ENG 3165 LECTURE 3

THERMODYNAMICS COMPONENT

The Laws of Thermodynamics

Introduction

- This Lecture gives an introduction to the **Laws of Thermodynamics**.
- **Energy** is defined in terms of **Work and Heat Transfer.**
- Several definitions of the **First Law of Thermodynamics** are given in relation to both closed and open systems: the **Non-Flow Energy Equation** and the **Steady Flow Energy Equation.**

REVIEWING MECHANICAL CONCEPTS OF ENERGY

- Newton's laws of motion, which provide the basis for classical mechanics, led to the concepts of **work**, **kinetic energy,** and **potential energy**, and these led eventually to a broadened concept of energy.

- The change in kinetic energy, $\Delta KE,$ is:

$$\Delta KE = KE_2 - KE_1 = \frac{1}{2} m(V_2^2 - V_1^2)$$

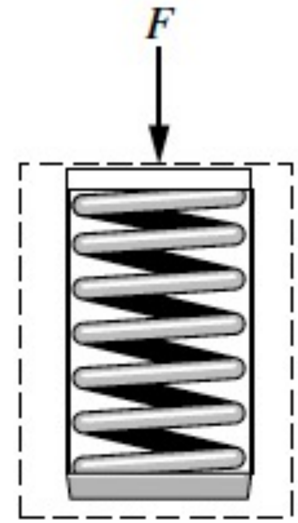
- Furthermore, the quantity ***mgz*** is the gravitational potential energy, PE. The change in gravitational potential energy, Δ***PE,*** is

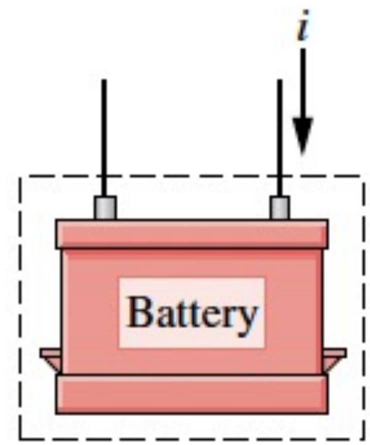
$$\Delta PE = PE_2 - PE_1 = mg(z_2 - z_1)$$

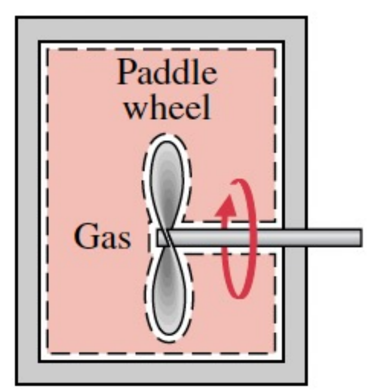
- In SI, the energy unit is the newton-meter, N m, called the joule, J.

INTERNAL ENERGY, U

- The **total energy, E** of a system, includes kinetic energy, gravitational potential energy, and other forms of energy.
- When work is done to compress a spring, energy is stored within the spring or when a battery is charged, the energy stored within it is increased. And when a gas (or liquid) initially at an equilibrium state in a closed, insulated vessel is stirred vigorously and allowed to come to a final equilibrium state, the energy of the gas is increased in the process.
- In each of these examples the change in system energy cannot be attributed to changes in the system's kinetic or gravitational potential energy. The change in energy can be accounted for in terms of **internal energy**.







INTERNAL ENERGY, U

- In engineering thermodynamics the change in the total energy of a system is considered to be made up of **three macroscopic contributions.**

1. One is the change in **kinetic energy,** associated with the motion of the system as a whole relative to an external coordinate frame.
2. Another is the change in **gravitational potential energy**, associated with the position of the system as a whole in the earth's gravitational field.
3. **All other energy changes are lumped together as the internal energy of the system**.

- Like kinetic energy and gravitational potential energy, internal energy is an extensive property of the system, as is the total energy.

INTERNAL ENERGY, U

- Internal energy is represented by the symbol ***U***, and the change in internal energy in a process is $U_2 - U_1$. The specific internal energy is symbolized by ***u***.
- The change in the total energy of a system is

$$E_2 - E_1 = (KE_2 - KE_1) + (PE_2 - PE_1) + (U_2 - U_1)$$

Or

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

- At the **microscopic level,** part of the internal energy of the gas is the translational kinetic energy of the molecules as well as the kinetic energy due to rotation of the molecules relative to their centres of mass and the kinetic energy associated with vibrational motions within the molecules.
- In addition, energy is stored in the chemical bonds between the atoms that make up the molecules. Energy storage on the atomic level includes energy associated with electron orbital states, nuclear spin, and binding forces in the nucleus.

INTERNAL ENERGY, U

- In this course we shall mainly be concerned with changes of U that are associated with changes of the thermal energy of the system. A useful way to think of thermal energy is Thermal energy: kinetic energy associated with random motions of molecules at the microscale. In fact, the temperature is a measure of the average internal energy
- In thermodynamics, one almost always considers situations where the macroscopic energy is constant: the system is immobile (macroscopically), does not change altitude, etc.
- The energy variations of the system are then **equal to the variations of the internal energy:**

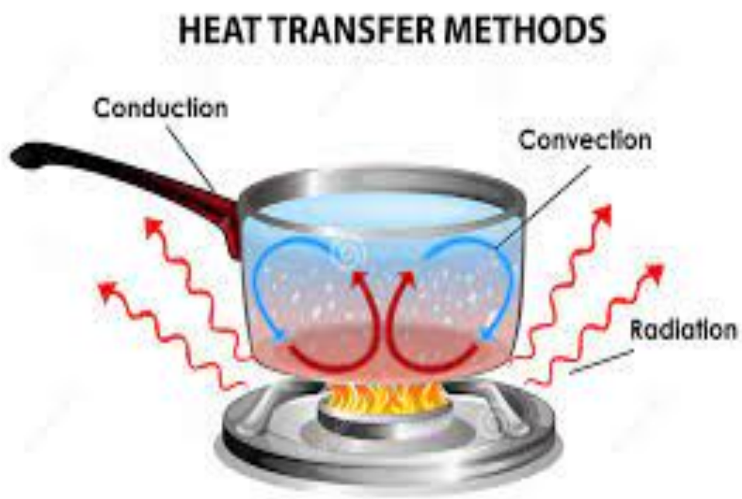
$$\Delta E = \Delta U$$

ENERGY TRANSFER BY HEAT

- Heat is usually defined as energy transport to or from a system due to a temperature difference between the system and its surroundings.
- This can occur by only three modes: conduction, convection, and radiation.
- Can occur only in the direction of decreasing temperature.
- The symbol **Q** denotes an amount of energy transferred across the boundary of a system in a heat interaction with the system's surroundings.
- Heat transfer into a system is taken to be positive, and heat transfer from a system is taken as negative.

Q $>$ 0: heat transfer to the system

Q $<$ 0: heat transfer from the system



WORK IN MECHANICS

- In mechanics, when a body moving along a path is acted on by a resultant force that may vary in magnitude from position to position along the path, the work of the force is written as the scalar product (dot product) of the force vector F and the displacement vector of the body along the path ds. That is:

$$Work = \int_1^2 F \cdot ds$$

- When the resultant force causes the elevation to be increased, the body to be accelerated, or both, the work done by the force can be considered a transfer of energy to the body, where it is stored as gravitational potential energy and/or kinetic energy.
- The notion that energy is conserved underlies this interpretation.

WORK IN THERMODYNAMICS (ENERGY TRANSFER BY WORK)

- **Work** is more difficult to define. It is often defined as a force moving through a distance, but this is only one type of work; there are many other work modes as well.
- Since the only energy transport modes for moving energy across a system's boundary are heat, mass flow, and work, the simplest definition of work is that it is any energy transport mode that is neither heat nor mass flow
- **In thermodynamic analysis, work is done by a system on its surroundings if the sole effect on everything external to the system could have been the raising of a weight.**
- **Moving System Boundary Work:** Whenever a system boundary moves such that the total volume of the system changes, moving system boundary work occurs. This is sometimes called expansion or compression work, and it has wide application in mechanical power technology

ENERGY TRANSFER BY WORK

: Sign Convention and Notation

- Engineering thermodynamics is frequently concerned with devices such as internal combustion engines and turbines whose purpose is to do work.
- Hence, it is often convenient to consider such work as positive. That is,

$W > 0$: work done by the system

$W < 0$: work done on the system

- This sign convention is not universal. Many physicists use precisely the opposite convention. Probably the reason for this convention is that thermodynamics is a science that was invented by engineers in the nineteenth century. And those engineers wanted to produce work from steam engines. Systems doing work were viewed favorably and endowed with a positive sign.
- **We associate energy with the ability to do work**

ENERGY ACCOUNTING :Energy Balance for Closed Systems

- The only ways the energy of a closed system can be changed is through transfer of energy by work or by heat. Further, a fundamental aspect of the energy concept is that energy is conserved. **This is the first law of thermodynamics** and can summarised as follows:

$$\left[\begin{array}{c} \textit{change} \text{ in the amount} \\ \text{of energy contained} \\ \text{within the system} \\ \text{during some time} \\ \text{interval} \end{array}\right] = \left[\begin{array}{c} \textit{net} \text{ amount of energy} \\ \text{transferred } \textit{in} \text{ across} \\ \text{the system boundary by} \\ \textit{heat} \text{ transfer during} \\ \text{the time interval} \end{array}\right] - \left[\begin{array}{c} \textit{net} \text{ amount of energy} \\ \text{transferred } \textit{out} \text{ across} \\ \text{the system boundary} \\ \text{by } \textit{work} \text{ during the} \\ \text{time interval} \end{array}\right]$$

$$E_2 - E_1 = Q - W$$

$$\Rightarrow \Delta KE + \Delta PE + \Delta U = Q - W$$

$$\Rightarrow \Delta U = Q - W$$

ENERGY ACCOUNTING : Other Forms of the Energy Equation

- The energy balance in differential form is:

$$dE = \delta Q - \delta W$$

- The instantaneous time rate form of the energy balance is:

$$\frac{dE}{dt} = \dot{Q} - \dot{W}$$

ENERGY ACCOUNTING : Other Forms of the Energy Equation

- The energy balance for any system undergoing a thermodynamic cycle takes the form

$$\Delta E_{cycle} = Q_{cycle} - W_{cycle}$$

- where Qcycle and Wcycle represent net amounts of energy transfer by heat and work, respectively, for the cycle. Since the system is returned to its initial state after the cycle, there is no net change in its energy. Therefore, the left side of the equation equals zero, and the equation reduces to

$$W_{cycle} = Q_{cycle}$$

ENERGY ACCOUNTING :Energy Balance for Closed Systems

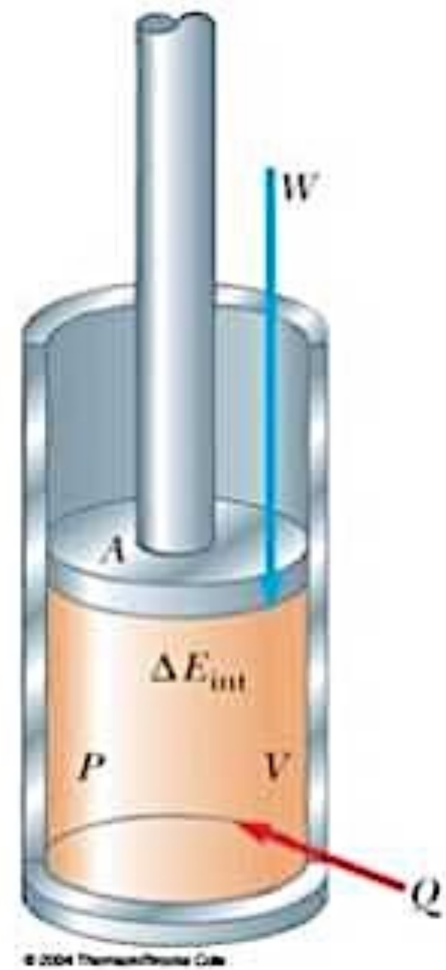
- The quantities symbolized by W and Q in the foregoing equations account for **transfers of energy** and not transfers of work and heat, respectively. The terms work and heat denote different means by which energy is transferred and not what is transferred.
- However, for simplicity, in subsequent discussions, W and Q are often referred to simply as work and heat transfer, respectively.
- This less formal manner of speaking is commonly used in engineering practice.

THERMODYNAMIC PROCESSES: ADIABATIC PROCESSES

- An adiabatic process is one during which no energy enters or leaves the system by heat

  $Q = 0$

  This is achieved by:
  - Thermally insulating the walls of the system
  - Having the process proceed so quickly that no heat can be exchanged



THERMODYNAMIC PROCESSES: ADIABATIC PROCESSES

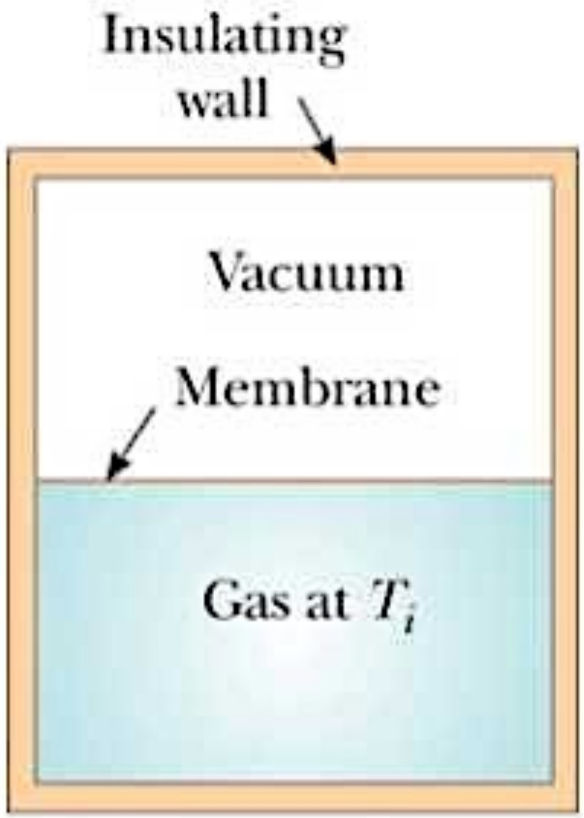
- Since $Q = 0$, $\Delta E_{int} = -W$
- If the gas is compressed adiabatically, W is **negative** so ΔE_{int} is positive and the temperature of the gas increases
- If the gas expands adiabatically, the temperature of the gas decreases

THERMODYNAMIC PROCESSES: ADIABATIC PROCESSES

- Some important examples of adiabatic processes related to engineering are:
  - The expansion of hot gases in an internal combustion engine
  - The liquefaction of gases in a cooling system
  - The compression stroke in a diesel engine

THERMODYNAMIC PROCESSES: ADIABATIC FREE EXPANSION

- This is an example of adiabatic free expansion
- The process is adiabatic because it takes place in an insulated container
- Because the gas expands into a vacuum, it does not apply a force on the membrane and $W = 0$
- Since $Q = 0$ and $W = 0$, $\Delta E_{int} = 0$ and the initial and final states are the same
  - No change in temperature is expected



THERMODYNAMIC PROCESSES: ISOBARIC PROCESSES

- An isobaric process is one that occurs at a constant pressure
- The values of the heat and the work are generally both nonzero
- The work done is $W = P\,(V_f - V_i)$ where P is the constant pressure

THERMODYNAMIC PROCESSES: ISOCHORIC/ ISOVOLUMETRIC PROCESSES

- An isovolumetric process is one in which there is no change in the volume
- Since the volume does not change, $W = 0$
- From the first law, $\Delta E_{int} = Q$
- If energy is added by heat to a system kept at constant volume, all of the transferred energy remains in the system as an increase in its internal energy

THERMODYNAMIC PROCESSES: ISOTHERMAL PROCESSES

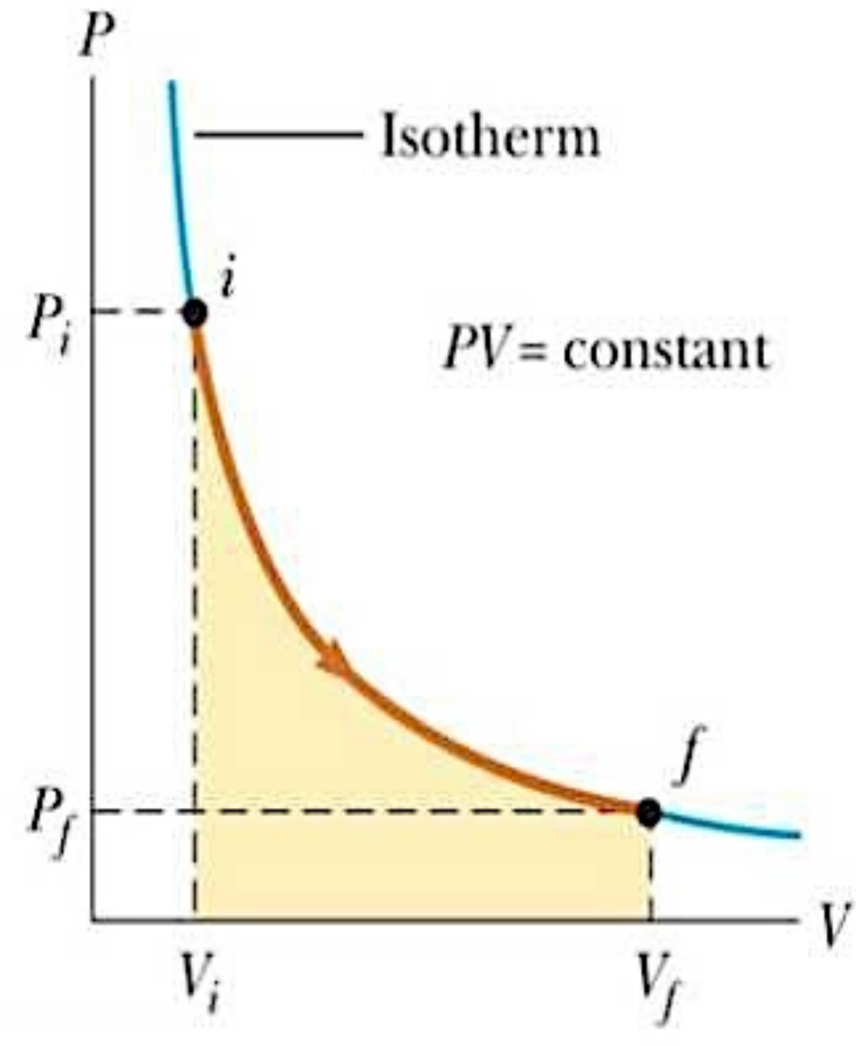
- An isothermal process is one that occurs at a constant temperature
  - Since there is no change in temperature,

$$\Delta E_{int} = 0$$

- Therefore, $Q = W$
- Any energy that enters the system by heat must leave the system by work

THERMODYNAMIC PROCESSES: ISOTHERMAL PROCESSES

- At right is a ***PV*** diagram of an isothermal expansion
- The curve is a hyperbola
- The curve is called as **isotherm**



THERMODYNAMIC PROCESSES: ISOTHERMAL EXPANSION

- Numerically, the work equals the area under the ***PV*** curve

- If the gas expands, $V_f > V_i$ and the work done on the gas is negative
- If the gas is compressed, $V_f < V_i$ and the work done on the gas is positive

SPECIAL PROCESSES SUMMARY

- Adiabatic

  No heat exchanged

  $Q = 0$ and $\Delta E_{int} = -W$

- Isobaric

  Constant pressure

  $W = P(V_f - V_i)$ and $\Delta E_{int} = Q - W$

- Isothermal

  Constant temperature

  $\Delta E_{int} = 0$ and $Q = W$

ZEROTH LAW OF THERMODYNAMICS

This law is concerned with thermal equilibrium. It states that *if two bodies are separately in thermal equilibrium with a third body then they must be in thermal equilibrium with each other*.

Thus, in Fig. 3.1, if bodies B and C are in thermal equilibrium with body A then bodies B and C must be in thermal equilibrium with each other.

By thermal equilibrium is meant that there is no change of state and hence the zeroth law implies that the bodies A, B and C will all be at the same temperature and further, that all bodies, if in thermal equilibrium, will be at the same temperature.

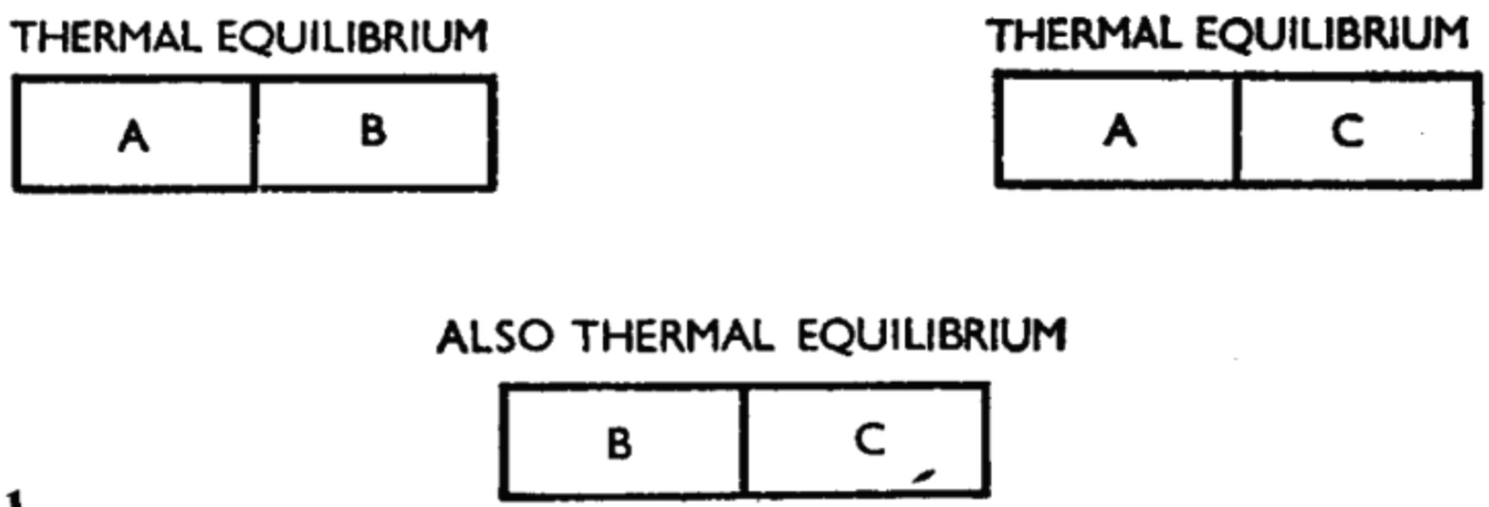


Fig. 3.1

THE FIRST LAW OF THERMODYNAMICS

This forms the basis for Heat Balance / Energy Balance.

Net change (increase / decrease) in the total Energy of the System during a Process

= Difference between Total Energy entering and Total Energy leaving the System during that Process.

Total Energy entering the System	–	Total Energy leaving the System	=	Change in Total Energy of the System
(E_{IN})		(E_{OUT})		(ΔE)

THE FIRST LAW OF THERMODYNAMICS

- To complete a cycle, a working substance is taken through a sequence of events and is returned to its original state. Its final properties are identical to its original properties.
- If work is transferred through the cycle then the energy to provide the work must have been transferred as heat and must exactly equal the work done.
- During some processes of the cycle, work is done by the substance, while during others, work is done on the substance.
- Similarly, during some processes, heat is transferred into the substance while during others, heat is transferred out

THE FIRST LAW OF THERMODYNAMICS

- Thus, for a cycle there is no net property change.

Net heat transfer – Net work transfer = 0

Or,

$$\Sigma Q = \Sigma W$$

Or as it is written symbolically,

$$\oint Q = \oint W$$

- The symbol $\oint$ means the summation around the cycle.

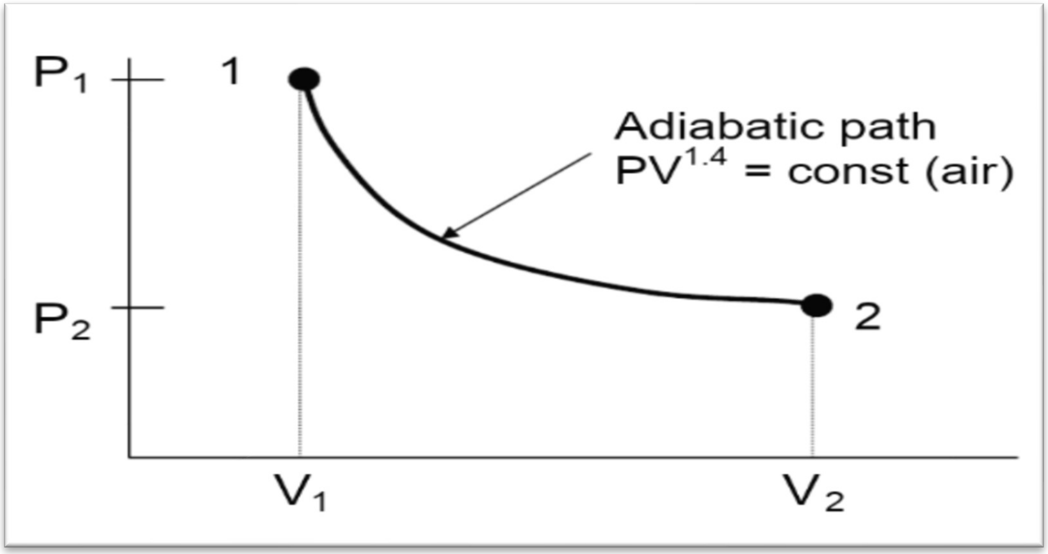
CONSERVATION OF ENERGY FOR A CLOSED SYSTEM

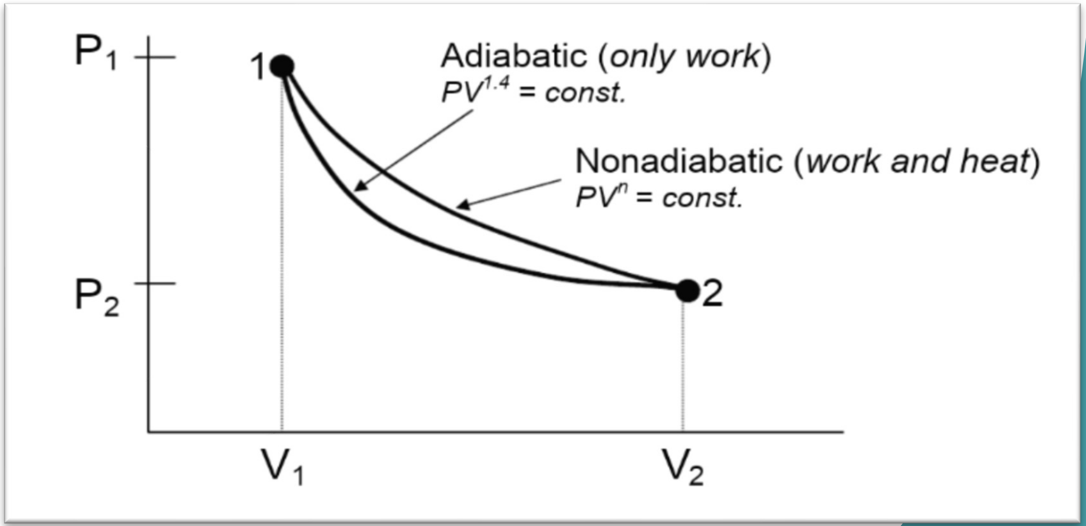
- A closed system can interact with its surroundings via work work as well as via heat transfer.
- A process that involves work transfer but does involve thermal interactions or heat transfer is called an adiabatic process as noted in the previous slide.
- A process with no thermal interactions is called a non-adiabatic process.
- It has been shown experimentally that the net work done by or on a closed system undergoing an adiabatic process depends solely on the end states and not on the details of the process.

$$E_2 - E_1 = -W_{out}$$

CONSERVATION OF ENERGY FOR A CLOSED SYSTEM

- Shown below is a **P-V (Pressure – Volume) diagram** for a qiasi-equilibrium adiabatic gas compression or expansion process.
- This processes are described by the equation $PV^{1.4} = constant$; with polytropic exponent n=1.4 for air.
- **The work done is the area under the graph.**





CONSERVATION OF ENERGY FOR A CLOSED SYSTEM

Since the area under the two curves is different the work done for each path is different, so $W_{ad} \neq W_{nonad}$

Since the end states for both processes are the same the system would experience exactly the same energy change in each of the processes, so

$$(E_2 - E_1)_{ad} = (E_2 - E_1)_{nonad} = E_2 - E_1$$

We know the energy change for the adiabatic process is

$$E_2 - E_1 = -W_{ad}$$

But since $W_{ad} \neq W_{nonad}$ we can infer that

$$E_2 - E_1 \neq -W_{nonad}$$

CONSERVATION OF ENERGY FOR A CLOSED SYSTEM

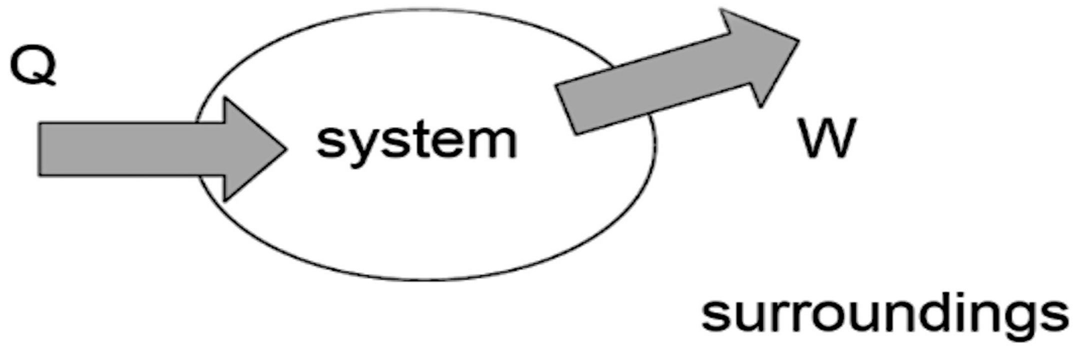
Since energy must be conserved the net energy transferred to the system in both processes must be the same. It follows that the heat interaction in the nonadiabatic process must involve energy transfer. The amount of energy transferred to the closed system by heat is Q

$$E_2 - E_1 = -W_{nonad} + Q$$

The **First Law of Thermodynamics** states:

$$\boxed{E_2 - E_1 = Q - W}$$

THE FIRST LAW OF THERMODYNAMICS



If a closed system undergoes a process from state 1 to state 2, then

$$\Delta E_{1\to 2} = \Delta KE_{1\to 2} + \Delta PE_{1\to 2} + \Delta U_{1\to 2} = Q_{1\to 2} - W_{1\to 2}$$

The increase in the KE + increase in PE + increase in internal energy = heat transferred into the system – work done by the system

For most situations change in KE and PE is negligible so

$$\Delta U_{1\to 2} = Q_{1\to 2} - W_{1\to 2}$$

$$\Delta U = (U_2 - U_1) = Q - W$$

THE FIRST LAW OF THERMODYNAMICS: Specific Quantities

Developing a thermodynamic model involves defining the system and defining the process characteristics such as:

- Adiabatic: $Q = 0$
- Constant volume: $\int PdV = 0$
- Constant pressure: $\int PdV = P\Delta V$
- Isothermal: $T = const \rightarrow \Delta U = 0$

First Law on a per unit mass basis

Take first Law and divide through by the system mass

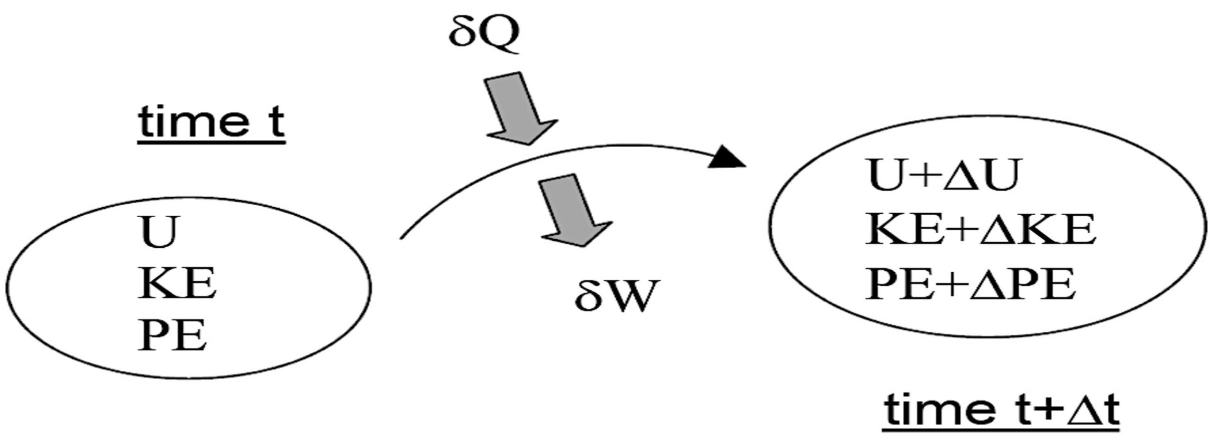
$$\frac{\Delta U}{M} = \frac{Q}{M} - \frac{W}{M}$$

$$\Delta u = q - w$$

where $u = U/M$, $q = Q/M$, $w = W/M$ are referred to as specific quantities

THE FIRST LAW OF THERMODYNAMICS: Differential and Specific Time Rate Forms

Consider the system changes in time Δt



Applying First Law to the system:

$$E(t + \Delta t) - E(t) = \delta Q - \delta W$$

$$[(U + \Delta U) - U] + [(KE + \Delta KE) - KE] + [(PE + \Delta PE) - PE] = \delta Q - \delta W$$

dividing through by Δt

$$\frac{\Delta E}{\Delta t} = \frac{\Delta U}{\Delta t} + \frac{\Delta KE}{\Delta t} + \frac{\Delta PE}{\Delta t} = \frac{\delta Q}{\Delta t} - \frac{\delta W}{\Delta t}$$

In the limit as Δt tends to 0, e.g., $\lim_{t \to 0}\left(\frac{\Delta U}{\Delta t}\right) = \frac{dU}{dt}$

THE FIRST LAW OF THERMODYNAMICS: Differential and Specific Time Rate Forms

$$\frac{dE}{dt} = \frac{dU}{dt} + \frac{d(KE)}{dt} + \frac{d(PE)}{dt} = \dot{Q} - \dot{W}$$

where

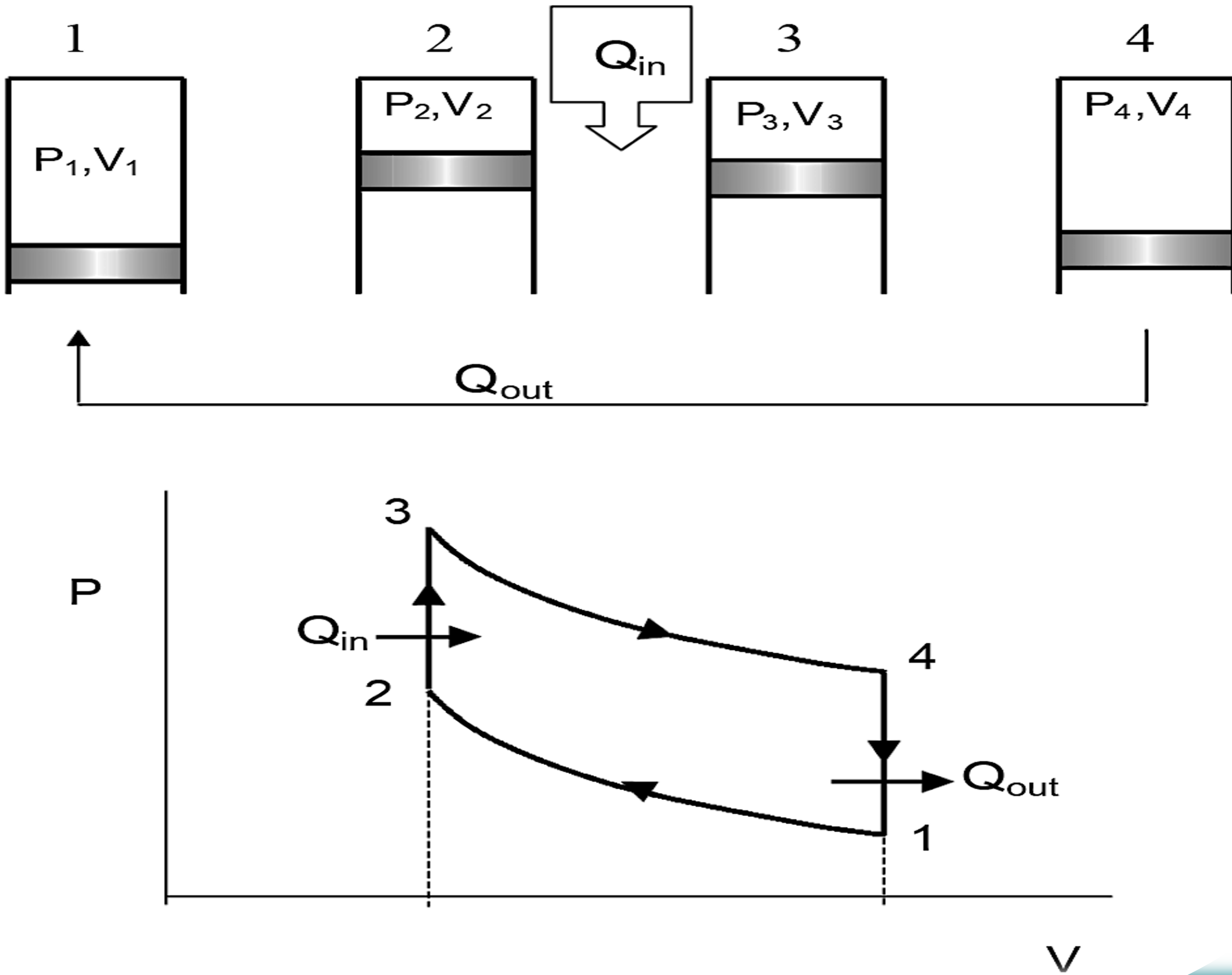
$\frac{dE}{dt}$ = time rate of changeof energy contained within the system

$\dot{Q}$ = net rate of energy transfer into the system by heat transfer

$\dot{W}$ = net rate of energy transfer out of the system by work

THE FIRST LAW OF THERMODYNAMICS: Closed System operating on a Cycle

In a cycle the system starts and ends at the same state after executing a number of processes, e.g,



THE FIRST LAW OF THERMODYNAMICS: Closed System operating on a Cycle

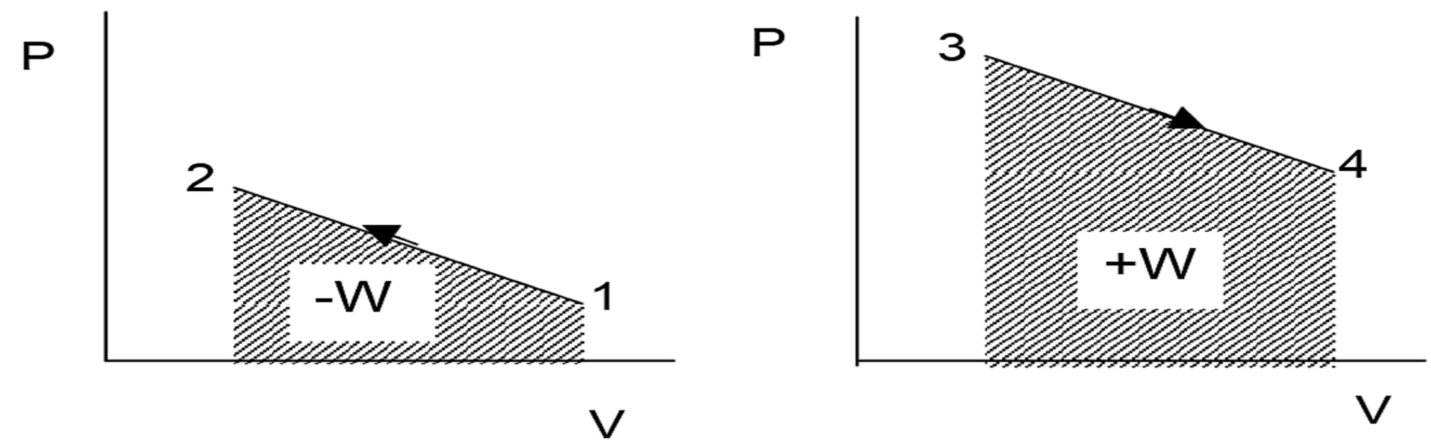
Applying First Law for the entire cycle ($\Delta KE = \Delta PE = 0$)

$$\cancel{\Delta E_{cycle}} = Q_{cycle} - W_{cycle}$$

$$\boxed{W_{cycle} = Q_{cycle}}$$

$$Q_{cycle} = \cancel{Q_{1\to 2}} + Q_{2\to 3} + \cancel{Q_{3\to 4}} + Q_{4\to 1} = Q_{in} - Q_{out}$$

$$W_{cycle} = W_{1\to 2} + \cancel{W_{2\to 3}} + W_{3\to 4} + \cancel{W_{4\to 1}} = \int_{V_1}^{V_2} PdV + \int_{V_3}^{V_4} PdV$$



$$W_{cycle} = \int_{V_3}^{V_4} PdV - \int_{V_2}^{V_1} PdV$$

THE FIRST LAW OF THERMODYNAMICS: Closed System operating on a Cycle

$$\text{since} \int_{V_3}^{V_4} PdV > \int_{V_2}^{V_1} PdV$$

$W_{cycle} > 0$ net work produced

When the net work for a cycle is positive it is referred to as a **Power Cycle**

For a power cycle

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

$$\text{since } W_{cycle} > 0 \quad \rightarrow \quad Q_{in} > Q_{out}$$

When the net work for the cycle is negative it is referred to as a **Refrigeration or Heat Pump Cycle**

THE NON-FLOW ENERGY EQUATION

- If a process is carried out on a substance in a closed system such that there is both Heat and Work Transfer, it is not necessarily the case that the algebraic sum of the energy transfers is zero, meaning

$$\sum \boldsymbol{W} \neq \sum \boldsymbol{Q}$$

- According to the Principle of Conservation of Energy:

Energy In = Energy Out

- Thus, if the Heat and Work Transfers are not equal, then any energy difference must have been added or lost from the substance.
- This again introduces the concept of **Internal Energy**, which is that energy residing within the substance.

THE NON-FLOW ENERGY EQUATION

- Thus with the inclusion if Internal Energy:

$$\boldsymbol{Q} = \Delta\boldsymbol{U} + \boldsymbol{W}$$

Where:
Q = Heat Transfer
ΔU= Change in Internal Energy
W=Work Transfer

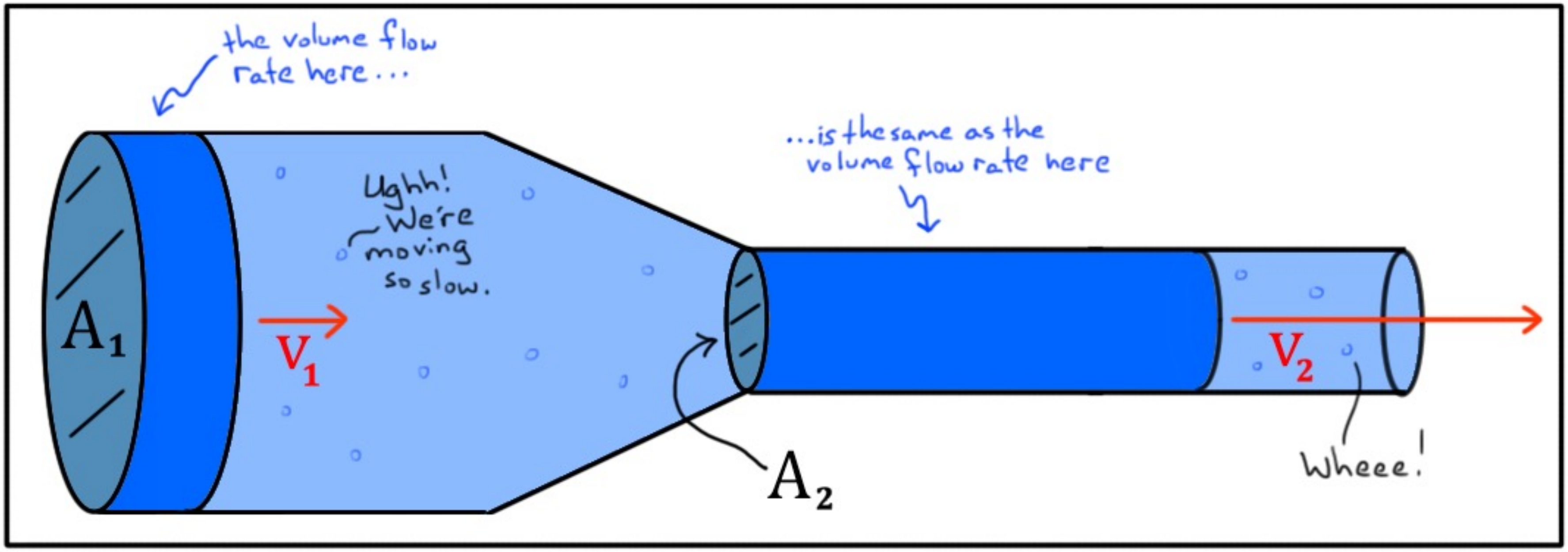
This is another statement of the First Law of Thermodynamics

THE CONTINUITY EQUATION

- The continuity equation is simply a mathematical expression of the principle of conservation of mass. For a control volume that has a single inlet and a single outlet, **the principle of conservation of mass** states that, for steady-state flow, the mass flow rate into the volume must equal the mass flow rate out.

- For a fluid substance flowing through a steady flow open system, the mass flow rate through any section in the system must be constant.

THE CONTINUITY EQUATION



At any section in the system:

$$\dot{m}_{in} = \dot{m}_{out}$$
$$(\rho AV)_{in} = (\rho AV)_{out}$$
$$\rho A_1 V_1 = \rho A_2 V_2$$
$$Mass\ entering\ per\ unit\ time = Mass\ leaving\ per\ unit\ time$$

And,

$$\dot{m} = \frac{AV}{\nu} = \rho AV$$

Where:

A = Cross sectional area of flow
V = Velocity of flow
ρ = density of fluid
ν = specific volume of fluid

THE STEADY-FLOW ENERGY EQUATION

- In a steady flow system (an open system or control volume), it is considered that the mass flow rate of fluid or substance throughout the system is **constant**.

- It is further considered the total energy of the fluid mass in the system remains constant.

- If this is the case, then:

$$E_1 = E_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Hence, $E_2 - E_1 = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$

- From this equation it follows that:

$$Q - W = (H_2 - H_2) + (KE_2 - KE_1) + (PE_2 - PE_1) \ldots(3)$$

This is known as the steady-flow energy equation (SFEE)

THE STEADY-FLOW ENERGY EQUATION

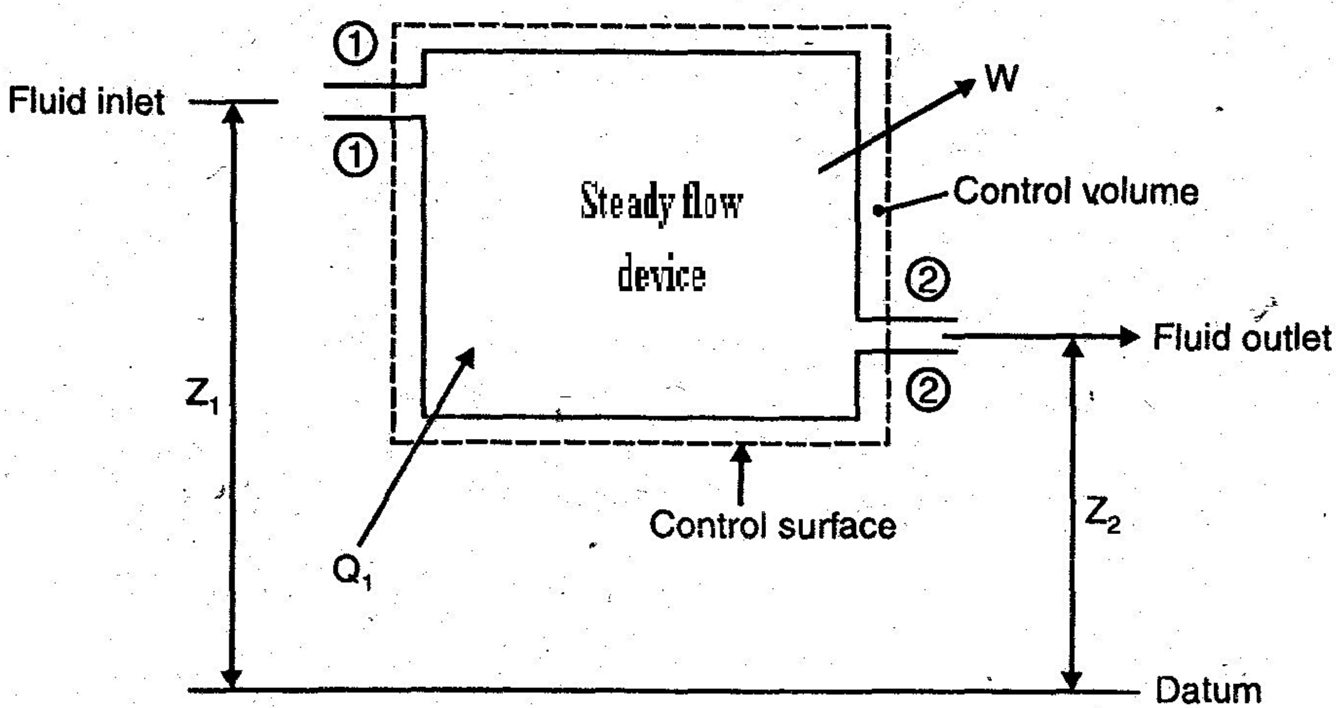
- Now assuming that $E_1 = E_2$ as before:

$$U_1 + P_1V_1 + KE_1 + PE_1 + Q = U_2 + P_2V_2 + KE_2 + PE_2 + W \dots (4)$$

- This equation is for any mass flow rate. It is often convenient to consider the flow of unit mass flow through a system, in which case specific quantities are used and the equation becomes:

$$u_1 + P_1v_1 + KE_1 + PE_1 + q = u_2 + P_2v_2 + KE_2 + PE_2 + w \dots (5)$$

The figure below illustrates a steady flow open system into which a fluid flows with pressure P_1 and specific volume v_1, and specific internal energy u_1.



THE STEADY-FLOW ENERGY EQUATION

- In its passage through the system, specific heat energy **q** and specific work **w** are transferred into or out of the system. The fluid leaves the system with pressure $\mathbf{P_2}$, specific volume $\mathbf{v_2}$, specific internal energy $\mathbf{u_2}$ and velocity $\boldsymbol{V_2}$.

$$u_1 + P_1 v_1 + \frac{V_1^2}{2} + gZ_1 + q = u_2 + P_2 v_2 + \frac{V_2^2}{2} + gZ_2 + w \ldots . (6)$$

- In thermodynamic systems, any changes in gravitational potential energy are mostly small compared with other energy forms. The terms **gZ** therefore neglected. Equation (6) then becomes:

$$u_1 + P_1 v_1 + \frac{V_1^2}{2} + q = u_2 + P_2 v_2 + \frac{V_2^2}{2} + w \ \ldots . (7)$$

- Also since $u_1 + P_1 v_1 = h = specific\ enthalty,$ equation (7) then becomes:

$$h_1 + \frac{V_1^2}{2} + q = h_2 + \frac{V_2^2}{2} + w \ldots\ldots\ldots (8)$$

ENTHALPY

- When a process takes place at constant pressure, the heat absorbed or released is equal to the Enthalpy Change.
- Enthalpy is an energy like property or state function – it has the dimensions of energy and is measured in units of joules
- Its value is determined entirely by the temperature, pressure and composition of the system, and not its history.
- It is denoted by **H**

$$H = U + \mathbf{PV},$$

Where:

$\mathbf{H = Enthalpy\ of\ the\ system}$

$\mathbf{U = Internal\ energy\ of\ the\ system}$

$\mathbf{P = Pressure\ of\ the\ system}$

$\mathbf{V = volume\ of\ the\ system}$

ENTHALPY

Enthalpy is not measured directly, however, the change in enthalpy (ΔH) is measured, which is the heat added or lost by the system. It is entirely dependent on the state functions T, p and U.

Enthalpy can also be written as

$$\Delta H = \Delta U + \Delta PV$$

At constant temperature, for the process heat flow(q) is equal to the change in enthalpy, this is represented as

$$\Delta H = q$$

Enthalpy Units

The Enthalpy is expressed as,

H = Energy/Mass

“We define thermodynamics … as the investigation of the dynamical and thermal properties of bodies, deduced entirely from the first and second law of thermodynamics, without speculation as to the molecular constitution.”

James Clerk Maxwell

Thank You

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