EN-203 Thermodynamics and Energy Conversion

EN-203 Notes

Introduction

Thermodynamics → Energy Transfer.
It's effect physical Properties

→ based on common experiences ⇒ Law of Thermodyanamics.

All field of Energy → Steam, nuclear P.P, IC engines, gas turbines, AC, fuel cell etc.

History :-

→ Lavoiser (1743–94) → Combustion Process.

→ Carnot (1796–1832) → Carnot Cycle. His work lead to 2nd law of Thermodyanamics.

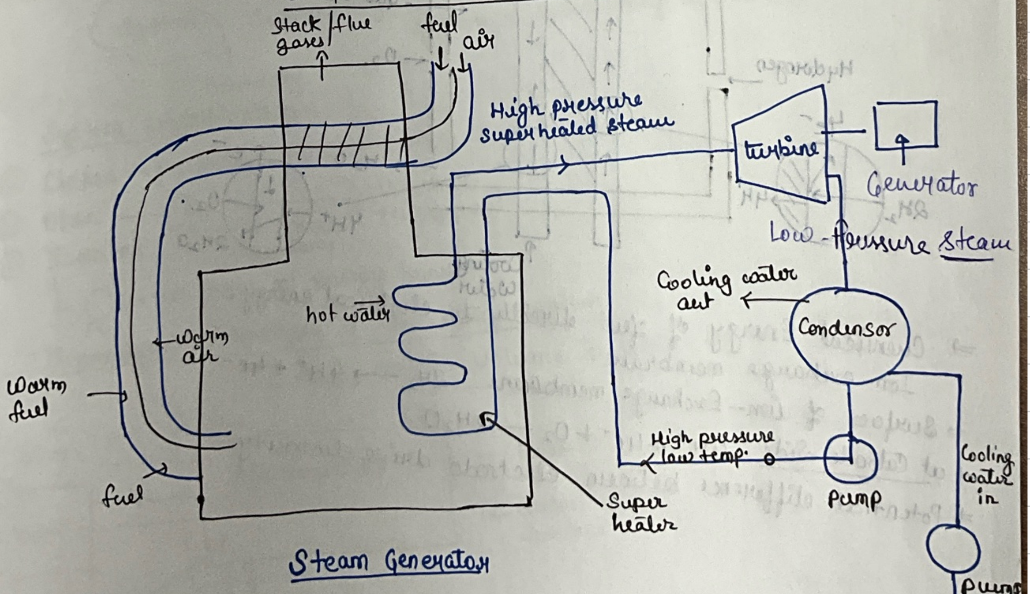
→ Joule (1818–1889) → heat is a form of energy - led to formation of Ist law of thermodynamics.

→ Thompson (1824–1907) → temp. Scale. absolute temp. Scale named after him.
(Kelvin) → discovery of available Energy

→ Clausius (1822–1888) → deal with abstract quantity "entropy".

→ Gibbs (1839–1903) → Thermodynamics, statistical mechanics, chemistry & Mathematics.
disreputed for odd ideas (not paid for 9 years)

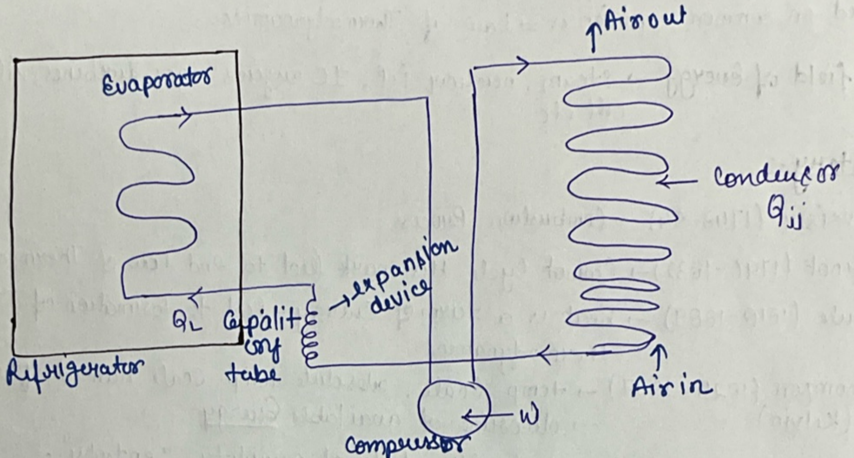
Simple Steam Power Plant



Steam Generator

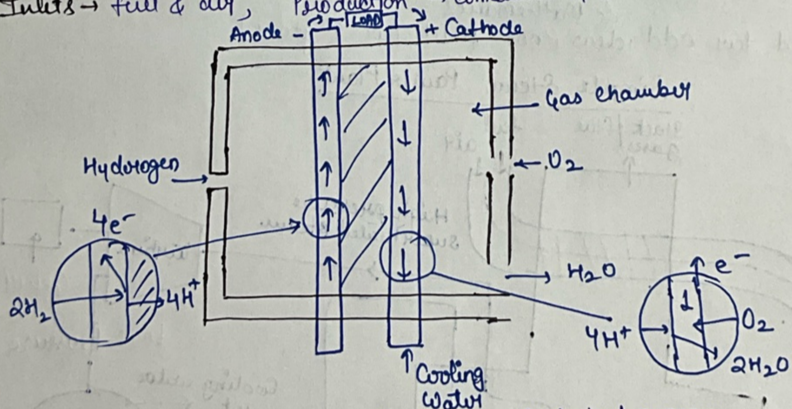
Domestic Refrigerator

→ Evaporator
→ Condenser
→ Expansion device



Fuel Cells

Inlets → fuel & air, Production → Combustion Gas



⇒ Chemical Energy of fuel directly to electrical energy.
Ion-exchange membrane.

⇒ Surface of ion-Exchange membrane $2H_2 \longrightarrow 4H^+ + 4e^-$

⇒ at Cathode Side $4H^+ + 4e^- + O_2 \longrightarrow 2H_2O$.

⇒ Potential difference between electrode drive electricity.

(4) **Macroscopic Vs Microscopic Viewpoint** ☐ → certain quantity.

Matter
- → Macroscopic → without consideration of molecular level
- ↳ Microscopic → myriad of molecules
  e.g. velocity, position, energy } for each molecules there changes very frequently via collision.

Behaviour of Gas ⇒ assuming up the behaviour of each molecule.
(microscopic or Statistical themodyanamics)

e.g. Macroscopic pressure
⇓
average rate of change in momentum due to molecular collision per unit area.

→ Macroscopic pressure measured using guage pressure

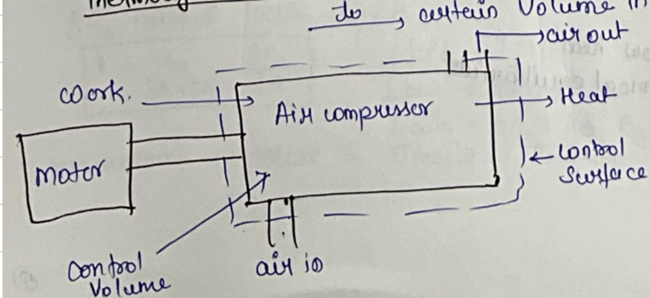
However,
all macroscopic properties classical thermodynamics properties can be derived from microscopic and statistical study of matter.

(5) **Thermodynamic System and Control Volume** -
⇓
Quantity of matter or a region space
⇓
everything outside /external called surrounding or environment.

(System) Surrounding System + surrounding ⇒ Universe.
↑
Boundary.

System! Classification -
- (a) Closed → no mass transfer across boundary.
  ↳ Energy → ◯ → No mass, → energy out
- (b) Open → ↳ matter crosses boundary
- (c) Isolated
  ↳ ☀ → no mass or energy transfer.

Thermodynamic analysis of an open system
To → certain Volume in space.



(6) Thermodynamic Properties, processes and Cycles:-

System Physical Characteristics defined by (V, T, P etc)

⇑

Properties of System

⇓

System in definite state.

→ Properties are co-ordinates to describe the state of the system (State variables)

→ Any operation when one or more of properties changes → state changes.

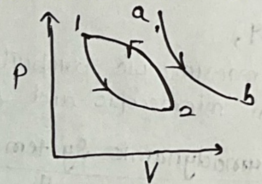
Succession of State change ⇒ Path

⇓

Path is specified ⇒ change of State is process.

Thermodynamic Cycle →

→ Series of state change such that the final state is identified by initial state



(7) Properties →

→ Intensive = independent of mass (P, T)

→ Extensive → related to mass (volume, energy etc)

⇓

extensive properties can be converted into intensive.

(eg. $\frac{\text{Volume}}{\text{Mass}}$, $\frac{\text{Volume}}{\text{moles}}$) specific volume.

→ **Homogenous & Heterogenous System →**

★ Thermodynamic Equilibrium → if system is isolated to surrounding & no properties changes → equilibrium.

★ Isolated system always reaches to equilibrium.

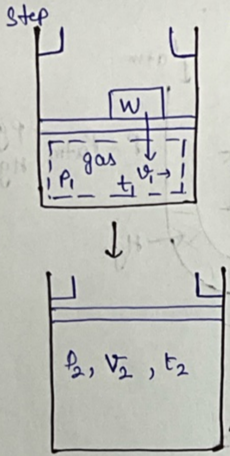
★ no-spontaneous changes in isolated system.

→ Thermodynamics studies mainly equilibrium properties.

→ Equilibrium → Mechanical
→ Chemical
→ Thermal

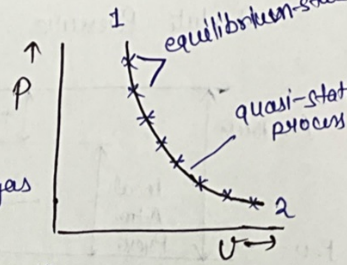
(8) Diathermal Wall → Only allow heat
↳ for mechanical & chemical equilibrium.

Quasi-Static Process



→ initially equilibrium state
→ P_1, v_1, t_1
weight of piston
balance force extorted by gas

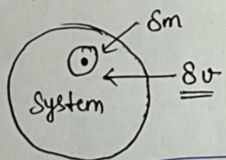
⇒ weight is removed
⇒ Under gas pressure system will move.

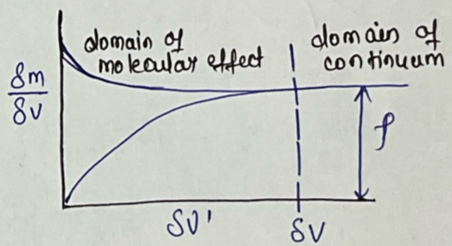


→ final equilibrium state.
what as aut intermediate states → non-equilibrium
(which can't be defined by thermodynamic co-ordinates)

→ if single weight is made of small pieces & small pieces are removed one by one very slowly. (only depart from equilibrium will be infinitely small)

(9) Concept of Continuum

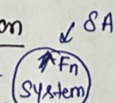




$$\boxed{\rho = \lim_{\delta v \to \delta v'} \frac{\delta m}{\delta v}}$$

→ No continuum if mean free path ~ diamension of vessel.

(10) Thermostatics — Unit & dimension



→ Pressure ⇒ normal force exerted by a system against unit area of the boundary surface.

→ if δA is small Area.
δA' is the smallest area where continuum is valid.
δF_n normal force to δA.

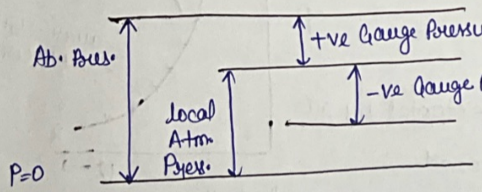
$$\boxed{P = \lim_{\delta A \to \delta A'} \frac{\delta F_n}{\delta A}}$$

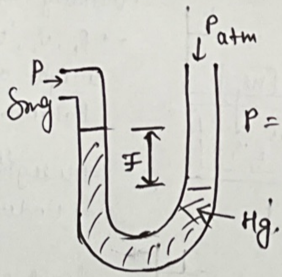
1 Pa = 1 N/m²
1 bar = 10^5 Pa
1 atm = 101,3.25 Pa

measurement → relative to atmosphere Pressure.

$P \geq 0$.

Absolute Pressure = Gauge Pressure + Atmosphere Pressure





$P = P_{atm} - \rho_{Hg} g z$

Energy → Joule or Nm (J)

Specific Energy J/kg , J/mole.

Power → rate of energy transfer.

$1W = 1 J/s = 1 Nm/s$

$1 kW = 1000 W.$