AUIS ENGR 352 (Thermodynamics), Assignment II

Submission deadline:[1] March 11, 2018

Tutorial discussion: March 27 and 29, 2018

1) Consider the following reversible cycle with the working fluid propane, to be approximated here as an ideal gas with the specific isochoric heat capacity $c_v = (\partial u/\partial T)_v = 5.50\,R$:

- Transition 1 → 2: **Isobaric** expansion, $p_1 = p_2 = 40$ kPa, to the volume $v_2 = 120$ l mol^{-1}.
- Transition 2 → 3: **Isochoric** cooling until the pressure $p_3 = 25$ kPa is reached.
- Transition 3 → 1: **Adiabatic** compression from $p_3 = 25$ kPa to $p_1 = 40$ kPa.

a) Draw a p-v diagram for this process. Is it a power or refrigeration cycle?

b) Determine the **net power received by** the gas and the **net heat transferred to** the gas per time for a (molar) substance flow rate of 2.7 mol s^{-1}. Pay attention to the signs. *To the fluid:* positive; *from the fluid:* negative. The molar mass of propane is $M = 44.10$ g mol^{-1}.

2) Going through an **adiabatic nozzle** that operates in a steady state, ethane, to be treated here as an ideal gas with the specific isobaric heat capacity $c_p = 1.333$ kJ K^{-1} kg^{-1}, is accelerated from its initial velocity, at the inlet, to an outlet velocity of 126 m s^{-1}. From inlet to outlet, the temperature decreases by $T_{\text{out}} - T_{\text{in}} = -3.9$ K.

Determine the velocity at the inlet. For an ideal gas, the speed of sound is $\mathcal{V}_s = (\kappa p v\ /\ M)^{1/2}$, where $\kappa = 1.262$ is the polytropic exponent of ethane at the conditions in the nozzle, p is the pressure, v is the molar volume, and $M = 30.07$ g mol^{-1} is the molar mass of ethane.

3) **R134a** enters an **adiabatic diffuser**, which operates in a steady state, at the temperature 20 °C and the velocity 270 m s^{-1}, in a **vapor-liquid coexistence** state with the quality 90%, and it leaves the diffuser with 70 m s^{-1} at 300 kPa. Use the log p-h diagram from the lecture to **determine the temperature difference** between the inlet and the outlet.

4) Isobaric heat transfer is characterized by the **specific isobaric heat capacity** $c_p = (\partial h\ /\ \partial T)_p$. Liquid phase and supercritical data for refrigerant R124 at $p = 8700$ kPa include:

$p = 8700$ kPa and $T = 340$ K:	$v = 793.5$ ml kg^{-1}	$u = 270.1$ kJ kg^{-1}	$c_v = 808.4$ J K^{-1} kg^{-1}
$p = 8700$ kPa and $T = 360$ K:	$v = 842.6$ ml kg^{-1}	$u = 293.7$ kJ kg^{-1}	$c_v = 830.9$ J K^{-1} kg^{-1}
$p = 8700$ kPa and $T = 380$ K:	$v = 906.1$ ml kg^{-1}	$u = 318.3$ kJ kg^{-1}	$c_v = 854.7$ J K^{-1} kg^{-1}
$p = 8700$ kPa and $T = 400$ K:	$v = 994.2$ ml kg^{-1}	$u = 344.3$ kJ kg^{-1}	$c_v = 880.3$ J K^{-1} kg^{-1}

Interpolate the specific isobaric heat capacity of liquid R124 at $p = 8700$ kPa and $T = 350$ K.

5) A **refrigerator** with the coefficient of performance $\varepsilon = 4$ uses **ammonia as working fluid** to transfer heat from a cold region at −11 °C to a hot region at 44 °C.

a) Is the second law satisfied? Assuming reversible heat transfer, calculate the total entropy change for the two regions while 10 kJ of heat are taken in from the cold region.

b) Is the second law satisfied if the two temperatures and the working fluid ammonia remain the same, but the coefficient of performance is specified as $\varepsilon = 6$?

6) A piston-cylinder device, with a constant pressure of $p = 40$ kPa inside, contains $m = 90$ g of water under vapor-liquid equilibrium conditions (both in the initial and the final state). Part of the liquid evaporates reversibly, and the volume increases by 140%. In the final state, $m^{I} = 78$ g of the water are liquid, while the remaining $m^{II} = 12$ g are steam.

How much **heat is transferred to** the fluid, and how much **work is done by** the fluid? Use the available resources to obtain the vapor-liquid equilibrium properties of water at 40 kPa.

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1 *Each problem contributes up to one credit to the overall grade. Submissions, individually or in groups of two, can be handed in on March 11 (at lecture time only), or deposited in the B-F2-01 mailbox by March 10.*