TOPIC: 1ST & 2ND LAW OF STEADY FLOW

1. **1st Law of Study Flow Explanation.**

Answer:

Core Concept: Conservation of Energy
It states that for a steady-flow process, the total energy entering a control volume must equal the total energy leaving it. It is an **energy accounting** tool.

The General Equation (per unit mass):
The most common form of the SFEE is:

$$\dot{Q} - \dot{W} = \dot{m}[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)]$$

Dividing by the mass flow rate ($\dot{m}$) gives the intensive form:

$$\boxed{q - w = (h_2 - h_1) + \frac{1}{2}(V_2^2 - V_1^2) + g(z_2 - z_1)}$$

Where:

- q = Heat transfer *to* the system per unit mass (kJ/kg)
- w = Work done *by* the system per unit mass (kJ/kg)
- h = Specific enthalpy ($= u + Pv$) (kJ/kg)
- V = Velocity (m/s)
- z = Elevation (m)
- Subscripts $_1$ and $_2$ refer to inlet and outlet states, respectively.

What it tells us: This equation calculates the relationship between **heat, work, and the change in the energy content of a flowing fluid**. It answers the question: "For a given device (like a turbine or compressor), how much work can we get out (or must we put in) for a certain heat and flow condition?"

Applications & Simplifications:
The SFEE is applied to various engineering devices by making reasonable assumptions:

Device	Assumptions (SFEE simplifies to...)	Application
Nozzle / Diffuser	$q \approx 0, w = 0, \Delta pe \approx 0$	$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$

Device	Assumptions (SFEE simplifies to...)	Application
Turbine	$q \approx 0, \Delta ke \approx 0, \Delta pe \approx 0$	$w = h_1 - h_2$
Compressor / Pump	$q \approx 0, \Delta ke \approx 0, \Delta pe \approx 0$	$-w = h_2 - h_1$
Boiler / Condenser	$w = 0, \Delta ke \approx 0, \Delta pe \approx 0$	$q = h_2 - h_1$
Throttling Valve	$q = 0, w = 0, \Delta ke \approx 0, \Delta pe \approx 0$	$h_1 = h_2$

Limitation of the First Law: The SFEE tells us if an energy balance is satisfied, but it **cannot tell us if a process is possible or not**. For example, it cannot tell you if heat can flow from a cold body to a hot body by itself, even though it might still balance energetically.

2. 2nd Law of Study Flow Explanation.

Answer:

Core Concept: Entropy Generation and Process Direction
It states that for a steady-flow process, entropy can be generated within the control volume due to irreversibilities, but it can never be destroyed. It is an **accounting of irreversibility and process feasibility**.

The General Equation (for the control volume):
The entropy balance for a steady-flow process is:

$$\sum \dot{m}_i s_i + \frac{\dot{Q}}{T} + \dot{S}_{gen} = \sum \dot{m}_e s_e$$

Rearranging for a single inlet and single outlet:

$$\dot{m} s_1 + \sum \frac{\dot{Q}_k}{T_k} + \dot{S}_{gen} = \dot{m} s_2$$

Dividing by the mass flow rate ($\dot{m}$) gives the intensive form:

$$\boxed{s_1 + \sum \frac{q_k}{T_k} + s_{gen} = s_2}$$

Where:

- s = Specific entropy (kJ/kg·K)

- q_k = Heat transfer per unit mass at a boundary where the temperature is T_k (kJ/kg)
- s_{gen} = Entropy generated *per unit mass* inside the control volume (kJ/kg·K)

The Central Principle:

$$s_{gen} \geq 0$$

- $s_{gen} = 0$ for a **reversible** process.
- $s_{gen} > 0$ for an **irreversible** (real) process.
- $s_{gen} < 0$ is **impossible**.

What it tells us: This equation determines:

1. **The Direction of a Process:** A process can only occur if it leads to a net increase in the total entropy (system + surroundings), i.e., $s_{gen} \geq 0$.
2. **The Degree of Irreversibility:** The magnitude of s_{gen} quantifies the "loss" or "waste" of work potential in a process. This is directly linked to the **Gouy-Stodola Theorem**: $I = T_0 \cdot \dot{S}_{gen}$, where I is the irreversibility (lost work).

Application Example:
For an **adiabatic steady-flow device** (like a turbine, compressor, or nozzle where $q = 0$), the Second Law simplifies to:

$$s_2 - s_1 = s_{gen} \geq 0$$

This means the **exit entropy must be greater than or equal to the inlet entropy**. If you calculate an exit entropy that is lower than the inlet entropy for an adiabatic process, you can immediately conclude that the process is **impossible**, even if it satisfies the First Law.

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