Heat and Temperature

The **heat** of an object is the total energy of all the molecular motion inside that object. Heat is the energy that is transferred from one body to another due to differences in temperature. The S.I. unit of heat is the joule (J), but it can also be measured in calories (Cal). The two units are related by the following conversion factor:

1 calorie = 4.186 joules

Temperature is the measure of the thermal energy or average heat of the molecules in a substance. Temperature is a physical quantity that expresses the coldness and hotness of a body. The SI unit of temperature is Kelvin. Temperature is a relative measure of a body's hotness or coldness.

Units of Temperature

1. Kelvin (K) – SI unit of temperature.
2. Celsius (°C) – Used in most scientific and everyday contexts.
3. Fahrenheit (°F) – Primarily used in the U.S. for non-scientific applications.
4. Rankine (°R) – Absolute temperature scale in Fahrenheit, mainly used in thermodynamic calculations in engineering.

The difference between Heat and Temperature are tabulated below:

Heat	Temperature
It is a form of energy.	It is the thermal state of a physical body.
It can flow from one body to another.	It is a parameter measurement of a body so it does not flow.
Total amount of heat in a body can only be measured during its flow.	Temperature of a body can be measured.
It is a path function.	It is a state function
It is a process between two matters.	It is the fundamental property of a matter.

In order to measure temperature, various primary effects that cause changes in temperature can be used. The temperature may change due to changes in physical or chemical states, electrical property, radiation ability, or physical dimensions. **Thermometer** (thermos: hot; metron: measure) is the universal instrument used to measure temperature. **Daniel Gabriel Fahrenheit** is considered to be the father of thermometers. He was a German physicist who dedicated his life to science and inventions. The modern mercury thermometer was invented by Fahrenheit. He is also credited for the invention of the mercury-in-glass thermometer.

Temperature can be sensed using many devices, which can broadly be classified into two categories: contact- and non-contact-type sensors. In case of contact-type sensors, the object whose temperature is to be measured remains in contact with the sensor. Inference is then drawn on the assessment of temperature either by knowing or by assuming that the object and the sensor are in thermal equilibrium.

Contact-type sensors are classified as follows: 1. Thermocouples 2. Liquid-in-glass thermometers 3. Resistance temperature detectors (RTDs) 4. Pressure thermometers 5. Thermistors 6. Bimetallic strip thermometers

In case of non-contact-type sensors, the radiant power of the infrared or optical radiation received by the object or system is measured. Temperature is determined using instruments such as radiation or optical pyrometers. Non-contact-type sensors are categorized as follows: 1. Radiation pyrometers 2. Optical pyrometers 3. Fibre-optic thermometers

LIQUID-IN-GLASS THERMOMETERS: The liquid-in-glass thermometer is the most popular and is widely used for temperature measurement. It comprises a bulb that contains a temperature-sensing liquid, preferably mercury. Alcohol and pentane, which have lower freezing points than mercury and do not contaminate if the bulb is broken, are also used. Since alcohol has a better expansion coefficient than mercury, it is also used. A graduated capillary tube is connected to the bulb. At the top of the capillary, a safety or expansion bulb is provided. A range cavity is provided just above the bulb to accommodate the range variation. The walls of the bulb should be thin in order to facilitate quick transfer of heat. Further, for the response to be quick, the volume of liquid should be small. However, the larger the volume of the liquid, the higher the sensitivity. Since speed of response depends on the volume of the liquid, a compromise needs to be made between sensitivity and response. The entire assembly is enclosed in a casing to provide protection from breakage. An extra-long stem may be provided to facilitate easy dipping into hot liquids. Calibration of thermometers has to be carried out for better results. Liquid-in-glass thermometers are simple, portable, and inexpensive. However, they are fragile and not suitable for remote applications and sensing surface temperature. Under optimal conditions, the accuracy of this type of thermometers is around 0.1°C.

Clinical thermometers/Hg thermometer is meant for clinical purposes. It is developed for measuring the human body temperature. Mercury is in a liquid state at room temperature and has the highest expansion coefficient. Therefore, even the slightest temperature change is notable. Also, the boiling point of the mercury makes it suitable for measuring higher temperatures. The other reason why mercury is used in thermometers is that it does not stick to the surface of the glass and has a shiny appearance. Another important factor, as a result of which mercury is used in thermometers, is that it can measure temperatures over a wide range. The lower limit being -37^0C and the upper limit being 357^0C. The range of a mercury thermometer can be increased by adding an inert gas to it such as nitrogen to it. Adding an inert gas increases the pressure on mercury as a result of which its boiling point increases. Hence it can be used to measure further higher values. The range of the thermometer can also be increased by increasing the diameter of the capillary tube.It is a long narrow glass tube with a bulb containing mercury at the end. The normal human body temperature is 37˚C, which can fluctuate between the ranges 35˚C to 42˚C. Hence, the clinical thermometers range from 35˚C to 42˚C.The level of mercury tells our body temperature in

˚C. Since mercury is a toxic element, thus these thermometers have been replaced by digital thermometers nowadays. It is used to measure the temperature under the arm, orally and rectally.

Scales of Temperature:

1. Celsius Scale (°C)

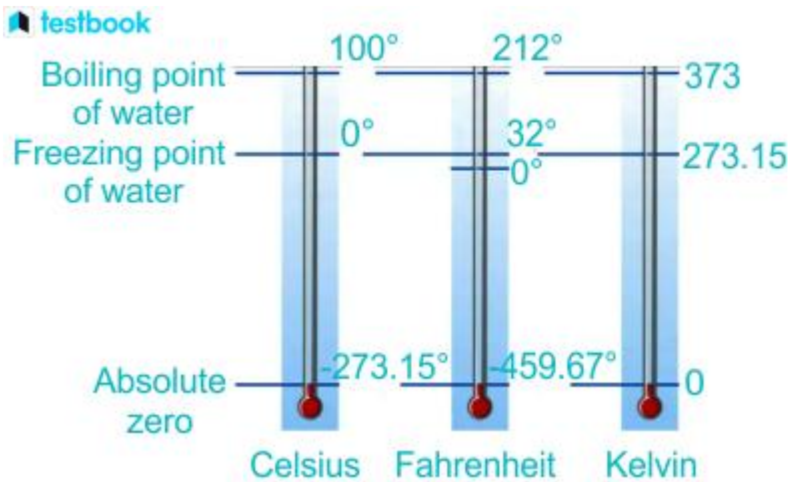
Water freezes at 0°C and boils at 100°C (at standard atmospheric pressure).
This scale is commonly used in daily life and most scientific measurements.

2. Fahrenheit Scale (°F)

- Water freezes at 32°F and boils at 212°F.
- The Fahrenheit scale is primarily used in the United States.

3. Kelvin Scale (K)

- The Kelvin scale is the SI unit of temperature.
- It is an absolute temperature scale with its zero point at absolute zero, the point where molecular motion theoretically stops.
- 0 K = -273.15°C
- Water freezes at 273.15 K and boils at 373.15 K.



Absolute Zero:

- Absolute zero (0 K) is the lowest temperature possible, where all molecular motion theoretically stops. At absolute zero, the entropy of a perfect crystal is zero, and the system contains no thermal energy.It corresponds to:
0 K = -273.15°C = -459.67°F

Heat Transfer: There are three modes of heat transfer:

• Conduction

• Convection

• Radiation

Conduction: Thermal conduction is the process by which thermal energy is transferred from the hotter to the colder part of a body or from a hot body to a cold body in contact with it without the transfer of material particles. Some of the examples of conduction which we experience in our day to day life are being burnt after touching a stove. Your hand is being cooled with ice. By putting a red-hot piece of iron into the water, it is brought to a boil.

Convection: Thermal convection is the process by which heat is transferred from one point to another by the actual movement of heated material particles from a higher temperature location to a lower temperature location. Forced convection occurs when the medium is forced to move by means of a fan or a pump. Natural or free convection occurs when a material moves due to differences in density in the medium. Examples of forced convection are circulatory system, cooling system, and heat connector of an automobile. Examples of natural convection are trade winds, sea breeze/land breeze, monsoons, and tea burning.

Radiation: It is a method of heat transmission in which heat travels directly from one location to another without the use of an intermediary medium. This radiation of heat energy takes the form of EM waves. These radiators are emitted as a result of their temperature, similar to how a red hot iron or a filament lamp emits light. Everybody both radiates and absorbs energy from its surroundings. The amount of energy absorbed is proportional to the color of the body. Black-body radiation is the thermal electromagnetic radiation emitted by a black body within or surrounding a body in thermodynamic equilibrium with its environment (an idealized opaque, non-reflective body).

The transfer of heat can take place mainly in three ways: conduction, convection, and radiation

Conduction:

- It is the type of heat in which the transfer occurs between the particles of higher kinetic energy and the particles of lower kinetic energy. In this, the higher kinetic energy particles heat the particles of lower kinetic energy and increase their kinetic energy as well resulting in them gaining heat. This sudden increase results in the sudden temperature increase of the body consisting of those particles. Conduction can only occur when the body is in direct contact with the heat.
- Example: touching hot metal.

Convection:

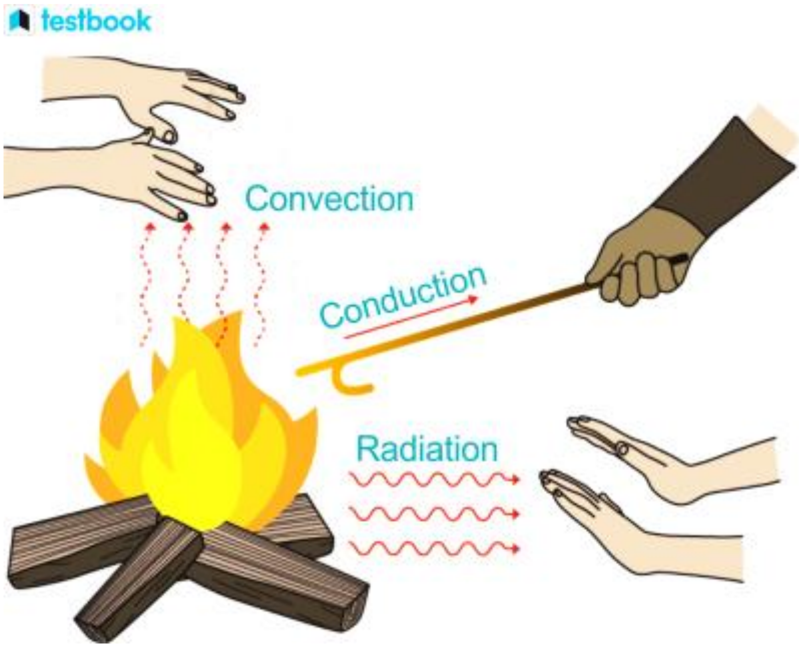
- It is the type of heat in which the transfer occurs by the movement of the molecules of the fluid from the regions of higher temperature to the regions of lower temperature. They keep doing it until there is no heat left to transfer to the lower region. As the temperature of the fluid starts to increase then the volume of the fluid should also keep on increasing by a similar factor. This effect produced by the convection on the volume of the fluid is known as displacement.
- Example: water boiling on gas.

Radiation:

- It is the type of heat transfer in which the transfer occurs due to the electromagnetic waves produced by it. In this, the electromagnetic waves which are produced by the charged electrons and protons of the heating body carry away their energy to the non-emitting body. This transfer can only occur through a transparent or vacuum medium which can either be solid or liquid. It is just caused by the random motion of the molecules present in a body.

- Example: Fire, Sun.

  The image given below depicts the types of heat and how they transfer heat from one body to another.



Characteristics of Thermal Radiations: Another name for heat radiation is thermal radiation.

1.Thermal radiation is the transfer of thermal energy without any contact between the bodies.

2.Thermal radiation is a surface phenomenon, unlike heat transfer by conduction or convection, the thermal radiations will not require any contact between the source and the receiver.

3.Every matter having nonzero temperature or temperature more than 0k emits thermal radiations.

4.Thermal radiations have a wavelength ranging from 0.1micrometer to 100micrometers.

5. While the transfer of any energy via conduction requires a medium to process, whereas for thermal radiations it does not require any medium for conduction. Radiation is the only mode of transfer that can be carried out even in a vacuum.