# CHAPTER FIVE

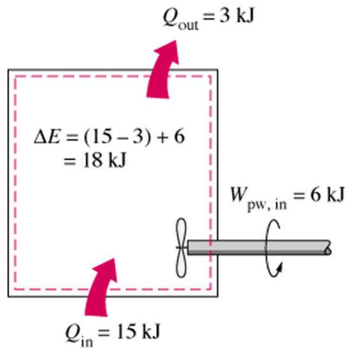
# FIRST LAW OF THERMODYNAMICS

**First Law of Thermodynamics (Section 5.1)**

- Energy can be neither created nor destroyed; it can only change form

Conservation of Energy Principle (Energy Balance)

The net change (increase or decrease) in the total energy of the system during a process is equal to the difference between the total energy entering and the total energy leaving the system during that process



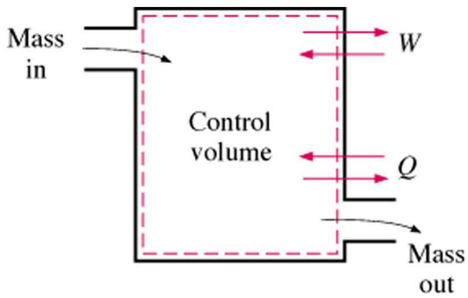

$$\begin{pmatrix}\text{Total energy}\\ \text{entering the system}\end{pmatrix} - \begin{pmatrix}\text{Total energy}\\ \text{leaving the system}\end{pmatrix} = \begin{pmatrix}\text{Change in the total}\\ \text{energy of the system}\end{pmatrix}$$

or: $E_{in} - E_{out} = \Delta E_{system}$

$\Delta E_{system} = E_{final} - E_{initial} = E_2 - E_1$

$\Delta E = \Delta U + \Delta KE + \Delta PE$

where: $\Delta U = m(u_2 - u_1)$ , $\Delta KE = \frac{1}{2}m\left(\mathcal{V}_2^2 - \mathcal{V}_1^2\right)$ , $\Delta PE = mg(z_2 - z_1)$




Special Case: Stationary Systems

$\Delta KE = \Delta PE = 0$

⇨ $\Delta E = \Delta U$

General Expression of the Energy Balance

$E_{in} - E_{out} = (Q_{in} - Q_{out}) + (W_{in} - W_{out}) + (E_{mass,in} - E_{mass,out}) = \Delta E_{system}$

Expanding all terms, the energy balance can be expressed as:

$$\left[\dot{Q}_{in} + \dot{W}_{in} + \sum m_i\left(h_i + \frac{V_i^2}{2} + gz_i\right)\right] - \left[\dot{Q}_{out} + \dot{W}_{out} + \sum m_e\left(h_e + \frac{V_e^2}{2} + gz_e\right)\right] = \Delta U + \Delta KE + \Delta PE$$

Closed System Undergoing a Cycle

$\Delta E_{system} = 0$

⇨ $Q_{in} - Q_{out} = W_{out} - W_{in}$

**Energy Balance for Steady-Flow Systems (Section 5.3)**

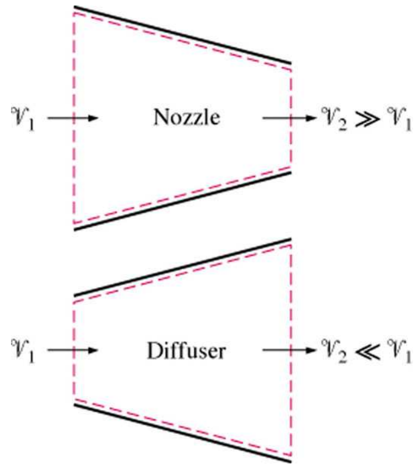
$\dot{E}_{in} - \dot{E}_{out} = \Delta\dot{E}_{system} = 0$

⇨ $\dot{E}_{in} = \dot{E}_{out}$

⇨ $\dot{Q}_{in} + \dot{W}_{in} + \sum \dot{m}_i\theta_i = \dot{Q}_{out} + \dot{W}_{out} + \sum \dot{m}_e\theta_e$

⇨ $\dot{Q}_{in} + \dot{W}_{in} + \sum \dot{m}_i\left(h_i + \frac{\mathcal{V}_i^2}{2} + gz_i\right) = \dot{Q}_{out} + \dot{W}_{out} + \sum \dot{m}_e\left(h_e + \frac{\mathcal{V}_e^2}{2} + gz_e\right)$

**Some Steady-Flow Engineering Devices (Section 5.4)**



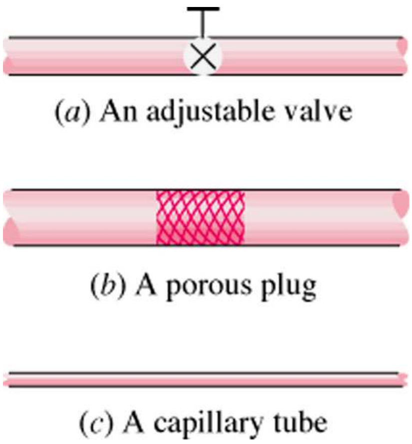

Type 1: Nozzles and Diffusers

- A nozzle is a device that increases the velocity of a fluid at the expense of pressure
- A diffuser is a device that increases the pressure of a fluid by slowing it down
- The rate of heat transfer between the fluid flowing through a nozzle or a diffuser and the surroundings is usually very small ($\dot{Q} \approx 0$)
- Nozzles and diffusers also typically involve no work ($\dot{W} = 0$) or change in potential energy ($\Delta$pe $\approx$0)

Type 3: Throttling Valves

- Throttling valves are flow-restricting devices that are usually used to control fluid flow
- They cause a significant pressure drop in the fluid and a large drop in temperature

*Examples of Throttling Valves*: adjustable valves, capillary tubes, and porous plugs

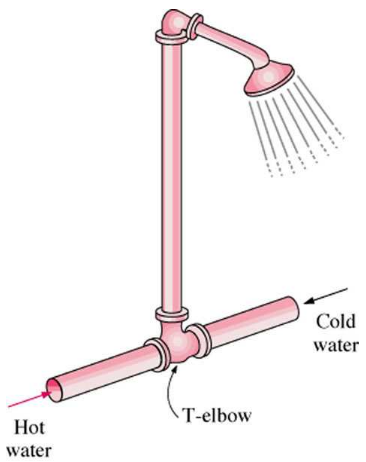



Features and Usual Assumptions

- Negligible heat transfer: $Q \approx 0$
- Negligible changes in potential energy: $\Delta$pe $\approx 0$
- Negligible changes in kinetic energy: $\Delta$ke $\approx 0$
- No work is done: $W = 0$
- As a result, the conservation of energy equation reduces to: $h_2 \approx h_1$
  ⇨ flow through throttling valves is usually called an **isenthalpic** process

Type 4a: Mixing Chambers

A mixing chamber is a section or an area where a mixing process takes place




Features and Usual Assumptions

- Negligible heat transfer: $Q \approx 0$
- Negligible changes in potential energy: $\Delta$pe $\approx 0$
- Negligible changes in kinetic energy: $\Delta$ke $\approx 0$
- No work is done: $W = 0$

**Energy Balance for Unsteady-Flow Processes (Section 5.5)**
Unsteady flow processes are ones that involve changes within the control volume with time.

Mass Balance

$$\sum m_i - \sum m_e = (m_2 - m_1)$$

Energy Balance

$$E_{\text{in}} - E_{\text{out}} = \Delta E_{\text{system}}$$

OR

$$\left[Q_{\text{in}} + W_{\text{in}} + \sum m_i \left(h_i + \frac{V_i^2}{2} + gz_i\right)\right] - \left[Q_{\text{out}} + W_{\text{out}} + \sum m_e \left(h_e + \frac{V_e^2}{2} + gz_e\right)\right] = (m_2 e_2 - m_1 e_1)_{\text{system}}$$

Special Case: Negligible kinetic energy and potential of the CV and fluid streams

$$\left(Q_{\text{in}} + W_{\text{in}} + \sum m_i h_i\right) - \left(Q_{\text{out}} + W_{\text{out}} + \sum m_e h_e\right) = (m_2 u_2 - m_1 u_1)_{\text{system}}$$