The Second Law of Thermodynamics

The 2^{nd} Law can be stated that heat flows spontaneously froma hot object to a cold object

- **The 2^{nd} Law helps determine the preferred direction of a process**
- **A reversible process is one which can change state and then return to the original state This is an idealized condition**
- **– all real processes are irreversible**
- **Definition of Entropy Change, ΔS**

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

  SI unit: J/K
- A gas has high entropy, crystal has low entropy.

$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$

a) if $\Delta S_{universe} = +$ the process is spontaneous *irreversible* real *process*

b) if $\Delta S_{universe} = -$ the process is not spontaneous *reversible* ideal *process*

c) $\Delta S = 0$: (*1*) a system in a reversible cyclic process

$$\Delta S_{cycle} = \Delta S_{hot} + \Delta S_{cold} = 0$$

(*2*) a system and its surroundings undergoing any reversible process.

d) As entropy increases, disorder will also increase. and vice versa

The heat absorbed at ***constant pressure and reversible process*** is given by equation

$$\frac{C_P\,dT}{T} = \frac{dq_{rev}}{T} = dS \qquad (3\text{–}44)$$

Integrating between T_1 and T_2 yields

$$\Delta S = C_P \ln \frac{T_2}{T_1} = 2.303\, C_P \log \frac{T_2}{T_1} \qquad (3\text{–}45)$$

Example 3-9

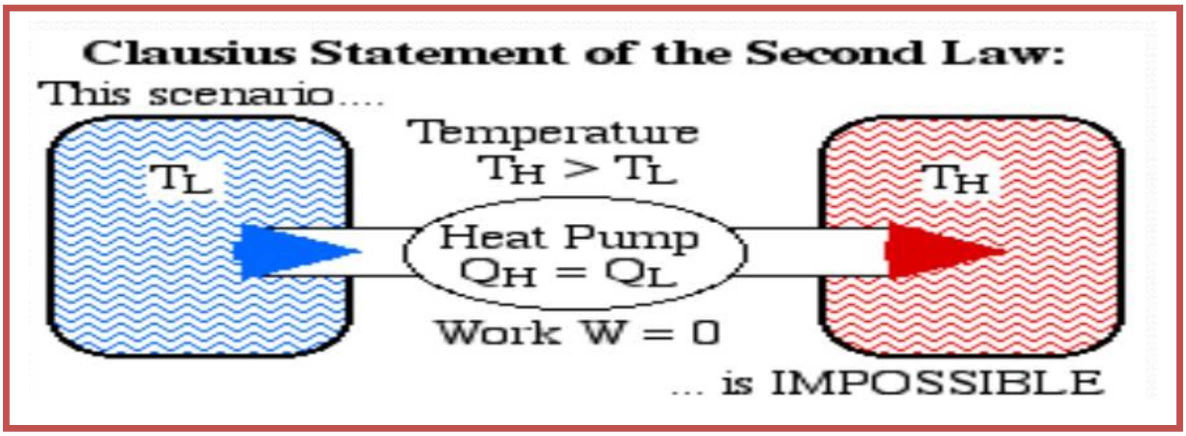
Second law of thermodynamics include two statements

1) Clausius statement
2) Kelvin- Plank statement

CLAUSIUS STATEMENT

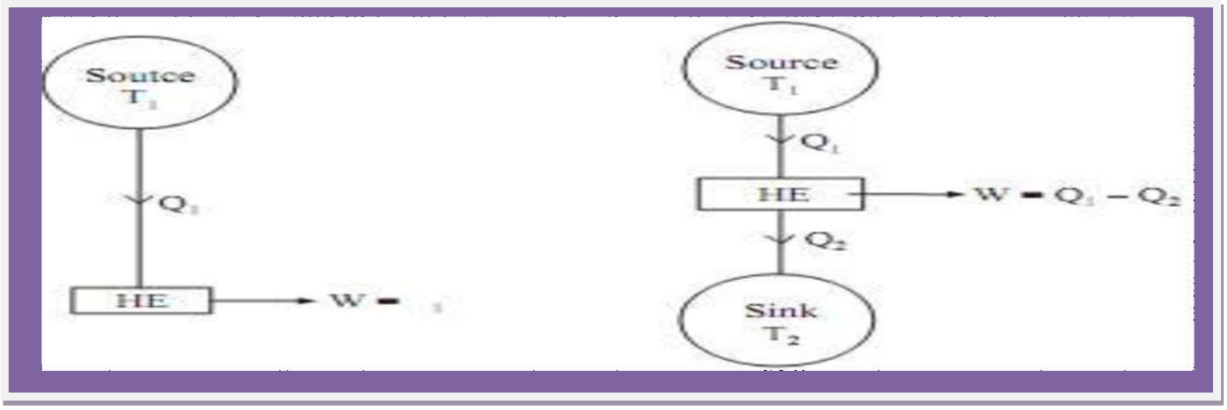
Heat cannot spontaneously flow from cold regions to hot regionswithout external work being performed on the system.

ϒ Ex: Refrigerator.



KELVIN-PLANK STATEMENT

- It is impossible to convert entire heat into the work.
- Ex: Heat Engine.



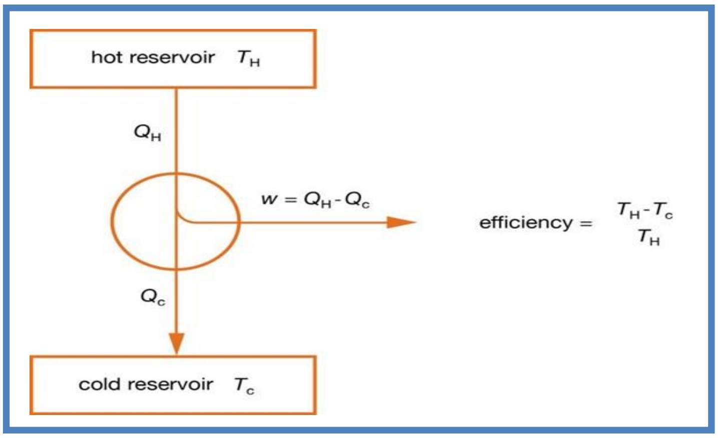
Efficiency

All heat engines have:

- **a high temperature reservoir**
- **a low-temperature reservoir**
- **a cyclical engine**

These are illustrated schematically here.

reservoirs (Carnot)



The efficiency is the fraction of the heat supplied to the

$$e = \frac{W}{Q_h}$$

An amount of heat Q_h is supplied from the hot reservoir to the engine during each cycle. Of that heat, some appears as work, and the rest, Q_c, is given off as waste heat to the cold reservoir.

$$W = Q_h - Q_c$$

engine that appears as work.

The efficiency can also be written:

> **Efficiency of a Heat Engine, *e***
>
> $$e = \frac{W}{Q_h} = \frac{Q_h - Q_c}{Q_h} = 1 - \frac{Q_c}{Q_h}$$
>
> SI unit: dimensionless

In order for the engine to run, there must be a temperature difference; otherwise heat will not be transferred.
An amount of heat Q_h is supplied from the hot reservoir to the engine during each cycle. Of that heat, some appears as work, and the rest, Q_c, is given off as waste heat to the cold reservoir.

- **all reversible engines operating between the same two temperatures, T_c and T_h, have the same efficiency.**

- **If the efficiency depends only on the two temperatures, the ratio of the temperatures must be the same as the ratio of the transferred heats. Therefore, the maximum efficiency of a heat engine can be written:**

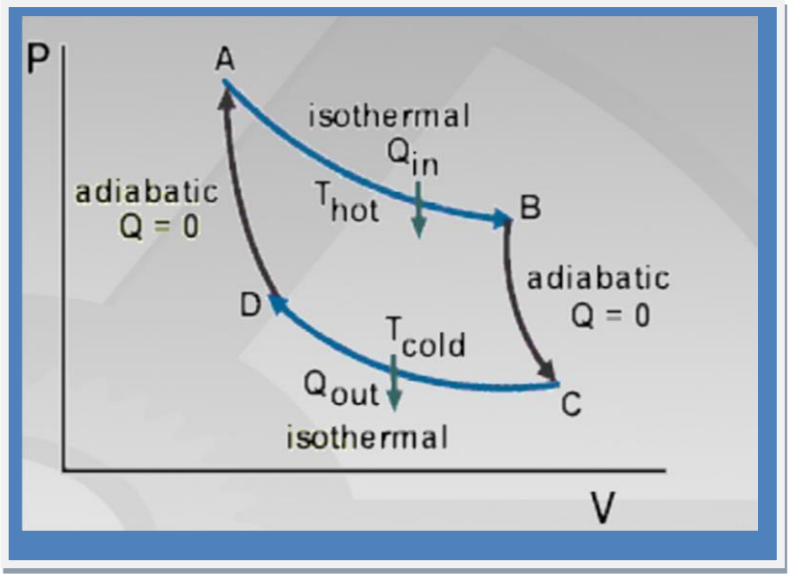
Maximum efficiency of a heat engine

$$e_{max} = \frac{\qquad}{T_h} = 1 - \frac{T_c}{T_h} \qquad\qquad T_h - T_c$$

Carnot Cycle:-

Reversing the Carnot cycle does reverse the directions of heat and work interactions. A refrigerator or heat pump that operates on the reversed Carnot cycle is called a Carnot refrigerator or a Carnot heat pump.

It consists 2 iso-thermal and 2 reversible adiabatic operations.



Process	Description
A-B	**Reversible isothermal expansion heat addition at high temperature** – **Work done *by* the gas**
B-C	**Reversible adiabatic expansion from high temperature to low temperature** – **Work done *by* the gas**
C-D	**Reversible isothermal compression heat rejection at low temperature** – **Work done *on* the gas**
D-A	**Reversible adiabatic compression from low temperature to high temperature** – **Work done *on* the gas.**