

Thermodynamics and energetics I: Exercise 3

The exercise deals with thermodynamic cycles and application of the 1st law to calculate work and heat transfer, and to draw p - v and T - v diagrams.

1. In a closed system, 3 kg of air (ideal gas) runs through the following cycle:

1-2: Isobaric expansion from 400 K to 550 K

2-3: Isothermal expansion from 10 bar to 7.5 bar

3-4: Isochoric cooling

4-1: Polytropic compression to the initial state ($n = 1.5$)

- (a) Draw the process in a p - v - and a T - v -diagram.
- (b) Calculate temperature, pressure, volume, and specific volume of the air in every state.
- (c) Calculate the work and heat transfer for all processes.
- (d) Check the energy change, the total heat intake, and the total work output of the system during the cycle.

Use $c_{v,\text{air}}(T = 400 \text{ K}) = 0.726 \text{ kJ}/(\text{kg}\cdot\text{K})$, $c_{v,\text{air}}(T = 550 \text{ K}) = 0.753 \text{ kJ}/(\text{kg}\cdot\text{K})$, $c_{v,\text{air}}(T = 295 \text{ K}) = 0.718 \text{ kJ}/(\text{kg}\cdot\text{K})$ and $M_{\text{air}} = 29 \text{ g/mol}$.

Assume $c_{v,\text{air}}$ can be approximated constant over a process and by the arithmetic average at the two end temperatures of the process.

Neglect changes in kinetic and potential energies.

2. 1.5 kg ammonia runs through the following cycle:

1-2: Isochoric heating from $p_1 = 10 \text{ bar}$, $x_1 = 0.6$ to saturated vapor

2-3: Isothermal expansion to $p_3 = p_1$, $Q_{23} = +228 \text{ kJ}$

3-1: Isobaric cooling

- (a) Draw the process in the p - v and T - v -diagrams.
- (b) Calculate the net work for the cycle and the work and heat transfer of each process. Neglect changes in kinetic and potential energy. You expected to use CoolProp for property evaluation.

3. 1.5 kg water runs through the following cycle:

1-2: Isochoric heating from $p_1 = 5$ bar, $T_1 = 160$ °C to $p_2 = 10$ bar

2-3: Isobaric cooling to saturated vapor

3-4: Isochoric cooling

4-1: Isothermal expansion where heat transfer with the environment of $Q_{41} = 1215.8$ kJ takes place

- (a) Draw the process in the p - v -diagram and T - v -diagram.
- (b) Calculate the net work for the cycle and the work and heat transfer of each process. Neglect changes in kinetic and potential energy. You expected to use CoolProp for property evaluation.