14.7 Change of Mechanical Energy for Closed System with Internal Non-conservative Forces

Consider a closed system (energy of the system is constant) that undergoes a transformation from an initial state to a final state by a prescribed set of changes.

> *Whenever the work done by a force in moving an object from an initial point to a final point depends on the path, the force is called a* ***non-conservative force****.*

Suppose the internal forces are both conservative and non-conservative. The work W done by the forces is a sum of the conservative work W_c, which is path-independent, and the non-conservative work W_{nc}, which is path-dependent,

$$W = W_c + W_{nc} . \qquad (14.6.1)$$

The work done by the conservative forces is equal to the negative of the change in the potential energy

$$\Delta U = -W_c . \qquad (14.6.2)$$

Substituting Equation (14.6.2) into Equation (14.6.1) yields

$$W = -\Delta U + W_{nc} . \qquad (14.6.3)$$

The work done is equal to the change in the kinetic energy,

$$W = \Delta K . \qquad (14.6.4)$$

Substituting Equation (14.6.4) into Equation (14.6.3) yields

$$\Delta K = -\Delta U + W_{nc} . \qquad (14.6.5)$$

which we can rearrange as

$$W_{nc} = \Delta K + \Delta U . \qquad (14.6.6)$$

We can now substitute Equation (14.6.4) into our expression for the change in the mechanical energy, Equation (14.4.17), with the result

$$W_{nc} = \Delta E_m . \qquad (14.6.7)$$

The mechanical energy is no longer constant. The total change in energy of the system is zero,

$$\Delta E_{\text{system}} = \Delta E_m - W_{nc} = 0 . \qquad (14.6.8)$$

Energy is conserved but some mechanical energy has been transferred into non-recoverable energy W_{nc}. We shall refer to processes in which there is non-zero non-recoverable energy as ***irreversible processes***.

14.7.1 Change of Mechanical Energy for a Non-closed System

When the system is no longer closed but in contact with its surroundings, the change in energy of the system is equal to the negative of the change in energy of the surroundings (Eq. (14.1.1)),

$$\Delta E_{\text{system}} = -\Delta E_{\text{surroundings}} \tag{14.6.9}$$

If the system is not isolated, the change in energy of the system can be the result of external work done by the surroundings on the system (which can be positive or negative)

$$W_{\text{ext}} = \int_A^B \vec{\mathbf{F}}_{\text{ext}} \cdot d\vec{\mathbf{r}} \, . \tag{14.6.10}$$

This work will result in the system undergoing ***coherent motion***. Note that $W_{\text{ext}} > 0$ if work is done on the system ($\Delta E_{\text{surroundings}} < 0$) and $W_{\text{ext}} < 0$ if the system does work on the surroundings ($\Delta E_{\text{surroundings}} > 0$). If the system is in thermal contact with the surroundings, then energy can flow into or out of the system. This energy flow due to thermal contact is often denoted by Q with the convention that $Q > 0$ if the energy flows into the system ($\Delta E_{\text{surroundings}} < 0$) and $Q < 0$ if the energy flows out of the system ($\Delta E_{\text{surroundings}} > 0$). Then Eq. (14.6.9) can be rewritten as

$$W^{\text{ext}} + Q = \Delta E_{\text{sys}} \tag{14.6.11}$$

Equation (14.6.11) is also called ***the first law of thermodynamics*.**

This will result in either an increase or decrease in random thermal motion of the molecules inside the system, There may also be other forms of energy that enter the system, for example *radiative energy*.

Several questions naturally arise from this set of definitions and physical concepts. Is it possible to identify all the conservative forces and calculate the associated changes in potential energies? How do we account for non-conservative forces such as friction that act at the boundary of the system?