CHAPTER TWO
THE FIRST LAW OF THERMODYNAMIC
CLOSED SYSTEM

2.1 **HEAT TRANSFER**

Heat is defined as the form of energy that transferred between systems (or system and surroundings) by virtue of a temperature difference.

Heat is energy in transition. It is recognized only as it crosses the boundary of a system.

A process during which there is no heat transfer is called an adiabatic process. The word adiabatic comes from the Greek word adiabatic which means not to be passed.

As a form of energy, heat has energy unit kJ(Btu) being most common one. The amount of heat transferred during the process between two states (states 1 and 2) is denoted $\mathbf{Q_{12}}$ or just **Q**. heat transfer per unit mass of a system is denoted **q** and is determined from $q = \frac{Q}{m} kJ/kg$. The heat transfer rate is denoted $\dot{Q}$, where the over dot stands for the time derivative, or per unit time. The heat transfer rate $\dot{Q}$ has the unit kJ/sec, which is equivalent to kW. When $\dot{Q}$ varies with time

$$Q = \int_{t_1}^{t_2} Qdt \text{ (kJ)}$$

Heat transfer to the system is positive and heat transfer from system is negative.

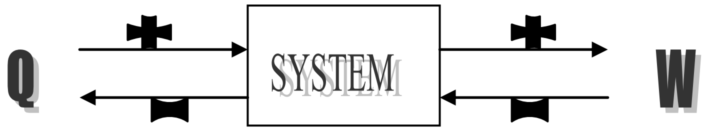
2.2 **WORK**

Work, like heat, is an energy interaction between a system and its surroundings. Therefore if the crossing the boundary of a closed system is not heat, it must be work.

Work is also a form of energy has energy units such as kJ. The work done during a process between states 1and 2 is denoted $\mathbf{W_{12}}$ or **W**. the work per unit mass of a system is denoted **w** and is defined as

$$w = \frac{W}{m} kJ/kg$$

the work done per unit time is called power and is denoted $\dot{W}$. The unit of the power is kJ/sec or kW. Work done by a system is positive, and work done on the system is negative, Fig (2.1)



Fig(2.1) the system and the effect of work and heat

Heat transfer and work are interaction between a system and its surroundings, and there are many similarities between phenomena.

1- Both are recognized at the boundaries of the system as they cross them. That, is both heat transfer and work are boundary phenomena.
2- Systems possess energy, but not heat transfer or work. That is, heat transfer and work are transfer phenomena.
3- Both are associated with a process, not a state. Unlike properties, heat transfer or work has no meaning at a state.
4- Both are path functions (i,e their magnitudes depend on the path followed during a process as well as the end states).

Path functions have inexact differentials designed by the symbol δ. Therefore, a differential amount of heat or work is represented by δQ or δW respectively instead of dQ or dW. Properties, however, are point functions and they have exact differentials designated by the symbol d. A small change in volume, for example, is represented by dV and the total volume change during a process between 1 and 2 is

$$\int_1^2 dV = V_2 - V_1 = \Delta V$$

and the integration of δW will give:

$$\int_1^2 \delta W = W_{12} = {}_1W_2 \quad (not \quad \Delta W)$$

Type of Works

1-Electrical Work

When N coulombs of electrons moves through potential difference V, the electrical work done is

$$W_e = VN(kJ)$$

which can also be expressed in the rate form as

$$\dot{W}_e = VI \quad [kJ]$$

where $\dot{W}_e$ is the electrical power and I is the number of electrons flowing per unit time i.e.(the current)

$$W_e = \int_1^2 VIdt \quad [kJ]$$

if both V and I remain constant during the time interval Δt, this equation will reduce to

$$W_e = IV\Delta t \quad [kJ]$$

the electrical work in fan, compressor and heater is negative.

2-Mechanical Form of Work

In elementary mechanics, the work done by a constant force F on a body which is displaced a distance S in the direction of force

$$W_m = FS \quad [kJ]$$

If the force is not constant, the work done is obtained by adding the differential amounts of work

$$W_m = \int_1^2 Fds \quad [kJ]$$

Example 2.1:

Find the electrical work done by heating of voltage 240V and the current passes is 5A operates for 15 minutes.

Solution: V=240 V I=5A and Δt=15 minutes =900sec

$$W_e = VI\Delta t = 240 \times 5 \times 900 = 1102500J = 1102.5kJ$$

3-Shaft Work

Energy transmission with a rotation is very common in engineering practice. Often the torque T applied to the shaft is constant, which means that the force F applied is also constant. For a specified constant torque, the work done during n revolutions is a determined as follows: A force F acting through a moment arm r generates a torque T which is determined from.

$$T = Fr \rightarrow F = \frac{T}{r}$$

This force acts through a distance S

$$S = (2\pi r)n$$

then the shaft work is determined from

$$W_{sh} = FS = \frac{T}{r}(2\pi rn) = 2\pi nT \quad [kJ]$$

The power transmitted through the shaft is the shaft work done per unit time, which can be expressed as

$$\dot{W}_{sh} = 2\pi\dot{n}T \quad [kW]$$

where $\dot{n}$ is number of revolution per second.

Example 2.2:

Determine the power transmitted through the shaft of a car when torque applied is 200N.m and the shaft rotates at a rate of 4000r.p.m

Solution: T=200N.m=0.2kN.m $\dot{n}$ =4000rpm=4000/60 rps

$$\dot{W}_{sh} = 2\pi\dot{n}T = 2\pi\frac{40000}{60}0.2 = 83.7kW$$