Thermodynamics and energetics I: Exercise 2

---

1. A gas in a piston-cylinder assembly undergoes an expansion process for which the relationship between pressure and volume is given by: $pV^n = \text{constant}$.

   (a) Determine the analytical solution for the energy transfer by work.

   (b) Evaluate the work for a ...

      i. isobaric (constant pressure) process (first consider $n = ?$)

      ii. isothermal (constant temperature) process

      iii. isochoric (constant volume) process

      iv. process with $n = 1.5$

      ... assuming the initial pressure is 3 bar, the initial volume is 0.2 m^3, the final volume 0.3 m^3, and the gas follows the ideal gas law.
      Sketch the processes in a pV-diagram

   (c) Evaluate the work for a two-step process consisting of an isothermal expansion from 0.1 m^3 at 3 bar to 0.15 m^3, followed by an isobaric expansion from 0.15 m^3 to 0.2 m^3.

   (d) Evaluate the work of the two-step process starting with isobaric expansion (from 0.1 m^3 at 3 bar to 0.15 m^3) followed by the isothermal expansion (from 0.15 m^3 to 0.2 m^3).

   (e) Sketch the two two-step processes in a pV-diagram.

2. Each line of the following table gives information about a process of a closed system. Complete the table. The sign convention follows what we defined in the lecture.

Q[kJ]	W [kJ]	U_1[kJ]	U_2[kJ]	ΔU[kJ]
	-20		50	70
50		20	50	
	-60		60	20
	-90		50	0
5	150	2		

3. An ideal gas undergoes a thermodynamic cycle consisting of the following three steps:

   Process 1–2: constant pressure $p_1 = 1.4$ bar, $V_1 = 0.028\text{m}^3$, $\text{W}_{1,2} = 10.5$ kJ

   Process 2–3: compression with pV = constant, $U_3 = U_2$

   Process 3–1: constant volume, U_1 - U_3 = -26.4 kJ

   Changes in kinetic and potential energy can be neglected.

   (a) Draw the three processes in a pV-diagram.

   (b) Calculate the net work of the cycle.

   (c) Calculate the energy transfer by heat in process 1-2.