Thermal energy

Thermal energy is the sum of the kinetic and potential energy of all the atoms or molecules in an object.

The higher the thermal energy, the faster the particles are moving.

$E_{Thermal} = KE_{av} + N.PE$

KE_{av} = average kinetic energy
PE = potential energy of each atom
N = total number of atoms (N)

Thermal equilibrium is a state where two objects transfer energy between them at the same rate and reach the same temperature.

Types of Thermometer

Clinical thermometers	Clinical thermometers are used by doctors to make precise measurements of our temperature. They usually have mercury inside them because mercury is sensitive to small temperature changes. The temperature range of clinical thermometers is from 35°C to 42°C because humans cannot survive outside this range.
Lab Thermometers	Thermometers used in science labs have a much higher range than clinical thermometers. They can measure temperature from -10°C to 110°C. This is because in a laboratory, it is useful to know the temperature of chemicals that can have a very large range of temperatures.
Household Thermometers	These thermometers generally use alcohol because it freezes at a low temperature.
industrial thermometers	Some industrial thermometers use alcohol and so can measure temperatures as low as -150°C. That is how cold industrial equipment used to make ice cream get!

Temperature scale

Celsius	**Celsius** is a scale for measuring temperature (*T*) in which water at sea level boils at 100°C and freezes at 0°C. It was developed in the 18th century by Anders Celcius, a scientist from Sweden.
Kelvin	**Kelvin** is a scale for measuring temperature (*T*) in which water at sea level boils at 373 K and freezes at 273 K. A kelvin is the base unit for temperature.
Fahrenheit	**Fahrenheit** is a scale for measuring temperature (*T*) in which water boils at sea level at 212°F and freezes at 32°F.

Absolute zero

Absolute zero is the lowest temperature possible. At this temperature, the atoms of an object do not have any kinetic or thermal energy. They do not move. This temperature corresponds to 0 K or -273.15°C.

Heat (*Q*)

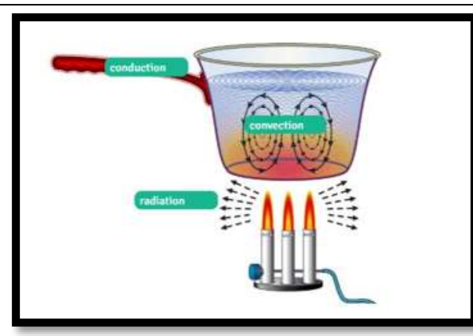
Heat (*Q*) is the transfer of thermal energy from one object to another. This transfer occurs naturally from a hotter object to a colder object. But for thermal energy to be transferred from a colder to a hotter object, work must be done.

The SI unit of heat is the joule (J) - the same unit of work and energy.

Q= + when heat added
Q= - when heat removed

Heat, or energy transfer, between objects happens in three ways.

Thermal conduction	**Thermal conduction** is the transfer of thermal energy from one particle to another when they collide, or bump each other. In solid, liquid, gas and Plasma Metals are good conductors of heat and materials like wood or plastic are poor conductors of heat, called insulators.
Thermal convection	**Thermal convection** is the transfer of thermal energy in a gas or liquid in which the warmer molecules move up and the cooler molecules move down in circular motion. Not in Solid
Thermal radiation	**Thermal radiation** is the transfer of thermal energy by **electromagnetic waves**, like **infrared radiation**. The Sun's rays heat the Earth by radiation. They transfer thermal energy through empty space where there are no molecules.

Conduction in solid, liquid, gas and Plasma Convection in liquids, gases and Plasma Radiation in vacuum	

Specific heat capacity (C)

Specific heat capacity (C)is the amount of energy that must be added to 1 kg of a material to increase its temperature by 1 kelvin (1 K).

Its SI unit is J/(kg.K).

Significance

1. Higher the heat capacity more time is required to heat and cool

2. Lower the heat capacity substance will cool and heat quickly.

$$Q = m\,c\,\Delta T$$

Q = energy transfered (joules)
m = mass of water (grams)
c = specific heat capacity
ΔT = temperature change (K or °C)

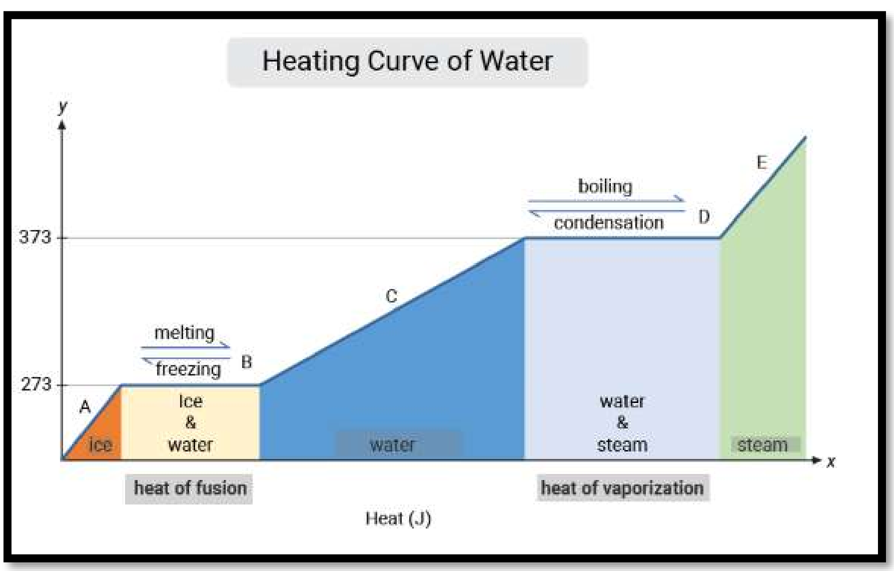
A calorimeter

A **calorimeter** is an instrument used to measure the specific heat capacity of a substance.

Based on Conservation of Energy

Heat during change of state is called heat of fusion **and** heat of vaporization

Heat of fusion (H_f)	**Heat of fusion** (H_f) is the amount of thermal energy needed to melt 1 kg of a solid material at its melting point. Its SI unit is joules per kilogram (J/kg).
Heat of vaporization (H_v)	**Heat of vaporization** (H_v) is the amount of thermal energy needed to evaporate 1 kg of a liquid at its boiling point. Its SI unit is joules per kilogram (J/kg).

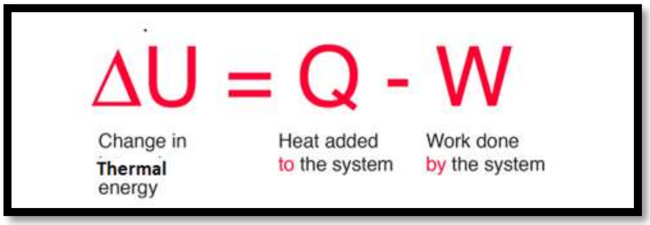


Thermodynamics

Thermodynamics is a branch of physics that describes the relationship of thermal energy to other forms of energy and work.

The **first law of thermodynamics** states that the change in thermal energy (ΔU) of a system is equal to the heat (Q) going *into* the system minus the work (W) done *by* the system or,

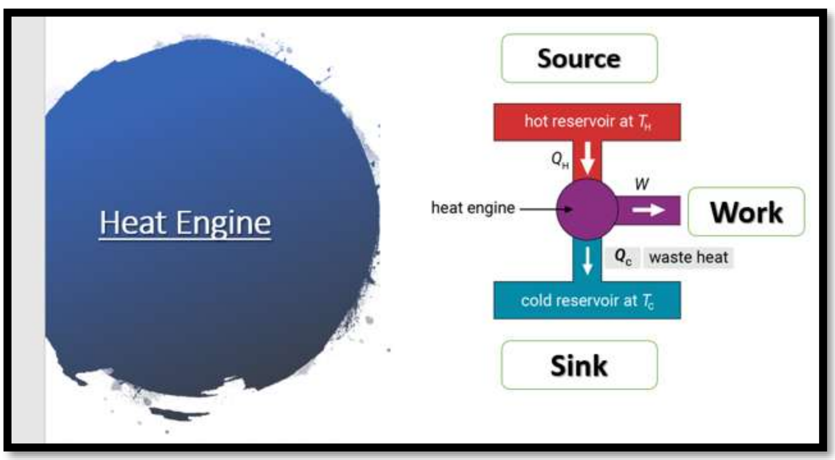
$\Delta U = Q - W$



All the terms are measured in Joules (J)

Heat engine

A **heat engine** is a machine that converts thermal energy into mechanical energy continuously. It has a high temperature source, a low temperature receiver called a sink, and a mechanism to convert thermal energy into mechanical energy.



Entropy (*S*)

Entropy (*S*) is the measure of the dispersal, or spreading out, of energy.

Entropy is measured in joules per kelvin (J/K)

A system where thermal energy is concentrated in one place has low entropy, while a system where it is spread out has high entropy.

NOTE

1. SI unit of Temperature is Kelvin.
2. Increase in temperature means increase in Kinetic Energy of Particles.
3. **Absolute zero** is the lowest temperature possible. At this temperature, the atoms of an object do not have any kinetic or thermal energy. They do not move. This temperature corresponds to 0 K or -273.15°C.
4. first law of thermodynamics is the same as the **law of conservation of energy**.

Formula

Degree Celsius to kelvin	Kelvin = Degree Celsius +273 $$K = C + 273$$
Kelvin to Degree Celsius	Degree Celsius = Kelvin – 273 $$°C = K - 273$$
Degree Celsius to Fahrenheit	Fahrenheit = Celsius x 1.8 + 32 $$°F = °C \times 1.8 + 32$$
Energy Transferred	Q=mC△T Q = heat in J m = mass in kg C = specific heat capacity in J/(kg.K) ΔT = difference in temperature in K
Specific Heat capacity	$$c = \frac{Q}{m\Delta T}$$ Specific Heat Capacity
The energy (Q) required for solid to liquid or liquid to solid	Q=mHf mass (m) and heat of fusion (H_f),

The energy (*Q*) required for gas to liquid or liquid to gas	Q= mHv Q=−mHf for freezing Q=−mHv for vaporization
First Law of Thermodynamics	$\Delta U = Q - W$ Sign convention No heat (*Q*) is added to the system by the outside world so $Q = 0$. **Q= + when heat added** **Q= - when heat removed** **W = + when piston is pushed up by the gas, or Volume increase** **W = - when piston is pushed up on the gas, or Volume Decrease**
Efficiency of Engine	The efficiency of the engine is the ratio of work (*W*) to input heat (Q_H) and is given by $\frac{W}{Q_H} \times 100\%$
Entropy	$S = \frac{Q}{T}$