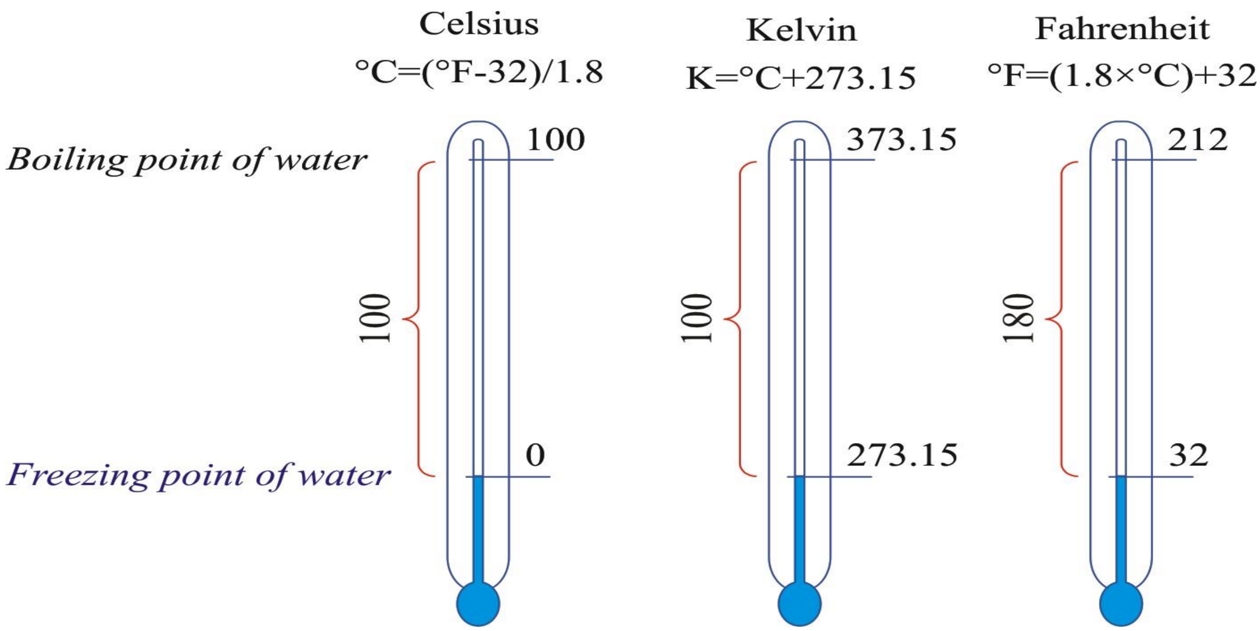
Laws of Thermodynamics

Thermodynamics

Types of Thermometric Scales



The general formula-

$$\frac{C}{5} = \frac{(F-32)}{9} = \frac{(K+273)}{5}$$

Where,

C - Temperature in Centigrade/Celsius scale

F - Temperature in Fahrenheit scale

K - Temperature in Kelvin scale

- -40° is the temperature at which both Celsius and Fahrenheit is equal.
- Absolute zero is 0 K which is equal to -273.15°C or -459°F.

Types of Heats

Specific Heat: It is the amount of heat given to a unit mass to raise its temperature by 1 °C.

$$Q = m \times C \times \Delta T$$

Where Q is Heat (Cal or J)

m is mass (in gm)

c is Specific Heat (J/g°K)

ΔT is Change in temperature

- 1 Cal = 4.18 J
- 1000 Cal = 1 kcal
- If Q is positive, the substance absorbed heat
- If Q is negative, the substance released heat

Table of specific heat capacities at 25 °C

Substance	Phase	Specific heat -cp- J/gK
Air	gas	1.0035
Aluminium	solid	0.897
Beryllium	solid	1.82
Cadmium	solid	0.231
Carbon Dioxide	gas	0.839
Helium	gas	5.1932
Hydrogen	gas	14.3
Iron	solid	0.412
Lead	solid	0.129
Nitrogen	gas	1.04
Oxygen	gas	0.918
Polyethylen	solid	2.3027
Sodium	solid	1.23
Steel	solid	0.466
Uranium	solid	0.116
Water (25°C)	liquid	4.1813
Water (100°C - steam)	gas	2.08

Latent Heat: It is the amount of heat added/removed to change the state of the body without changing its temperature

$$Q = m \times L$$

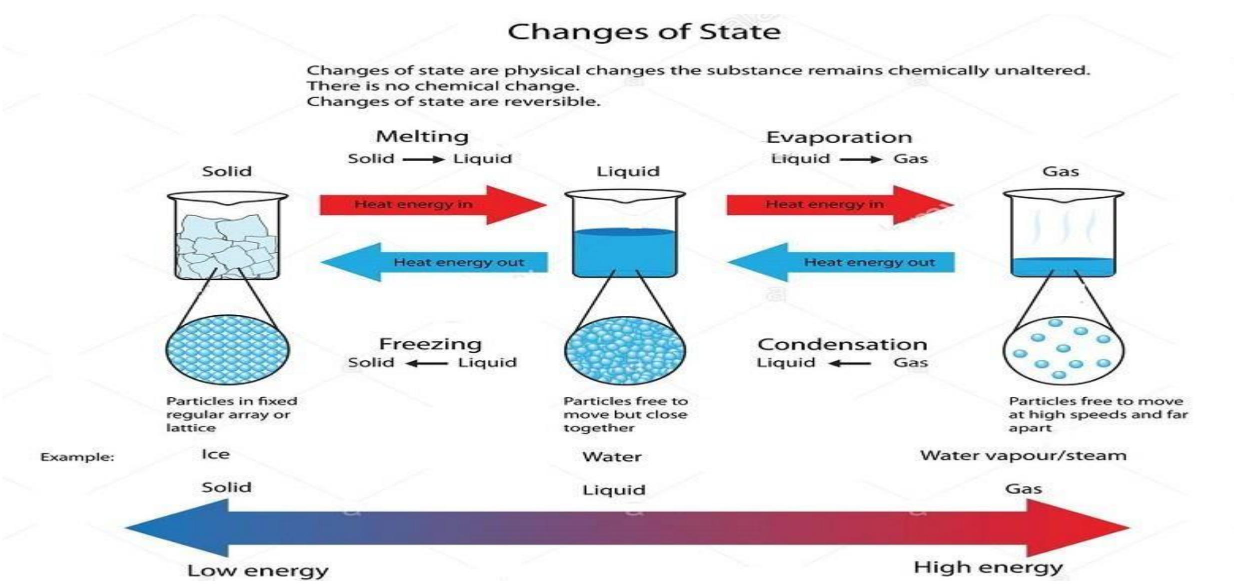
Where, Q = Heat Change (J or Nm)

m = mass (Kg)

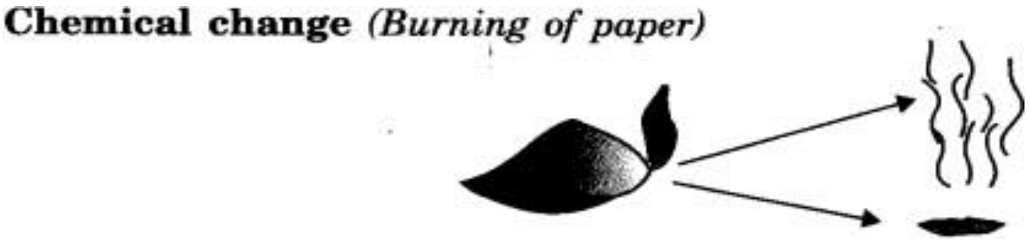
L = Specific Latent Heat (J/Kg)

What will happen when the heat is supplied?

Physical change



Chemical Change

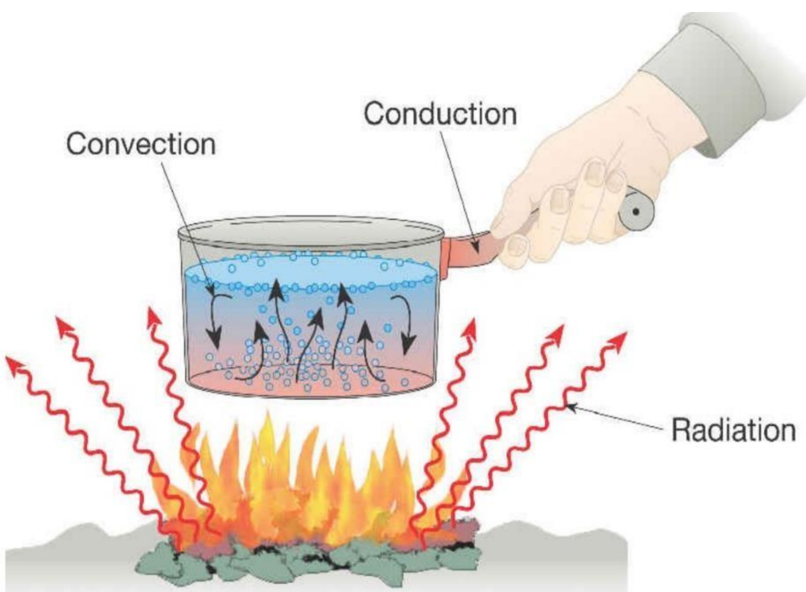


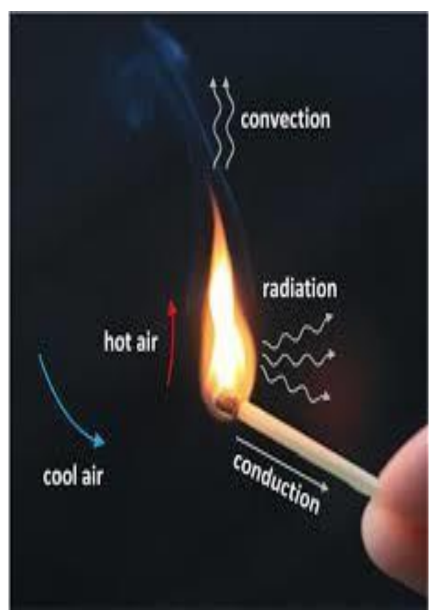
A chemical change is a transformation of materials into another, new materials with different properties and one or more than one new substances are created.

Heat Transfer

Heat transfer also referred to simply as heat, is the movement of the thermal energy of different temperatures from one thing to another. The heat can transfer three different ways: conduction (by direct contact), convection (through fluid movement), or radiation (through electromagnetic waves).

Modes of Heat Transfer





Conduction

This is a flow of heat by direct contact. Heat travels from a warmer object toward a colder object. Pan warming on a stove is an example.

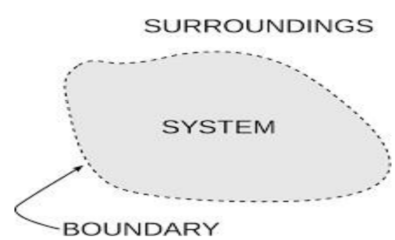
Convection

This is a transfer of heat by mixing a fluid. Convection occurs within liquids and gases. Examples include boiling water and when warm water mixes with cold water. In meteorology, convection is a common heat transfer mechanism in the troposphere.

Radiation

Radiation is the transfer of energy by electromagnetic radiation. Radiation does not require a medium in which the energy needs to transmit through. Solar radiation warming the Earth's surface is an example. The radiation transfers from the sun through space and then strike the Earth. All objects emit radiation. Colder objects emit longer wavelength radiation while warmer objects emit shorter-wavelength radiation.

Thermodynamics



It is the branch of physical science that deals with the relations between heat and other forms of energy (such as mechanical, electrical, or chemical energy), and, by extension, of the relationships between all forms of energy. It was born in the 19th century as scientists were first discovering how to build and operate steam engines.

Thermodynamic Processes

The thermodynamic state of a system is characterized by its parameters P, V and T. A change in one or more parameters results in a change in the state of the system.

A process by which one or more parameters of a thermodynamic system undergo a change is called a **thermodynamic process** or a thermodynamic change. One example of a thermodynamic process is increasing the pressure of gas while maintaining a constant temperature.

Isobaric Process

An **isobaric process** is a thermodynamic process, in which the **pressure** of the system **remains constant** (p = const). The heat transfer into or out of the system does work but also changes the internal energy of the system. Since there are changes in internal energy (dU) and changes in system volume (ΔV), engineers often use the **enthalpy** of the system, which is defined as:

$$H = U + pV$$

In many thermodynamic analyses, it is convenient to use the **enthalpy** instead of the internal energy. Especially in case of the **first law of thermodynamics**.

Two very important thermodynamic cycles (**Brayton and Rankine cycle**) are based on **two isobaric processes**; therefore, the study of this process is crucial for power plants.

Isochoric Process

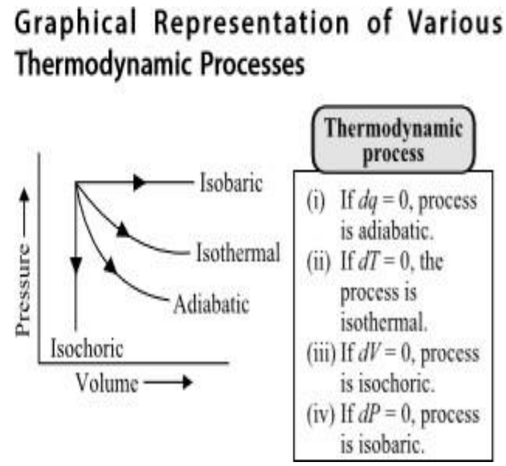
An **isochoric process** is a thermodynamic process, in which the **volume** of the closed system **remains constant** (V = const). It describes the behaviour of gas inside the container, that cannot be deformed. Since the volume remains constant, the heat transfer into or out of the system does not require the $p\Delta V$ work, but only changes the **internal energy** (the temperature) of the system. In engineering of **internal combustion engines**, isochoric processes are very important for their thermodynamic cycles (Otto and Diesel cycle); therefore, the study of this process is crucial for automotive engineering.

Isothermal Process

An **isothermal process** is a **thermodynamic process**, in which the **temperature** of the system **remains constant** (T = const). The heat transfer into or out of the system typically must happen at such a slow rate in order to continually adjust to the temperature of the reservoir through heat exchange. In each of these states, the **thermal equilibrium** is maintained. For an **ideal gas** and a polytropic process, the case ***n = 1*** corresponds to an **isothermal** (constant-temperature) process. In contrast to **adiabatic process**, in which ***n = κ*** *and a system exchanges no heat with its surroundings (Q = 0; $\Delta T \neq 0$), in an isothermal process there is no change in the internal energy (due to $\Delta T = 0$) and therefore $\Delta U = 0$ (for ideal gases) and $Q \neq 0$.* An adiabatic process is not necessarily an isothermal process, nor is an isothermal process necessarily adiabatic.

Adiabatic Process

An **adiabatic process** is a thermodynamic process, in which there is **no heat transfer** into or out of the system (Q = 0). The system can be considered to be **perfectly insulated**. In an adiabatic process, energy is transferred only as work. The assumption of no heat transfer is very important since we can use the adiabatic approximation only in **very rapid processes**. In these rapid processes, there is not enough time for the transfer of energy as heat to take place to or from the system. In real devices (such as turbines, pumps, and compressors) **heat losses** and losses in the combustion process occur, but these losses are usually low in comparison to overall energy flow, and we can approximate some thermodynamic processes by the adiabatic process.

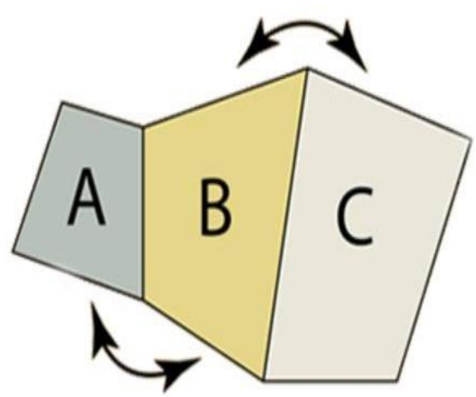


Laws of Thermodynamics

1) **Zeroth Law of thermodynamics:** It states that if two thermodynamic systems are each in thermal equilibrium with a third one, then they are in thermal equilibrium with each other.

   Examples:

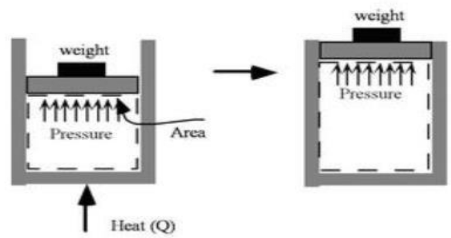
   - ❖ consider two cups *A* and *B* with boiling water.
   - ❖ When a thermometer is placed in cup *A*, it gets warmed up by the water until it reads 100°C.
   - ❖ When it read 100°C, we say that the thermometer is in equilibrium with cup *A*.
   - ❖ Now when we move the thermometer to cup *B* to read the temperature, it continues to read 100°C.
   - ❖ The thermometer is also in equilibrium with cup B.
   - ❖ From keeping in mind the zeroth law of thermodynamics, we can conclude that cup *A* and cup *B* are in equilibrium with each other.



2) **1st Law of Thermodynamics:** It states that the total energy of an isolated system is constant. Energy can be transformed from one form to another, but can neither be

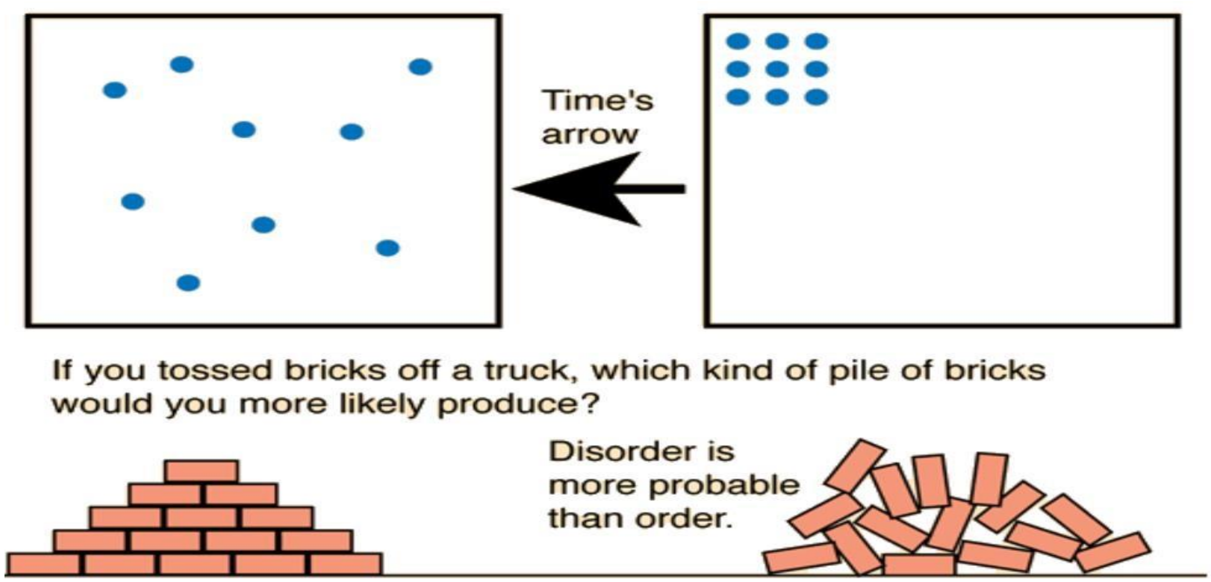
created nor destroyed. According to this law, some of the heat given to system is used to change the internal energy while the rest in doing work by the system.

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



3) 2nd Law of Thermodynamics:

- It states that the heat energy cannot transfer from a body at a lower temperature to a body at a higher temperature without the addition of energy.
- **Kelvin-Planck statement:** It is impossible to convert all the heat extracted from a hot body into work
- **Clausius statement:** It is not at all possible to transfer heat from a cold body to a hot body without the expenditure of work by an external energy source.
- **Examples-** Carnot Engine, Refrigerator, Heat Pump etc.
- **Entropy:** Chemical and physical changes in a system may be accompanied by either an increase or a decrease in the disorder of the system, corresponding to an increase in entropy ($\Delta S > 0$) or a decrease in entropy ($\Delta S < 0$), respectively. As with any other state function, the change in entropy is defined as the difference between the entropies of the final and initial states: $\Delta S = S_f - S_i$. When a gas expands into a vacuum, its entropy increases because the increased volume allows for the greater atomic or molecular disorder. The greater the number of atoms or molecules in the gas, the greater the disorder. The magnitude of the entropy of a system depends on the number of microscopic states, or microstates, associated with it (in this case, the number of atoms or molecules); that is, the greater the number of microstates, the greater the entropy.



4) **3rd Law of Thermodynamics:** The Third Law states, "The entropy of a perfect system is zero when the temperature of the system is equal to absolute zero (0 K)." Because a temperature of absolute zero is physically unattainable, the Third Law may be restated to apply to the real world as: the entropy of a perfect system approaches zero as its temperature approaches absolute zero.