# 5.3 First law for open systems

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

**KEY WORDS** control volume • enthalpy • nozzle

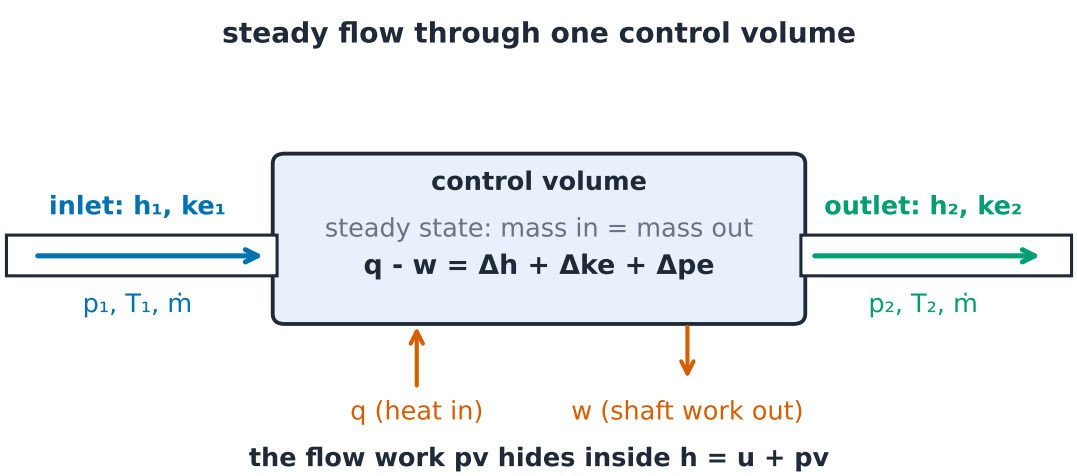
## Objective

Run the steady-flow energy equation across real devices: enthalpy at the ports, the turbine two-step, pump work and nozzle kinetic energy.

## 1 Key knowledge and worked examples

### ■ One equation, three devices

$q - w = \Delta h + \Delta ke + \Delta pe$; $h = u + pv$ absorbs the flow work. Turbine: isentropic leg, then $\eta_t$. Pump: $w_p \approx v\,\Delta p$.




*Enthalpy in, enthalpy out, shaft work and heat at the ports

### ■ Worked example. The turbine two-step

$s_{2s} = s_1$: $x_{2s} = 0.8966$, $h_{2s} = 2407.4$; $w_s = 823.5$; with $\eta_t = 0.85$: $w = 0.85 \times 823.5 = 700.0$ kJ/kg ✓, $h_2 = 3230.9 - 700.0 = 2530.9$.



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## 2 Practice

All devices run at steady state; take $g\,\Delta z$ as negligible.

**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 ($v = 0.001005$ m$^3$/kg) from 800 kPa to 5.0 MPa: the work input (two decimals, kJ/kg). [3]

**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]



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