valve, as shown in Fig. Each has a volume of 200 L and tank A has R-12 at 25°C, 10% liquid and 90% vapor by volume, while tank B is evacuated. The valve is now opened and saturated vapor flows from A to B until the pressure in B has reached that in A, at which point the valve is closed. This process occurs slowly such that all temperatures stay at 25°C throughout the process. How much has the quality changed in tank A during the process?

27. A cylinder has a thick piston initially held by a pin as shown in Fig. The cylinder contains carbon dioxide at 200 kPa and ambient temperature of 290 K. The metal piston has a density of 8000 kg/m3 and the atmospheric pressure is 101 kPa. The pin is now removed, allowing the piston to move and after a while the gas returns to ambient temperature. Is the piston against the stops?

28. A balloon behaves such that the pressure inside is proportional to the diameter squared. It contains 2 kg of ammonia at 0°C, 60% quality. The balloon and ammonia are now heated so that a final pressure of 600 kPa is reached. Considering the ammonia as a control mass, find the amount of work done in the process.4.54

29. A piston/cylinder assembly has 1 kg of R-134a at state 1 with 110°C, 600 kPa, and is then brought to saturated vapor, state 2, by cooling while the piston is locked with a pin. Now the piston is balanced with an additional constant force and the pin is removed. The cooling continues to a state 3 where the R-134a is saturated liquid. Show the processes in a P-V diagram and find the work in each of the two steps, 1 to 2 and 2 to 3.

30. The refrigerant R-22 is contained in a piston/cylinder as shown in Fig. 17, where the volume is 11 L when the piston hits the stops. The initial state is −30°C, 150 kPa with a volume of 10 L. This system is brought indoors and warms up to 15°C. a. Is the piston at the stops in the final state? b. Find the work done by the R-22 during this process.

31. A vertical cylinder has a 61.18-kg piston locked with a pin trapping 10 L of R-22 at 10°C, 90% quality inside. Atmospheric pressure is 100 kPa, and the cylinder cross-sectional area is 0.006 m2. The pin is removed, allowing the piston to move and come to rest with a final temperature of 10°C for the R-22. Find the final pressure, final volume and the work done by the R-22.

32. A rigid cylinder contains different volumes of saturated liquid water and saturated vapour (20L and 30 L) at a temperature of 150C. Determine the quality of the mixture expressed as a percent.

33. Water vapour initially at 10 bar and 400 C is contained within a piston cylinder arrangement. The water is cooled at constant volume until its temperature is 150 C. the water is then condensed isothermally to saturated liquid. For the water as the system, evaluate the work.

34. A closed, rigid tank contains 2 kg of water initially at 80 C and a quality of 0.6. Heat transfer occurs until the tank contains only saturated vapour. Kinetic and potential energy effects are negligible. For the water as a system, determine the amount of energy transfer by heat.

35. A two phase liquid-vapour mixture of H2O initially at 1 MPa with a quality of 90%, is contained in a rigid, well insulated tank. The mass of H2O is 2kg. an electric resistance heater in the tank transfers energy to water at a constant rate of 60 W for 1.95 hrs. determine the final temperature of the water in the tank.

36. A system consisting of 2 kg of ammonia undergoes a power cycle composed of the following processes. Process 1-2: constant volume fromp1=10 bar, x1=0.6 to saturated vapour. Process 2-3: constant temperature to p3=p1, Q23=228 kJ, process 3-1: constant pressure. Sketch the cycle on p-v and T-v diagrams. Neglecting the KE and PE changes, determine the network for the cycle and the heat transfer for each process, all in kJ.