Department of Physics Dr. Yuh-Lang Lin
https://mesolab.org ylin@ncat.edu

Lecture 8 The First Law of Thermodynamics

(Ch. 3 First Law of Thermodynamics)

Principle of Conservation of Energy: The energy of all sorts (e.g., *KE*, *PE*, *work*, *heat*) can neither be created nor destroyed.

Note, however, energy can be converted to different forms by various means and can be transferred among different systems and regions.

When energy is added to (extracted from) a system, the final energy is equal to the original energy plus (minus) the energy added (extracted).

For a closed system (constant mass), the first law of thermodynamics can be expressed mathematically as:

$$\Delta Q = \Delta E + \Delta W \tag{3.14}$$

or

$$\Delta E = \Delta Q - \Delta W \tag{3.15}$$

where ΔE: total energy change,
ΔQ: heat added to the system,
ΔW: work done on the environment by the system.

Equation (3.14) states that for a closed system, the amount of heat added to the system can be used to increase the total energy of the system and/or to cause the system to do work.

In other words, for a closed system, the total energy change is the difference between the heat added to the system and the work done by the system.

The above statements are also called the First Law of Thermodynamics (Eq. (3.14) or (3.15)).

In thermodynamics, the total energy change of a system (ΔE) consists of three different types of energy:

$$\Delta E = \Delta KE + \Delta PE + \Delta U \tag{3.16}$$

where ΔKE: Change in macroscopic kinetic energy
ΔPE: Change in macroscopic potential energy
ΔU: Change in internal energy

The *internal energy* (U) is composed by:

(1) *Microscopic kinetic energy* in forms of molecular random motions - manifested as increases in the temperature of the body,

$$KE = \frac{1}{2} m \overline{v^2} = \frac{3}{2} kT$$

(2) *Microscopic potential energy* in forms of intermolecular configuration.

If there is no change in macroscopic kinetic and potential energy (e.g. a stationary system), then (3.15) becomes

$$\Delta U = \Delta Q - \Delta W \tag{3.17}$$

or in differential form:

$$dU = dQ - dW \tag{3.18}$$

Dividing (3.18) by mass *m* leads to,

$$du = dq - dw, \tag{3.19}$$

or

$$dq = du + dw$$

[heat added]

[increase internal energy of the system] [work done on the environment]

where *du* is the *change in specific internal energy*,
dq = *dQ/m* is the *change in specific heat*,
dw = *dW/m* is the *change in specific work*.

Either (3.17), (3.18), or (3.19) expresses the First Law of Thermodynamics. That is, the change of total internal energy of a closed system is equal to the heat transferred to the system minus the work done by the system on its environment.

Recall that

$$dw = p d\alpha. \tag{3.3}$$

Substituting (3.3) into (3.19) yields another form of the first law,

$$du = dq - p d\alpha.$$

or

$$dq = du + p d\alpha. \tag{3.20}$$