Tutorial 2: Properties of Pure Substances & First Law Analysis

Note: numerical solution are based on one approach to solving the tutorial questions. Other approaches can also be correct and could lead to slightly different numerical answers.

Conceptual Questions:

1. Water in a kettle is heated at constant pressure. Describe the immediate changes in phase, temperature, and volume if the initial water is:

(a) saturated vapor

(b) compressed liquid

(c) saturated liquid

(d) superheated vapor

2. Why are temperature and pressure dependent properties in the saturated mixture region?

3. Is it possible to have water vapour at 0°C? If so, how?

4. Describe the variables in the relationship: $u = u_f + xu_{fg}$. Particularly, what do the subscripts indicate? Where does one find these properties for a given substance?

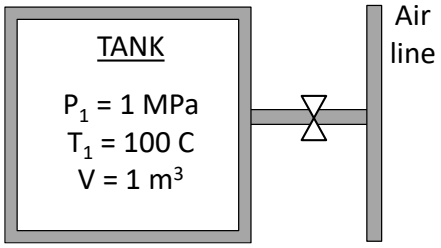
Problem Solving Questions:

5. (a) A sealed, rigid container holds 2kg of nitrogen at 101.3 kPa (1.013 bar) and 30°C. What is the volume of the container and how many moles of nitrogen are present? What is the molar mass of nitrogen? (R_{N2} = 0.2968 kJ/kg K and R_u = 8.314 kJ/kmol K).

(b) The container is heated so that the temperature of nitrogen increases by 100°C. Assuming ideal gas, what is the change in pressure in the container***?***

[ans: (a) V = 1.78 m^3, N = 0.072 kmol, M = 28 kg/kmol, (b) $P_2 – P_1$ = 33.4 kPa]

6. A 1-m^3 rigid tank with air at 1 MPa and 100°C is connected to an air-line. A valve is opened and allows additional air to enter the tank until the pressure reaches 5 MPa. The valve is then closed and the temperature inside the tank is 160°C. Assume air as an ideal gas with R = 0.287 kJ/kgK.



(a) What is the mass of air inside the tank before and after the process?

(b) Heat is transferred from the tank to the surroundings and cools the air in the tank down to room temperature (25°C). What is the pressure inside the tank afterward?

[(a) m_1 = 9.34 kg, m_2 = 40.2 kg (b) 3439 kPa]

7. Complete the following table for the following property substances. Use tables in back of book for various substances

	Substance	***P [kPa]***	***T [°C]***	***Quality, x***	***v [m^3/kg]***	***u [kJ/kg]***	***h [kJ/kg]***	***Phase***
A	R-134a		0	0.6				
B	R-134a		20					Sat. vapour
C	R-134a		-10		0.1200			
D	Ammonia[1]	1000	200					
E	Ammonia[1]		-20			997		
F	Nitrogen[1]	500	100 K					
G	CO_2 [1]	1000	-5					

[1] Tables can be found in 'Fundamentals of Thermodynamics (8th Ed.)' by Borgnakke and Sonntag

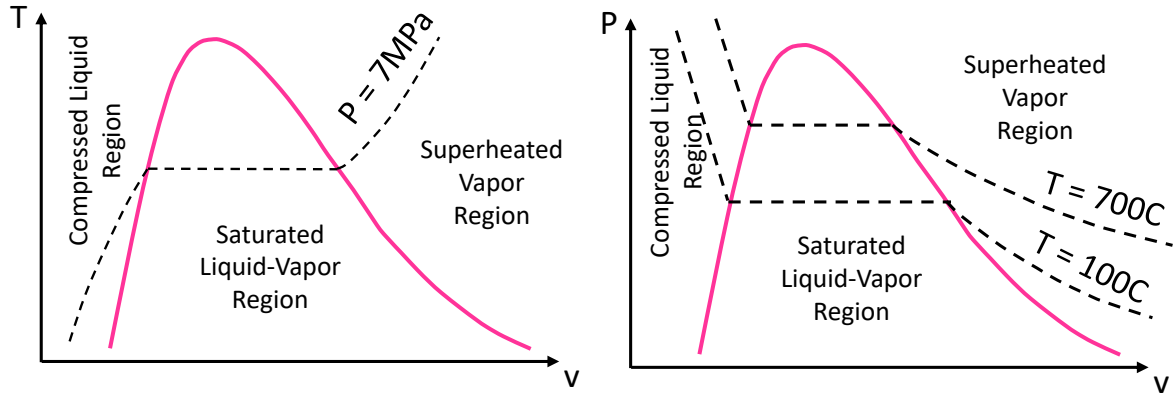
8. A 0.15 m^3 rigid tank contains 2 kg of water at 150 kPa (1.5 bar). Determine the

a) Temperature
b) Enthalpy
c) Mass of each phase of water

[(a) T = 111.37C (b) 609.6 kJ/kg, (c) m_g = 0.128 kg, m_f = 1.872kg]

9. Find the specific internal energy of water at the given states for 7 MPa (70 bar) and plot the states on T-v, P-v diagrams. Show where the states lie with respect to the saturated liquid-vapor dome. (Note: rough estimations of state location on the diagrams are expected if exact numerical values on axis are not provided).

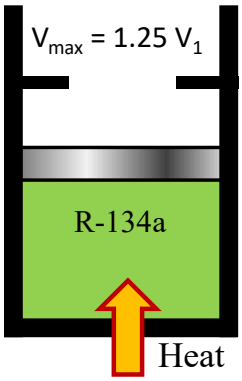
a) Saturated vapor
b) Saturated liquid
c) T = 700°C
d) T = 100°C
e) Quality (x) = 95%



[(a) 2580.48 kJ/kg, (b) 1257 kJ/kg, (c) 3448.6 kJ/kg. (d)416.94 kJ/kg, (e) 2514.33 kJ/kg]

10. A piston/cylinder device with initial volume of 0.5 L contains refrigerant R134a at -10°C, 200 kPa. Stops are placed so that the cylinder can expand an additional 25% of the initial volume. Heat is transferred to the cylinder until the refrigerant temperature reaches 30°C.

(a) Is the piston at the stops in the final state?
(b) What is the work done during this process?
(c) What is the heat transfer during the process?
(d) If the diameter of the piston is 0.04 m atmospheric pressure of 101.3 kPa is acting on the piston, what is the mass of the piston in kg?



[(a) no, (b) 18.6 J, (c) 0.172 kJ, (d) 12.6 kg]