**AUIS ENGR 352 (Thermodynamics), Section 1, Course Assignment 3**

Deadline:[1] October 22, 2017
Tutorial Discussion: October 31, 2017

**1)** Sketch a log $p$-$h$ diagram and a $p$-$v$ diagram, containing

**a)** the "dome" (binodal) for vapor-liquid coexistence (i.e., the bubble line and the dew line),

**b)** a **subcritical isotherm**, i.e., a line containing all states at one temperature $T$ with $T_3 < T < T_c$,

for an idealized fluid where the liquid phase is assumed to be incompressible and the vapor phase is assumed to be an ideal gas (while the binodal is shaped as usual). Explain how the shape of the isotherm reflects the **incompressibility of the liquid** and the **ideality of the vapor**.

**2)** A stationary control volume has two inlets and a single outlet, all at the same pressure $p$ = 300 kPa. There, a stream of **liquid R134a** entering at −30 °C from the first inlet, with a mass flow rate of 10 g s$^{-1}$, is combined with **R134a vapor** entering via the second inlet.

The outgoing flow is supposed to be liquid R134a only. Considering this requirement, **determine the maximum possible mass flow rate at the outlet**. Neglect changes in kinetic and potential energy of the fluid, and assume that no technical work is done, i.e., that there is no work other than flow work. Use any available resources (e.g., the log $p$-$h$ diagram on the LMS, the NIST database, or other reliable sources), to look up required thermodynamic data.

**3)** Argon undergoes a sequence of alternating transitions: In one step, the gas, which is initially at $p_1$ = 200 kPa, is **expanded adiabatically** until it reaches the pressure $p_2$ = 180 kPa; then it is **heated isochorically** until the pressure $p_1$ is reached again; then, it is again expanded adiabatically (from $p_1$ to $p_2$), heated isochorically (from $p_2$ to $p_1$), and so on. Note that this is not a cycle, only the pressure alternates repetitively between two levels.

How often can this procedure be repeated, starting at the temperature $T_{init}$ = 250 K, without exceeding $T_{max}$ = 500 K? Assume that argon can be considered as an **ideal gas** with $c_p = 2.5\,R$.

**4)** **R134a** vapor enters an **adiabatic nozzle**, which operates in a steady state, at a temperature of 50 °C and a velocity of 200 m s$^{-1}$ and leaves with 400 m s$^{-1}$ at 300 kPa in a vapor-liquid equilibrium state with a quality of 90%. Use the log $p$-$h$ diagram from the lecture (available on the AUIS LMS) to **determine the pressure difference** between the inlet and the outlet.

**5)** **Nitrogen** is **adiabatically throttled** from 4 bar to 1 bar, entering the throttling valve with a volume flow rate of 250 ml s$^{-1}$ at the inlet. After throttling, the fluid has a temperature of 300 K. **Determine the mass flow rate**, assuming that the throttling valve operates in a steady state; in particular, the inlet and the outlet have the same mass flow rate.

The thermodynamic properties of $N_2$ can be approximated by the **ideal gas law**. The molar mass of nitrogen is $M$ = 28.01 g mol$^{-1}$, and the speed of sound at $p$ = 1 bar and $T$ = 300 K is $\mathcal{V}_s$ = 353 m s$^{-1}$. Note that no technical work is done during throttling and, as usual for throttling, neglect changes in potential and kinetic energy of the fluid.

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1 *Each problem contributes 0.5% to the overall grade. Submissions (paper only), individually or in groups of two, can be handed in on October 22 (after the lecture), or deposited in the mailbox (room B-F2-01) by October 21.*