The Laws of Thermodynamics

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THE FIRST LAW OF THERMODYNAMICS

The change in internal energy of a closed system will be equal to the energy added to the system minus the work done by the system on its surroundings.

$$\Delta U = Q - W \quad (15\text{-}1)$$

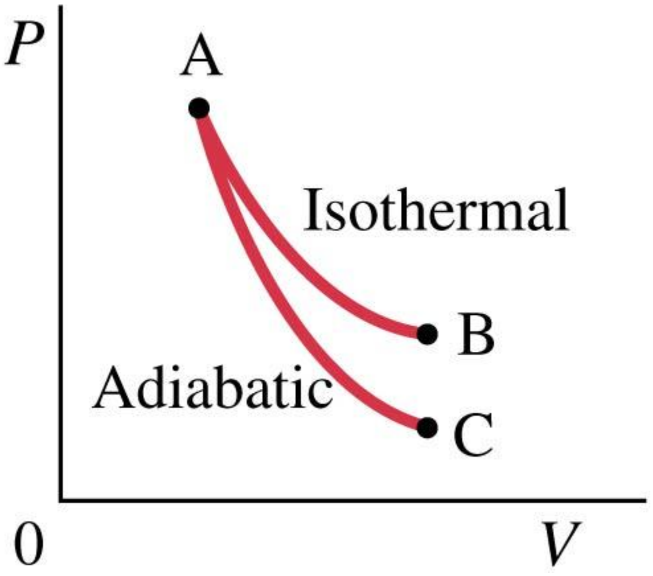
This is the law of conservation of energy, written in a form useful to systems involving heat transfer.

THERMODYNAMIC PROCESSES

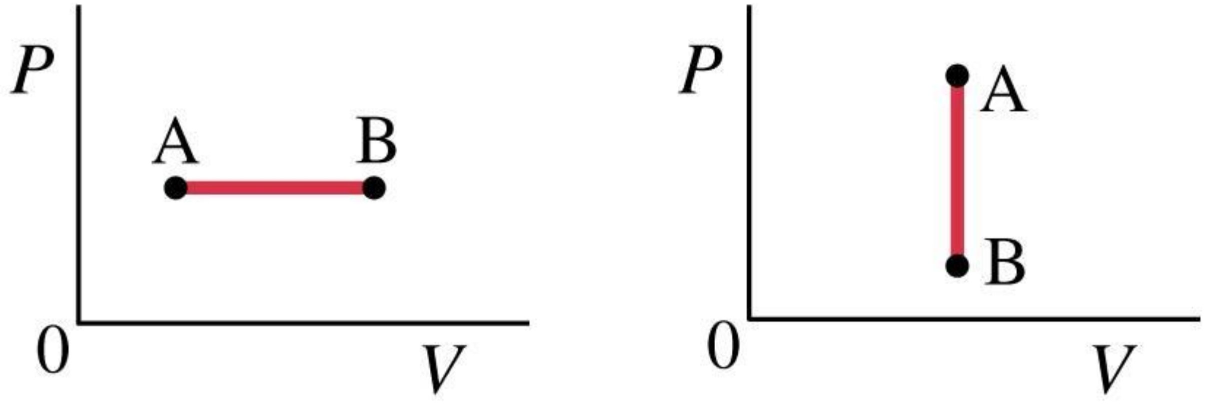
In order for an isothermal process to take place, we assume the system is in contact with a heat reservoir.

In general, we assume that the system remains in equilibrium throughout all processes.

An adiabatic process is one where there is no heat flow into or out of the system.

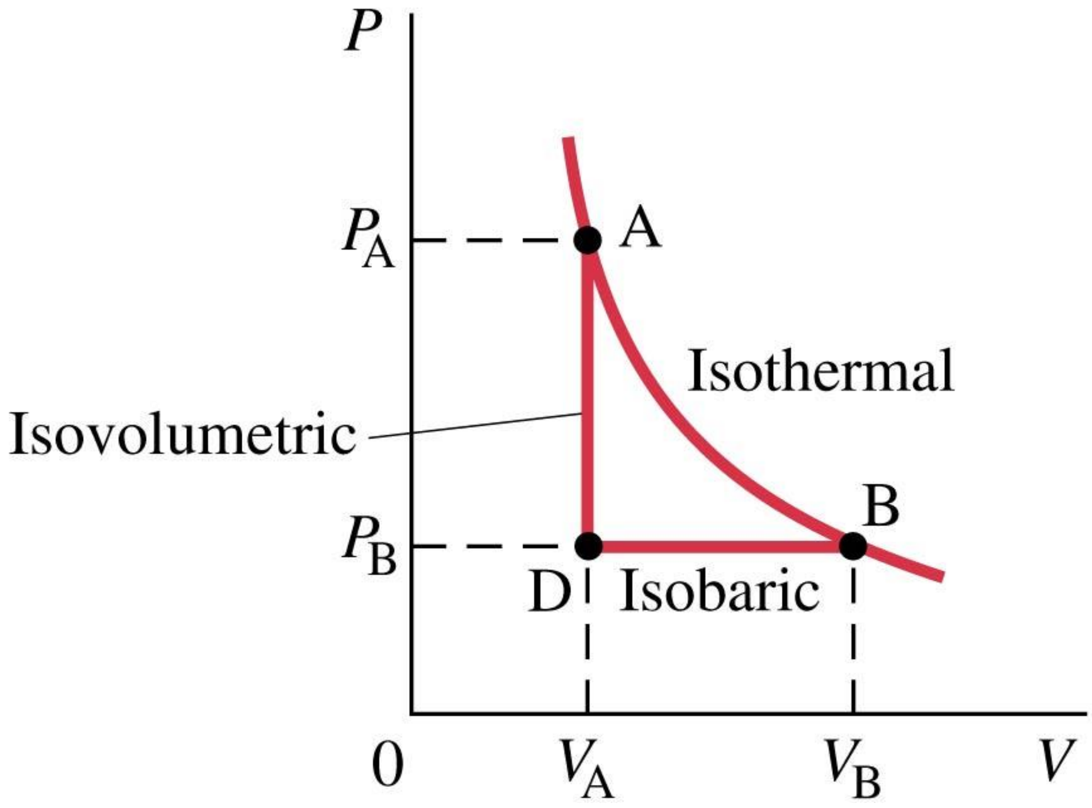


An isobaric process (a) occurs at constant pressure; an isovolumetric one (b) at constant volume.



(a) Isobaric (b) Isovolumetric

For processes where the pressure varies, the work done is the area under the *P*-*V* curve.



THE SECOND LAW OF THERMODYNAMICS

The absence of the process illustrated above indicates that conservation of energy is not the whole story. If it were, movies run backwards would look perfectly normal to us!

The second law of thermodynamics is a statement about which processes occur and which do not. There are many ways to state the second law; here is one:

Heat can flow spontaneously from a hot object to a cold object; it will not flow spontaneously from a cold object to a hot object.

HEAT ENGINES

We will discuss only engines that run in a repeating cycle; the change in internal energy over a cycle is zero, as the system returns to its initial state.

The high temperature reservoir transfers an amount of heat Q_H to the engine, where part of it is transformed into work W and the rest, Q_L, is exhausted to the lower temperature reservoir. Note that all three of these quantities are positive.

The efficiency of the heat engine is the ratio of the work done to the heat input:

$$e = \frac{W}{Q_H}. \quad (15\text{-}4a)$$

Using conservation of energy to eliminate *W*, we find:

$$e = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H}$$

or

$$e = 1 - \frac{Q_L}{Q_H}.$$

The Carnot engine was created to examine the efficiency of a heat engine. It is idealized, as it has no friction. Each leg of its cycle is reversible.

The Carnot cycle consists of:

- Isothermal expansion
- Adiabatic expansion
- Isothermal compression
- Adiabatic compression

An example is on the next slide.

REFRIGERATORS, AIR CONDITIONERS, AND HEAT PUMPS

These appliances can be thought of as heat engines operating in reverse.

By doing work, heat is extracted from the cold reservoir and exhausted to the hot reservoir.