First Law of Thermodynamics

Overview

- *First Law of Thermodynamics* also known as the *Law of Conservation of Energy* provides a sound basis for studying the relationships among the various forms of energy and energy interactions.
- *Law of Conservation of Energy* states that energy can neither be created nor destroyed but can only be transformed from one energy form to another.

First Law of Thermodynamics

- During any cycle, that a thermodynamic system has undergone, the net heat transfer is proportional to the net work transfer.

$$\oint \delta Q \,\alpha \oint \delta W$$

$$\oint \delta Q = \oint \delta W$$

$$\sum \delta Q = \sum \delta W$$

First Law of Thermodynamics contd..

- Traditionally the *First Law* is defined for a cycle.
- However in practice, we often encounter thermodynamic processes in addition to cycles.
- Hence, it would be useful to deduce the *First Law* for such processes.

First Law for Processes

- Consider a System undergoing a process, from State 1 to State 2.

$$\Delta Q = \Delta W + \Delta E_{system}$$

$$\Delta Q = Q_2 - Q_1 = Q_{12}$$

$$\Delta W = W_2 - W_1 = W_{12}$$

$$\Delta E_{system} = E_2 - E_1 = E_{12}$$

Hence $$Q_{12} = W_{12} + E_{12}$$

- The subscript '12' signifies the change in each of the quantities during the process 1..2.

First Law for Processes contd..

- The *First Law* can be written in differential form as follows (for reversible processes)

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

- In terms of rate of energy transfer the *First Law* can be written as follows.

$$\dot{Q} - \dot{W} = \frac{dE}{dt} \quad \text{or} \quad \dot{Q} - \dot{W} = \dot{E}$$

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

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

Energy Balance contd..

- This statement is often referred to as the *Energy Balance* of the system and is applicable to any system undergoing any type of process.
- The successful use of this relationship to solve engineering problems depends on understanding the various forms of energy and the forms of energy transfer.

Change of Energy of a System

- The determination of the energy change of a system during a process (ΔE_{system}) involves the evaluation of the energy of the system at the beginning and at the end of the process, and taking the difference. Hence

$$\text{Energy change} = \text{Energy at final state} - \text{Energy at initial state}$$

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

Change of Energy of a System contd..

- Energy can exist in different forms such as Internal energy, Kinetic energy, Potential energy, Electrical energy, Magnetic energy etc.
- The sum of the aforementioned energy forms constitutes the total energy of the system (E_{system}) .
- For simple systems, the change in the total energy of a system during a process is the sum of the changes in its Internal Energy (U), Kinetic Energy (KE) and Potential Energy (PE).

Change of Energy of a System contd..

$$\Delta E_{system} = \Delta U + \Delta KE + \Delta PE$$

where

$$\Delta U = m\left(u_2 - u_1\right)$$

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

$$\Delta PE = mg\left(z_2 - z_1\right)$$

Change of Energy of a System contd..

- Most thermodynamic systems encountered in practice are stationary and do not involve any changes in kinetic energy and potential energy during a process. Hence for stationary systems

$$\Delta PE = \Delta KE = 0$$

$$\Delta E_{system} = \Delta U$$

Change of Energy of a System contd..

- Hence the *First Law of Thermodynamics* can be expressed for stationary systems undergoing a certain process, in the general form as follows.

$$\Delta Q - \Delta W = \Delta E_{system}$$

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

$$\delta Q - \delta W = dU$$

$$\dot{Q} - \dot{W} = \dot{U}$$