* Unit - 1 *
(Fundamental)

* Introduction to mech. Engg:-

mechanical engg. is one of the core branches of engg. that deals with the design, analysis, manufacturing and maintenance of mechanical systems. It combines principles from physics & materials science to develop machinery & mechanical systems for various application in industries, automobiles, aerospace, energy & more.

Concept of Thermal engg:-

Thermal engg focuses on the study of heat energy & its transfer, conversion & management in mechanical system.

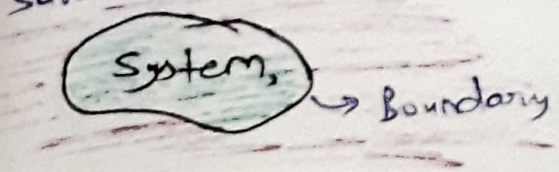
it includes - - Thermodynamics
- Heat transfer mechanism
  - Conduction
  - Convection
  - Radiation
- Thermal system - Engine, Refrigerators, power plant, IC engine.

Conservation of energy - energy can't be created or destroyed. only transformed from one to another.

System - A quantity of matter or a region in space chosen for study.

Surrounding - The mass or region outside the system.

Boundary - Real / imaginary
That separate the system & surrounding



* Types of System -

Isolated system	Closed system	Open system
Neither mass nor energy can cross the boundary. Ex well-insulated, closed thermos bottle	Only energy can cross the boundary Ex A tightly capped cup of coffee.	Only both mass & energy can cross boundary. Ex Air compressor

Thermodynamic properties -

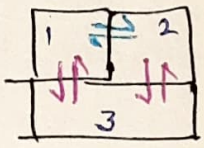
- Intensive - Are independent of amount of mass.
  Ex Temp, Pressure, density
- Extensive - varies directly with the mass
  Ex - mass, volume, energy, enthalpy

Relation: Intensive = Extensive / m
(Specific Properties)

Thermodynamic Law

(1) Zeroth law of Thermodynamic -

" If two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.



2) First law of Thermo -

(Energy conservation law)

In thermodynamic system, net heat supplied to the system from surrounding is equal to net work done by system on surrounding.

$$dW = pdV \iff dU = dQ - dW$$

- dU : Internal energy
- dQ : enthalpy
- dW : work done

Second law of thermo -

According to clausius - It is impossible to construct a device which operates on a cycle to which can convert whole work done into heat some losses of heat occurs.
in other way, Efficiency cannot be 100%.

* Thermodynamic Process

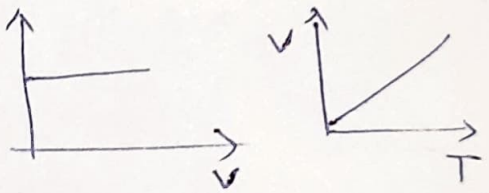
- **Reversible process** - System & surrounding can be returned to their original state.

Δ entropy = 0, cyclic process. (equilibrium state)

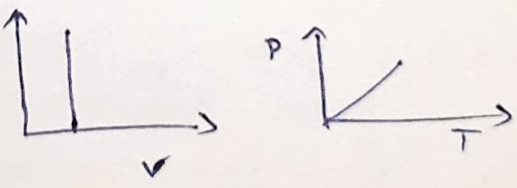
- **Irreversible Process** - Non-equilibrium state.
  Initial point & final point are different.
- **Cyclic Process** - Initial & final point are same.
  total internal energy = 0

$$\boxed{\Delta U = 0}$$

- **Isobaric Process** -
  Pressure remains constant $\Delta P = 0$
  $P_1 = P_2$
  Work done (W) $= \Delta V \cdot P$
  $PV = nRT \Rightarrow (V \propto T)$

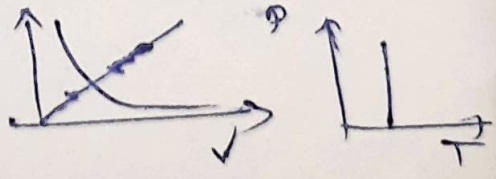


- **Isochoric Process** -
  Volume remains constant.
  $\boxed{W = 0}$ $\Delta V = 0$
  $PV = nRT \Rightarrow P \propto T$



- **IsoThermal Process** -
  Temp. remains constant $\Delta T = 0$

$$\boxed{W = nRT \ln\left(\frac{T_2}{T_1}\right)}$$



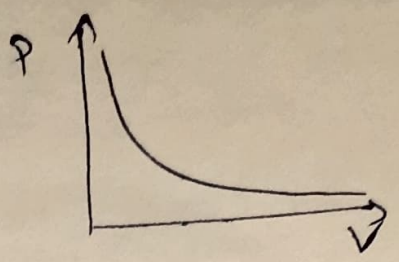
- **Adiabatic Process** –

No Heat exchange

$$\boxed{\Delta Q = 0}$$

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

$$\gamma = \frac{C_P}{C_V} \quad \& \quad \boxed{PV^{\gamma} = \text{Constant}}$$



* **Heat transfer** → Transfer of heat between bodies or within a body due to temp difference.

modes

Conduction Transfer of heat through a solid from high to low temp. (without any movement)

$$\left(Q = -kA\frac{dT}{dx}\right)$$

Convection Transfer of heat in a fluid ~~condu~~ due to combined effect of fluid motion & conduction. $(Q = hA(T_s - T_\infty))$

Radiation – Transfer of heat through electromagnetic waves without any medium.

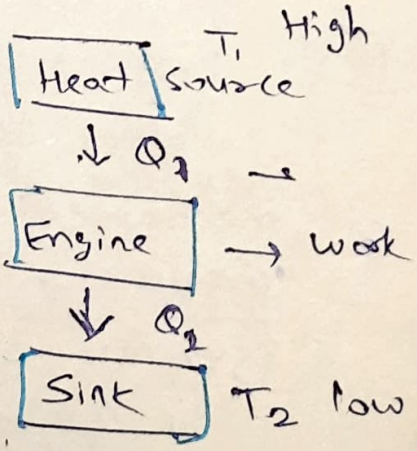
$$\boxed{Q = \epsilon \sigma A T^4}$$

* **Heat engine** – converts heat energy → Mechanical energy.

↳ hot source
↳ Cold sink.

working

- Absorbs Q_1 of hot source
- convert into Work (W)
- Remaining Q_2 is rejected to sink.
- working fluid returns into initial state & cycle →



Efficiency :- ratio of work output to heat input

$$\eta = \frac{W}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

for carnot Heat engine.

$$\eta = 1 - \frac{T_2}{T_1}$$

(T_2 → Sink, T_1 → Heat)

Note: Automobile => IC engines.
Power plants => steam turbines.

* Mechanical machine design :- mechanical machine design involves the creation of mechanical components & systems that meet specific fuctional requirement under defined constraints.

- Design principle - stress - strain analysis, factor of safety.
- Machine element - gear, bearing, shaft, spring.
- .

* Industrial engineering - It aims to optimize complex processes, systems or organizations

It involves

- Operation research.
- Production planning
- Quality control & sy supply chain management.
- Focuses on efficiency, productivity, cost reduction

Note: Properties of steam -

Vapor form of water, widely fused in mechanical & thermal engg.

pressure, temp, enthalpy, entropy, internal energy

Dryness fraction.

(0 to 1)

* Steam boiler :-

It is a closed vessel in which water is heated to produce steam using the heat energy from combustion of fuel. Generated steam is used in power generation, industrial heating & mechanical work.

main components

- Furnace - Provide heat by fuel combustion.
- Safety valve - avoid over pressure.
- Steam stop valve - Stop & regulate steam flow
- Vent valve - To vent air from steam drum during starting
- pressure gauge → To indicate steam pressure inside
- Boiler Drum - Stores water & steam.

Working [Same For all type of boiler]

(1) Fuel combustion in Furnace -

→ Fuel is burned in the Furnace. This combustion release a large amount of heat energy.

(2) Heat transfer to water -

→ The heat from the burning fuel is transfer to water stored in the boiler's drum or shell. It occurs due to conduction / convection.

(3) water converts to steam -

→ As water absorbs heat, its temp ↑ & eventually reaches at boiling point.

→ water evaporates into steam.

(4) Steam collection & Delivery

→ The steam rises & collects in the steam space above water level.

→ It is ~~drained~~ drawn out via steam stop valve

(5) Fuel gases exit through chimney.

* Classification of steam boiler

- Based on Axis
  Horizontal & Vertical boiler
- Based on Flow of water & Hot gases
  Fire tube & water tube boiler
- Based on pressure
  Low pressure & High Pressure

Boiler type	Feature
• Cochran boiler	Vertical, fire tube, compact shaped.
• Lancashire boiler	Horizontal, fire tube, large shaped.
• Babcock & wilcox	Water tube, high pressure, efficient Horizontal.
• Locomative Boiler	Horizontal, mobile, fire tube.

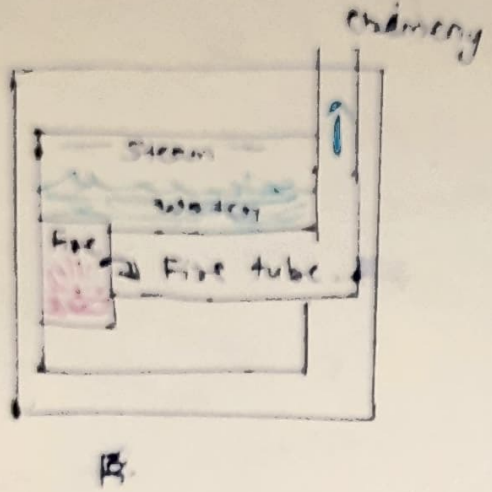
Horizontal Boiler - Horizontal shell & tubes.
High efficiency, steam output high, longer size, easy maintenance

Vertical Boiler → Vertical shell & tubes.
low efficiency, steam output low, compact size, Harder maintenance.

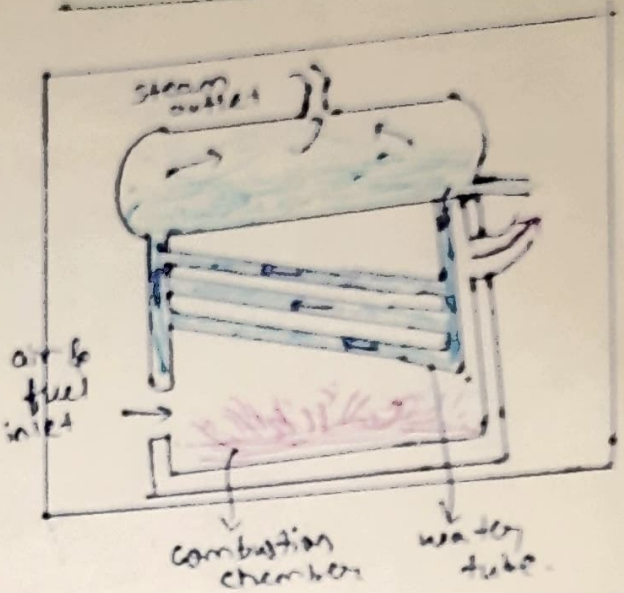
Advantages ...

* Fire tube and Water tube boiler:

Fire tube boiler



Water tube boiler



i) It is compact in construction	– It is not compact.
ii) Capicity range = 12000 kg/hr	– Capicity range = 4500 to 12000 kg/hr
iii) Obtained 18 kg/cm² pressure	– Very high pressure in order 140 kg/cm² obtained.
iv) transportation is easier.	– Transportation is difficult.
v) It is cheap in cost	– Expensive in cost.
vi) Time taken is large & less efficiency.	– large heating surface & high efficiency
vii) Fuel gases (hot) in pipes water outside	– water in pipes. fire outside
viii) Rate of steam production is lower	– Rate of steam production is higher.
ix) Water treatment is not so necessary.	– Water treatment is necessary.
~~used for trio~~	* Used for high steam demand & pressure requirement.
Ex: Cochran, locomotive boiler, lancashire boiler	Ex: Babcock, Wilcox, boiler.

Selection of a boiler -

→ Working pressure & quality of steam
→ Boiler generation rate
→ Floor area available
→ Accessibility for repair & inspection.
→ The fuel & water available.
→ Operating & maintenance cost.

* Steam Turbine :-

A Mechanical device that converts thermal energy of steam into mechanical work (rotational energy).

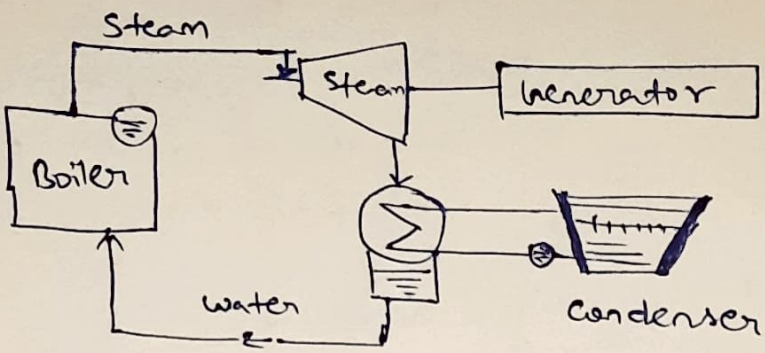
Component -

Nozzles - Converts steam pressure into high velocity jets.
Rotor (Shaft) - Hold the rotating blade & transmit torque.
Blades - Steam strike these to rotate
Casing - Encloses the turbine & maintain Pressure
Bearing - Support the rotor & reduce friction.
Governer - Control speed of Turbine.
Condenser - Converts exhaust steam back to water.

* Working - High pressure steam form the boiler enters the turbine.
- Steam is directed onto blades & nozzles arranged on a rotor.
- The force of steam pushes the blades, causing the rotor to spin.
→ As the steam expands, it loses pressure & temp.
→ The shaft rotation is used to drive a generator pump or mechanical equipment.

Type Impulse Turbine – steam expansion in nozzel only, hits moving blades with high velocity.

Reaction Turbine – Steam expands in both fixed & moving blades.



Advantage – High efficiency for large power generation
- Smooth & continuous rotary motion.
- Suitable for high pressure & temp condition
- low maintenance & long life.

* Power Plant Power plant is an industrial unit where electric power is generated from natural or artificial energy source. Then transmitted to homes industries & comercial facilities.

Types – Nuclear Power Plant
Thermal Power Plant
Diesel Power Plant
Steam Power Plant.

(1) Nuclear Power Plant – Heat energy is generated by splitting atoms in a reactor, which then produce steam & generate electricity by steam turbine

Components

Nuclear reactor – Site of the fission reaction, generates heat.

Fuel rods – Contain enriched uranium or plutonium U^{235} or Pu^{239}

Moderator – Slow down neutrons Commonly Heavy water (D_2O) or graphite.

Control rods – Absorbs excess neutrons to regulate the reaction. (Boron / Cd)

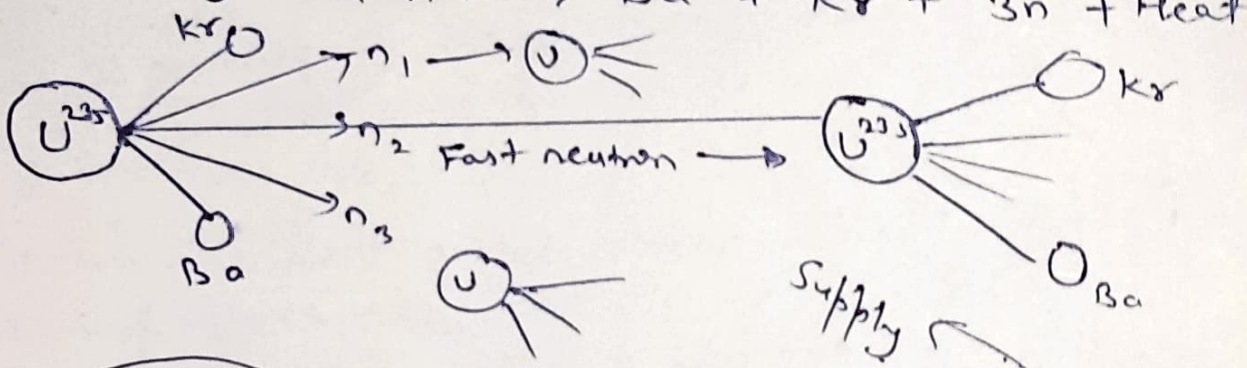
Coolant – Tranfer heat from reactor to steam generator.

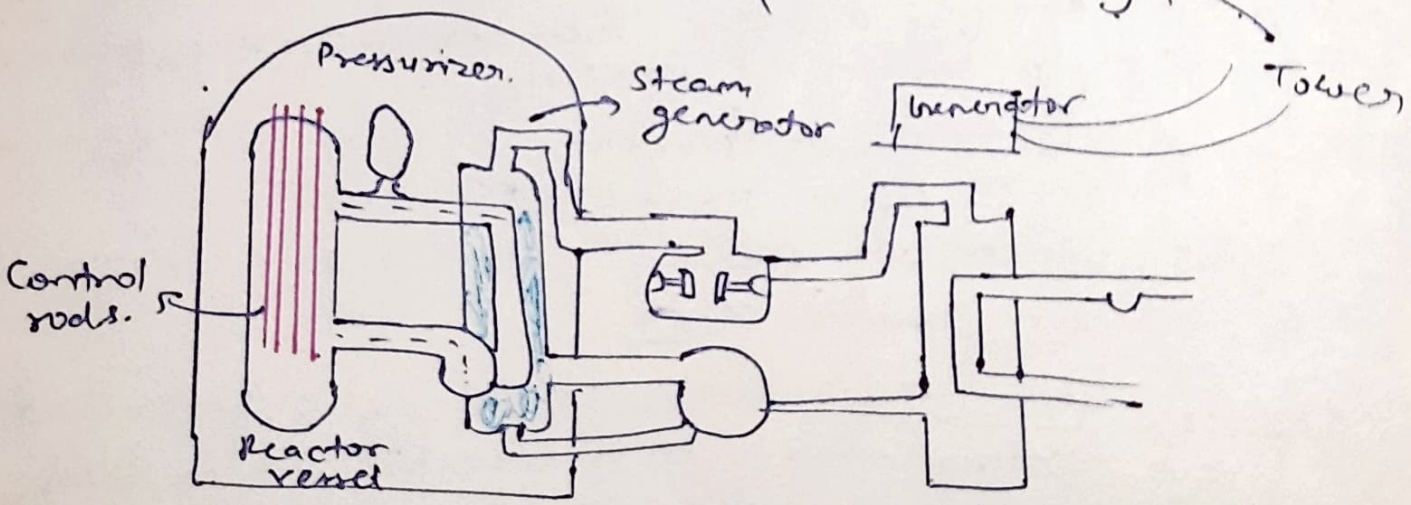
Steam generator, condenser.

Containment Building – Sealed structure to prevent leakage of radiation.

Reaction

$$U^{235} + n \longrightarrow Ba^{141} + Kr^{92} + 3n + \text{Heat}$$

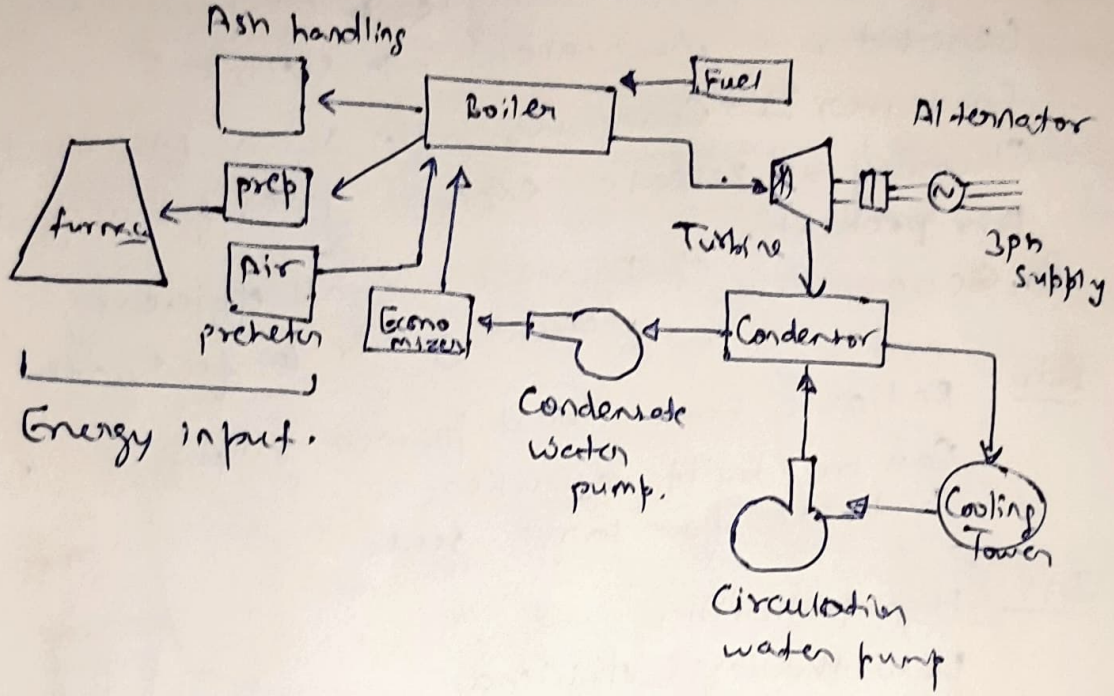




Advantage → emit low amount of CO_2,
→ emission of green house gases less.
→ Readily available.
→ Generate high amount of energy

Disadvantage → Radioactive waste
→ High Risk.
→ It can be misused as terrorist attacks or nuclear weapons.

(2) Thermal (steam) Power Plant:-



Power generating system that converts chemical energy of fuel into thermal energy → mechanical energy. → electrical energy.

working.

- Fuel combustion → coal is burned in boiler to produce heat.
- Steam generator → heat converts water into high pressure steam.
- Steam expension → Steam is directed into blade of a turbine, causing it to spin.
- power generation → turbine shaft + generator ⇒ Power

- **Condensation** exhaust steam is passed into a condensor, where it is cooled & condensed back into water.
- **Water circulation** - Feed pump sends the condensed water back to the boiler.

Components

Boiler - converts water into steam
Superheater → Increase temp of steam
Turbine → thermal energy ⟺ mechanical energy
Generator → mechanical → electrical
Condenser → Condenses ~~wat~~ steam into water.
Chimney → Release exhaust gases from combustion
Air preheater & Economizer → Increase overall efficiency by preheating air & feedwater

Adv
Reliable base-load power supply
Can be built anywhere.
Suitable for large scale

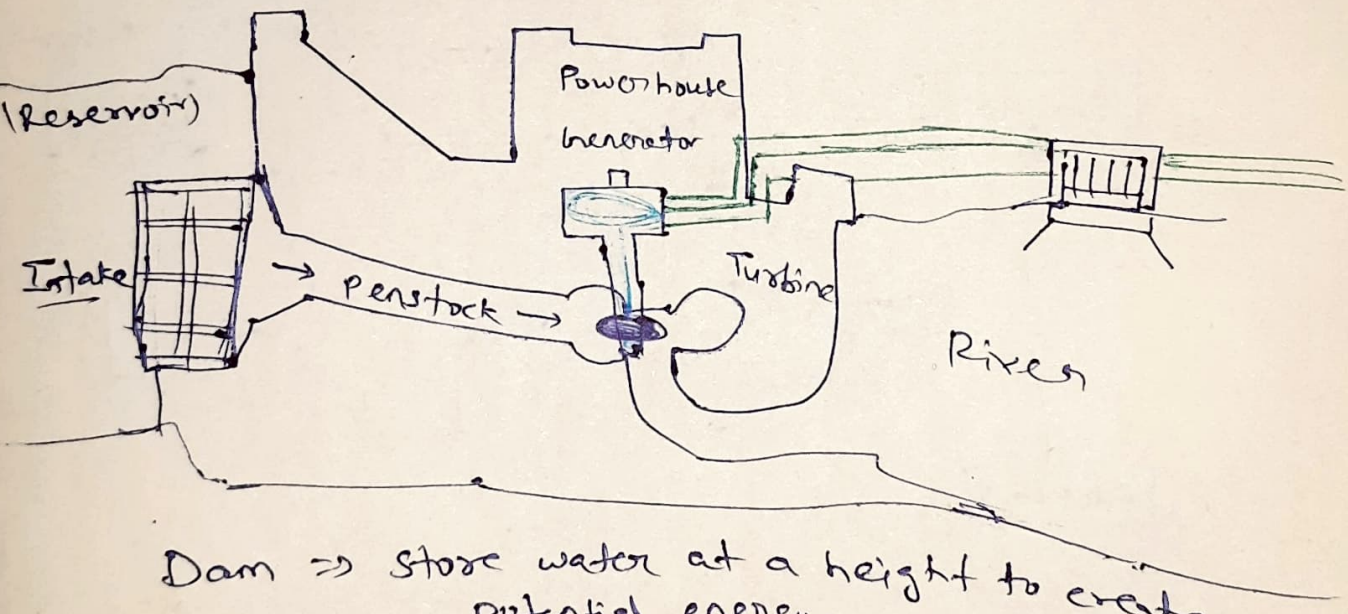
Dis
High pollution
Low thermal efficiency.
High water consumption.

Hydroelectric Power Plant :-

It is a renewable energy facility that generates electricity by harnessing the energy of falling or flowing water to spin a turbine connected to a generator.

Working

- **Water storage** - Water stored at height in a dam reservoir.
- **Water flow** - Water is released through a penstock
- **Turbin Rotation** - The force of water turns the turbine blades at the base.
- **Electricity generation** - The rotating turbine shaft spins a generator, producing electricity
- **Water Discharge** - After passing through the turbine water is discharged back into the river.



Dam ⇒ Store water at a height to create potential energy.

Penstock → A pressure conduit that carries water from the reservior the turbine

Surge tank ⇒ Controls pressure variation in penstock

Diesel power Plant -

A diesel power plant is a power generating station in which a diesel engine is used to drive an alternator for generating ~~activity~~ electricity.

Working

Air intake - Air is drawn into the engine cylinder.

Compression - The piston compresses the air, raising its temperature.

Fuel injection - Diesel is injected and auto ignites due to high temp.

Power stroke - Explosion forces piston downward, rotation the crankshaft.

Exhaust - Burnt gases are expelled through the valve

Power generation - The rotating crankshaft turns the alternator to generate electricity