

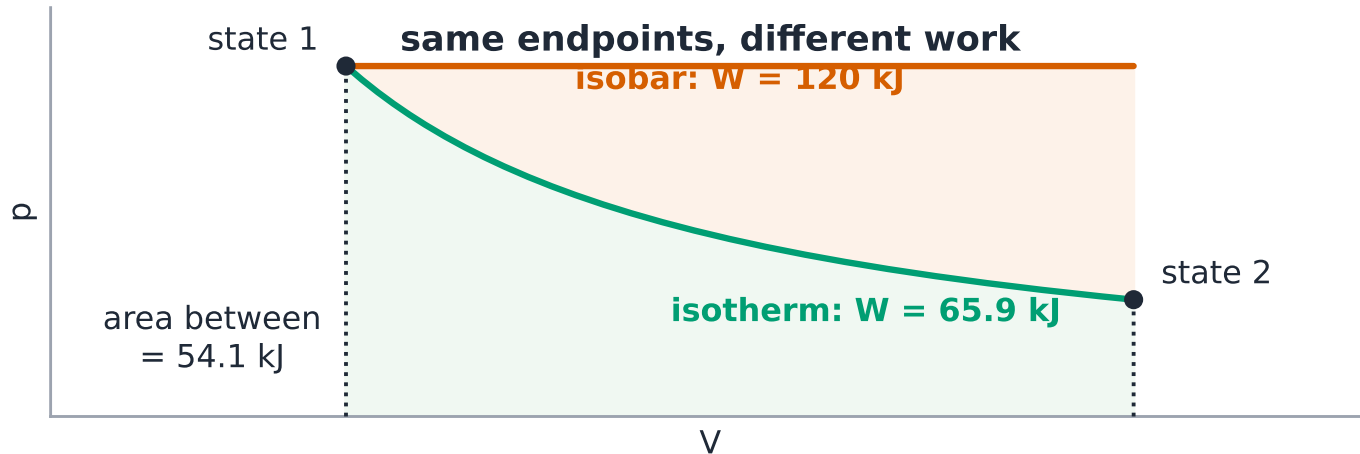
Exercise walk-through

5.2

First law for closed systems

University Mechanical Engineering

First law, closed systems: work is area



Same endpoints, three paths: isobaric $W = 120 \text{ kJ}$, isothermal $p_1 V_1 \ln 3 = 65.9 \text{ kJ}$ - the 54.1 kJ gap is the area between the curves. Adiabatic compression to half volume: $p_2 = 527.8 \text{ kPa}$, $W = -48 \text{ kJ}$, $\Delta U = +48 \text{ kJ}$.

Exercises 2.1·2.2

2.1 Air at 300 kPa, 0.2 m³ expands isobarically to 0.6 m³: the boundary work, and the heat transfer if $\Delta U = +84$ kJ (one decimal, kJ). [4]

2.2 The same gas, from 300 kPa, 0.2 m³ to 0.6 m³, connected isothermally instead: the boundary work (one decimal, kJ). [3]

Exercises 2.1-2.2

2.1 Air at 300 kPa, 0.2 m³ expands isobarically to 0.6 m³: the boundary work, and the heat transfer if $\Delta U = +84$ kJ (one decimal, kJ). [4]

2.1

- $W = p\Delta V = 300 \times (0.6 - 0.2) = \mathbf{120.0}$ kJ.
- $Q = \Delta U + W = 84 + 120.0 = \mathbf{204.0}$ kJ.

2.2 The same gas, from 300 kPa, 0.2 m³ to 0.6 m³, connected isothermally instead: the boundary work (one decimal, kJ). [3]

2.2

- $W = p_1 V_1 \ln(V_2/V_1) = 300 \times 0.2 \times \ln 3 = \mathbf{65.9}$ kJ.

Exercises 2.3-2.4

2.3 The gas ($\gamma = 1.4$), starting again at 300 kPa, 0.2 m³, is compressed adiabatically to 0.1 m³: the final pressure (one decimal, kPa), the work (one decimal, kJ) and the change in internal energy (one decimal, kJ). [5]

2.4 One sentence each: why is boundary work path-dependent, and why does $\Delta U = mc_v\Delta T$ still hold on a non-constant-volume path for an ideal gas? [2]

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2.3

- $p_2 = 300 \times (0.2/0.1)^{1.4} = 300 \times 2.639 = \mathbf{791.7}$ kPa.
- $W = (p_2 V_2 - p_1 V_1)/(1 - \gamma) = (79.17 - 60)/(1 - 1.4) = -\mathbf{47.9}$ kJ.
- $Q = 0$, so $\Delta U = -W = +\mathbf{47.9}$ kJ ✓.

2.4 One sentence each: why is boundary work path-dependent, and why does $\Delta U = mc_v \Delta T$ still hold on a non-constant-volume path for an ideal gas? [2]

2.4

- The integral $W = \int p dV$ runs along the chosen curve $p(V)$, so different connective paths enclose different areas between the same endpoints.
- u is a state function of T alone for an ideal gas, so its differential $mc_v dT$ is a property relation, valid on every path.