LAWS OF THERMODYNAMICS

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THERMODYNAMICS

Thermodynamics is a branch of Physics that deals with temperature, heat and their relation to energy, radiation, work and properties of matter. The energy can be of any forms such as electrical, mechanical and chemical energy. William Thomson coined the term thermodynamics in 1749.

The word **thermodynamics** is a combination of two words, **thermo-related to temperature or energy** and **dynamics–related to motion of the atoms or molecules.** Thus, the term thermodynamics means heat movement or heat flow.

Thermodynamics is concerned with macroscopic (i.e., Large-scale bulk properties which are measurable such as volume, elastic moduli, temperature, pressure and specific heat and it belongs to classical Physics) behavior rather than the microscopic behavior of the system.

LAWS OF THERMODYNAMICS

The laws of thermodynamics define the fundamental physical quantities like energy, temperature and entropy that characterize thermodynamic systems at thermal equilibrium. There are four laws of thermodynamics such as

- ❖ **Zeroth law of thermodynamics**
- ❖ **First law of thermodynamics**
- ❖ **Second law of thermodynamics**
- ❖ **Third law of thermodynamics**

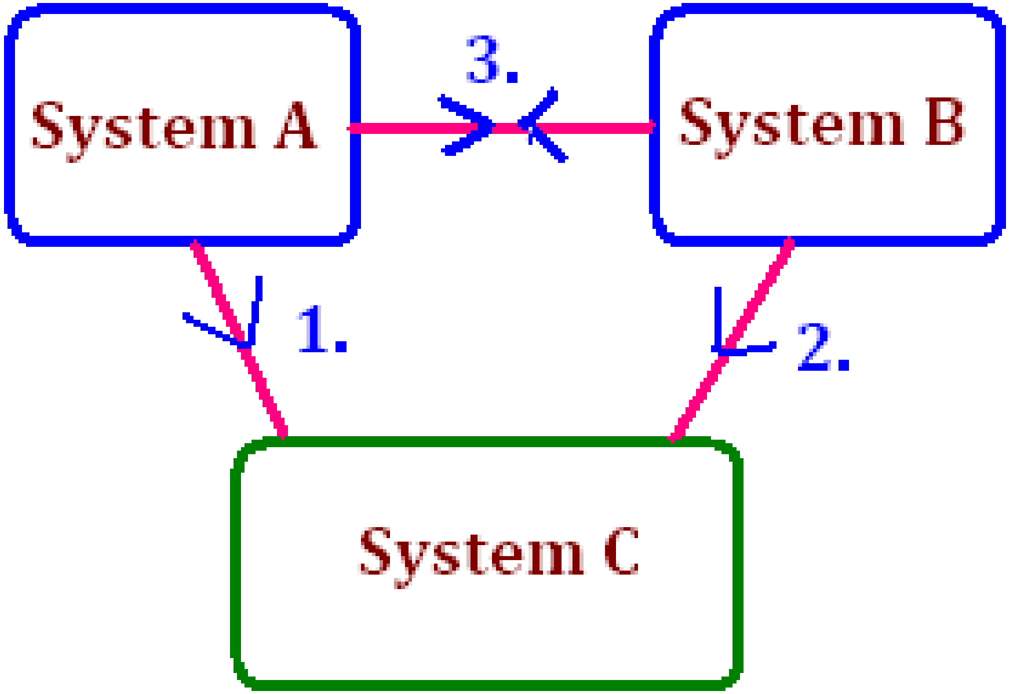
ZEROTH LAW OF THERMODYNAMICS (MEASUREMENT OF TEMPERATURE)

STATEMENT

If two systems are both in thermal equilibrium with a third system, then the first two systems are also in thermal equilibrium with each other.

EXPLANATION

Consider a system (A) at a high temperature in contact with a system (B) at a low temperature. Heat is transferred from the high temperature system (A) to the lower temperature system (B) until the temperatures are equalized. When this equal, constant temperature is reached and maintained, the two bodies are said to be in thermal equilibrium and the process of obtaining thermal equilibrium is called the zeroth law of thermodynamics.



1. A & C are in thermal equilibrium
2. B & C are in thermal equilibrium

then

3. A & B are also in thermal equilibrium with each other

BLOCK DIAGRAM OF ZEROTH LAW OF THERMODYNAMICS

EXAMPLES

- ❖ Consider a hot cup of tea. After about twelve hours, the saucer, the cup and the tea will all be at the same temperature. i.e.,

1. **The saucer is in equilibrium with the cup**
2. **The cup is in equilibrium with the tea**
3. **Therefore the tea is in equilibrium with the saucer**

They are each in thermal equilibrium with each other.

- ❖ If you take a glass of ice water and a glass of hot water and place them on the kitchen countertop for a few hours, they will eventually reach thermal equilibrium with the room, with all 3 reaching the same temperature.
- ❖ If you place a package of meat in your freezer and leave it overnight, you assume that the meat has reached the same temperature as the freezer and the other items in the freezer.

FIRST LAW OF THERMODYNAMICS (CONSERVATION OF ENERGY)

STATEMENT

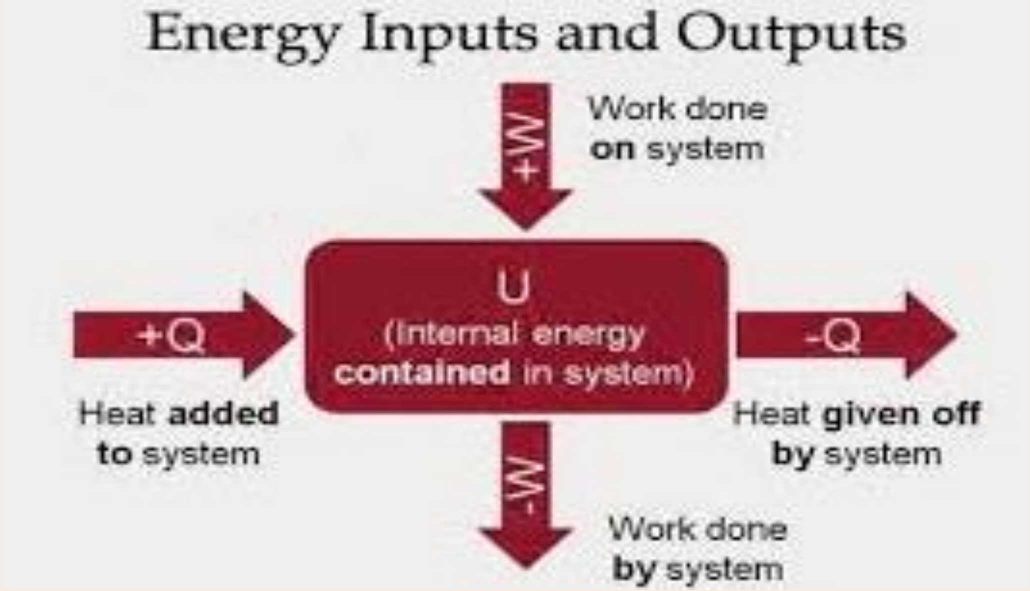
The change in the internal energy (ΔU) of a system is equal to the amount of heat supplied (ΔQ) to the system, minus the amount of work (ΔW) performed by the system on its surroundings.

$$\Delta \mathbf{U} = \Delta \boldsymbol{Q} - \Delta \mathbf{W}$$

EXPLANATION

According to the first law of thermodynamics, it is possible to create or destroy the energy, but energy changes from one form to another form, and the total quantity of energy in the universe remains constant. It is based on conservation of energy.

The internal energy of a system can be changed by adding heat to a system or by removing heat from a system and by doing work on a system or work done by the system. The total internal energy in a system is the sum of all the kinetic energies and potential energies of its particles.



BLOCK DIAGRAM OF FIRST LAW OF THERMODYNAMICS

Heat is added to the system = Value of **Q** is positive **(endothermic reaction)**

Heat is lost by the system = Value of **Q** is negative **(exothermic reaction)**

In the same way:

Work done on the system = **W** is positive

Work done by the system = **W** is negative

EXAMPLES

- Fans convert electrical energy to mechanical energy.

- The batteries we use to convert chemical energy into electrical energy. Also the electric bulbs transform electrical energy into light energy.

- Car engine transforms chemical energy into kinetic and heat energy.

SECOND LAW OF THERMODYNAMICS (ENTROPY)

STATEMENT

Energy in the form of heat only flows from regions of higher temperature to that of lower temperature but never spontaneously in the reverse direction.

Different statements of the second law as follows

KELVIN-PLANCK STATEMENT

It is impossible to convert all the heat extracted from a hot body into work. In the heat engine, the working substance takes heat from the hot body, converts a part of it into work and gives the rest to the cold body.

There is no engine that can convert all the heat taken from the hot body into work, without giving any heat into the cold body. This means that for obtaining continuous work, a cold body is necessary.

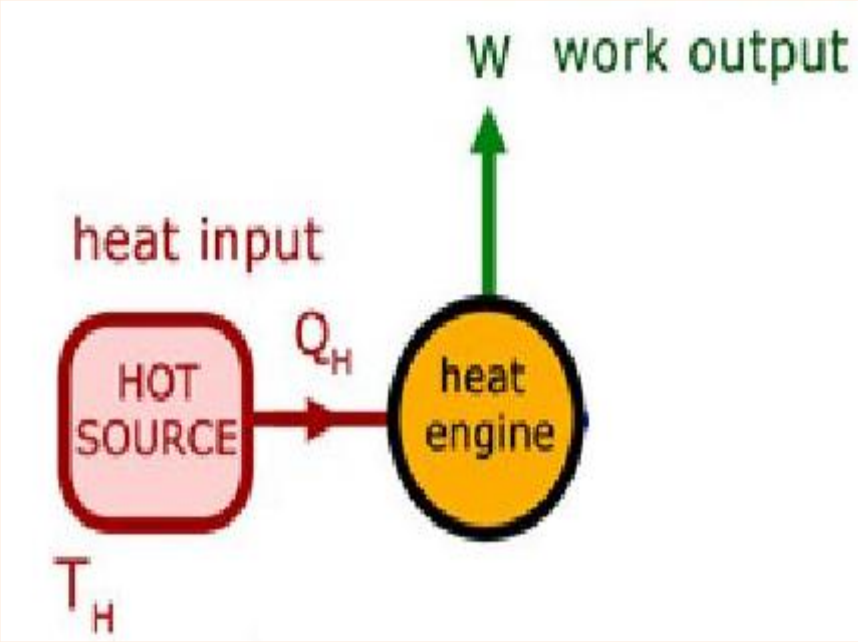


Fig 1:Impossible-Kelvin-Planck Statement

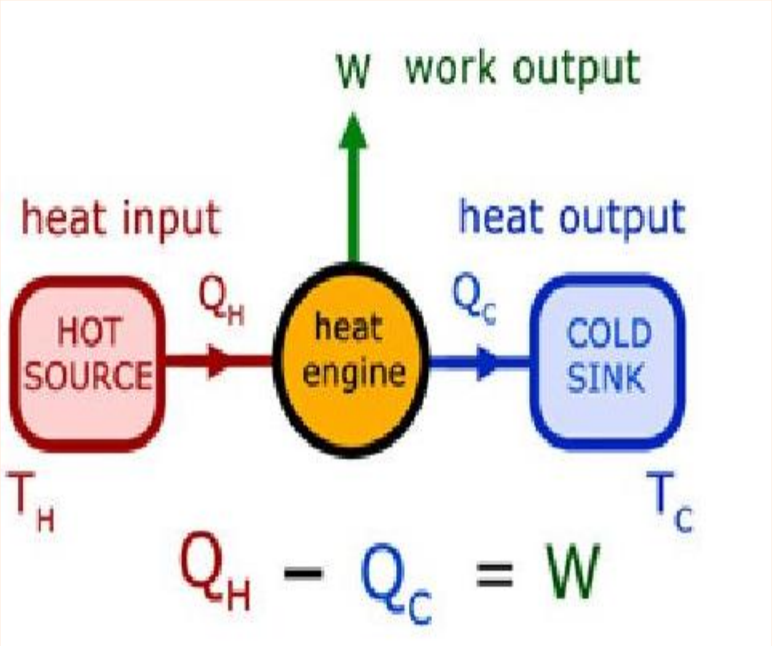


Fig 2 : Possible-Kelvin-Planck Statement

CLAUSIUS STATEMENT

It is impossible to transfer heat from a cold body to a hot body without at the same time converting some work into heat. In other words, a refrigerator will not operate unless its compressor is driven by an external power source.

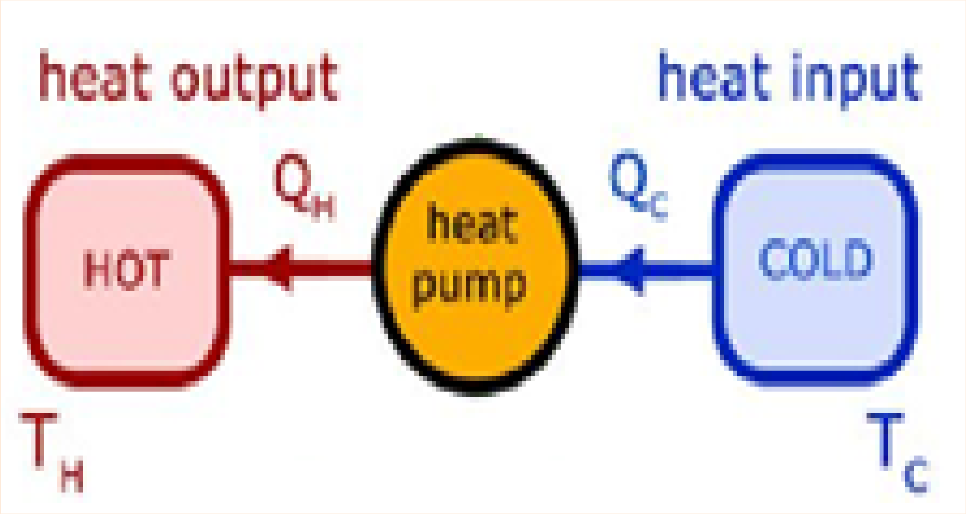


Fig 3: Impossible-Clausius Statement

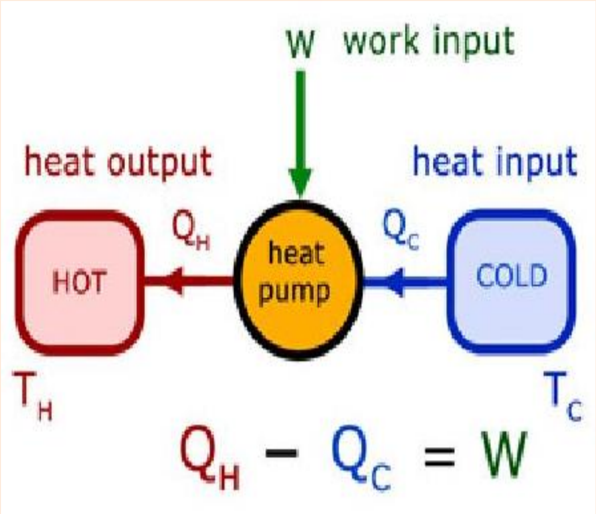


Fig 4 : Possible-Clausius Statement

EXPLANATION

EQUIVALENCE OF TWO STATEMENTS

There is a refrigerator that transfers an amount of heat from a cold body to a hot body without having any supply of external energy. So this is the violation of **Clausius statement**. Now suppose an engine working between the same hot and cold bodies takes in heat from a hot body is converted into work and gives the remaining heat to the cold body.

The engine alone does not violate the second law of thermodynamics. But if the engine and refrigerator combine together, they form a device that takes up all the heat from the hot body and converts all into work without giving any amount of the cold body. It violets the **Kelvin-Planck statement**. So, we say that the two statements of the second law of thermodynamics are equal.

EXAMPLE

- Someone might put an ice cube into a glass of lemonade and then forget to drink the beverage. An hour or two later, they will notice that the ice has melted, but the temperature of the lemonade has cooled. This is because the total amount of heat in the system has remained the same, where both the former ice cubes (now water) and the lemonade are the same temperature. The lemonade will eventually become warm again, as heat from the environment is transferred to the glass and its contents.

THIRD LAW OF THERMODYNAMICS
(ENTROPY AT ABSOLUTE ZERO)

The third law was developed by chemist Walther Nernst during the years 1906–1912 and therefore often referred to as **Nernst's theorem** or **Nernst's postulate**. The third law of thermodynamics says: **"The entropy of a pure perfect crystal is zero at zero Kelvin (0°K)."** The Kelvin scale is absolute, meaning 0° Kelvin is mathematically the lowest possible temperature in the universe. This corresponds to about -273.15° Celsius, or -459.7 Fahrenheit.

In general, no object or system can have a temperature of zero Kelvin, because of the Second Law of Thermodynamics (heat can never spontaneously move from a colder body to a hotter body).

EXAMPLE

Water in gas form (when you boil water, the water changes from a liquid state to a gas) has molecules that can move very freely. Water vapor has very high entropy (randomness). As the gas cools, it becomes liquid. The liquid water molecules can still move around, but not as freely. They have lost some entropy.

When the water cools further, it becomes solid ice. The solid water molecules can no longer move freely, but can only vibrate within the ice crystals. The entropy is now very low. As the water cools more, (closer to absolute zero), the vibration of the molecules diminishes. If the solid water reached absolute zero, all molecular motion would stop completely. At this point, the water would have no entropy (randomness) at all.

Thank You