Medical Physics

The First Stage

Second Term –Lecture no. Six

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Some Definitions

Heat and Internal Energy

Internal energy is all the energy of a system that is associated with its micro- scopic components—atoms and molecules—when viewed from a reference frame at rest with respect to the center of mass of the system.

Heat is defined as a process of transferring energy across the boundary of a system because of a temperature difference between the system and its sur- roundings. It is also the amount of energy Q transferred by this process.

Units of Heat

The calorie (cal), which is defined as the amount of energy transfer necessary to raise the temperature one grame of material one degree celsius (ex: 1 g of water from 14.5°C to 15.5°C.1) (The “Calorie,” written with a capital “C” and used in describing the energy content of foods, is actually a kilocalorie.)

The joule has already been defined as an energy unit based on mechanical processes.

$$1 \text{ cal} = 4.186 \text{ J}$$

Work and Heat in Thermodynamic Processes

1- In thermodynamics, we *describe the state of a system* using such variables as *pressure, volume, temperature, and internal energy*.

As a result, these quantities belong to a category called state variables. For any given configuration of the system, we can identify values of the state variables.

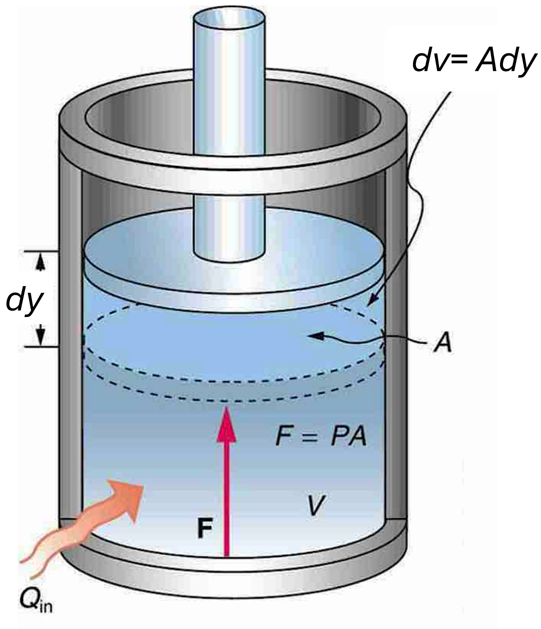
2- (For **mechanical systems**,we have a state variables include kinetic energy K and potential energy U.) A state of a system can be specified only if the system is in thermal equilibrium internally.

In the case of a gas in a container, internal thermal equilibrium requires that every part of the gas be at the same pressure and temperature.

3- Also there are *variable for the system such as energy is transfer variables*. Such a *variable has a non-zero value* if a process occurs in which energy is transferred across the system's boundary. The transfer *variable is positive or negative, depending on whether energy is entering or leaving the system*.

Now In this section, we study another important transfer variable for thermodynamic systems, work.

Consider a gas contained in a cylinder fitted with a movable piston next figure.



At equilibrium, the gas occupies a volume "V" and exerts a uniform pressure "P" on the cylinder's walls and on the piston. If the piston has a cross-sectional area "A", the magnitude of the force exerted by the gas on the piston is ($F = PA$).
By Newton's third law, the magnitude of the force exerted by the piston on the gas is also "$F=PA$".

Now let's assume we push the piston inward and compress the gas quasistatically, that is, slowly enough to allow the system to remain essentially in internal thermal equilibrium at all times.

The point of application of the force on the gas is the bottom face of the piston.

From difination of the work "Work is the product of the component of the force in the direction of the displacement الشغل هو نتاج تأثير القوة في اتجاه الإزاحة";

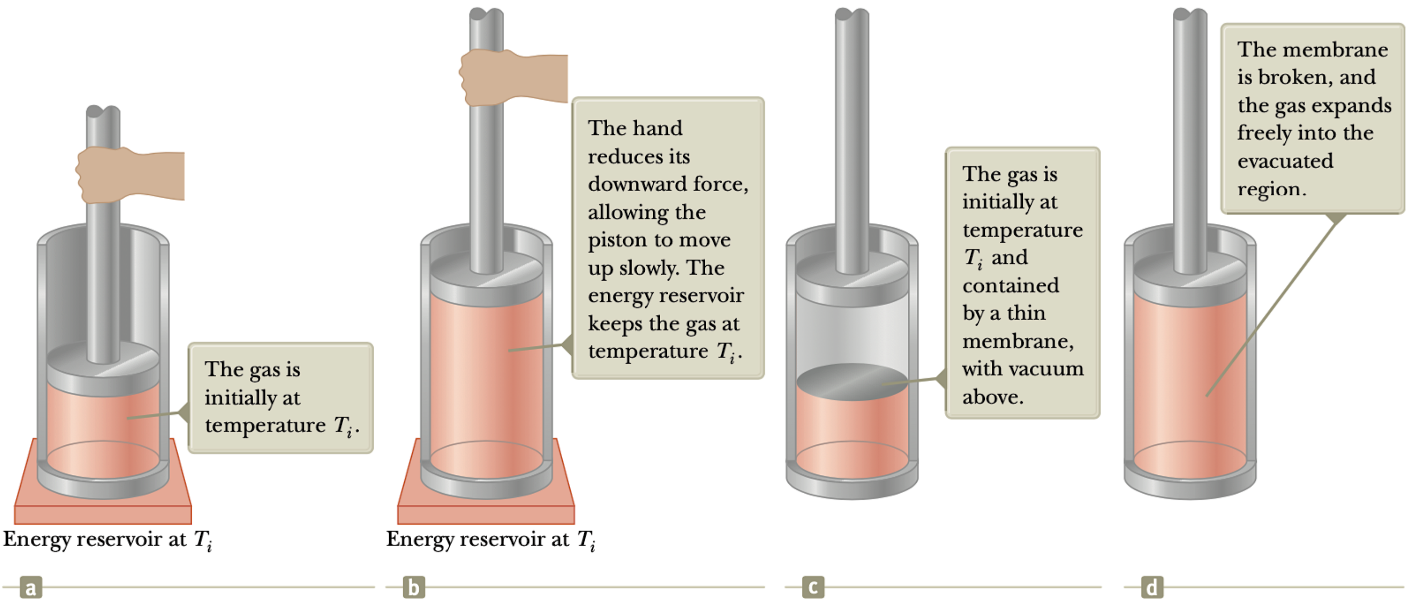
so,

$$W = -Fdy = -PAdy = -PdV$$

The total work done on the gas as its volume changes from "V_i" to 'V_f' is given by the integral of Equation

$$W = -\int_{V_i}^{V_f} PdV$$

Special Case



Gas in a cylinder. (a) The gas is in contact with an energy reservoir. The walls of the cylinder are perfectly insulating, but the base in contact with the reservoir is conducting. (b) The gas expands slowly to a larger volume. (c) The gas is contained by a membrane in half of a volume, with vacuum in the other half. The entire cylinder is perfectly insulating. (d) The gas expands freely into the larger volume.

The First Law of Thermodynamic

Important Concept

Heat (Q) and work (W) are the two ways to add or remove energy from a system. The processes are very different. Heat is driven by temperature differences, while work involves a force exerted through a distance. Nevertheless, heat and work can produce identical results.

For example, both can cause a temperature increase. Heat transfers energy into a system, such as when the sun warms the air in a bicycle tire and increases the air's temperature. Similarly, work can be done on the system, as when the bicyclist pumps air into the tire. Once the temperature increase has occurred, it is impossible to tell whether it was caused by heat or work. Heat and work are both energy in transit—neither is stored as such in a system. However, both can change the internal energy, U, of a system.

The law of conservation of energy states that the total energy of an isolated system remains constant; it is said to be conserved over time. In the case of a closed system the principle says that the total amount of energy within the system can only be changed through energy entering or leaving the system. Energy can neither be created nor destroyed; rather, it can only be transformed or transferred from one form to another.

ينص قانون الحفاظ على الطاقة على أن إجمالي الطاقة لنظام معزول يظل ثابتا؛ ويقال إنه يتم الحفاظ عليه بمرور الوقت. في حالة النظام المغلق، ينص المبدأ على أنه لا يمكن تغيير الكمية الإجمالية للطاقة داخل النظام إلا من خلال دخول الطاقة إلى النظام أو مغادرته. لا يمكن إنشاء الطاقة أو تدميرها؛ بل لا يمكن تحويلها أو نقلها إلا من شكل إلى آخر.

The *first law of thermodynamics* is a *special case* of the *law of conservation of energy* that describes processes in which only the internal energy changes and the only energy transfers are by heat and work:

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

Or we can written in form of

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

Where U is the internal energy of the system.

Special Cases of first law of thermodynamic

1- Isolated system, that is, one that does not interact with its surroundings, as we have seen before. In this case, no energy transfer by heat takes place and the work done on the system is zero; hence, the internal energy remains constant. That is, because Q= W =0, it follows that $\Delta E_{Int} = 0$; therfore $\Delta E_{Int,i} = \Delta E_{Int,f}$; We conclude that the internal energy E_{Int} of an isolated system remains constant.

2- A case of a system that can exchange energy with its surroundings and is taken through a cyclic process, that is, a process that starts and ends at the same state. In this case, the change in the internal energy must again be zero because E_{Int} is a state variable; therefore, the energy Q added to the system must equal the negative of the work W done on the system during the cycle. That is, in a cyclic process,

$$\Delta E_{Int} = 0 \quad \& \quad Q = -W$$

Quick Quiz:

(Q1)

(Q2)

(Q3)

(Q4)

(Q5)

(Q6)

(Q7)

(Q8)

(Q9)

(Q10)