Non-Metals:-

→ Non-metallic materials are also used in engineering practice, due to Principally their low-cost, flexibility & resistance to heat & Electricity.

The following are important from design point of view:-

(1) Timber

(2) Rubber

(3) Plastics

① Timber – This is a relatively low cost Material and a bad conductor of heat and electricity.

It has also good elastic & frictional properties and its widely Used in foundry Patterns and as water lubricated bearings.

Leather – Its flexibility & wear Resistance

Used for Belt drives, Washers and such other applications.

② Rubber:- It has high bulk modulus

Used for drive elements, sealing, Vibration Isolation & Similar application

③ Plastics:- are Synthetic materials which can be moulded into desired shapes under pressure with (or) without heat.

Used in Various industrial application for their Corrosion resistance, dimensional stability & low cost.

There are two main types of plastics:.

ⓐ Thermosetting plastics:- Thermosetting plastics are formed Under heat & Pressure.

→ Initially softens and with Increasing heat & Pressure, Polymerisation takes place. This results in hardening of the material.

→ These plastics cannot be deformed (or) Remolded again under heat & Pressure.

→ Examples – phenol formaldehyde (Bakelite)
phenol – furfural (Durite)
epoxy Resins, phenolic resins etc.

Material	characteristics	Application
Epoxy (Araldite)	Excellent Mechanical properties & Corrosion Resistance, good electrical properties	Electrical molding, sinks, protective coatings, etc. Laminates
Phenolic (Bakelite)	Excellent thermal stability (>150°c), Inexpensive	Motor housings, telephones, auto distributors, electrical fixture.

(b) Thermoplastics:- Thermoplastics do not become hard with the application of heat & Pressure & no chemical change takes place.

→ They remain soft at elevated temperature until they are hardened by cooling.

→ These can be re-melted and remolded by application of heat & Pressure.

→ Some examples of thermoplastics are cellulose nitrate (celluloid), polythene, polyvinyl acetate, polyvinyl chloride (PVC) etc.

	Material	characteristics	Applications
①	Polyethylene	chemically resistant, tough low friction coefficient, low strength	Flexible bottles, toys battery parts, ice trays.
②	Vinyl	low-cost general purpose material, rigid, can be made flexible	Floor Covering, Pipe, electrical wire Insulation.

Ceramics:-

→ Ceramic materials are inorganic compounds of metallic and non metallic elements and their atoms are held together by ionic (or) covalent bond.

→ Ceramics are hard & brittle materials with high melting pts

Characteristics:-

1. Resistance to high temperature
2. Low electrical & thermal conductivity.
3. Resistance to wear & corrosion
4. Low ductility
5. Poor conductors
6. High dielectric strength (Insulation)
7. Magnetic properties are good.

Applications:-

Sanitary ware
Floor tiles
Building materials
Spark plugs
Cylinder liners
Bushing & Bearings
~~clay products~~

Classifications:-

1. clay Products ⇒ Small particles of complex alumina silicate
   Used for porcelain ware, electrical insulators, sub bar & fire brick
2. Refractories – (SiO_2, Al_2O_3, MgO, CaO, Cr_2O_3 etc) ⇒ withstanding high temperature without appreciable deformation (or) failure.
   Application:- chemical Reactor lining
   Blast surface.
   Heat treatment surface.
3. Glasses
4. Abrasives

③ Glasses - defined as a amorphous solid that has been cooled to a rigid condition without crystallization.

→ Very hard & Brittle materials
→ low thermal conductivity
→ High electrical Resistivity.

Application: Window glasses
Bottles
Lenses
Bulbs, tubes.

④ Abrasives :- Hard Material that can cut (or) abrade other Substances.

It is a small hard Particle having Sharp edges & Irregular shape.

Used in grinding wheels. & also used to hone, lap, buff and Polish the work Piece. Types :- Al_2O_3, CBN (cubic boron Nitride), Diamond etc.

Composites :-

Composite Materials :- Composite is material Composed of two (or) more difference material bonded together with one serving as the continuous matrix and other as a reinforcing material. The properties of composites are superior to those of the individual materials that make up the composite.

→ Different types of materials such as metals ceramics, glass & polymers may be combined in composite materials & in different forms.

→ Composites a class of engineering materials posses superior properties of high strength, stiffness & corrosion resistance over conventional materials.

... law as T.D ... of thermodynamics ...

→ It is Quantitative law formed by Joule.

→ It is also non-directional law.

Significance:
⇒ 1st of T.D gives us the Concept of Internal energy (U).

Def:- ①

"It is always observed that whenever a system undergoes a cyclic change, the net work done on the System was always equal to the amount of energy removed from the system as heat"

$$\boxed{\oint dQ = \oint dw}$$

Def:- ②

"If a System is operated through a closed cycle, then the net heat transfer is directly proportional to the net work transfer."

$$\boxed{\oint dQ \propto \oint dw}$$ ie $\oint dQ = (J)\oint dw$

↳ proportionality constant (or) Joule constant

Note:- Law of Conservation of energy:-

"Energy can neither be created nor be destroyed but it can be transformed from one form to another form.

Corollaries of the first law:-

Corollary ①:- {1st law T.D applied to a closed system, but not cyclic process (non-flow process)}

"If a system follows a process which is not cyclic, there exists a property of a System, called E, such that a change in its value is (dE) equal to the difference between the heat supplied and the work done during any change in state".

ie $dE = dU = \boxed{dQ - dw}$

ie, $U_2 - U_1 = Q - W$

$Q = (U_2 - U_1) + W$

$$\boxed{Q = \Delta U + W}$$

→ The above eqn is called the non-flow energy equation

→ The above equation is obtained when the system process not cyclic and the system is closed system.

Corollary (2): [1st law of T.D applied to a Isolated System]

Def: "In an Isolated System, the energy of the System remains Constant. This Corollary is also known the law of Conservation of energy."

ie, Energy is neither created nor destroyed, but only gets transformed from one form to another.

$Q=0, \quad W=0$

$\Delta U = U_2 - U_1 = 0$, so, isolated system have a Constant internal energy ($U=C$) ie $\Delta U=0$

Corollary (3):

"A perpetual Motion machine of first kind is impossible (PMM 1)."

PMM - 1: A perpetual motion machine of first kind is a device, which will produce a continuous supply of work without absorbing energy from the surrounding.

The above converse of the above statement, ie, there can be no machine which would continuously consume work without some other form of energy appearing.

ie, Acc. to 1st law of T.D.

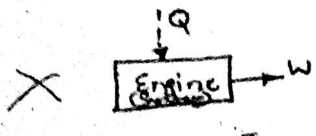


fig: PMM-I (Impossible)

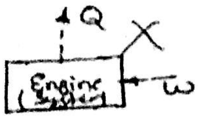
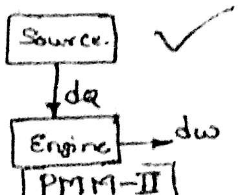


fig: Converse of PMM-I (Impossible)



(Possible engine)

Application of 1st law of T.D:

(1) 1st of law of T.D to a non-flow process (closed system) $\boxed{Q = \Delta U + W}$

Eg: (1) Constant volume process ($V=C$) (3) Constant Temperature process ($T=C$)
(2) Constant pressure process ($P=C$) (4) Adiabatic process ($S=C$) etc.

(2) 1st of law of T.D to a flow process (Open System)

Eg: (a) steady flow process. Eg; nozzles, turbines, Compressors, I.C engines, pumps, boilers, diffuser, steam condensers, steam engines.

(b) Un-steady flow process Eg: Tank filling, tank emptying process.

Limitations of First law of T.D:-

→ First law of T.D states that a certain energy balance will hold when a system undergoes a change of state or a thermodynamic process.

But 1st law doesnot give any information on whether that change of state or the process is at all feasible or not.

→ Acc. to First law of T.D, Heat can be convertible into work and work can be convertible into heat.

However, it will not specify whether such a conversion is possible or not. It says only when conversion is possible, it must obey the law of conservation of energy.

So, to decide whether a process is possible or not, first we apply second law of T.D, After confirming it, then we have to use first law.

→ First law don't give direction, but the second law gives a direction. So, 1st of T.D is a non-directional law.

→ First law is quantitative law, but the second law is qualitative law.

→ First law fails, to state the conditions under which energy conversions are possible. etc.

Second law of Thermodynamics :-

Significance of 2nd law of T.D

→ 2nd law of T.D decides, whether the process is possible or not possible, through the development of "Concept of Entropy (S)"

→ 2nd law is a Directional law.

→ It is a Qualitative law

⇒ **TER** → Thermal Energy reservoir — 2 Types: Hot Source. / Cold Sink

Hot Source (or) Source:-

'Any amount of heat is withdrawn from it, the temperature remains unchanged' Eg: Sun, boiler furnace, Combustion chamber, nuclear reactor etc.

Cold Sink (or) Sink:-

"Any amount of heat is supplied to it, the temperature remains unchanged. Eg: Ocean (or) Sea water, Atmosphe...

The most common statements of 2nd law of T·D are the Kelvin - planck statement and the Clausius statement.

Kelvin - planck statement of 2nd law of T·D:-

Def:- "It is Impossible, to Construct a reversible cyclic engine which produces work continuously by sharing heat with single fixed temperature reservoir."

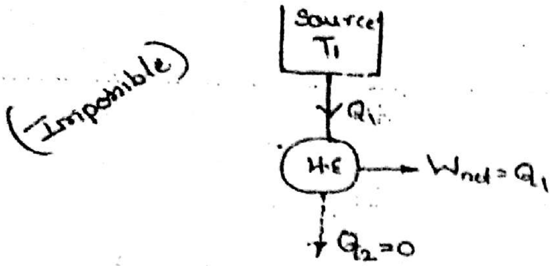
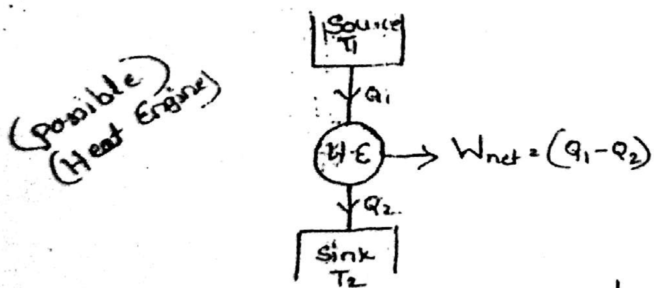


fig: PMM-II (it is impossible. Acc to Kelvin-planck)
(or)
Violating of Kelvin- plank statement.

→ Acc to 1st law of T·D, PMM-I is impossible, but PMM-II is possible.

→ But, Acc to 2nd law of T·D PMM-II also Impossible, possible one is Heat Engine, Heat pump & Refrigerator etc.

Possible Kelvin - planck statement Eg: $\boxed{\text{Heat Engine}}$



→ Heat engine receives energy as heat from a high temperature (Source T_1) body, converts part of it into work and rejects the rest to a low temperature (Sink, T_2) body.

→ The performance of the Heat Engine is calculated by using efficiency (η)

ie Thermal efficiency $(\eta_{th}) = \dfrac{\text{Net work output}}{\text{Total heat supplied}}$

$$\eta_{th} = \frac{W_{net}}{Q_1}$$
(or)
$$\eta_{th} = \frac{Q_1 - Q_2}{Q_1}$$
(or)
$$\eta_{th} = 1 - \frac{Q_2}{Q_1} \quad \text{(or)} \quad \eta_{th} = 1 - \frac{T_2}{T_1}$$

Clausius statement of Second law of T.D:

Defⁿ: "It is impossible to construct a device which operating in a cycle, will produce no effect other than the transfer of heat from lower temperature to a body at higher temperature."

(Impossible)

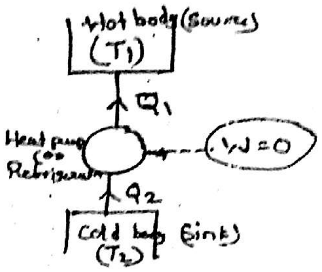
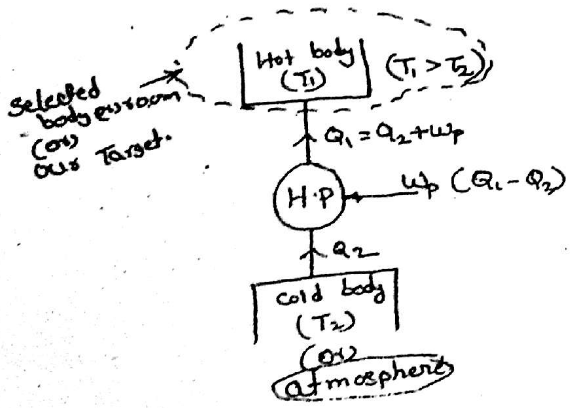


fig: Violating of Clausius statement

Possible Clausius statements are:

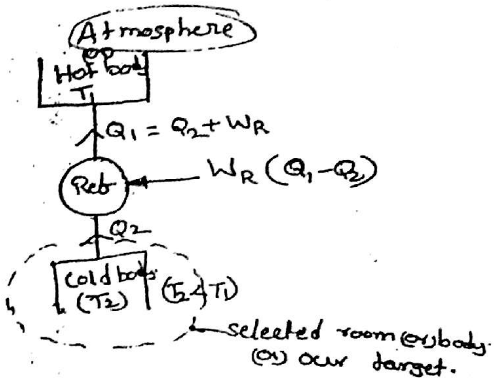
Eg: ① Heat pump

Defⁿ: A Heat pump is a device, operating in a cycle, maintains a body (room) at a temperature higher than the temp. of the surrounding (or) atmosphere.



Eg: ② Refrigerator.

Defⁿ: "A Refrigerator is a device, operating in a cycle, maintains a body (room) at a temperature lower than the temp. of the surroundings".



⇒ The performance of a Heat pump or Refrigerator is expressed in terms of Co-efficient of performance (C.O.P).

ie, $C.O.P = \dfrac{\text{Useful output (desired effect)}}{\text{Required Input (as work)}}$

$$(C.O.P)_{H.P} = \frac{Q_1}{W_p} = \boxed{\frac{Q_1}{Q_1 - Q_2}} = \boxed{\frac{T_1}{T_1 - T_2}}$$

$$(C.O.P)_{Ref} = \frac{Q_2}{W_R} = \boxed{\frac{Q_2}{Q_1 - Q_2}} = \boxed{\frac{T_2}{T_1 - T_2}}$$

$$\Rightarrow (C.O.P)_{H.P} = \boxed{1 + (C.O.P)_{Ref}} = \frac{1}{\eta_E}$$

Third law of Thermodynamics:

Third law of thermodynamics states that "the entropy of pure crystaline substance at the absolute zero temperature is zero

ie, $\Delta S = 0$ [at $-273°C$]