

Exercise walk-through

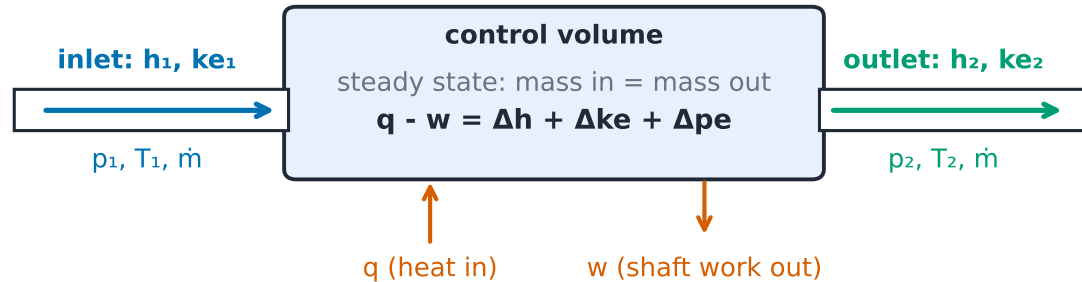
5.3

First law for open systems

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First law, open systems: enthalpy carries it

steady flow through one control volume



the flow work p_v hides inside $h = u + p_v$

Steady flow: $q - w = \Delta h + \Delta ke + \Delta pe$. Pump 0.5 $\rightarrow$ 3 MPa: $w_p = v \Delta p = 2.5$ kJ/kg. Nozzle 10 $\rightarrow$ 300 m/s: $\Delta h = -44.95$ kJ/kg. Turbine 3 MPa, 400°C to 50 kPa at $\eta_t = 0.85$: $w = 700.0$ kJ/kg.

The turbine two-step

- 1 **Isentropic leg** $s_{2s} = s_1$: $x_{2s} = (6.9212 - 1.0910)/6.5029 = \mathbf{0.89655}$, so
 $h_{2s} = 340.49 + 0.89655 \times 2305.4 = \mathbf{2407.4}$ kJ/kg.
- 2 **Price the loss** $w_s = 3230.9 - 2407.4 = \mathbf{823.5}$ kJ/kg; real
 $w = 0.85 \times 823.5 = \mathbf{700.0}$ kJ/kg.
- 3 **Back-solve** $h_2 = 3230.9 - 700.0 = \mathbf{2530.9}$ kJ/kg - the exit **state** the cycle sees.

Exercises 2.1·2.2

2.1 An adiabatic compressor takes air from $h_1 = 295.2$ to $h_2 = 480.5$ kJ/kg: the shaft work per kilogram (one decimal, kJ/kg, sign stated) and the power at a mass flow of 1.5 kg/s (one decimal, kW). [4]

2.2 A pump lifts liquid water ($v = 0.001005$ m³/kg) from 800 kPa to 5.0 MPa: the work input (two decimals, kJ/kg). [3]

Exercises 2.1-2.2

2.1 An adiabatic compressor takes air from $h_1 = 295.2$ to $h_2 = 480.5$ kJ/kg: the shaft work per kilogram (one decimal, kJ/kg, sign stated) and the power at a mass flow of 1.5 kg/s (one decimal, kW). [4]

2.1

- $w = h_1 - h_2 = 295.2 - 480.5 = -\mathbf{185.3}$ kJ/kg - negative because it is work input.
- $\dot{W} = \dot{m} |w| = 1.5 \times 185.3 = \mathbf{278.0}$ kW.

2.2 A pump lifts liquid water ($v = 0.001005$ m³/kg) from 800 kPa to 5.0 MPa: the work input (two decimals, kJ/kg). [3]

2.2

- $w_p = v \Delta p = 0.001005 \times (5000 - 800) = \mathbf{4.22}$ kJ/kg.

Exercises 2.3-2.4

2.3 An adiabatic nozzle accelerates air from 20 to 320 m/s with no shaft work: the enthalpy change (one decimal, kJ/kg) and the direction of the change. [4]

2.4 One sentence each: why is the kinetic-energy term kept for a nozzle and dropped for a pump, and why does the open-system ledger run on h rather than u ? [3]

Exercises 2.3-2.4

2.3 An adiabatic nozzle accelerates air from 20 to 320 m/s with no shaft work: the enthalpy change (one decimal, kJ/kg) and the direction of the change. [4]

2.3

- $\Delta ke = (320^2 - 20^2)/2 = 51,000 \text{ J/kg} = \mathbf{51.0 \text{ kJ/kg}}$.
- $q = w = 0$ gives $\Delta h = -\Delta ke = -\mathbf{51.0 \text{ kJ/kg}}$: enthalpy falls ✓.

2.4 One sentence each: why is the kinetic-energy term kept for a nozzle and dropped for a pump, and why does the open-system ledger run on h rather than u ? [3]

2.4

- The nozzle's product IS velocity, so Δke is the point of the device; a pump moves slow liquid, so Δke is negligible against $v \Delta p$.
- Pushing each kilogram through a port costs pv of flow work; absorbing it into u gives h , so ports balance in h .