## HEAT:

In Physics and Thermodynamics, heat is energy transferred from one body, region or thermodynamic system to another due to thermal contact or thermal radiation when the systems are at different temperatures.

It is often described as one of the fundamental processes of energy transfer between physical entities.

In this description, it is an energy transfer to a body in any other way than due to the thermodynamic work, which is a concept of work more broad than mechanical work.

In engineering, the discipline of heat transfer classifies energy transfer in or between systems resulting in the change of thermal energy of a system as either thermal conduction, first described scientifically by Joseph Fourier, by fluid convection, which is the mixing of hot and cold fluid regions due to pressure differentials, by mass transfer, and by thermal radiation, the transmission of electromagnetic radiation described by black body theory.

Thermodynamically, energy can only be transferred as heat between objects or .regions there in, with different temperatures, as described by the Zeroth law of thermodynamics. This transfer happens spontaneously only in the direction to the colder body, as per the second law of thermodynamics. The transfer of energy by heat from one object to another object with an equal or higher temperature can happen only with the aid of a heat pump via mechanical work, or by some other similar process

in which entropy in increases in the universe in a manner that compensates for the decrease of entropy in the cooled object, due to the removal of the heat from it. For example, heat may be removed against a temperature gradient by spontaneous evaporation of a liquid.

A related term is thermal energy, loosely defined as the energy of a body that increases with its temperature. Thermal energy is sometimes referred as heat, although the strict definition of heat requires it to be in transfer between two systems.

**Theory:**

Heat flows spontaneously, from systems of higher temperature to systems of lower temperature. When two systems come into thermal contact, they always exchange thermal energy due to the microscope interactions of their particles. When the systems are different temperatures the net flow of thermal energy is t zero and is directed from the hotter region to the cooler region, until their temperatures are equal and the flow of heat ceases. At this point they obtain a state of formal equilibrium, exchanging thermal energy at an equal rate in both directions.

The first law of thermodynamics states that the energy of an isolated system is conserved. Therefore, to change the energy of a system, energy must be transferred to or from the system. For a closed system, heat and work are the only mechanisms by which energy can be transferred; work performed on a system is by definition, an energy transfer to the system that is due to a change to external parameters of the system, such as the volume, magnetization, center of mass in a gravitational field. Heat is the energy transferred to the system in any other way.

In the case of systems close to thermal equilibrium where notions such as the temperature can be defined, heat transfer can be related to temperature difference between systems. It is an irreversible process, which leads to the systems coming closer to mutual thermal equilibrium.

Human notions such as hot and cold are relative terms and are generally used to compare one system's temperature to another or its surroundings.

**Definitions:**

James clerk Maxwell, in his classic theory of heat, outlined four stipulations for the definition of heat.

♦ It is something which may be transferred from one body to another, according to the second law of thermodynamics.

♦ It is a measurable quantity, and thus treated mathematically.

♦ It cannot be created as a substance, because it may be transformed into something that is not a substance. E.g.: Mechanical work.

♦ Heat is one of the forms of energy.

**Modern definitions of heat are:**

♦ The energy transferred from a high-temperature system to a lower-temperature system is called heat.

♦ Any spontaneous flow of energy from one system to another caused by a difference in temperature between the systems is called heat.

In a thermodynamic sense, heat is never regarded as being stored within a system. Like work, it exists only as energy in transit from one system to another or between a system and its surroundings. When energy in the form of heat is added to a system, it is stored as kinetic and potential energy of the atoms and molecules in the system.

**Units:**

As a form of energy heat has the unit joule (J) in the international system of units. However, in many applied fields in engineering the British Thermal Unit (BTU) and the calorie are often used.

The standard unit for the rate of heat transferred is the watt (W) defined as joules per second.

The total amount -of energy transferred as heat is conventionally written as Q for algebraic purposes. Heat released by a system into its surroundings is by convention a negative quantity (Q < 0), when a system absorbs heat from its surroundings, it is positive (Q>0). Heat transfer rate, or heat flow per unit time is denoted by

$$Q = \frac{d\theta}{dt}$$

Heat flux is defined as rate of heat transfer per unit cross-sectional area, resulting in the unit watts per square metre.

Internal energy and enthalpy:

In the case where the number of particles in the system is constant, the first law of thermodynamics states that the differential change in internal energy dU of a system is given by the differential heat flow δQ into the system minus the differential work δW exerted by the system.

$dU = \delta Q_{in} - \delta W_{out}$ (first law)

The differential transfer of heat, $\delta Q_m$, makes differential contributions, not only to internal energy, but also to the work done by the system.

$\delta Q_{in} = dU + \delta W_{out}$

The work done by the system includes boundary work, which causes the boundaries of the system to expand, in addition to other work.

$\delta Q_{in} = dU + \delta W_{boundary} + \delta W_{other}$

$dU + \delta W_{boundary}$ is equal to the differential enthalpy change (dH) of the system.

**Substitution gives:**

$\delta Q_{in} = dH + \delta W_{other}$

Both enthalpy, H and internal energy U, are state functions. In cyclical processes, such as the operation of a heat engine, state functions return to their initial values. Thus the differentials for enthalpy and energy are exact differentials, which are dH and dU respectively. The symbol for exact differentials is the lower case letter d.

In contrast, Q nor W represents the state of the system. Thus, the infinitesimal expressions for heat and work are inexact differentials, δQ and SW respectively. The lowercase greek letter, δ is the symbol for inexact differentials. The integral of any inexact differential the time it takes to leave and return to the same thermodynamic state does not necessarily equal zero. However, for processes involving no change in volume (i.e. dV = 0), applied magnetic field, or other external parameters (i.e. $\delta W_{out} = 0$ and $\delta W_{in} = 0$), δQ forms the δQ exact differential, $dS = \frac{\delta Q_{rev}}{T}$, where in the following relation applies.

$dU = TdS = \delta Q_{rev}$

Likewise, for an isentropic process (i.e. dQ = 0 and dS = 0), dW forms the exact differential, $dV=\frac{\delta W_{rev}}{P}$, where in the following relation applies. dU = -pdV = $-\delta W_{rev}$

**Latent and sensible heat:**

Latent heat is the heat released or absorbed by a chemical substance or a thermodynamic system during a change of state that occurs without a change in temperature. Such a process may be a phase transition, such as the melting of ice or the boiling of water. The term was introduced around 1750 by Joseph Black as derived from the Latin latere (to lie hidden), characterizing its effect as not being directly measurable with a thermometer.

Sensible heat, is contrast to heat, is the heat exchanged by a thermodynamic system that has as its sole effect a change of temperature. Sensible heat therefore only increases the thermal energy of a system.

**Specific heat:**

Specific heat also called specific heat capacity, is defined as the amount of energy that has to be transferred to or from one unit of mass (kilogram) or amount of substance (mole) to change the system temperature by one degree Specific heat is a physical property, which means that if ends on the substance under consideration and its state as specified by its properties.

The specific heats of monatomic gases (e.g. helium) are nearly constant with temperature Diatomic gases such as hydrogen display some temperature dependence, and diatomic gases (e.g. carbon dioxide) still more.

**Entropy:**

In 1856, German physicist Rudolf Clausius defined the second fundamental theorem (the second law of thermodynamics) in the mechanical theory of heat (thermodynamics) “it two transformations which, without necessitating any other permanent change, can mutually replace one another, be called equivalent, then the generations of the quantity of heat Q from work at the temperature T, has the equivalence - value.

$$\frac{Q}{T}$$

In 1865, he came to define this ratio as entropy symbolized by S, such that, for a closed, stationary system.

$$\Delta S = \frac{Q}{T}$$

and thus, by reduction, quantities of heat 8Q (an inexact differential) are defined as quantities of TdS (an exact differential).

$\delta Q = TdS$

In other words, the entropy function S facilitates the quantification and measurement of heat flow through a thermodynamic boundary.

To be precise, this equality is only valid, if the heat δQ h applied reversibly. If, in contrast, irreversible processes involved, e.g. some sort of friction, then instead of the above equation one has

$\delta Q \leq TdS$ (second law)

This is the second law of thermodynamics.

**Heat transfer in engineering:**

The discipline of heat transfer, typically considered an aspect of mechanical engineering and chemical engineering deals with specific applied methods by which heat transfer occurs. Note that although the definition of heat implicitly means the transfer of energy, the term heat transfer has acquired this traditional usage in engineering and other contents. The understanding of heat transfer is crucial for the design and operation of numerous devices and processes.

Heat transfer may occur by the mechanisms of conduction, radiation and mass transfer. In engineering, the term convective heat transfer is used to describe the combined effects of conduction and fluid flow and is often regarded as an additional mechanism of heat transfer. Although separate physical laws have been discovered to describe the behaviour of each of these methods, real systems may exhibit a complicated combination. Various mathematical methods have been developed to solve or approximate the results of heat transfer in systems.

**Application:**

In accordance with the first law, heat energy may be changed to work. This happens in so called heat engines, e.g. the steam engine. But here the second law comes into play. This results in the general rule that - to keep the "lost heat" small the final temperature should be low. In contract, so called heat-pumps can take heat at low temperatures from a "reservoir", e.g. from the soil, and deliver it by means of electrical work at a higher temperature for heating purposes. Now the temperature difference should be small, to keep the "lost electrical work" small.

**Thermodynamics is the connection between Heat and Work:**

Thermodynamics is the study of the connection between heat and work and the conversion of one into the other.

The study is important because many machines and modern devices change heat into work (such as an automobile engine) or turn work into heat (or cooling, as in a refrigerator). There are two laws of thermodynamics that explain the connection between work and heat. But first, it must be shown how mechanical energy can be equivalent to heat energy.

**Mechanical equivalent of heat:**

Experiments showed that the amount of heat created is proportional to the work done. This relationship is called the mechanical equivalent of heat and can be expressed by the equation.

W = JH

where, W is the work done in joules (J)

J is the relationship constant 4.18 joules/calorie

(J/C)

H is the heat created from the work in calories.

A calorie is the amount of heat required to raise the temperature of one gram of water 1°C. It is not to be confused with a calorie (capital "C") used in dieting.

**Application:**

Using this equation we could calculate the amount of heat generated from the work required to stop a moving car.

The way we do this is to calculate the kinetic energy (KE) of a car from its mass and velocity in joules $\left(KE = 12mv2\right.$. Since the work required to stop a moving car equal its kinetic energy, the total amount of heat generated in the brakes and tries to stop the car would be

H = (KE)/ 4.18

**Laws of thermodynamics:**

**First Law:**

The first law is the law of conservation of Energy. It states that energy cannot be created or destroyed. Instead it is converted from one form to another, such as from mechanical work to heat, from heat to light, from chemical to heat or such.

One example of that is how the kinetic energy of a moving car is converted into heat energy at the brakes and tire surfaces.

Another example is when chemical energy is released in burning and is converted into light and heat energy.

**Second Law of Thermodynamics:**

The second law of thermodynamics has several variations, which is explained below:

**Some heat is wasted in conversion:**

One version of the second law of thermodynamics states that some heat is wasted when converting heat into mechanical energy.

In other words, in a car engine, not all of the heat created from the exploding gasoline is used in turning the engine or moving the car. Some of the heat simply heats the engine. The percentage of heat turned to work is called the thermal efficiency of the engine.

**Heat flows from high to low:**

The second law of thermodynamics also states that heat normally flows from high temperature to low temperature. For example, when you heat the end of a metal rod, the heat will gradually travel to the cool end and heat it up.

**Heat Sink:**

Another example of this pact of the second law of thermodynamics concerns what is called a heat sink, which is an object that absorbs heat from another. Usually it is a large mass that absorb heat from an object of smaller mass.

The effect is seen in waterbeds. The reason waterbeds use heaters to warm the water is because otherwise the heat from human body (at 98.6°F) will flow to the cooler water (at room temperature of 72°F). Since there is so much water in a waterbed, it would take much energy from human body to heat the water to body temperature. Thus, human can feel chilled from the loss of body heat.

**Entropy:**

Another variation on the second law of thermodynamics states that the energy available for work in the universe is continually decreasing.

This is also stated as the entropy of the universe is continually increasing. Entropy is the .measure of the disorder of a system. In other word, in any closed system, objects are getting more and more mixed. Mixtures do not "unmix" by themselves.

**Applications of energy conversion:**

**Internal Combustion engines:**

An application of the conversion of energy is the type of engine used in a car, an internal combustion engine.

The way this engine works is that gasoline and mixed and exploded is a cylinder. That explosion is internal combustion, changing chemical energy to heat energy.

Since gases want to expand when they are heated, they exert pressure on the piston in the cylinder, causing it to move and turn a shaft. Thus, the heat energy is converted into mechanical energy.

**Refrigerator:**

Another application of energy conversion is the refrigerator. Electrical energy is converted into mechanical energy in an electric motor. This motor operates a pump, which expands the gas, causing it to become cold. This is converting mechanical energy into heat (cold) charges.

When a gas in a cylinder is compressed it heats up. The pump in the refrigerator compresses a special gas condensing it into a liquid at a higher temperature. The liquid is held in a tube called a condenser. In most refrigerators, a fan forces air across the condenser, transfering the heat to the surrounding air.

If a gas in a cylinder expands, it cools off. The liquid refrigerant is then expanded through a restriction device into an evaporator inside the refrigerator where it becomes a gas again. It is this expansion that absorbs heat from inside the refrigerator, thus cooling the contents of the refrigerator. Another fan spreads the cold air through the refrigerator by convection.