# Heat Engine :

Device that chemical energy (fuel) → Thermal Energy → Mechanical Energy

**EC Engine** : Combustion outside the engine

ex : steam turbine

**IC Engine** : Combustion inside the engine

ex : petrol, diesel, CNG etc.,

classification

- No. of Strokes
  - 2 (banned)
  - 4
- Nature of Thermodynamic cycle
  - Otto
  - Diesel
  - Dual
- Ignition Systems
  - Spark
  - Compression
- Fuel Used
  - Gas
  - Petrol
  - Diesel
  - Bi-fuel
- Arrangement of cylinders
  - In-line
  - V-type
  - opposed Cylinder
  - opposed Piston
  - Radial
- Cooling Systems
  - Water
  - Air
- Fuel Supply
  - Carbeurator
  - Air injection
  - Airless/solid Mechanical injection

## Arrangement of Cylinders

→ **In-line** : 1 Cylinder Bank, All Cylinders arranged linearly, transmit power to single crankshaft

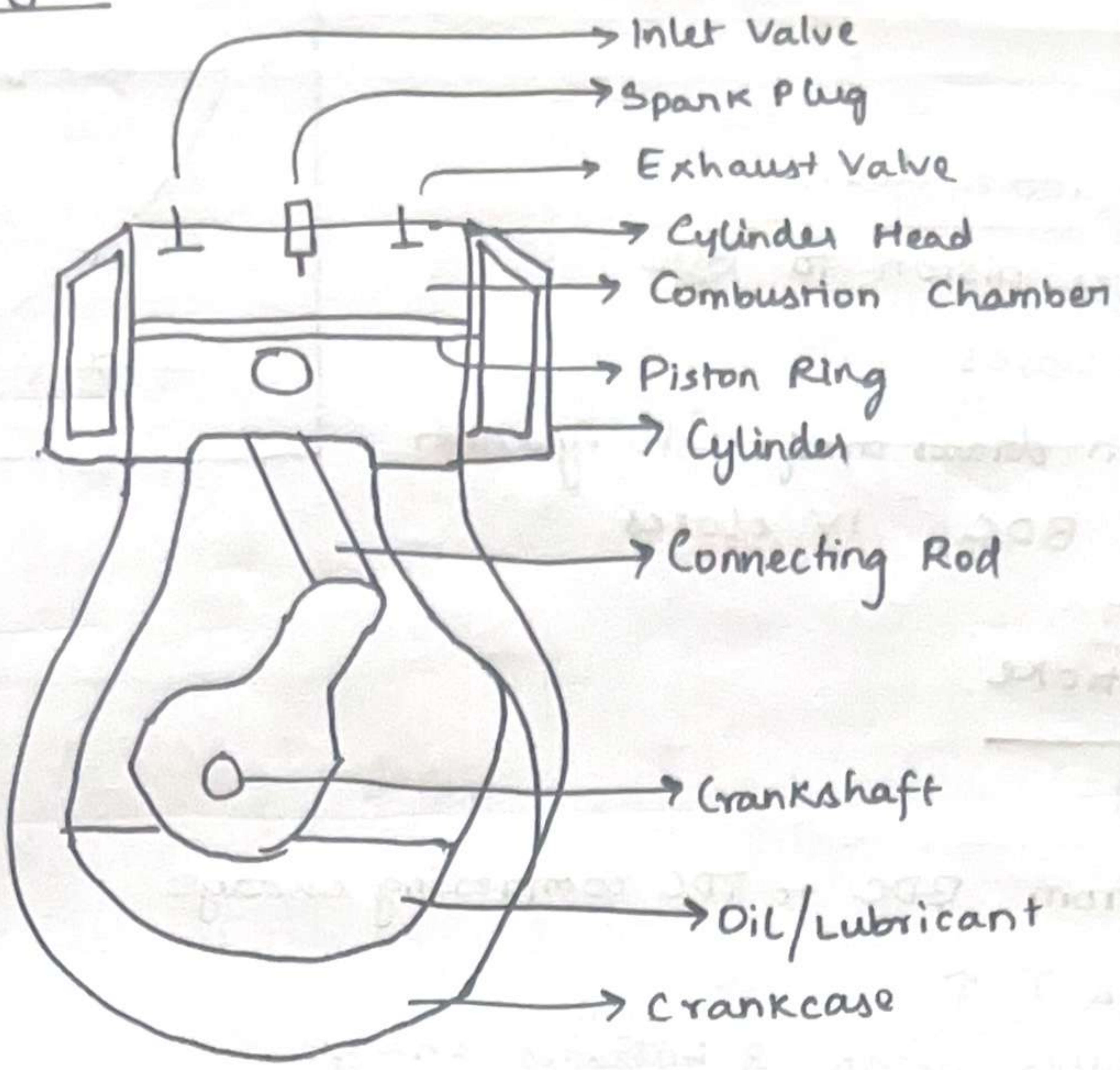
→ **V-Type** : 2 Cylinder Banks, inclinder at an angle to each other, 1 crankshaft, used if > 6 cylinders

→ **Opposed-cylinder** : 2 Cylinder Banks on opp. sides of crankshaft, 2 in-line arrangements 180° apart, used in small aircrafts

→ **Opposed-Piston** : 1 cylinder, 2 pistons, each driving diff. crankshafts movement is synchronised by coupling crankshafts

→ **Radial** : More than 2 cylinder in each row equally Spaced around crankshaft, used in air-cooled air craft engines

IC Engine :




Cylinder : Hollow cylindrical structure, closed in 1 end ~~other end~~ with cylinder head, combustion inside cylinder, heart of engine Produces power, high thermal conductivity & hard material

Cylinder Head : Covers 1 end of cylinder, has valves/ports & spark plug / injector

Piston : Placed inside cylinder, connected to connecting rod with gudgeon pin, Transfers power produced by combustion of fuel to crankshaft

Piston Rings : Outer periphery of piston has several grooves into which they are fitted, upper ring → compression ring, ↳ compress air/ air-fuel mixture
lower rings → oil rings
↳ collect surplus lubricatant on surface

Connecting Rod : Connects piston & crankshaft, smaller to piston, larger to crankpin
It transfers reciprocating motion of piston to rotary motion of crankshaft

Valves : Mushrom shaped poppet type, regulates charge inflow & combustion product's outflow

Crankcase : Bottom portion of cylinder, sump for lubricating oil

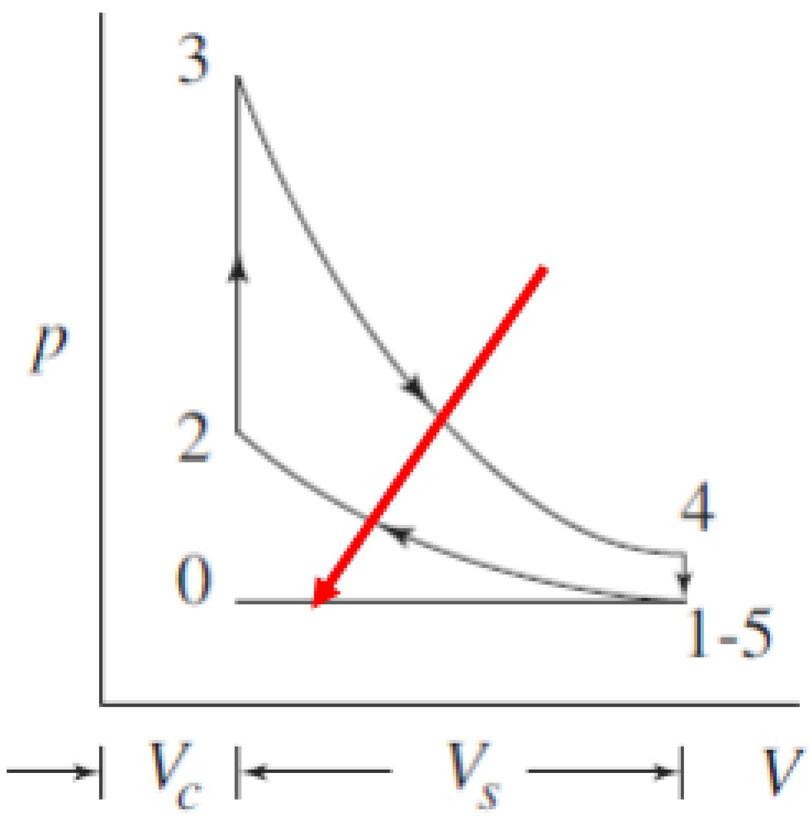
Flywheel : Heavy wheel mounted on crankshaft to minimize cyclic variations, absorbs energy during power-stroke & releases energy during non-power-stroke

Crankshaft : Principal rotating part of engine which controls sequence of reciprocating motion of pistons. Consists several bearings & crank pins

# 4S Petrol Engine Working

## 1) Suction Stroke

(0→1) • Piston at TDC, moves down
- Crankshaft moves piston to BDC
- IV opens, EV closes
- Suction of piston draws charge into cylinder
- Piston reaches BDC, IV closes




## 2) Compression Stroke

(1→2) • IV & EV closed
- piston moves from BDC to TDC compressing charge
- Volume ↓, P & T ↑
- spark plug initiates spark & ~~initiates~~ ignites charge

(2→3) • P ↑ const. volume

## 3) Power Stroke

- IV & EV closed
- Piston moves TDC to BDC by pressure from burning gas

(3→4) • V ↑ Pres ↓

(4→5) EV opens, hot gas discharges at const. volume

## 4) Exhaust Stroke

- IV closed
- Piston moves BDC to TDC & pushes remaining gas out

(5→0) • P const, V ↓
- EV closes

## 4S Diesel Engine Working

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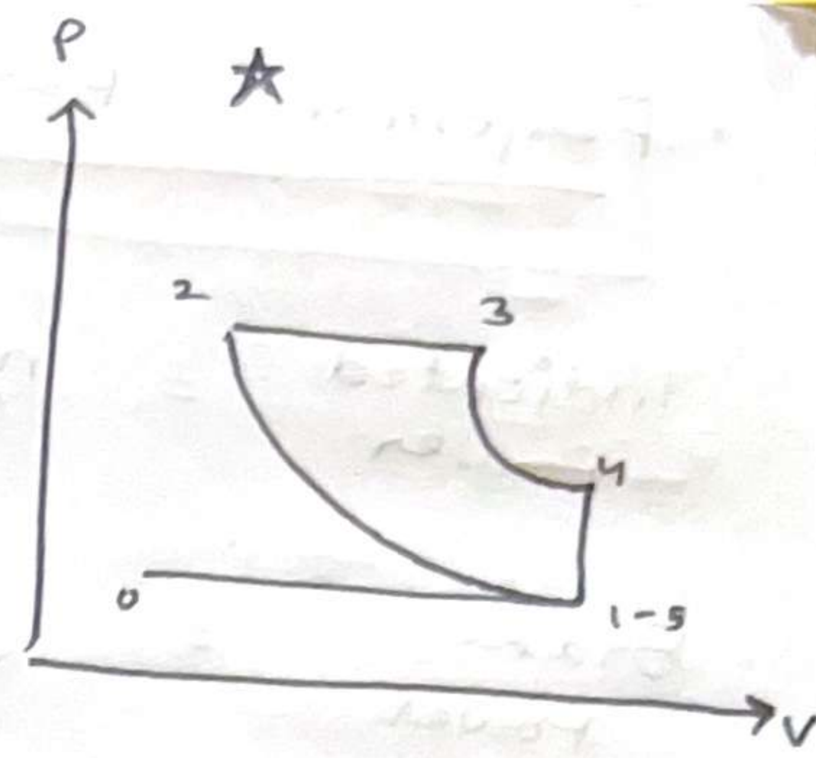


### 1) Suction Stroke

(0→1) • Crankshaft moves piston TDC → BDC
- IV open, EV closed
- Suction causes air to enter cylinder.
- IV closes

### 2) Compression Stroke

- IV & EV closes
- Piston BDC ⟶ TDC

(1→2) • Volume ↓ P ↑
- fuel injector opens, fine spray of fuel enters & burns

(2→3) • P constant, V ↑
- Fuel supply cut off

### 3) Power Stroke

- IV & EV closed
- Hot gas pressure push piston TDC → BDC

(3→4) • V ↑, P ↓

(4→5) • EV opens, hot gas escape at const Volume

### 4) Exhaust Stroke

- IV closed
- Piston BDC → TDC
- Pushes remaining gas out
- P const, V ↓
- EV closes

- Performance Parameters of IC Engine

Indicated Power $= \dfrac{n P_m LANK}{60 \times 1000}$ ; $P_m = \dfrac{Sa}{l}$

Brake Power $= \dfrac{2\pi NT}{60 \times 1000}$ ; $T = (W-S)\dfrac{(D+d)}{2}$

Friction Power $=$ IP $-$ BP

Mechanical Effeciency % $= \dfrac{BP}{IP} \times 100$

Indicated Thermal efficieny $= \eta_{ith} = \dfrac{IP}{CV \times m_f}$

Brake Thermal efficiency $= \eta_{bth} = \dfrac{BP}{CV \times m_f}$

Indicated specific fuel consumption $= \dfrac{\text{mass of fuel consumed (kg/hr)}}{\text{IP (kW)}}$

Brake specific fuel consumption $= \dfrac{\text{mass of fuel consumption (kg/hr)}}{\text{BP (kW)}}$

# Performance Parameters Numericals

1. The following data refers to a test on single cylinder engine working on 4 stroke cycle:

Diameter of Brake drum = 60cm

Rope diameter = 3cm

Load on brake drum = 25kg

Spring balance reading = 5kg

speed of engine = 400 rpm

Area of indicator diagram = $4cm^2$

Length of indicator diagram = 6cm

Spring stiffness = 12 bar/cm

Bore = 10 cm

Stroke = 15cm

calculate i) IP (ii) BP (iii) Mech efficiency

A. $IP = \frac{n P_m L A N K}{60 \times 1000}$ ; $P_m = \frac{sa}{l} = \frac{12\ bar/cm \times 4cm^2}{6cm} = 8\ bar$

$= 8 \times 10^5\ N/m^2$

$$IP = \frac{1 \times 8 \times 10^5 \times 15 \times 10^{-2} \times \frac{\pi}{4} \times (10 \times 10^{-2})^2 \times 400 \times \frac{1}{2}}{60 \times 1000}$$

$$= \frac{120 \times 10^3 \times \pi}{60 \times 1000 \times 2} = \pi = 3.14\ KW$$

$BP = \frac{2\pi N T}{60 \times 1000}$ $\quad T = (W - S) \times \left(\frac{D+d}{2}\right) = (25-5) \times 9.81 \times \left(\frac{0.6+0.03}{2}\right)$

$= 61.803\ Nm$

$$= \frac{2\pi \times 400 \times 61.803}{60 \times 1000}$$

$= 2.589\ KW$

$\eta_{mech} = \frac{BP}{IP} = \frac{2.589}{3.141} = 0.8241 = 82.41\%$

2. The following observations are taken during trial on 4S engine

Cylinder diameter = 25cm

Stroke = 40cm

Speed = 250rpm

Brake load = 70kg

Brake drum diameter = 2m

Mean effective pressure = 6 bar

Diesel oil consumption = 0.1 lit/min

Specific gravity of fuel = 0.78

Calorific value of fuel = 43900 kJ/kg

Determine i) IP ii) BP iii) $\eta_{mech}$ iv) $\eta_{BTh}$ v) $\eta_{ITh}$

A. i) $IP = \frac{n P_m L A N K}{60 \times 1000} = \frac{1 \times 6 \times 10^5 \times 40 \times 10^{-2} \times \frac{\pi}{4} \times (25 \times 10^{-2})^2 \times 250 \times \frac{1}{2}}{60 \times 1000}$

$= \frac{\pi \times 625 \times 10^{-4} \times 250}{2} = 24.54 \text{ kW}$

ii) $BP = \frac{2\pi NT}{60 \times 1000} = \frac{2\pi \times 250 \times 70 \times 9.81 \times \frac{2}{2}}{60 \times 1000} = 17.98 \text{ kW}$

iii) $\eta_{mech} = \frac{BP}{IP} = \frac{17.98}{24.54} = 0.7326 = 73.26\%$

iv) $\eta_{BTh} = \frac{BP}{m_f \times CV} = \frac{17.98}{\frac{0.1 \times 0.78 \times 1000}{60 \times 1000} \times 43900} = 0.315 = 31.5\%$

v) $\eta_{ITh} = \frac{IP}{m_f \times CV} = \frac{24.54}{\frac{0.1 \times 0.78 \times 1000}{60 \times 1000} \times 43900} = 0.4299 = 42.9$

3. A 4 cylinder 4S engine develops 30 KW at 2500 rpm. Mean effective pressure on each piston is 8 bar & $\eta_{mech}\% = 80\%$. Calculate diameter & stroke of each cylinder. $\left(\frac{L}{d} = 1.5\right)$

A. $\eta_{mech} = \frac{BP}{IP}$

$$IP = \frac{BP}{\eta_{mech}} = \frac{30}{0.8} = 37.5\ KW = \frac{nP_m LANK}{60 \times 1000}$$

$$37.5 = \frac{4 \times 8 \times 10^5 \times L \times \frac{\pi}{4} d^2 \times 2500 \times \frac{1}{2}}{60 \times 1000} \Rightarrow Ld^2 = 7.16 \times 10^{-4}$$

$$\frac{L}{d} = 1.5 \Rightarrow 1.5d^3 = 7.16 \times 10^{-4} \Rightarrow d = 0.078\ m$$
$$= 78\ mm$$
$$L = 117\ mm$$

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4. A diesel engine develops 5KW. $\eta_{Ith} = 30\%$ & $\eta_{mech} = 75\%$. Estimate fuel consumption i) in Kg/hr ii) in lit/hr. Also find ISFC & BSFC. $CV = 42000\ KJ/Kg$ & specific gravity of fuel = 0.87

A. $BP = 5KW$

$$IP = \frac{BP}{\eta_{mech}} = \frac{5}{0.75} = 6.67\ KW$$

$$\eta_{ITh} = \frac{IP}{m_f \times CV} \Rightarrow m_f = \frac{6.67}{0.3 \times 42000} = 5.293 \times 10^{-4}\ Kg/s$$

$$= 5.293 \times 10^{-4} \times 3600\ Kg/hr = 1.9057\ Kg/hr \quad (i)$$

(ii) $$m_f = \frac{1.9057}{0.87 \times 1000} = 2.19 \times 10^{-3}\ m^3/hr = 2.19 \times 10^{-3} \times 10^3\ lit/hr$$

$$ISFC = \frac{m_f}{IP} = \frac{1.9057}{6.67} = 0.2857\ Kg/KWhr$$

$$BSFC = \frac{m_f}{BP} = \frac{1.9057}{5} = 0.38114\ Kg/KWhr$$

5. A six cylinder 4 stroke IC engine develops 50K of Indicated Power at MEP of 700 KPa. The bore & stroke length are 70mm & 100 mm respectively. If speed of engine is 3700 rpm, Determine average misfires per unit time

A. $IP = \frac{n P_m LANK}{60 \times 1000}$

$N \text{ (Theoretical Speed)} = \frac{IP \times 60000}{n P_m LAK}$

$= \frac{50 \times 60000}{6 \times 700 \times 10^3 \times 0.1 \times \frac{\pi}{4} \times (0.07)^2 \times \frac{1}{2}}$

$= 3712$ rpm

⇒ No. of cycles/min (or) No. of explosions/min $= \frac{N}{2}$

$= \frac{3712}{2}$

$= 1856$

⇒ Actual explosions/min $= \frac{N'}{2} = \frac{3700}{2} = 1850$

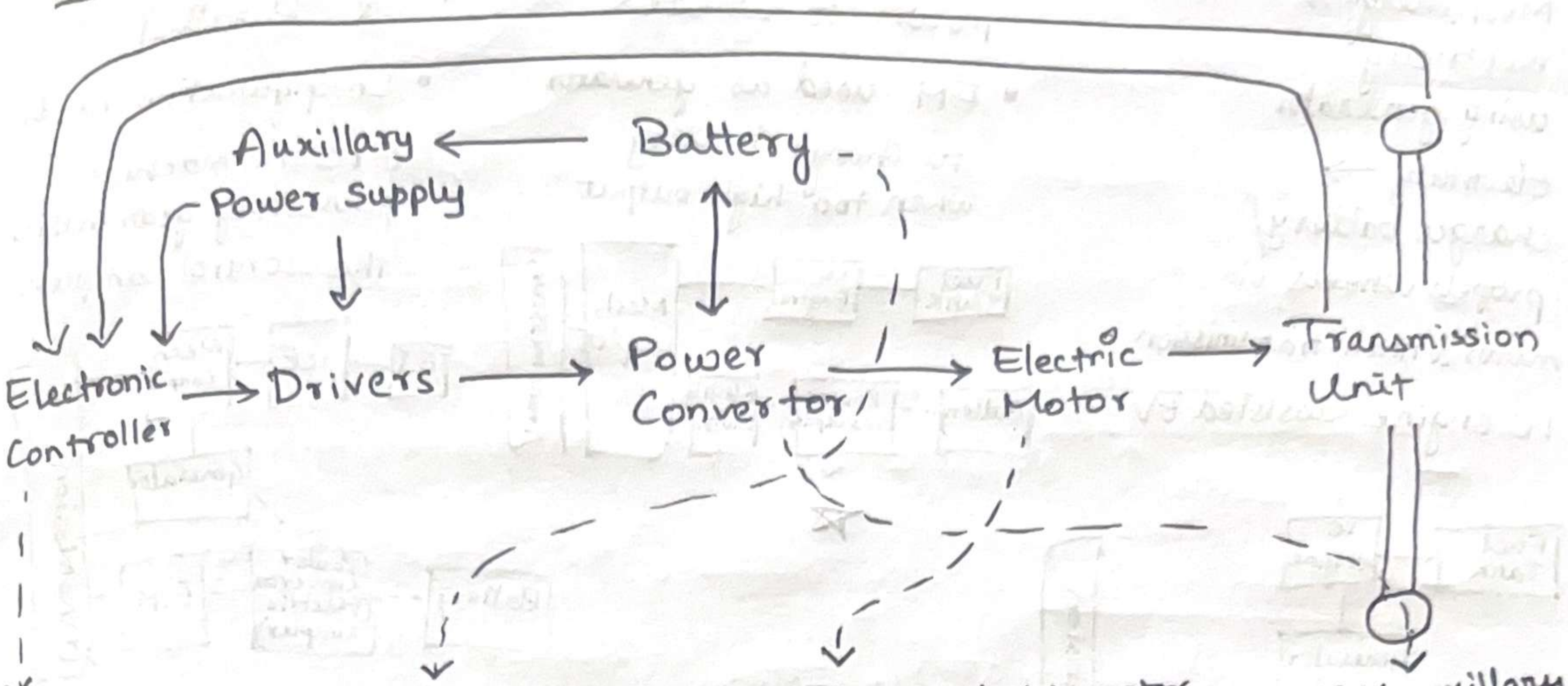
⇒ No. of misfires $= 1856 - 1850$

$= 6$

# Electric Vehicles

→ Vehicles which use electric motor for propulsion

## Major Components of EV




- Regulates flow of energy from battery to motor in direct relation to pressure on accelerator

Use 3 types of batteries
i) Pb-Acid
ii) NiMH
iii) Li-ion

- High Torque electric motor
- Converts energy stored into mechanical motion, delivered directly to wheels / transaxle
- While braking, it acts as generator & recharges batteries (regenerative braking)

- 12 V auxillary battery to power lights, horns etc.,
- EVs use DC convertor which taps full battery pack voltage & regulates 13.5 V output

### Charger
- EVs have on board charger converts AC to DC power to charge power back

### Energy Management System
- Brain of EVs, monitors & controls all functions
- Computer optimizes charging & energy output to maximize range & improve performance

## → EV Classification

1) **Battery Electric Vehicle (BEV):**
- runs on electric motor & battery
- no IC engine
- external electricity source to charge
- charge by regenerative braking

ex: Tesla Model S, BMW i3

2) **Hybrid Electric Vehicle (HEV):**
- Supplement source of fuel required for electricity
- IC engine & electric motor
- can't be charged from electricity grid
- regenerative braking

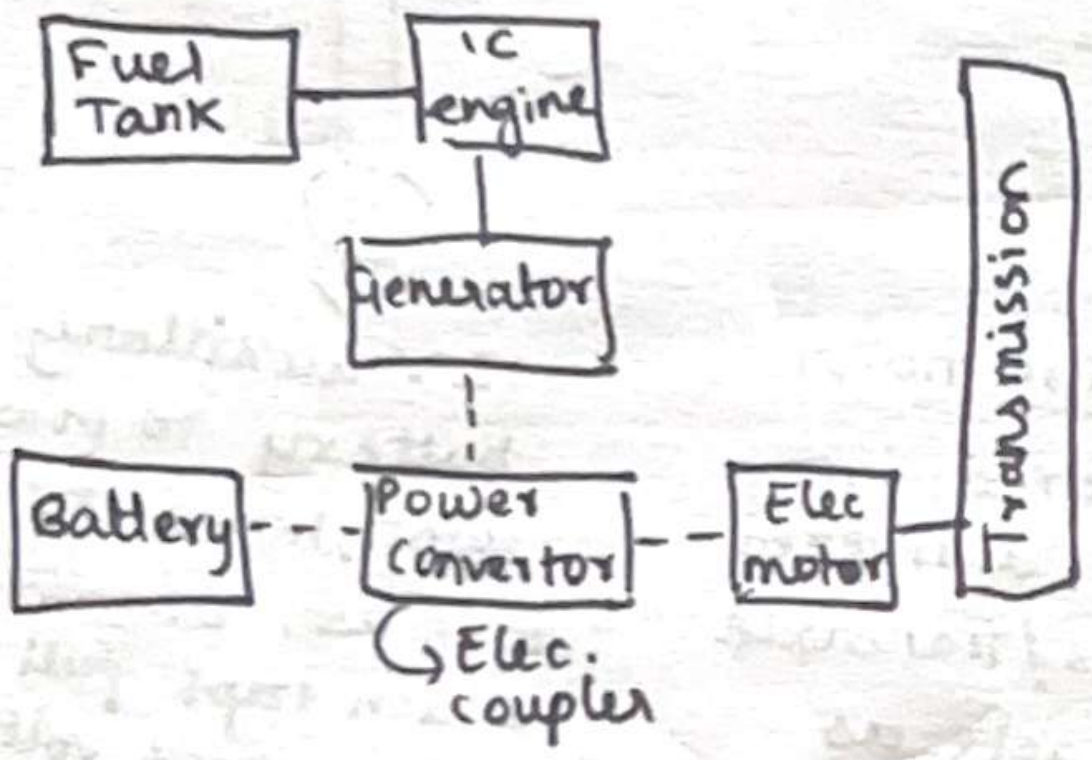
3) **Plug-in Hybrid Electric Vehicle (PHEV):**
- Electric motor & battery
- Power grid to charge
- IC also used to charge
- saves fuel cost than HEV

ex: Cadillac ELR, Toyota Prius

# HEV Architecture

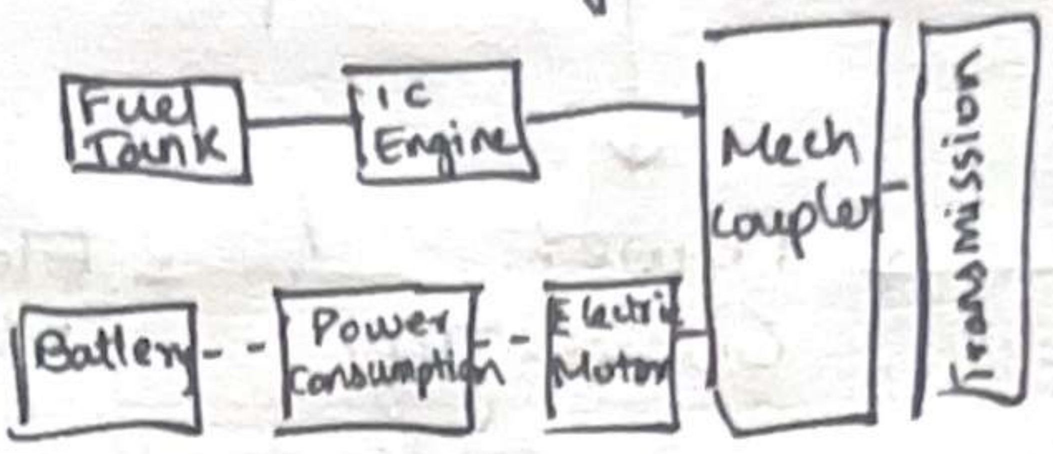
## Series

- Mech.energy → electricity using generator
- Electricity → charges battery/ propels wheels via motor & mech. transmission
- IC engine assisted EV



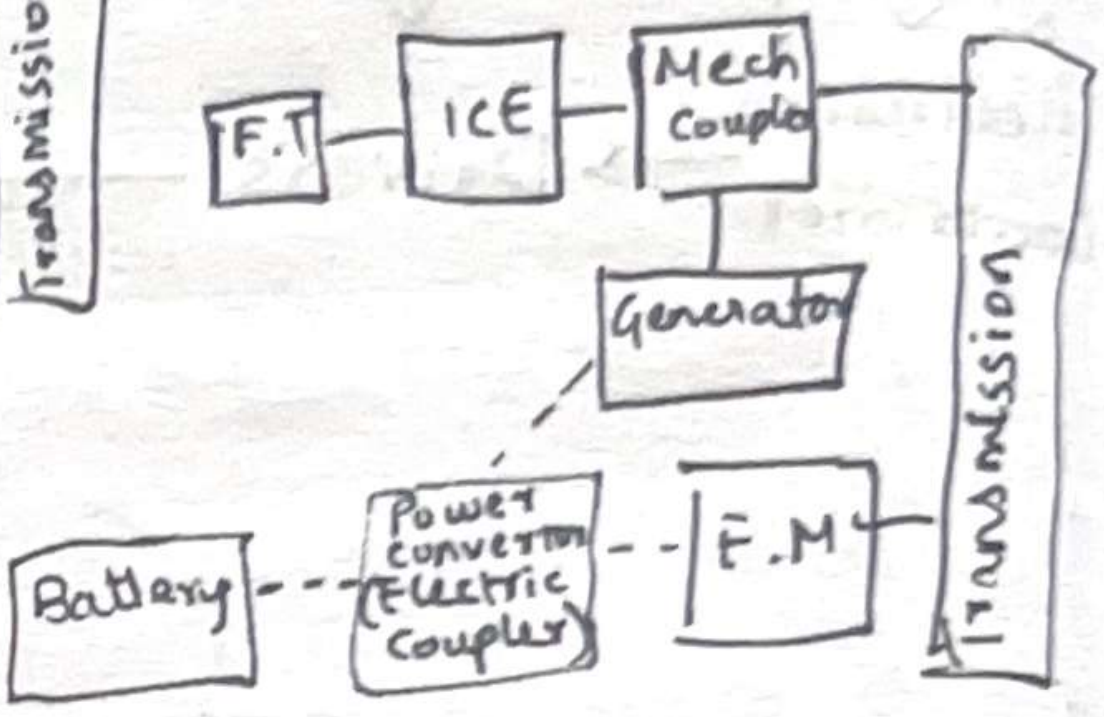

## Parallel

- ICE & EM deliver power to wheels
- EM used as generator to charge battery when too high output




## Series-Parallel

- Features of Series & Parallel
- Configuration needs Electric machine & planetary gear making the control complex



# Power Plant Engineering

→ Branch of engineering dealing w conversion of various forms of energy to electrical energy

- Thermal P.P
- Hydroelectric P.P
- Nuclear P.P
- Diesel P.P
- Tidal P.P
- Geothermal P.P
- Windmill

## Thermal Power Plant

- coal / gas based
- coal is burned, heat energy converts water into super heated steam
- SHS passed through steam turbine & converts to shaft power which is coupled to generator to generate electricity

## Steam Turbine ~~De Laval Turbine~~

- Heat energy ⟶ Mechanical energy by expanding high pressure & high temp. steam
- Impulse Steam Turbine / De Laval Turbine
  - Consists of nozzles & moving blades
  - high pressure steam enters nozzle & expands back to low pressure
  - Pressure $\xrightarrow{\text{converted}}$ KE, velocity of stream ↑
  - High velocity stream is directed onto blades, which gives rise to momentum cuz of direction change, & therefore, a force.
  - The force moves the blades, which rotates rotor. This rotation is used for electricity rotation
  - $V_{final} > V_{inlet}$ (single stage turbine), So, Loss in KE
  - Pressure constant throughout

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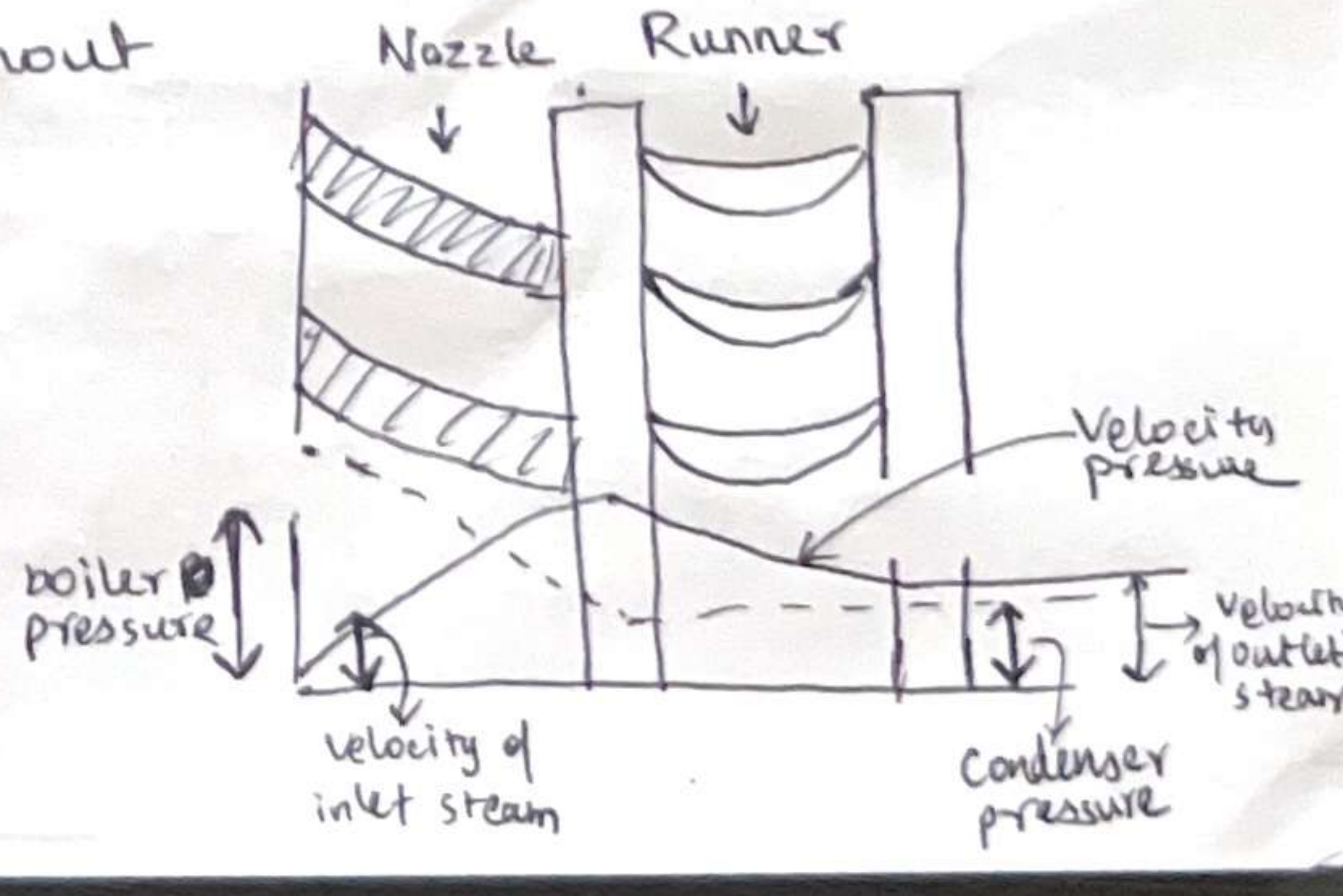
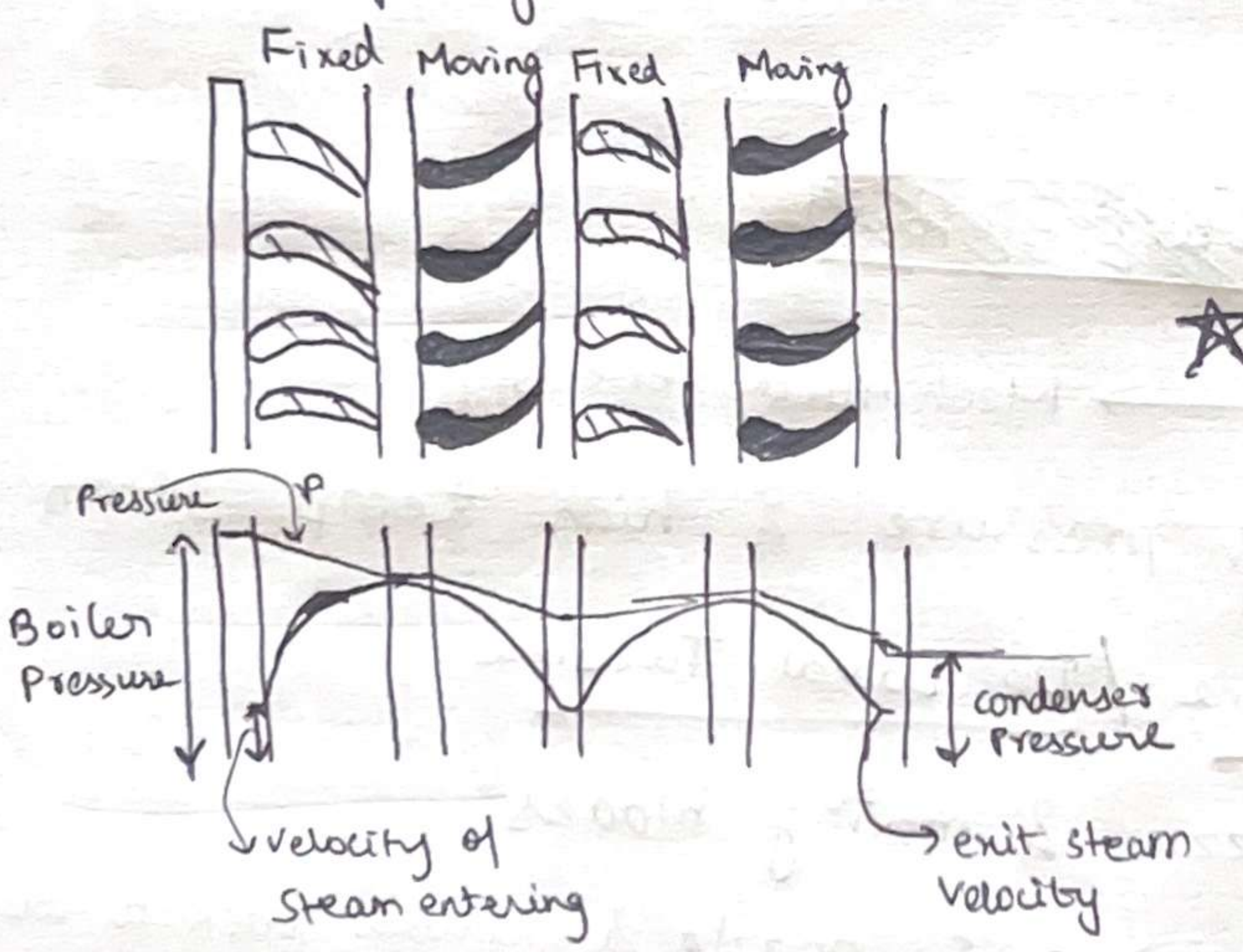


- <u>Impulse reaction Steam Turbine</u> (Parson's Turbine)
  - Steam expands in both fixed & moving blades
  - Pressure drops partially in fixed blades & drops partially & continuously in moving blades
  - Fixed blades are attached to casing, moving blades are attached to rotor containing shaft
  - Steam enters throughout the circumfrence (unlike impulse steam turbine where it enters thru nozzles)
  - Velocity ↑, Pressure ↓ when it enters fixed blades
  - Steam enters moving blades, direction changes, momentum created, force created.
  - P drop gives rise to KE




→ More efficient

→ Comparitively low speed than IST

→ Bulkier (More floor area) than IST

→ Blades are non-symmetrical

# Gas Turbine

## • Open Cycle Gas Turbine

- Air drawn into compressor.
  After compression, passes to combustion chamber
- Energy supplied in combustion chamber by spraying fuel into air stream
- Hot gases expand through turbine to atmosphere
- Rotary compressor & Turbine mounted on common shaft, So turbine performs more work than required, leading to mechanical losses.
- Combustion products out of turbine exhausted to atmosphere
- Working fluid (air & fuel) must be replaced continuously

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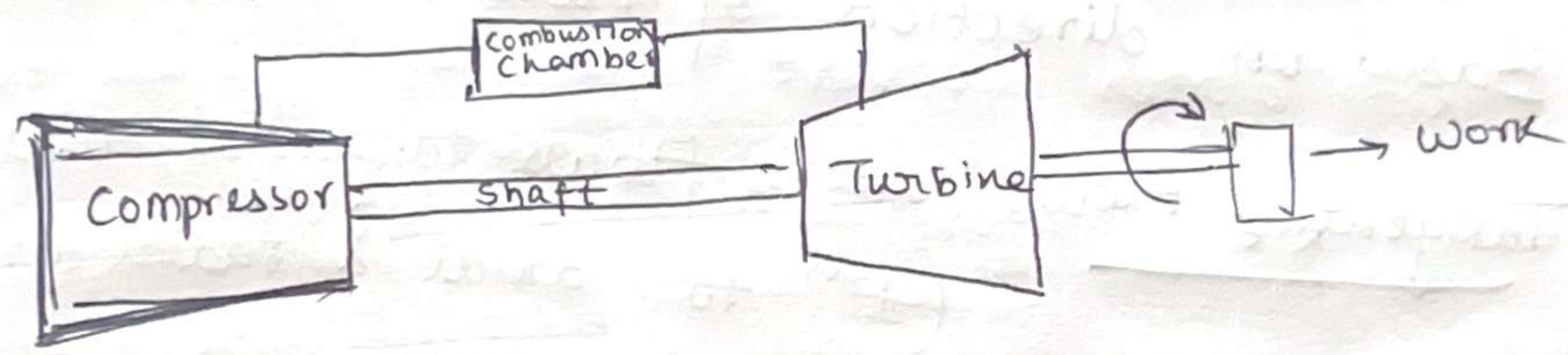


## • Closed Cycle Gas Turbine

- Atmospheric air / stable Gas (Ar, He etc.,) used as working fluid
- Working fluid compressed to high pressure in compressor, then heated by passing through heater by external source
- Working fluid doesn't come in contact with combustion prods, heat transferred using heat exchanger
- high pressur & temp fluid made to flow through turbine blades, heat energy converted to mechanical work
- fluid passed from turbine to cooler, cooled back to original temp
- low temp & pressure fluid passed into compressor for next cycle

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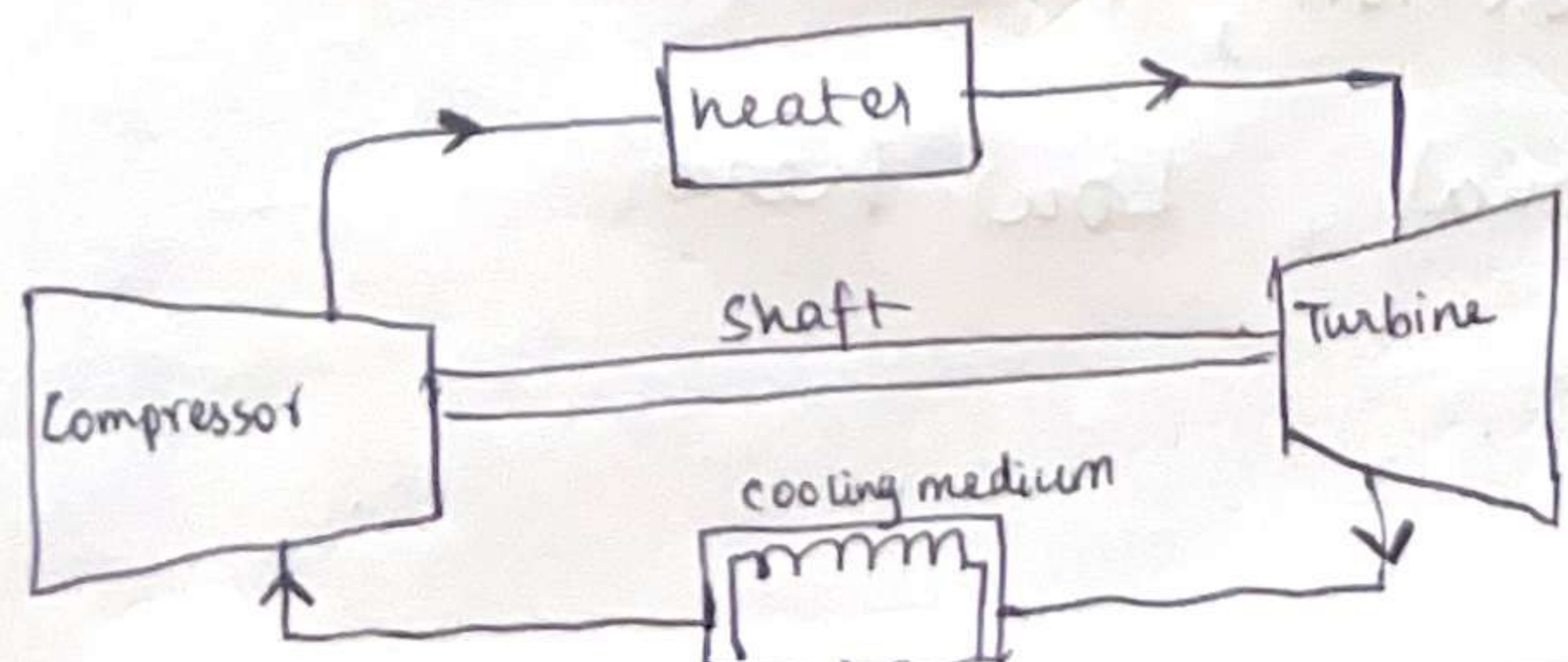


# Hydraulic Turbines

→ Machine that converts hydraulic energy into mechanical energy

→ Uses KE & PE of water to set rotor in motion by dynamic action of water flowing from high level

## Classification

- Based on inlet form of energy

i) Impulse Turbine : Energy in kinetic form

ii) Reaction Turbine : Energy in kinetic & pressure form

- Based on direction of flow of water thru runner

i) Tangential Flow: Water flows tangential to path of rotation ($\perp^{ar}$ to axial & radial directions)

ii) Radial Flow : Water flows in radial direction thru runner

iii) Axial Flow : Water flows $\parallel^{el}$ to axis of turbine

- Based on head under which turbine works

i) High head turbine : Head of water at inlet ⇒ 300 – 1000m

ii) Medium head turbine : " ⇒ 50 – 400 m

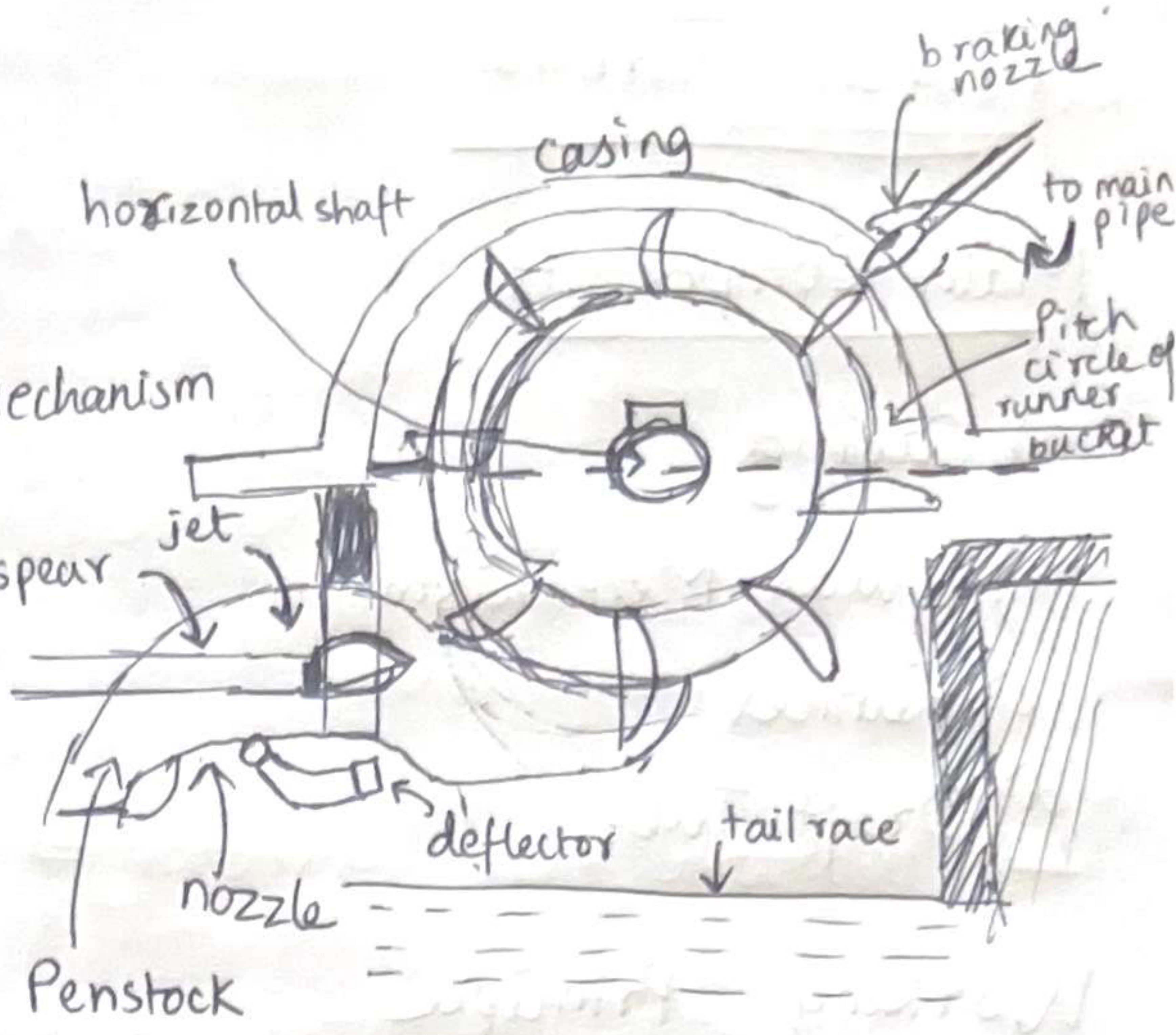
iii) Low head turbine : " ⇒ < 50m

Pelton ⇒ Impulse, ~~Reaction~~ Tangential, High head

Francis ⇒ Reaction, Radial, Medium head

Kaplan ⇒ Axial, Low head

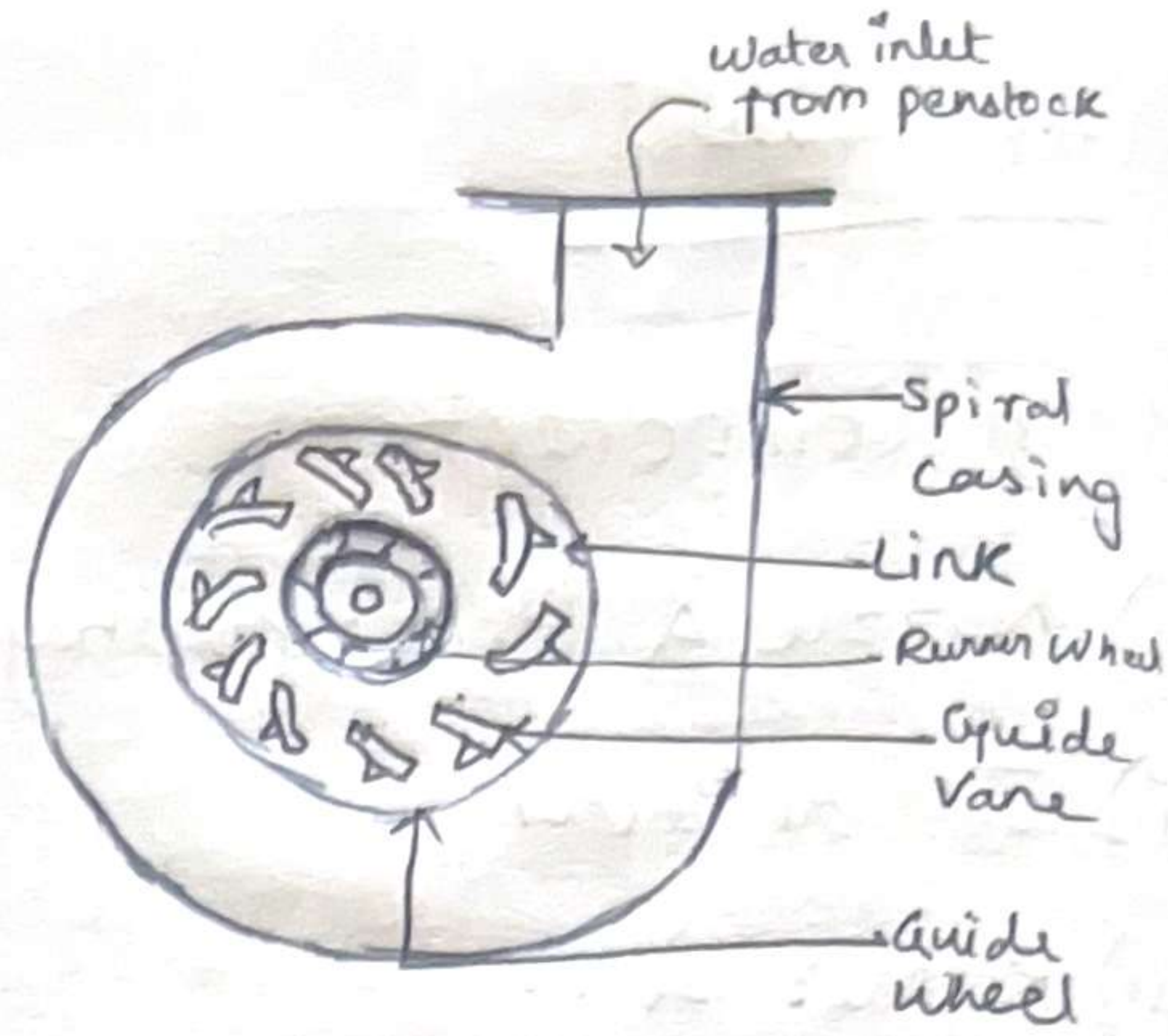
# Pelton Wheel




- Main components :
  - i) Nozzle & flow regulating mechanism
  - ii) Jet deflector
  - iii) Runner & bucket
  - iv) Casing
  - v) Braking Jet

- Working Principle
  - → Water flows from reservoir to turbine through penstock. which is fitted with 1 or more nozzles
  - → Pressure energy converted to KE in nozzle. High velocity water jet emerging from nozzle strikes bucket (blades) and sets it in rotary motion
  - → Water flows in tangential direction, buckets change direction of jet, change in momentum, wheel rotates
  - → KE of jet is transferred to rotating wheel (velocity of water at exit of runner is sufficient to enable it to move out ~~~~ the runner)
  - → Static pressure of water at enterance & exit is same as atmospheric pressure
  - → Water discharged at tail race after doing work on ~~~~ runner

# Francis Turbine




## Main Components

a) Casing
b) Guide. Mechanism
c) Runner
d) Draft Tube

## Working Principle

→ Water flows from reservoir to turbine through penstock & feed water to row of fixed blades through casing

→ Fixed blades convert part of pressure energy into KE before water enters runner.

→ Water enters runner in radial direction & leaves in axial direction. This is mixed flow

→ Pressure energy changed to KE as water flows over vanes.

→ Rotor rotates due to reaction of water leaving

→ Rotation of runner is partly due to impulse action & partly due to change in presssure energy over blades, Hence called reaction turbine

# Heat Transfer

→ Heat ⇒ Energy in transit. Measured in temperature

→ Heat transfer occurs 2 bodies of different temperature are brought in contact with each other

## Conduction

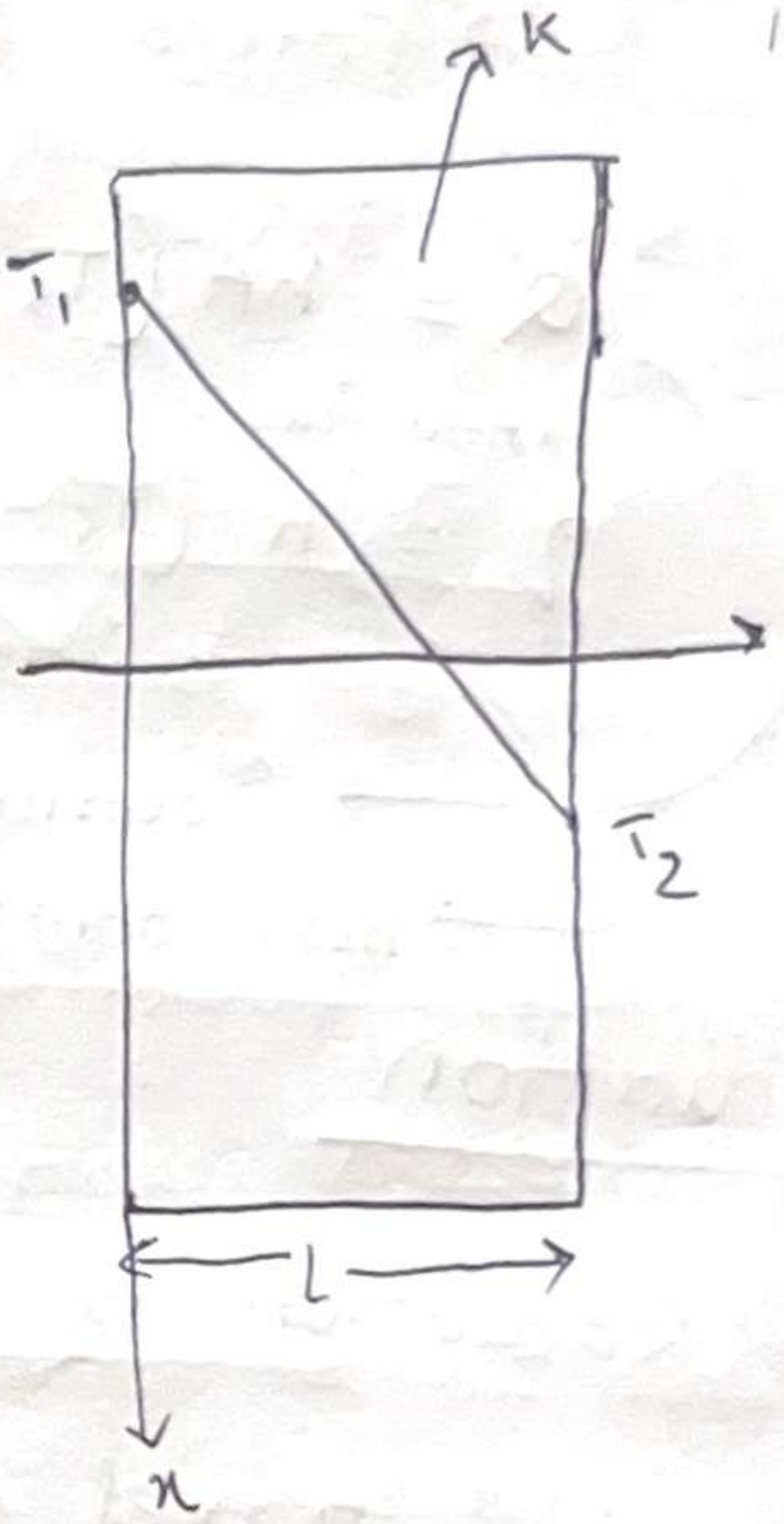
→ Rate of flow of heat (in conduction) is directly proportional to area normal to direction of heat flow & gradient of temperature in that direction

→ $Q_x = -KA \dfrac{dT}{dx}$ (unit : W) → Governed by Fourier's Law

rate of heat transfer

$$= \frac{-KA(T_2 - T_1)}{L}$$

$$= \frac{KA(T_1 - T_2)}{L}$$




$q_x = -K \dfrac{dT}{dx}$ (unit : $W/m^2$)

Heat flux

$$= \frac{K(T_1 - T_2)}{L}$$

→ K varies .

- $0.022 \dfrac{W}{m.C^\circ}$ for air
- $0.51 \dfrac{W}{mC^\circ}$ for water
- $0.095 \dfrac{W}{mC^\circ}$ for asbestos
- $19.3 \dfrac{W}{mC^\circ}$ for stainless steel
- $407 \dfrac{W}{mC^\circ}$ for pure silver

at 20°C

# Convection

→ Fluid flows over a body at temperature diff. than itself, then heat transfer occurs

→ Fluid particles move & carry energy from high temp level to low temp level

→ Natural / Free Convection ⇒ Motion due to density diff.

Forced Convection ⇒ Motion due to pump, fan

↳ Forced > Natural

→ $\underset{\text{rate of heat transfer}}{Q} = hA(T_s - T_f) \longrightarrow W$

$\underset{\text{heat flux}}{q} = h(T_s - T_f) \longrightarrow W/m^2$

$T_s$ → Surface temp

$T_f$ → Fluid temp / Ambient Temp

→ Governed by Newton's law of cooling

$h$ → heat transfer coefficient → usually h varies but it is a good practise to write mean value

# Radiation

→ Radiation is emitted as electromagnetic waves which travel at speed of light & obey all laws of light

→ Radiation at 0.1μm to 100μm range is called thermal radiation cuz radiation converts to heat when absorbed by a body

→ Thermal radiation is a volume phenomenon.

→ When radiation falls, it may be attenuated within short distance from surface / get reflected from surface / pass thru body

→ In vaccum, radiation propagates w/o attenuation

$$\boxed{q_{abs} = \alpha q_{inc}}$$

$\alpha$ → absorpivity

Governed by Stefan Boltzmann Law ← $E_b = \sigma T^4 \longrightarrow W/m^2$

$E_b$ → B.B emissive power

$\sigma$ → Stefan Boltzmann Const $= 5.67 \times 10^{-8}\ W/m^2K^4$

$T$ → Temp

$E = \varepsilon E_b$

$E$ → Emissive power of practical body

$\varepsilon$ → Emissivity

## Applications of Heat Transfer

1) Mechanical engineering
   - Boilers, Heat exchangers, Turbine systems, IC engines etc,

2) Metallurgical engineering
   - Furnaces, heat treatment of components etc.,

3) Electrical engineering
   - Cooling systems for Electric motors, generators, transformers etc,

4) Cryogenic engineering
   - In production, storage, transportation & utilisation of cryogenic liquids (100K – 4K) for industrial, research & defence applications.

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Q. Asbestos layer of 10mm thickness ($K = 0.116\ W/mK$) used as insulation over a boiler wall. Consider area of $0.5m^2$ & find out rate of heat flow as well as heat flux if temperatures on either side are $300°C$ & $30°C$

A.
$$Q = -KA\frac{dT}{dx}$$
$$= -0.116 \times 0.5 \times \frac{(30-300)}{0.01}$$
$$= 0.116 \times 0.5 \times \frac{270}{0.01}$$
$$= 1566\ W$$

$$q = \frac{Q}{A} = \frac{1566}{0.5} = 3132\ W/m^2$$

Q. A small metallic sphere of emissivity 0.9 loses heat to the surroundings at a rate of 450 W/m² by radiation & convection. If ambient temperature is 300K & the convective heat transfer coefficient b/w sphere & ambient air is 15 W/m²K, find out surface temperature of sphere

A.
$$q_{lost} = q_{convection} + q_{radiation}$$
$$450 = h(T_s - T_f) + \varepsilon\sigma(T_s^4 - T_f^4)$$
$$450 = 15(T_s - 300) + 0.9 \times 5.67 \times 10^{-8}(T_s^4 - 300^4)$$
$$5363.343 = 15T_s + 0.9\sigma T_s^4$$
$$T_s = 321.3 \text{ (or) } -756.46 \text{ (or) } 217.58 \pm 620.54i$$

Q. Electronic power devices are mounted to a heat sink having an exposed surface area of 0.045 m² & emissivity of 0.8. When devices dissipate total power of 20W and air and surroundings are at 27°C, the average sink temperature is 42°C. What average temperature will the heat sink reach when devices dissipate 30W for same environmental conditions?

A.
$$Q = hA(T_s - T_f) + A\varepsilon\sigma(T_s^4 - T_f^4)$$
$$20 = h \times 0.045(315 - 300) + 0.045 \times 0.8 \times 5.67 \times 10^{-8}(315^4 - 300^4)$$
$$h = 24.351 \text{ W/m}^2\text{K}$$

Now $T_s$ if $Q = 30W$
$$30 = 24.351 \times 0.045(T_s - 300) + 0.045 \times 0.8 \times 5.67 \times 10^{-8}(T_s^4 - 300^4)$$
$$375.272 = 1.095T_s + 2 \times 10^{-9}T_s^4$$
$$T_s = 322.53 \text{ (or) } -904.39 \text{ (or) } 290.927 \pm 736.66i$$

# Principle of Refrigeration

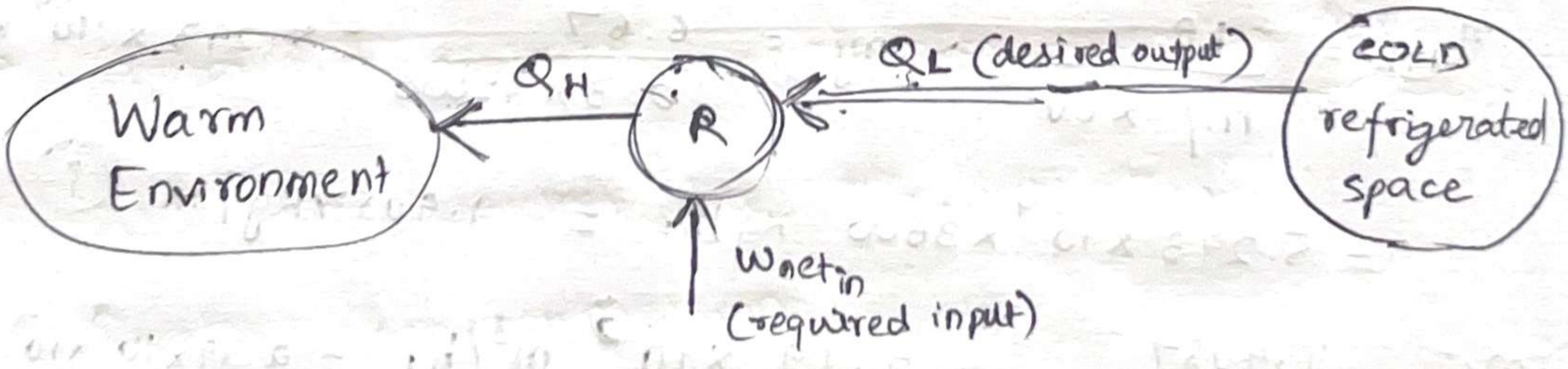
→ Process of cooling (or) reducing temperature of a substance below that of surrounding atmosphere & maintaining this lower temperature within boundary of a given space

→ Heat must be continuously removed from given substance to keep the substance cold

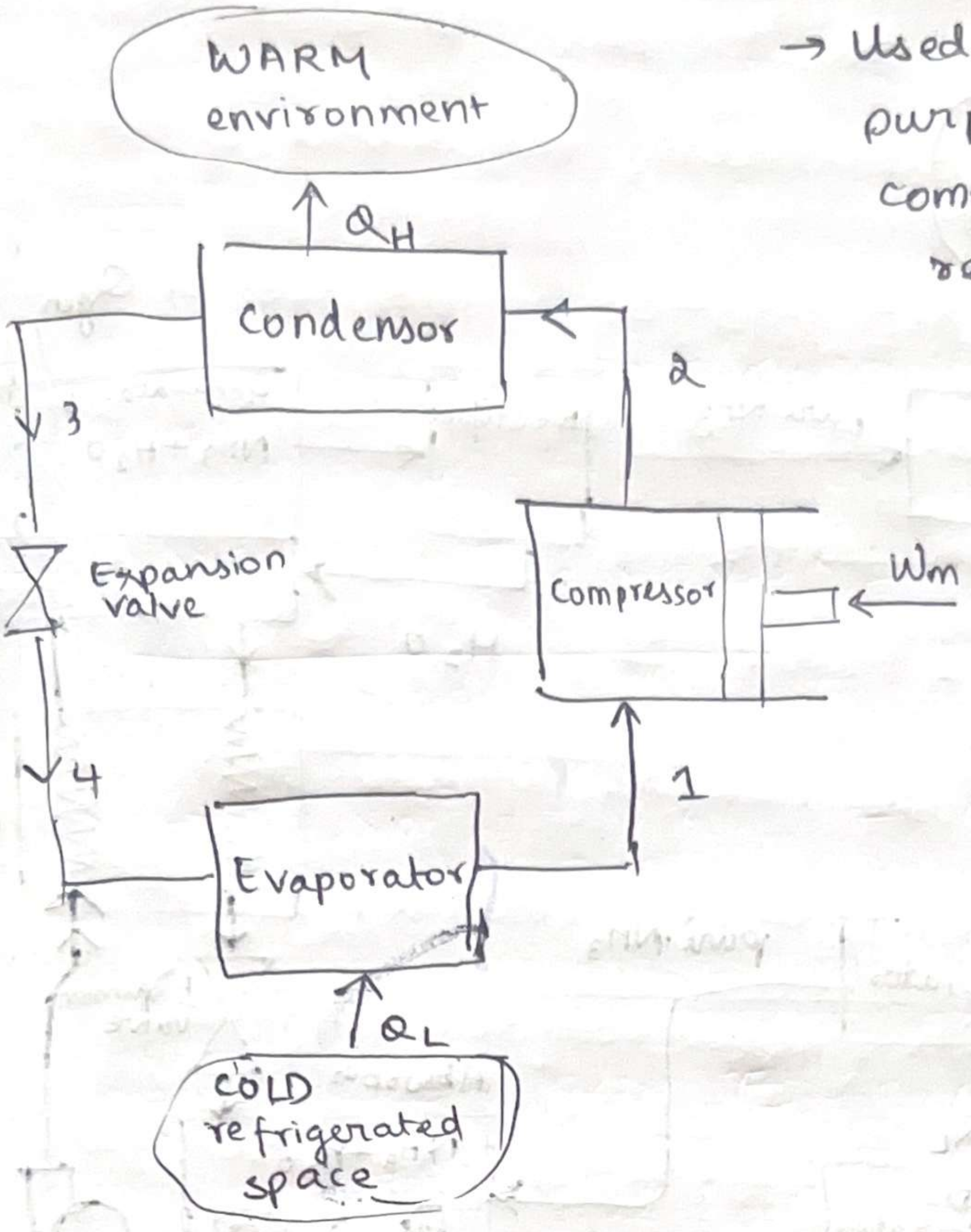
→ Some work must be performed if heat as to flow from cold substance to hot substance.

→ Refrigeration works on principle that heat is continuously extracted from low temp substance by performing mechanical work. This heat is rejected to surrounding atmosphere

→ Refrigerants ⇒ $NH_3$, $CO_2$, $CH_3Cl$, Freon CFC etc.)



# Vapour Compression Cycle




→ Used in household purposes, large commercial & industrial refrigeration

→ Evaporator – Inside cabinet where substance to be cool

→ Condensor – Back of refrigerator

→ Compressor – Bottom

→ Compressor driven by electric motor (AC supply driven)

→ Low pressure & temp liquid refrigerant in evaporator absorbs heat from inside cabinet & undergoes change from liquid to vapour

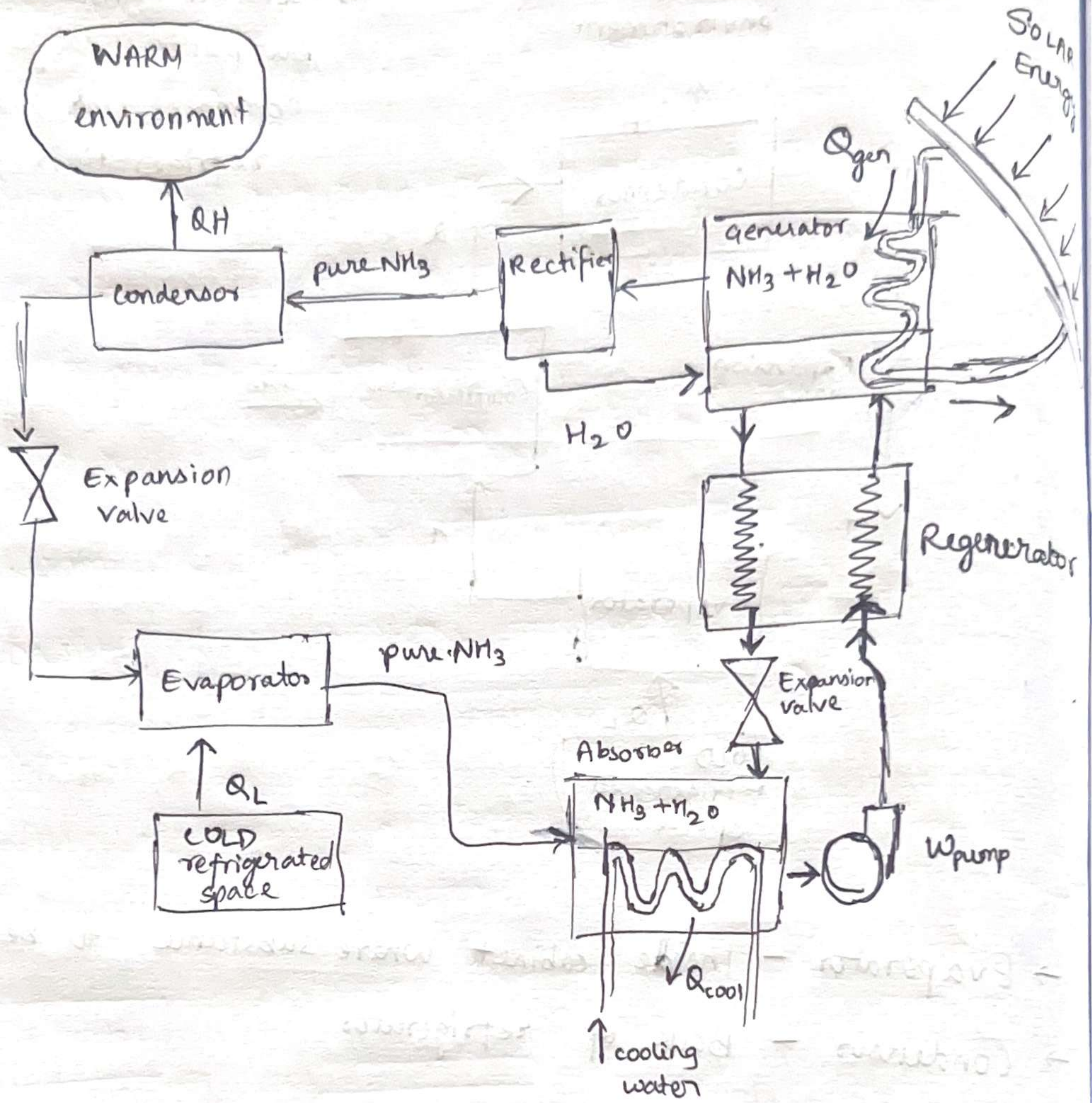
→ Vapour drawn to compressor to get compressed to high temp & pressure, which circulates to condensor

→ Refrigerant gives heat to cooling medium (either air / water flowing around condensor coils)

→ Vapour refrigerant condensed to liquid state. Temp↓ Pres const

→ Refrigerant flows to expansion valve & expands to low p & temp which then enters evaporator & repeats the cycle

# Vapour Absorption Cycle




- → Compressor replaced by absorber, generator & pump
- → Use heat sources like LPG, Solar etc.,
- → Quieter than compression
- → Refrigerant must be highly soluble in absorbent
- → Common combinations ⇒ $\underset{\text{(refrigerant)}}{NH_3} + \underset{\text{(absorbent)}}{H_2O}$, $\underset{\text{(refrigerant)}}{H_2O} + \underset{\text{(absorbent)}}{LiBr}$
- → Used in industrial environments (exhaust waste heat used as energy to drive cooling systems)

Chiller in offices & hospitals

Working :

- liq $NH_3$ refrigerant in evaporator absorbs heat from inside cabinet & phase changes from liq to vapour
- low p & low temp $NH_3$ vapour passed to absorber containing weak soln of $NH_3 + H_2O$
- Water absorbs ammonia vapour of low pressure from evaporator & dissolves in weak ammonia soln in absorber resulting strong $NH_3$ soln
- Heat released, exothermic r/n
- Strong $NH_3$ soln pumped to generator through heat exchanger at high pres.
- Next $NH_3$ soln enters generator & heated by external source
- Due to heating, vapour gets seperated from solution & flows through heat exchanger to absorber
- High pres & High temp $NH_3$ vapour from generator enters condensor, gives away heat to cooling medium, condensed to liquid
- High pres & low temp $NH_3$ liq refrigerant enters expansion valve where it is expanded to low pres & temp
- Low pres & low temp liq refrigerant enters evaparator & absorbs heat from cabinet & evaporates.
- Cycle repeats

# Air Conditioning

→ Process of simultaneous control of temperature, humidity, cleanliness, air motion of confined space

→ Similar to refrigeration, except w/o an insulated box

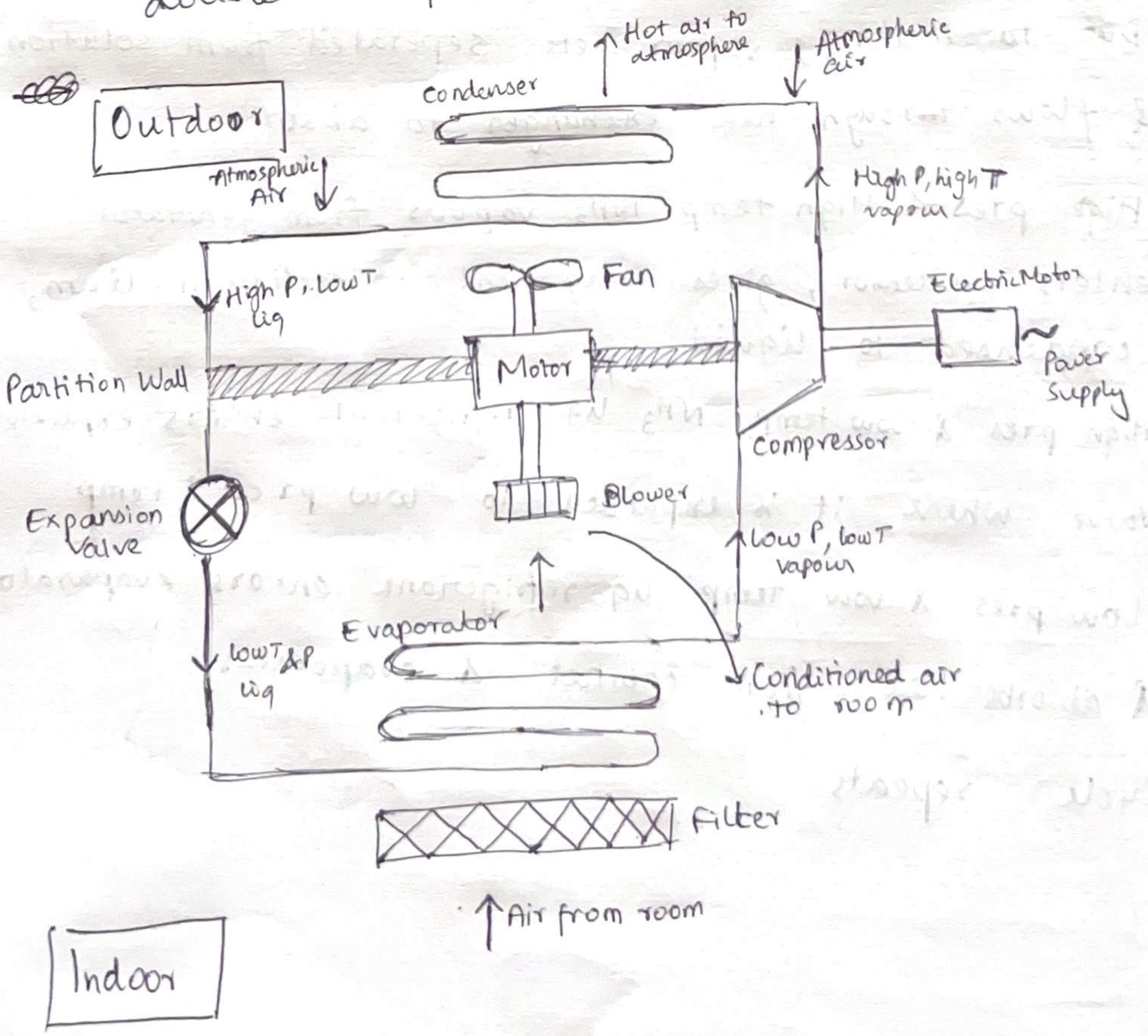
→ Cooling achieved by vapour compression refrigeration cycle

→ Refrigerant - Freon 22, HFC (R134A)

→ Room AC also called window unit

→ Consists of compressor, condensor, expansion valve & evaporator. (vapour compression cycle)

→ Also includes air filter, control panel, double shaft motor,



## Working

→ Blower draws warm air from room through air filter over evaporator coils.

→ Low pres & temp liquid refrigerant flowing through evaporator coils absorb heat from warm air & undergo phase change from liquid to vapour

→ Blower delivers cool air to room by mixing with room air & bringing down temperature & humidity of room

→ Low Temp & Pres vapour refrigerant from evaporator is drawn by suction of compressor which compresses it to high Temp & Pres. vapour

→ High Temp & Pres vapour flows through condensor coil

→ Fan located at outdoor side draws atmospheric air & blows it over the condensor coils

→ Heat contained in refrigerant is dissipated to the atmosphere & resulting vapour refrigerant condenses to liq.

→ High pres & ~~temp~~ low temp ~~vapour~~ liquid now enters expansion valve to expand to low pres & temp

→ Low pres & low temp liq enters evaporator coils, absorbs heat from warm air & cycle repeats