Unit - 4 Convensional & Non-conventional Energy sources

Conventional Energy Sources (Non- Renewable)

- Conventional energy sources refer to traditional forms of energy that have been widely used for many years. These sources are generally well-established and have significant structure supporting their extraction, processing and distribution.
- The examples of these sources are fossil fuels (coal, petroleum, Natural gas) and Nuclear energy.
- These sources have been backbone of global energy production for decades.
- Their impact on the environment includes CO & CO_2 emissions.
- These sources are limited on the earth.

Non - Conventional Energy Sources (Renewable)

- These sources refer to methods of generating energy that are more sustainable and have less environmental impact compared to traditional fossil fuels and nuclear energy.
- The examples of these sources are solar energy, wind energy, Hydro power, Geothermal energy, biomass energy and Tidal/wave energy.
- These energy sources contribute to sustainable and resilient energy system, with many benefits for the environment, economy and society.

Primary Energy Sources:- Primary energy sources are found in nature and have not been converted or transformed. These are the raw energy materials that are used directly or converted into other forms of energy.

Primary energy sources include:

1) Fossil fuels
   - Coal
   - oil (Petroleum)
   - Natural gas
2) Renewable Resources:
   - Solar energy (Sunlight)
   - Wind energy (wind)
   - Hydro power (flowing water)
   - Geo thermal energy (heat from the earth)
   - Bio mass (wood, agricultural waste)
3) Nuclear Energy
   - Uranium & Plutonium

Secondary Energy Sources:- These sources are derived from the conversion of primary energy sources. They are products that are used to provide energy in a more usable form.

Secondary energy sources include:

1) Electricity: Generated from primary sources like coal, natural gas, nuclear power or renewable sources.

2) Refined Fuels:
- Gasoline & Diesel (Refined from crude oil)
- Ethanol & Biodiesel (Produced from biomass)

3) Heat: Produced from combustion of fuels or solar energy.

4) Hydrogen Fuel: Produced through processes like electrolysis of water (using electricity) or steam reforming of natural gas.

Biological Energy Sources

These are derived from biological materials, such as plants and animals. They include sources like biomass (wood, agricultural waste), biofuels (ethalnol, biodiesel) and biogas.

- These sources are renewable as long as the biological materials are managed sustainably.
- These sources are environment friendly but sometimes large scale biofuel production can lead to deforestation and other ecological issues.

Fossil Fuels

These are derived from the remains of ancient plants and animals buried underground and subjected to geological processes over millions of years.

- They include coal, oil and natural gas.
- These are non-renewable on human time scales
- Burning fossil fuels releases CO_2 & other pollutants, contributing to climate change & environmental degradation.

Fluid dynamics:- Fluid dynamics is the study of the movement of fluids (liquids & gases). It involves understanding the behaviour of fluids in motion and the forces acting on them.

Fluid Properties

1) **Density:** It is defined as the mass per unit volume of a fluid. It is denoted by ρ.(rho)

$$\left\{ \rho = \frac{m}{V} \right\}$$ Unit : kg/m^3

2) **Viscosity:** Viscosity is a measure of a fluid's resistance to deformation and flow. It describe the internal friction within a fluid.
It is denoted by μ.(mew).

$$\left\{ F = \mu A \frac{du}{dy} \right\}$$

where
F : viscous force
μ : viscosity
$\frac{du}{dy}$: Rate of shear deformation

Unit of viscosity

$$\mu = \frac{F}{A \times du/dy}$$

$$\text{Unit of } \mu = \frac{N}{m^2 \times \frac{\cancel{m}/s}{\cancel{m}}} = \frac{N\text{-}s}{m^2}$$ or {Pascal-Second}

OR $$\text{Unit of } \mu = \frac{kg\,\cancel{m}}{s^{\cancel{2}}} \times \frac{\cancel{s}}{m^{\cancel{2}}}$$

$$\text{Unit of } \mu = \frac{kg}{ms}$$

3) <u>Weight density</u> :- It is also known as specific weight. It is weight per unit volume of a fluid.

$$\left\{ D = \frac{w}{V} \right\} \qquad \text{unit : } \frac{N}{m^2}$$

$$\text{or } \quad D = \frac{m \cdot g}{V}$$

$$\text{or } \left\{ D = \rho \cdot g \right\}$$

4) <u>Specific Volume</u> :- It is defined as the ratio between Volume of fluid to mass of fluid.

$$\left\{ \nu = \frac{V}{m} \right\} \qquad \text{unit : } \frac{m^3}{Kg}$$

$$\text{OR } \left\{ \nu = \frac{1}{\rho} \right\}$$

It is reciprocal of density (ρ).

5) <u>specific Gravity</u> :- It is the ratio of the density of a substance to the density of a reference substance

$$\text{For liquid } \left\{ S.G = \frac{\rho_{sample}}{\rho_{water}} \right\}$$

$$\text{For Gas } \left\{ S.G = \frac{\rho_{sample}}{\rho_{air}} \right\}$$

- It is unitless quantity.

Types of Fluid Flow

Fluid Flow

① Based on flow characteristics
- Steady Flow
- Unsteady flow
- Uniform flow
- Non-uniform flow

② Based on flow velocity
- Laminar Flow
- Turbulent Flow
- Transitional Flow

③ Based on viscosity effect
- Viscous flow
- Non-viscous (ideal) flow

④ Based on Compressibility
- Incompressible Flow
- Compressible Flow

⑤ Based on Flow dimension
- 1-D Flow
- 2-D Flow
- 3-D Flow

① F

① Steady Flow :- Fluid properties at a point do not change with time.

② Unsteady Flow :- Fluid properties at a point change with time.

③ Uniform Flow :- Fluid properties is constant at every point along the flow direction,

④ Non-uniform Flow :- Fluid properties changes from one point to another along the flow direction.

⑤ Laminar Flow :- A type of flow where the fluid moves in parallel layers, with no disruption between them. The flow is orderly and smooth.

⑥ Turbulant Flow :- A type of flow characterized by chaotic changes in pressure and flow velocity. It involves eddies, vortices and other flow instabilities.

⑦ Transitional Flow :- A flow that exists between laminar and turbulant flow. The flow can alternate between laminal & turbulant states.

⑧ Viscous Flow :- Flow where viscous forces are significant, and the fluid exhibits resistance to flow.

⑨ Non-viscous flow :- It is an idealized flow where viscous forces are negligible.

(10) <u>In Compressible Flow</u> :- A flow where fluid density remains nearly constant, typically for most liquids.

(11) <u>Compressible Flow</u> :- A flow where fluid density varies in response to pressure change, typically for most gases.

<u>Continuity Equation</u> :- According to continuity equation of fluid flow, the product of the cross-sectional area of pipe and the velocity of the fluid at any given point along the pipe is constant.

$$\{ q = A \cdot V = \text{Constant} \}$$

where $q \rightarrow$ Volume flow rate

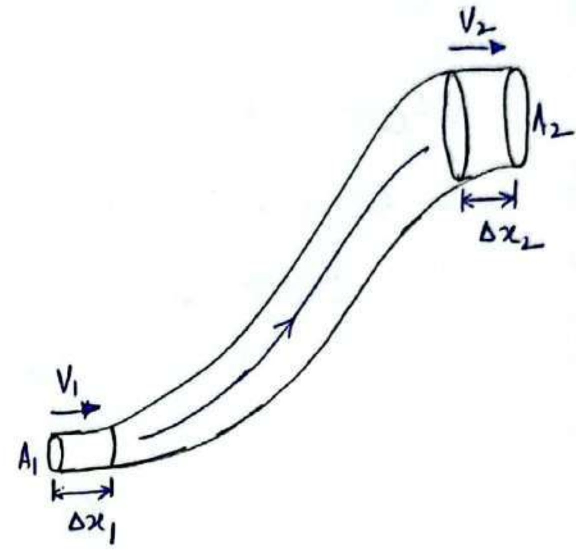
$A \rightarrow$ Flow area

$V \rightarrow$ Flow velocity

<u>Assumption of Coninuity equation</u>

1) Fluid Flow must be steady
2) Flow is in compressible
3) The fluid flowing in the tube is non-viscous
4) The tube is having a single entry and single exit.

Derivation of Continuity Equation



Let us Consider that the fluid flows in the tube for a short duration Δt. During this time, the fluid will cover a distance of Δx_1 and with a velocity of v_1 in the lower part of the pipe.

$$\because \quad v_1 = \frac{\Delta x_1}{\Delta t} \quad \text{or} \ \{\Delta x_1 = v_1 \times \Delta t\}$$

Now in the lower part of the pipe, the volume of fluid flow into the pipe is

$$V_1 = A_1 \Delta x_1 = A_1 v_1 \Delta t$$

$$\because \quad \text{mass} = \text{density} \times \text{volume}$$

$$\text{so} \quad \Delta m_1 = \rho_1 \times V_1 = \rho_1 A_1 v_1 \Delta t$$

$$\text{mass flux at lower part} = \frac{\Delta m_1}{\Delta t} = \rho_1 A_1 v_1$$

Similarly mass flux at upper part $= \frac{\Delta m_2}{\Delta t} = \rho_2 A_2 v_2$

Accoding to assumption, the mass flux at lower part is equal to the mass flux at upper part of the pipe.

$$\text{Thus} \quad \rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

$$\text{or} \ \{\rho A v = \text{Constant}\}$$

Density of fluid is same through out the pipe

$$\text{so} \quad \rho_1 = \rho_2$$

$$\& \ A_1 v_1 = A_2 v_2$$

$$\text{or} \ \{Q = A v = \text{Constant}\}$$

Bernoulli's Theorem :- It states that in a steady, ideal flow of an incompressible fluid, the total energy at any point of the fluid is constant.

The Bernoulli's equation is

$$\left\{ P + \frac{1}{2}\rho v^2 + \rho g h = \text{Constant} \right\}$$

where P : pressure of fluid
ρ : density of ~~fo~~flowing fluid
g : acceleration due to gravity
v : mean velocity of fluid flow
h : height of elevation of centre

- This theorem or principle is applied in airplane wings, sail boats, baseball curves, engines etc.

Derive expression for wind power / wind Energy

Wind turbine converts Kinetic energy of wind to mechanical power which then transformed into electricity.

The kinetic energy of the wind with mass m and velocity v under Constant acceleration is equal to the work done in displacing that wind from its original position.

$$K.E = \frac{1}{2} m v^2 \quad \text{—— (i)}$$

$$\because \text{density } (\rho) = \frac{\text{mass } (m)}{\text{Volume } (V)}$$

$$\text{so } \{ m = \rho \times V \}$$

$$\{m = \rho \times A \times length\}$$

$\because K.E = \frac{1}{2} m v^2$

after putting the value of m

$$K.E = \frac{1}{2} \times \rho \times A \times length \times v^2$$

$\because$ Power (P) $= \frac{K.E}{t}$

$$\therefore \quad P = \frac{1}{2} \rho A \times \frac{length}{t} \times v^2$$

$$P = \frac{1}{2} \rho A v \times v^2$$

Wind Power $\boxed{P = \frac{1}{2} \rho A v^3}$

- Small changes in wind speed have a large impact on the amount of power available in the wind.
- If the wind speed doubles, there is eight times more energy in the wind.

<u>Wind mills</u> :- The principle of power generation in wind-mills, or wind turbine is based on Converting the Kinetic energy of wind into electrical energy. Wind passes over the blades of windmill and causing the blades to turn. Rotating blades rotate a connecting shaft. The Gearbox increases the rotation speed. Then Fast-rotating shaft drives a generator, producing electricity. The generated electricity is transmitted through power lines to a transformer, where it is stepped up to a higher voltage for transmission over long distances.

Wind Farm :- A wind farm is a group of wind mills or wind turbines in the same location used to produce large scale of electricity. Wind farms can be located onshore (on land) or offshore (in bodies of water). They vary in size from a few turbines to several hundred, depending on the area and energy needs they are meant to fulfill.

- A wind farm is also called a wind park, wind power station or wind power plant.
- The Gansu wind farm, China (Capacity - 20GW) is the world's largest wind farm.
- The Muppandal wind farm, Kanyakumari, India (1500MW) is the India's largest wind farm.

Wind turbine Design :- Designing a wind turbine is a complex process that involves various engineering discipline, including aerodynamics, structural engineering and mechanical engineering.

- In aerodynamic design, we design the blade profile, their length & twist, rotor diameter and Tip speed ratio (TSR).

$$TSR = \frac{\text{speed of blade tip}}{\text{wind speed}}$$

- In structural design, we select the blade material (fiber glass - reinforced plastic or FRP), design the tower to support the nacelle and rotor, and analyse the turbine load.

- In Mechanical design, we design the nacelle to house key components like gear box, generator and control system. We also design the brake system to safety stop the turbine during maintenance or in high speed conditions.
- In electrical design, we select or design a generator, power electronics to convert the generated electricity to the desired form (AC or DC) and control system to optimize turbine performace.

Parameters related to wind turbine

When designing and evaluating wind turbines, several key parameters are considered to ensure optimal performance, reliability and economic viability.

1) Rated Power :- The maximum power output the turbine can produce under optimal wind cond^n.
2) Cut-in wind speed :- The minimum wind speed at which the turbine starts generating power.
3) Cut-out wind speed :- The wind speed at which the turbine shuts down to prevent damage
4) Rotor diameters :- The diameter of the turbine's rotor blades, which affects the amount of wind energy captured.
5) Hub height :- The height of the turbine's hub from the ground, impacting wind speed and turbine efficiency.

Betz' Law (to receive max. energy) :-

Betz's law, developed in 1919 by German physicist Albert Betz, states that no wind turbine can capture more that 59.3% of the kinetic energy in wind.
This is known as the Betz limit and is represented by the factor 16/27 (0.593), which is called Betz's coefficient.

- Betz limit states that

$$C_p = \frac{16}{27} = 59.3\%$$

for a single rotor wind turbine

- According to Betz' law, the maximum energy formula would be

$$\left\{ P = \frac{1}{2} \rho A v^3 \times C_p \right\}$$

Geothermal Energy :- It is derived from the heat stored inside the earth surface.

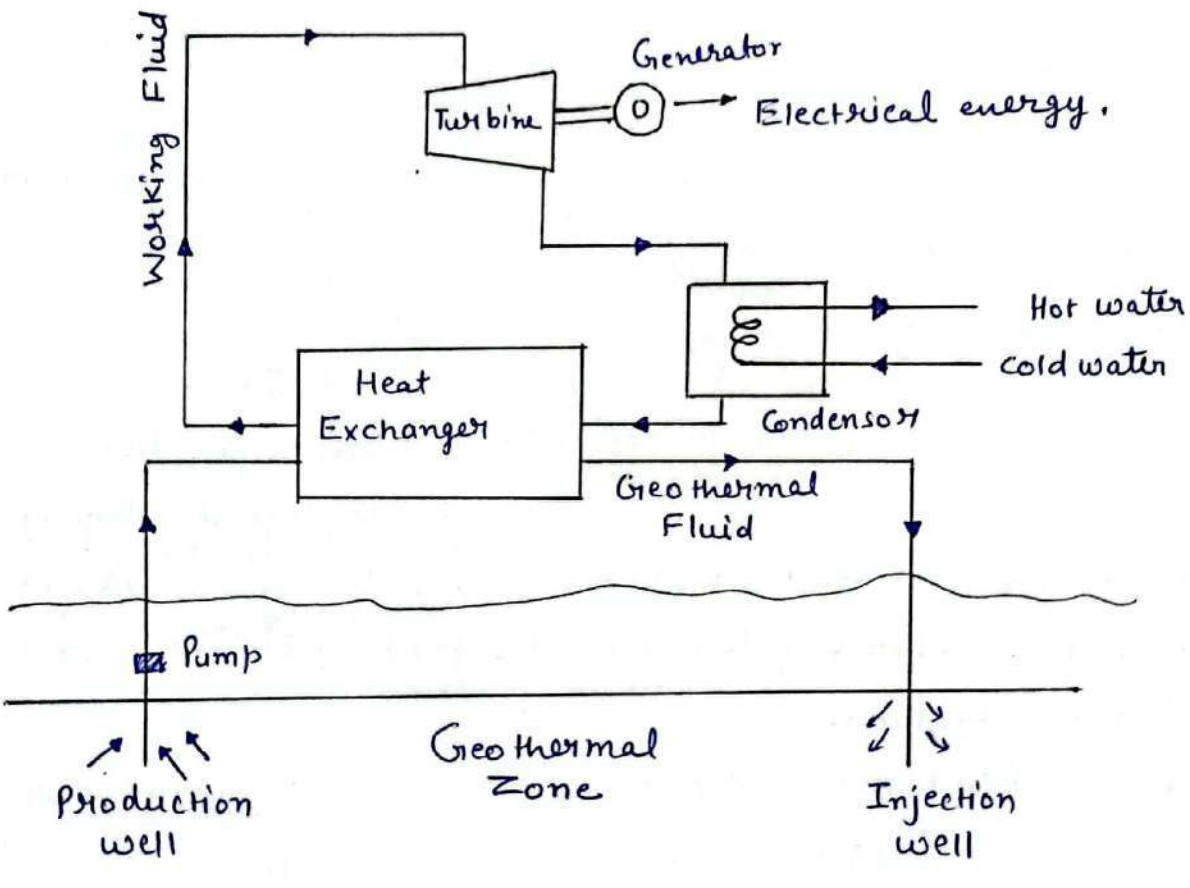
This heat can be in the form of hot water, hot gases and molten lava.

This heat can be converted into electricity by geothermal power plant.

Geothermal heat pumps are used for heating and cooling buildings.

Geothermal energy is a reliable and consistent energy source, not subject to the fluctuations of fossil fuels markets or weather conditions.

Geothermal Power Plant



In geothermal power plant, The heat energy from the geothermal fluid is transferred to the working fluid in the heat exchanger.
As the result, the working fluid vaporizes and then drives the turbine. The spend fluid passes through the condenser and the cycle repeats.
The geothermal fluid is injected back into the reservoir through the injection well.

Advantages

- Renewable energy source
- No harmful gases emitted
- No green house effect
- Cost of fuel is negligible
- Capital Cost is 40-60% less than other plants
- Short construction period.

Disadvantages

- Availability at certain regions only (where magma is nearer to the surface)
- Low efficiency (10-12%)

Geothermal energy extraction :- Geothermal resources are identified through geological surveys and exploration, focusing on areas with high heat flow, often near tectonic plate boundaries or volcanic regions.
Wells are drilled into geothermal reservoirs to access steam or hot water trapped underground.

Tidal energy :- Tidal energy or tidal power is a form of hydropower that converts energy from tides into electricity or other useful forms of power.

It is renewable energy source driven by the gravitational pull of the moon and the sun on the Earth's oceans.

Advantages

- Renewable and predictable energy source.
- Low operational Cost
- No green house gas emission
- Long life span
- Potential for energy storage.

Disadvantages

- High Initial Cost
- Environmental impact on marine ecosystem
- Limited Suitable Locations
- Complex Engineering challenges.

Present Status in India :- As of now, tidal energy in India is still in the early stages of development. India has identified several sites with the potential for tidal energy.

1) The Gulf of Khambat (Cambay) in Gujarat.
2) The Gulf of kutch in Gujarat
3) Sundarbans in west Bengal.

Single Basin System :- A single basin system consists of one tidal basin created by constructing a barrage (dam) across an estuary or bay.

- This system utilizes the natural rise and fall of tides to generate electricity.
- It has simpler design and lower initial cost. (Advantage)
- Energy generation is intermittent, depending on tidal cycles. (Disadvantage)

Two Basin System :- Two basin system involves two separate basins, typically referred to as the upper and lower basins.

- They works between high tide and low tide.
- The water flows between upper & lower basins through turbines to generate electicity.
- It is more consistent and flexible in operation allows it in varying tidal conditions (advantage)
- More Complex & Costly design (disadvantage)
- Greater environmental impact due to extensive infrastructure (disad)

Ocean Thermal Energy Conversion (OTEC)

OTEC is a technology that generates electricity by exploiting the temperature difference between warm surface waters and cold deep ocean waters. Here's how it works:

1) Warm water from the surface is pumped through a heat exchanger to vaporize a working fluid (usually ammonia, which has a low boiling point).
2) The vaporize working fluid expands and drives a turbine connected to generator, producing electsicity.
3) Cold seawater from the deep ocean is pumped through another heat exchanger which condenses the vaporized working fluid back into a liquid.
4) The condensed working fluid is then pumped back to the heat exchanger to be vaporized again, continuing the cycle.

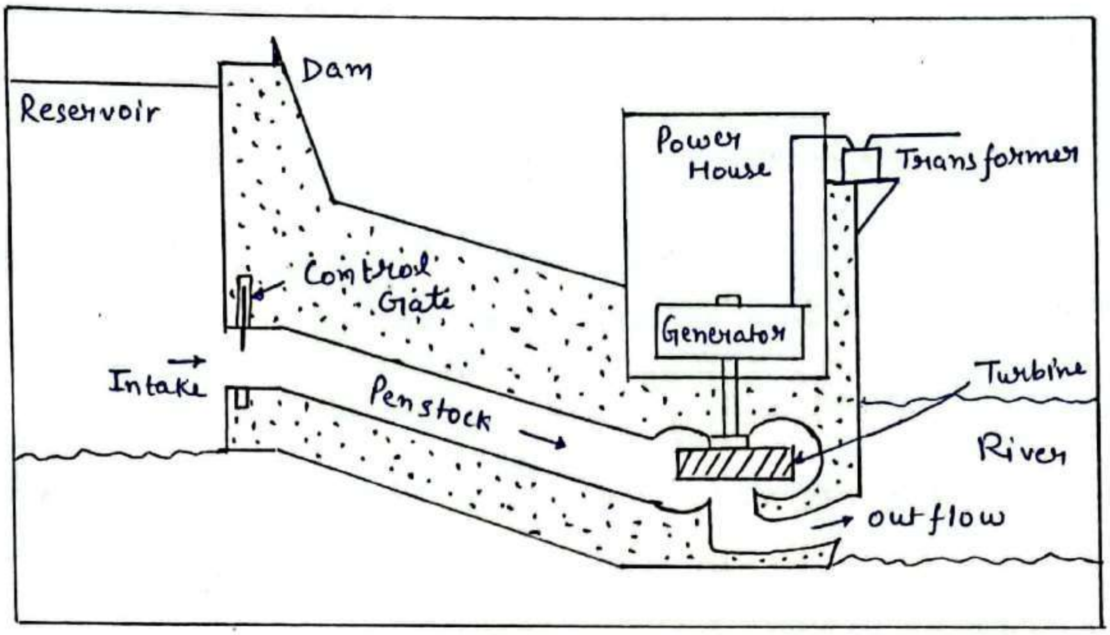
Types of OTEC

1) Closed-cycle OTEC :- Uses a working fluid with a low boiling point, ammonia. It is two loop cycle.
2) Open-cycle OTEC :- Uses seawater directly as the working fluid. This system is open because it uses seawater only once.
3) Hybrid OTEC :- Combines elements of both closed cycle and open cycle system. This approach aims to maximize the efficiency.

Hydropower :- Hodropower, also known as hydroelectric power, is a renewable energy source that harnesses the energy of flowing or falling water to generate electricity.

It is one of the oldest and most widely used form of renewable energy.

Hydro power plant



- Construction of a dam on a river to create a reservoir or use of natural water falls.
- water from the reservoir is released through a penstock, a large pipe that channels the water down to the turbines.
- The flowing water strikes the blades of the Turbine, causing it to spin. The K.E of water is converted into mechanical energy.
- This mechanical energy drives the generator to produce electricity.

- The generated electricity is then transmitted through power lines to homes, businesses and other users.
- After passing through the turbine, the water is released back into the river downstream.

Biomass and Biogas

- <u>Biomass</u> refers to an organic material from plants and animals that can be used as a source of energy. This includes wood, agricultural crops, animal manure and other biological materials. Biomass can be burned directly to produce heat or converted into biofuels like ethanol or biodiesel through processes like fermentation or transesterification.
- <u>Biogas</u> is a type of bioenergy produced from the anaerobic digestion of organic materials by microorganisms. It primarily consists of methane (CH_4) and carbon dioxide (CO_2). Biogas is generated from the decomposition of organic waste in the environments devoid of oxygen, such as in landfills, digesters, or septic tanks. It can be used as a fuel for heating, electricity generation and even a vehicle fuel.

Unit-4 Important Questions & PYQ (AKTU)

-1- What are conventional and non-conventional energy sources?

-2- What are Renewable and non-renewable energy sources?

-3- What are primary and secondary energy sources?

-4- Derive the continuity equation for 1-D fluid flow. Also derive the expression for wind power.

-5- State Bernoulli's theorem for fluid flow.

-6- Write down the principle of power generation in wind mills. Derive an expression for maximum efficiency.

-7- Discuss some physical properties of fluids in brief.

a) Density or mass density

b) weight Density

c) Specific Volume

d) Viscosity

e) specific Gravity.

-8- Explain the types of flow.

-9- Discuss all parameters related to wind turbine.

-10- Write a short note on wind farm.

-11- Explain geothermal power plant with diagram

-12- Identify the potential of geothermal energy and how it can be extracted.

-13- Explain working principle of ocean thermal energy Convervison (OTEC). Define their types.

-14- How are wind turbines designed?

-15- Write a short notes on:

a) Fluid dynamics in wind energy Conversion.

b) Betz law to receive maximum energy

c) Effect of no. of rotor blades on performance efficiency.

- 16- What is tidal energy? Discuss tidal power plant with their advantages & limitations. Also give present Status of tidal power in INDIA.
- 17- Define hydropower. sketch hydro power plant.
- 18- Describe the 'single basin' and 'two basin' systems of tidal power harnessing. Discuss their advantages and limitation.

19- Describe the process of gasification of solid biomass. What is the general composition of the gas produced and what is its heating value? what are its applications?

20- Describe Deenbandhu biogas plant.

Energy :- Energy is the ability to do work or cause change.

It is a scaler quantity.

Modern civilisation is possible because people have learned how to change energy from one form to another and then use it to do work.

Units of energy :- Because energy is measured in terms of work, the unit of energy is same as the unit of work.

(i) **Joule (J)** :- One joule equals one newton metre, in terms of SI units.

$$\left\{ \begin{array}{c} 1\,J = 1\,Nm \\ \text{or} \\ 1\,J = 1\,kg\,\frac{m^2}{s^2} \end{array} \right\}$$

(ii) **Calorie** : A calorie is the energy that it takes to raise the temperature of 1 gram of water by $1^\circ C$.

$$\left\{ \begin{array}{c} 1\,Cal = 4.184\,J \\ \text{and} \\ 1\,J = 0.239\,Cal \end{array} \right\}$$

(iii) **Kilowatt-hour (kWh)** :- It is a unit of measurment for energy or electricity that is equal to one kilowatt (1,000 watts) of power used for one hour.

$$\left\{ \begin{array}{c} 1\,kWh = 3.6 \text{ mega joules} \\ \text{or} \\ 1\,kWh = 3.6 \times 10^6\,J \end{array} \right\}$$

(iv) British thermal unit (Btu) :- one Btu is the energy or heat that it takes to raise the temperature of one pound of water by 1°F.

$$\left\{ \begin{array}{c} 1\ Btu = 251.9\ Cal \\ or \\ 1\ Btu = 1055.06\ J \end{array} \right\}$$

Scales of energy → It relates to the amount of energy used or transferred in a physical process.

Factor	Name	Symbol	Usage
10^{24}	yotta	Y	Energy of galaxy or universe
10^{21}	zetta	Z	
10^{18}	exa	E	Energy used in world or countries
10^{15}	peta	P	
10^{12}	tera	T	Power plants
10^{9}	giga	G	
10^{6}	mega	M	
10^{3}	kilo	k	Energy used on Domestic level
10^{2}	hecto	h	
10^{1}	deka	da	small devices or circuits
10^{-1}	deci	d	
10^{-2}	centi	c	In laboratries
10^{-3}	milli	m	
10^{-6}	micro	μ	
10^{-9}	nano	n	Energy captured at atomic level
10^{-12}	pico	p	
10^{-15}	femto	f	
10^{-18}	atto	a	
10^{-21}	zepto	z	
10^{-24}	yocto	y	

Forms or types of Energy

- Mechanical Energy
- Thermal Energy
- Nuclear Energy
- Chemical Energy
- Solar Energy
- Geo thermal Energy
- Electrical Energy
- Sonic or Sound Energy
- Kinetic Energy
- Potential Energy
- Tidal Energy
- Wind Energy
- Light Energy
- Wave Energy
- Gravitational Energy
- Ionization Energy

Mechanical Energy :- The mechanical Energy is the total amount of kinetic energy (energy of motion) and potential energy (stored energy of position) of an object that is used to do a specific work.

Total Mechanical Energy = Kinetic Energy + Potential Energy

or

$$\{ TME = K.E + P.E \}$$

Examples of Mechanical Energy

(i) Riding a bicycle

(ii) Sharpening a pencil

(iii) Typing on a keyboard

(iv) Clocks

(v) Transportation

(vi) Windmills

(vii) See saws

(viii) Bouncing a ball

Kinetic Energy :- Kinetic Energy is the energy, an object has because of its motion.

$$\left\{ KE = \frac{1}{2} m v^2 \right\}$$

Potential Energy :- The energy that is stored in an object.

$$\left\{ P.E = mgh \right\}$$

Note :- The sum of kinetic Energy and Potential Energy of any object is always constant. This is known as Conservation of mechanical Energy.

Transport of Mechanical Energy

Mechanical Energy can be transported in some ways:

(i) Mechanical work :- When a force moves an object over a distance. This is known as mechanical work.

(ii) Waves :- Waves transport mechanical Energy from one place to another without moving the material itself.

(iii) Pumps :- Pumps can transport mechanical Energy across a chain in one pumping cycle.

Heat Energy :- Heat Energy or thermal Energy is the energy
(thermal Energy) produced by the collision or movement of atoms or molecules in any object.

- Heat Energy flows from higher temperature to lower temperature without doing any work.

  e.g. :- Heater, Ironing, Mix hot and Cold water, Freezing your hand by touching ice.

- Heat Energy can be flow from lower temperature to higher temperature by doing a work.

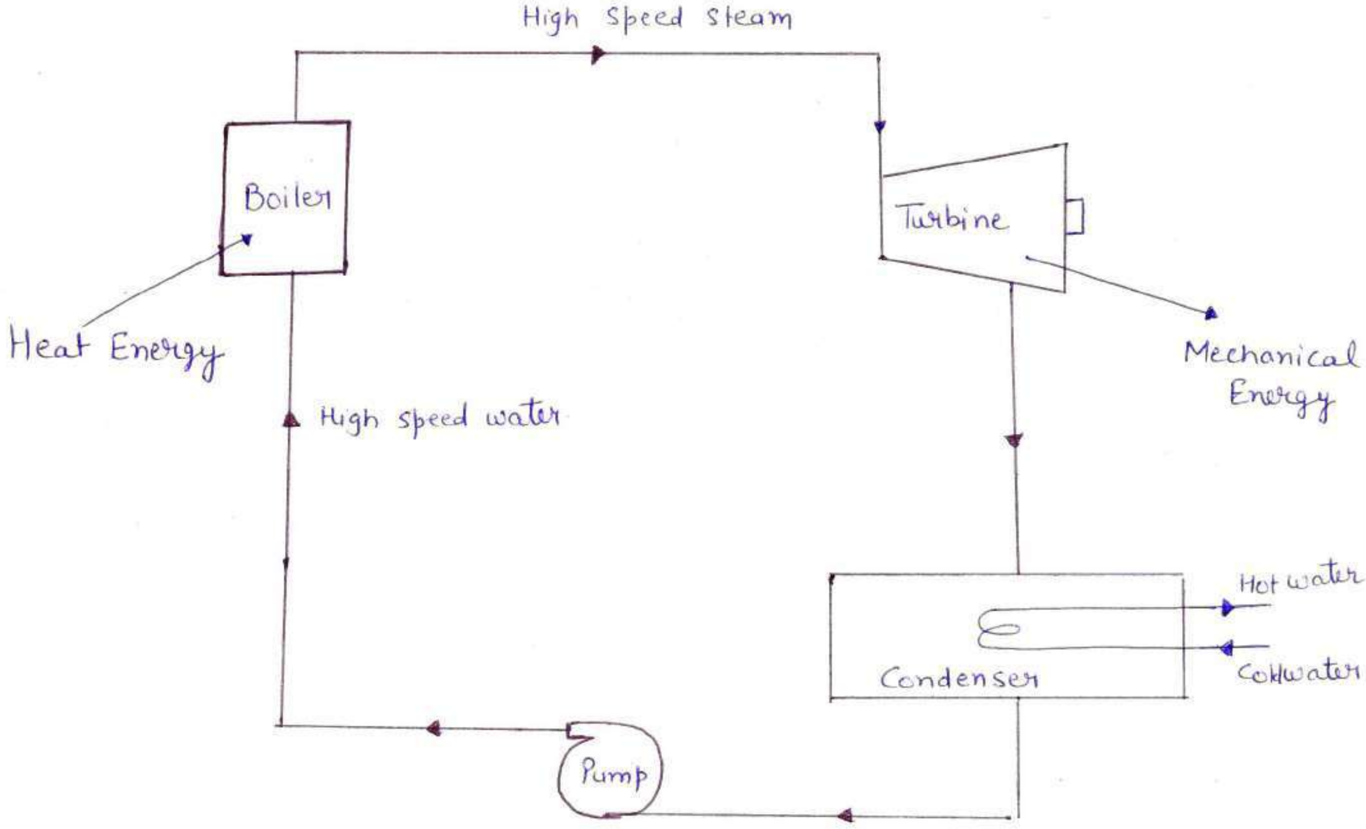
  e.g :- Air Conditioner and refrigerators.

Conversion between heat and mechanical Energy

The Conversion between heat and mechanical Energy is a fundamental Concept in thermodynamics.
It is based on the System's internal energy Can be changed by adding heat or doing work to it.

- Now a days 80 % mechanical Energy are poducing by heat Engine or power plants.
- All fuel based vehicles run over a heat Energy of fuel.
- Two third of power plants are based on heat Energy of fuel. which is Called thermal power plant.
- In thermal power plants we use heat Energy to make high speed steam then this steam produces mechanical energy by rotating a steam turbine.

Block diagram of thermal power plant



The mechanical energy obtained from turbine, can be used to convert into electrical energy by generator.

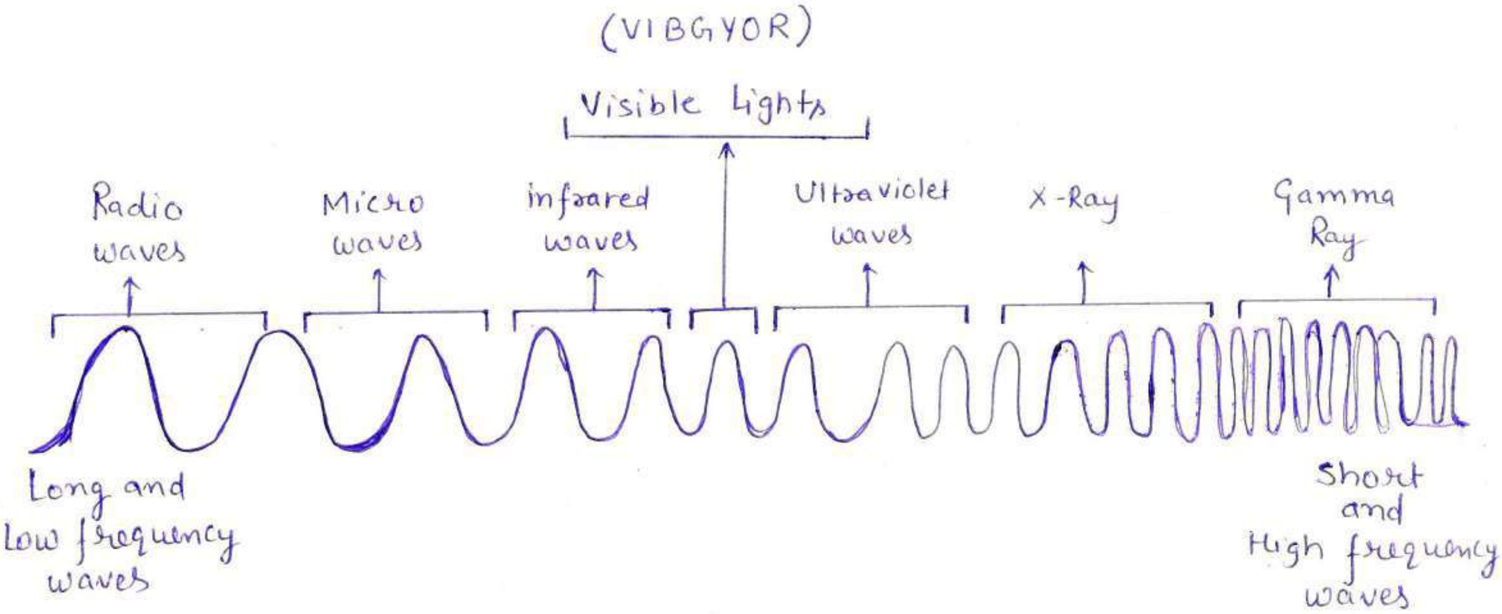
- Mechanical energy can be converted into heat energy through friction, compression and refrigeration.

Electromagnetic Energy :- Electromagnetic Energy can be termed electromagnetic radiation.

These radiation Consists of electromagnetic waves, which are Synchronized oscillation of electric and magnetic fields.

⇒ Electromagnetic waves are emitted by electrically charged particles undergoing acceleration.

⇒ These waves carry energy, momentum and angular momentum away from their source particle and can impart those quantities to matter with which they interact.



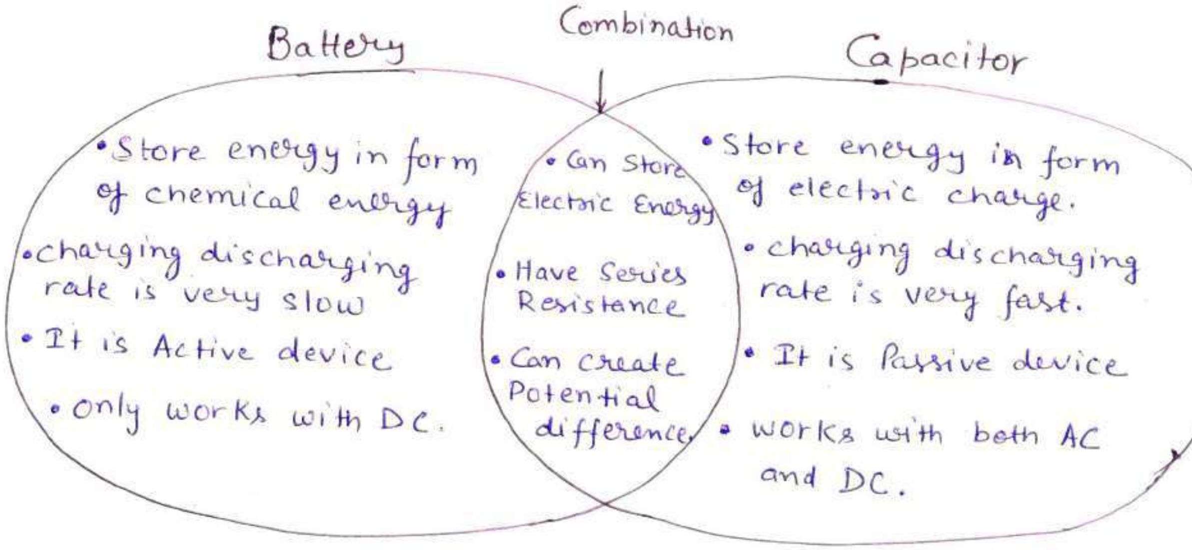
⇒ All waves except visible lights are invisible waves.

Storage :- Electromagnetic Energy Can be stored in a variety of ways. when it Comes to circuits and electronic devices, energy is typically stored in one of two places.

(i) The first, a battery, stores energy in chemicals.

(ii) Second, Capacitors, they store energy in an electric field.

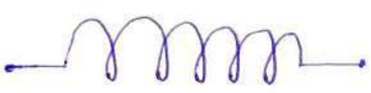
⇒ Engineers choose to use a battery or Capacitor based on the circuit. Even Combination of batteries and Capacitors Can also be used.



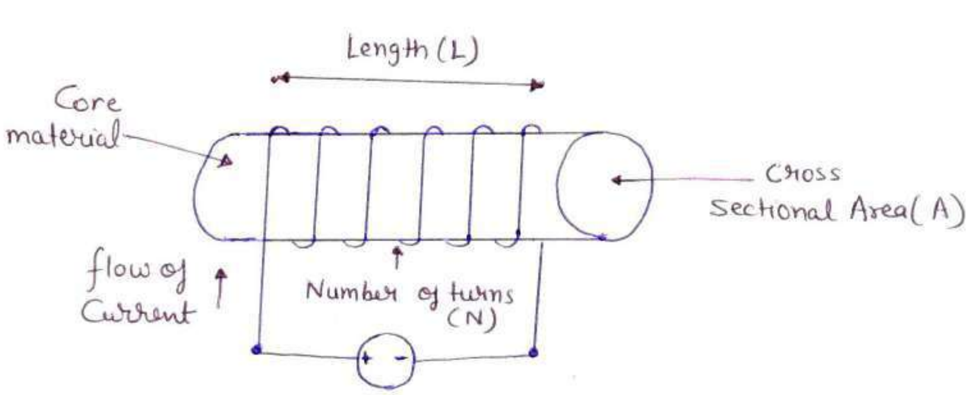
⇒ Energy Can be stored in magnetic field by an inctor or superConding magnetic energy storage (SMES) system.

Inductor :- An inductor, is a passive two terminal electrical Component that stores energy in a magnetic field when electric current flows through it.

Inductor is also Called a coil, choke or reactor.

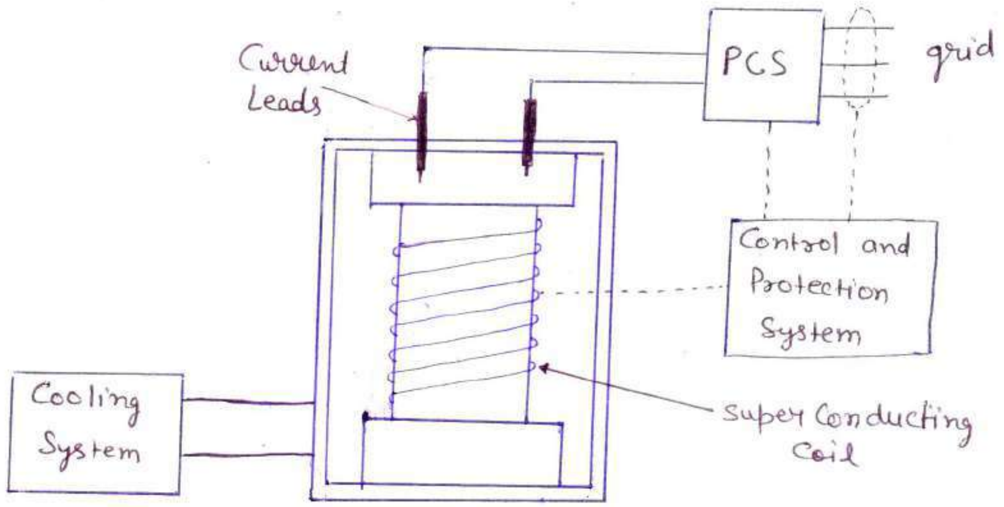


Symbol



Super Conducting magnetic Energy storage (SMES)

A SMES System uses a Super Conducting coil that's cooled below its critical temperature to generate a magnetic field that stores energy.
Because the wire is made from a super Conducting material, electric current can pass through it with almost no resistance. That's why the energy can be stored for a longer period of time.



PCS : Power Conditioning System.

Conversion:- Electromagnetic Energy Conversion is the process of changing EM energy into other forms of energy.

(i) Polymeric materials can convert EM energy from sun into electric power.

(ii) Radio frequency power harvesting uses an antenna and rectifier circuit to convert AC or radio frequency power into DC voltage.

Transmission :- The EM energy transmission is the process of moving electromagnetic waves through space or a medium.

Examples:- (i) Transmission of electrical energy.

(ii) Broadcasting of radio signals

(iii) Phenomenon of visible lights

(iv) Radar waves used to guide airplanes.

(v) Infrared used for electric heaters.

Radiation :- Radiation refers to the emission or transmission of energy in the form of waves or particles through space or a material medium.

Each type of radiation behaves differently and interects with matter in various ways.

(i) Ionizing Radiation :- This includes high energy electromagnetic waves (X-rays, gamma rays) and particles (α and β particles, neutrons) that have enough energy to ionize atoms and molecules, potentially causing damage to biological tissues.

(ii) Non-ionizing Radiation :- This includes low energy EM waves (radio waves, microwaves, infrared and visible Light) that don't have enough energy to ionize atoms but can still Cause biological effects, such as heating tissues.

Source of Radiation :- Radiation can originate from natural sources (like Sun, radioactive materials in the Earth) and artificial source (such as medical X-rays, nuclear reactors and microwave ovens).

Direct and diffuse radiation

The radiations are commonly used in the Context of solar radiation and its distribution on Earth's surface :

1. Direct Radiation :- This type of solar radiation travels directly from the sun to a specific point on Earth's surface without being scattered or reflected by the atmosphere.

2. Diffuse Radiation :- This type of solar radiation is scattered and redirected in all directions by molecules and particles in the Earth's atmosphere.

Both direct and diffuse radiation Contribute to the total solar radiation received at a given location on Earth.

Quantum :- Quantum refers to the branch of physics that deals with phenomena at very small scales, such as atoms and subatomic particles.

Quantum mechanics :- Quantum mechanics is the theory that describes the rules and principles governing phenomena of quantum.

Key principles of quantum mechanics includes:

(i) Wave-particle duality :- Particles such as electrons exhibit both particle-like and wave-like properties.

(ii) Quantization :- Certain properties of particles, such as energy levels in an atoms, are discrete rathar than continuous.

(iii) Uncertainty Principle :- It is impossible to know the exact position and momentum of a particle simultaneously.

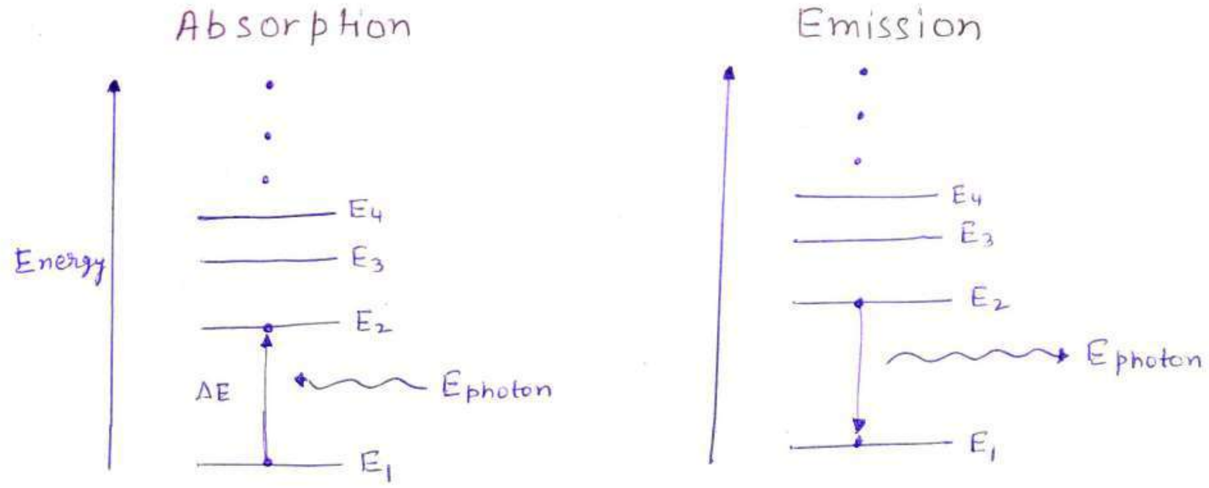
(iv) Superposition :- Quantum system can exist in multiple states or locations at once, until they are measured or observed.

(v) Entanglement :- When particles are entangled, their quantum states are linked in a way that the measurement of one particle's state instantaneously determines the state of the other particle, no matter how far apart they are.

Energy Quantization :- OR (Quantization of Energy)

Quantization of Energy refers to the absorption or emission of energy in discrete packets or 'quanta'.

In other words, An electron can radiate or absorb energy as radiation only in limited amounts or bundles called quanta.



⇒ This is a planck's experiment of energy quantization where ΔE = change in Energy level by absorbing or emitting of photon.

or

$$\Delta E = E_2 - E_1$$

or

$$\{\Delta E = hf\} \longrightarrow \left\{\begin{array}{l}\text{Also known as} \\ \text{Planck's radiation Law}\end{array}\right\}$$

where $h \rightarrow$ A fundamental Constant Called planck's Constant

$f \rightarrow$ frequency

The Value of Planck's Constant

$$\boxed{h = 6.626 \times 10^{-34} \text{ J.s}}$$

Energy in chemical system :- Energy in chemical System is popularly known as chemical Energy. This type of energy is stored in the bonds of chemical compounds, like atoms and molecules.
This energy is released when a chemical reaction takes place. Once chemical energy has been released from a substance, that substance is transformed into a completely new substance.

For example, when any fuel (e.g. gasoline, Petrol etc.) reacts with oxygen (O_2) in the presence of heat or spark, it undergoes a combustion reaction. During the reaction, the bonds between carbon and hydrogen atoms are broken, releasing energy in the form of heat and light. This is known as exothermic reaction.

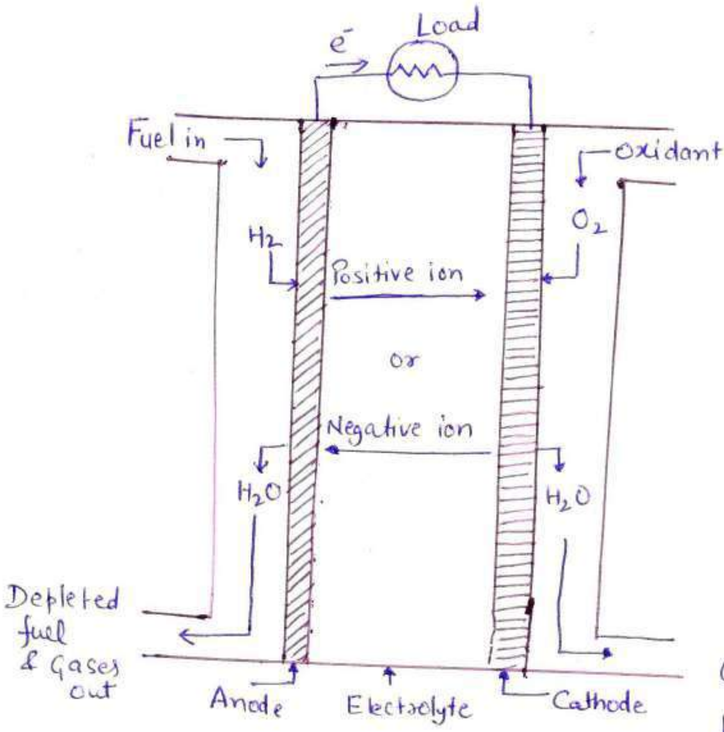
Some other examples:

- Biomass formed during photosynthesis
- Digestion of food
- Batteries store chemical energy to be changed into electricity
- Fermentation process
- Rusting
- Fuel cell

Fuel Cell :- A fuel Cell is a device that Converts chemical energy into electrical energy through a chemical reaction.

Hydrogen is the most Commonly used fuel, Called Hydrogen fuel cells. Other fuels are methanol, ethanol, natural gas, gasoline etc. oxygen or air is most commonly used as oxidant.

Working :- Fuel cells Consist of an electrolyte layer sandwiched between two electrodes - the fuel electrode (anode) and the oxygen electrode (Cathode). The fuel is fed Continuously to the fuel electrode where catalyst helps it split into protons and electrons.



The protons pass through the electrolyte to the oxygen electrode while the electrons travel in an external circuit creating electricity.

At the oxygen electrode, the electrons Combine with protons and oxygen to produce water and a little heat.

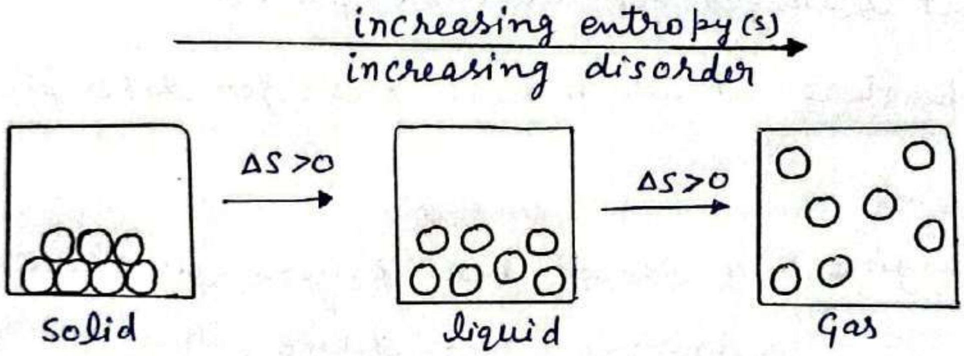
Applications of fuel Cells

- Ballard fuel cells based truck and buses in Europe and U.S.A.
- small methanol fuel cells during natural disasters.
- Indian Railways is testing fuel cell-battery hybrid Systems to power coaches and reduces diesel consumption.
- DRDO is developing portable methanol fuel cells to charge military batteries and equipment in the field.

Entropy and Temperature :- Entropy and temperature are closely related Concepts in thermodynamics.

Entropy :- Entropy is a measure of the disorder or randomness of a system. In simple terms, it quantifies the number of microscopic Configurations (arrangements of particles) that correspond to a thermodynamic system's macroscopic state.

The entropy of a system tends to increase over time in an isolated system, reflecting the tendency of systems to move towards a state of greater disorder.
Entropy is denoted by S. And change in Entropy is denoted by ΔS.



Temperature :- Temperature is a measure of the average kinetic Energy of the particles in a system.
It determines the direction of heat flow between two bodies in thermal contact.
Heat flows from a hotter body to a colder one until thermal equilibrium is achieved.

Relationship between Entropy and Temperature

The relation between entropy and temperature is expressed through the second law of thermodynamics, which states the entropy of an isolated system always increases over time, except in reversible process.

- The change in entropy of a system due to heat transfer is related to the temperature at which the heat transfer occurs:

$$\left\{ \Delta S = \frac{q_{rev}}{T} \right\} \Rightarrow \text{Unit} = \frac{\text{Joule}}{\text{Kelvin}} \text{ or } J/K$$

ΔS = change in entropy

q_{rev} = heat transfer for reversible process

T = temperature at which heat transfer takes place.

Carnot heat Engine :- A Carnot heat Engine is a theoretical thermodynamic device that operates on the principles of the Carnot Cycle.

It's named after French engineer Sadi Carnot.

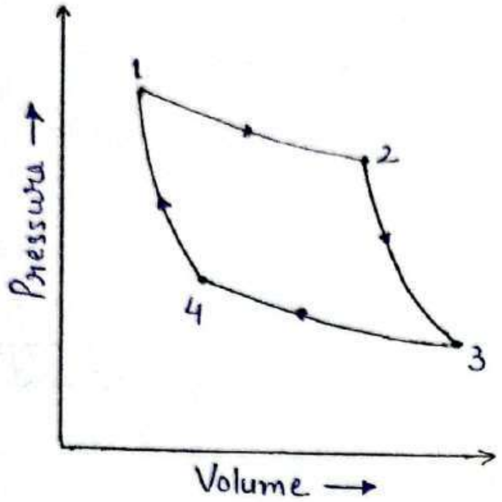
It is an idealized engine that achieves maximum efficiency between two reservoirs.

Carnot Cycle :- It is a theoretical thermodynamic cycle that represents the most efficient heat Engine cycle possible.

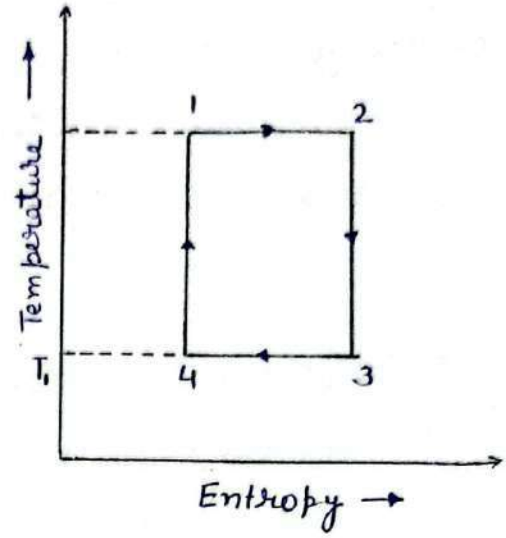
It Consists of four reversible processes:

two isothermal processes (Constant temperature)

two adiabatic processes (no heat exchange).



P-V diagram



T-S diagram

The four processes of the carnot cycle are:

- Process 1-2 It is isothermal expansion or heat addition process in the boiler.
- Process 2-3 It is adiabatic expansion process in the steam turbine.
- Process 3-4 It is isothermal Compression or heat rejection process in the condenser.
- Process 4-1 It is adiabatic compression process in the water pump.

Efficiency :- The efficiency of a Carnot cycle depends only on the temperature of two reservoirs (hot and Cold reservoirs). It is given by

$$\left\{ \eta_{Carnot} = 1 - \frac{T_c}{T_h} \right\}$$

where T_c :→ absolute temperature of Cold reservoir

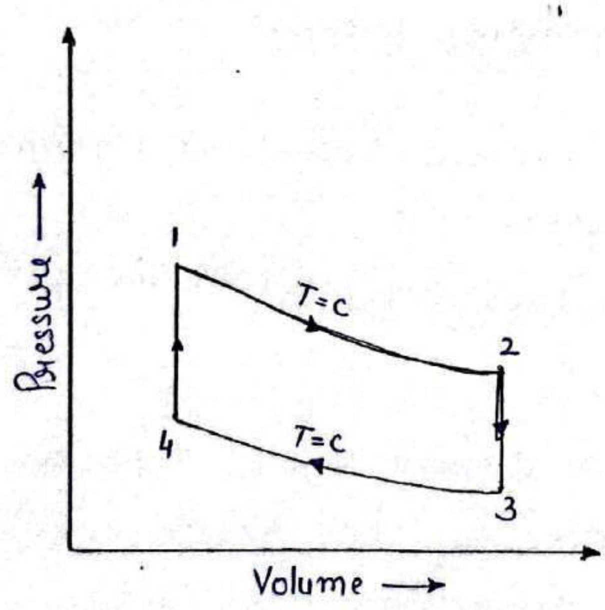
T_h :→ absolute temperature of hot reservoir

Que Why Carnot Cycle is important ?

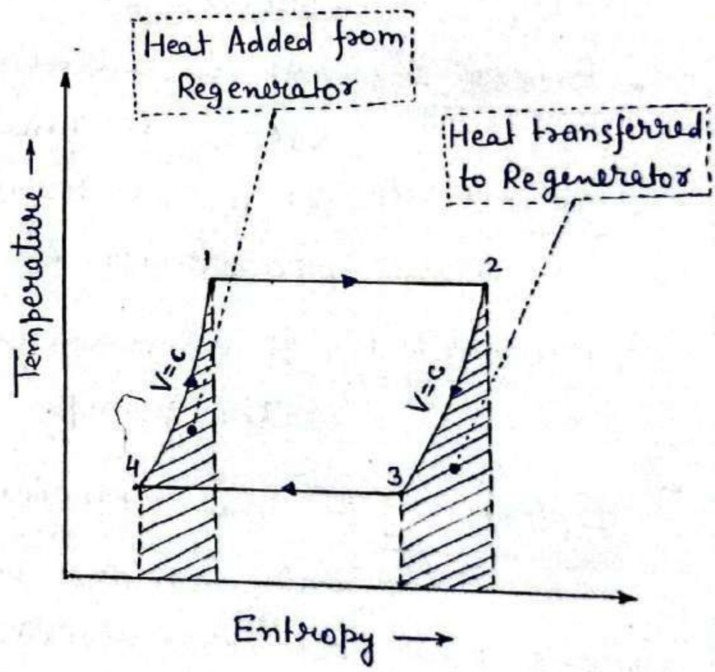
Ans The Carnot cycle is important because it establishes the theoretical limits of thermal efficiency, provides a framework for understanding the second law of thermodynamics, and guides the design and analysis of real-world thermal systems.

Stirling Heat Engine :- This engine works on a closed loop thermodynamic cycle, typically involving a fixed amount of gas that is alternately heated and cooled, thus converting thermal energy into mechanical energy.

This cycle includes four main process. These are two isothermal and two Consant volume processes.



P-V diagram



T-S diagram.

Process 1-2 Isothermal expansion from state 1 to state 2. Heat Energy will be added here from external Source.. Volume will be increased but pressure will be reduced during this process.

Process 2-3 Constant Volume process, internal heat transfer from the working fluid to regenerator and therefore this process is termed as constant Volume regeneration process.

Process 3-4 Isothermal Compression from state 3 to state 4. Heat Energy will be rejected here to the external sink. Volume will be reduced but pressure will be increased during this process.

Process 4-1 Constant Volume process, internal heat transfer from the regenerator back to the working fluid.

Q. What is regenerator?

A. A regenerator is often used to improve the engine's efficiency by recovering heat from the exhaust gas and transferring it to the incoming gas.

Efficiency :- The efficiency of Stirling engine is equal to the ideal Carnot cycle.

$$\left\{ \eta_{St} = 1 - \frac{T_c}{T_h} \right\}$$

Application :- Stirling Cycle applications in the following areas:

- Electricity generation in remote areas.
- Power source for deep space missions.
- Waste heat recovery in industries.
- Home heating and cooling systems.
- Cryogenic referigeration for research and medical purposes.

Phase change :- A phase change is when matter changes from one state (solid, liquid, gas, plasma) to another.

These changes occur when sufficient energy is supplied to the system or a sufficient energy is lost.

These changes also occur when pressure on the system is changed.

The temperature and pressure under which these changes happen differ depending on the chemical and physical properties of the system.

The energy associated with these phase changes is called latent heat.

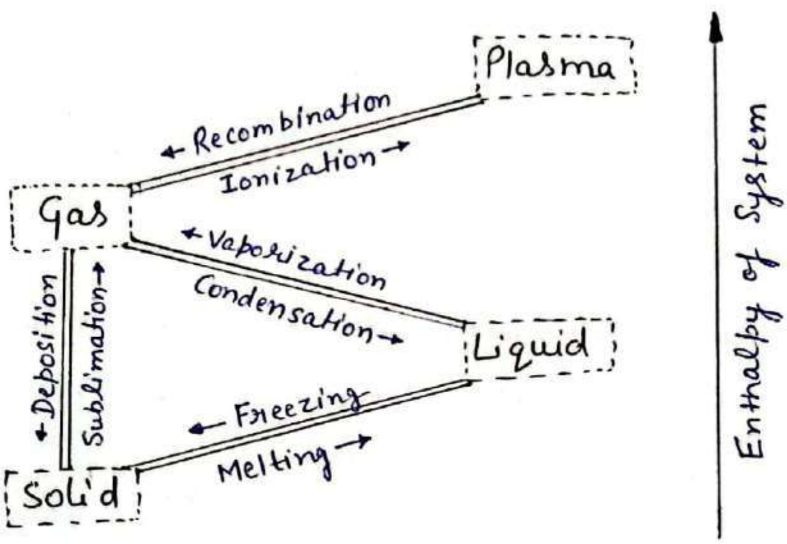


Fig : Diagram of Phase change

Specific heat :- The specific heat of a substance is the amount of energy required to raise the temperature of 1 kg of that substance by 1 K.

Enthalpy (Latent heat) :- The enthalpy or latent heat of a substance is the heat required to change states (phase change).

Heat Engine :- A Heat engine is a system that converts thermal energy into mechanical Energy.

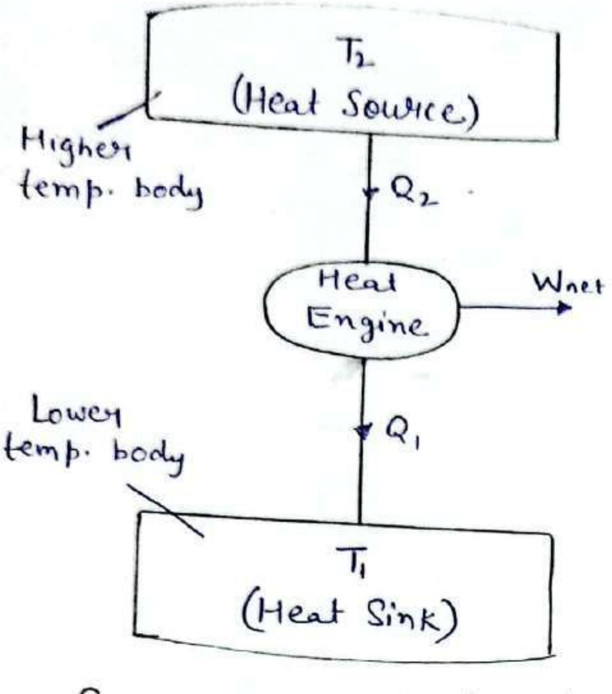


fig: Working of heat engine

In heat engine, the heat supplied to the engine is converted into useful work. If Q_2 is the heat supplied to the engine and Q_1 is the heat rejected from the heat engine then the net work done by the engine is given by

$$\{ W = Q_2 - Q_1 \}$$

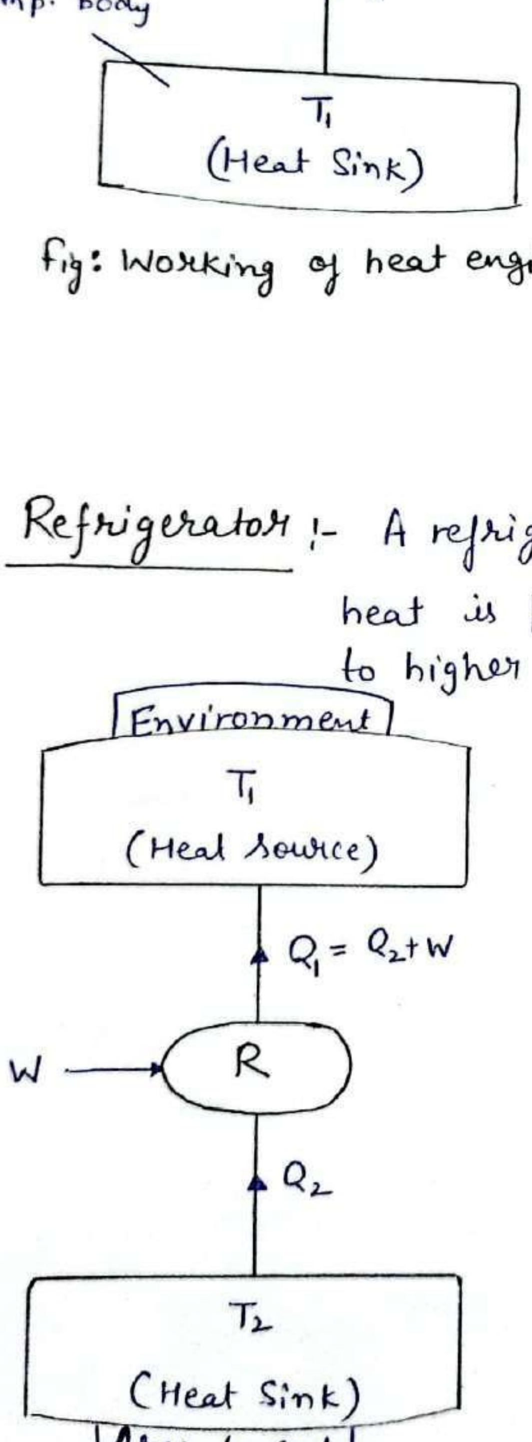
And the the efficiency is calculated as

$$\eta = \frac{\text{net work}}{\cancel{\text{net}}\text{Heat Supplied}}$$

$$\eta = \frac{W}{Q_2}$$

$$\text{or} \left\{ \eta = \frac{Q_2 - Q_1}{Q_2} \right\}$$

Refrigerator :- A refrigerator is a reversed heat engine, where heat is pumped from low temperature (Heat Sink) to higher temperature (Heat source) by doing a work.



The Performance of a refrigerator is the ratio of the amount of heat taken from the cold body to the amount of work to be done on the system.

$$C.O.P. = \frac{Q_2}{W}$$

Here $W = Q_1 - Q_2$

$$\text{so} \left\{ COP = \frac{Q_2}{Q_1 - Q_2} \right\}$$

* COP : Coefficient of Performance.

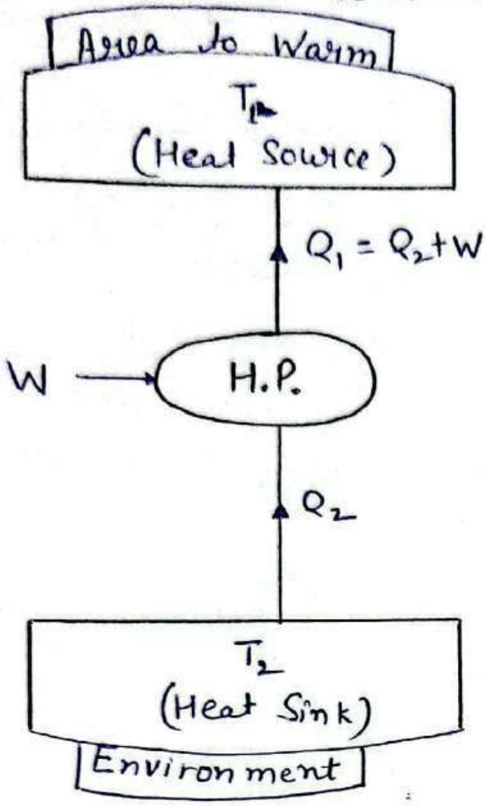
Refrigeration :- Refrigeration, or cooling process, is the removal of unwanted heat from a selected object, substance or space and it transfer to another object, substance or space.

Removal of heat or lower the temperature can be done by the use of ice, snow, chilled water, coolent or mechanical refrigeration.

Application of Refrigeration :- Refrigeration has many applications, including:

- household refrigerators.
- Industrial freezers.
- Processing food & Beverages.
- Chemical and petrochemicals.
- Data centres.
- Air Conditioning.

Heat Pump :- Heat pump is a mechanical compression cycle that can be reversed to either heat or cool a controlled space.



Basically heat pump is same as refrigerator that extract heat from a cold body and delivers it to a hot body.

The main difference between them is in their operating temperature.

A refrigerator used for cooling in summer where heat pump is used for heating in the winter seasons.

$$COP_{HP} = \frac{\text{Heat to Source Area}}{\text{Work in}}$$

$$COP_{HP} = \frac{Q_1}{W}$$

$$\text{or } \left\{ COP_{HP} = \frac{Q_1}{Q_1 - Q_2} \right\}$$

Application :→ Heat pumps are used in many categories.

- HVAC and Potable water cooling
- Bathing, sanitation etc.
- Process heating
- Boiler feed water heating

Relation between COP of refrigerator and Heat Pump

$$(COP)_{Refrigerator} = \frac{Q_2}{Q_1 - Q_2} \quad \text{and} \quad (COP)_{Heat\ Pump} = \frac{Q_1}{Q_1 - Q_2}$$

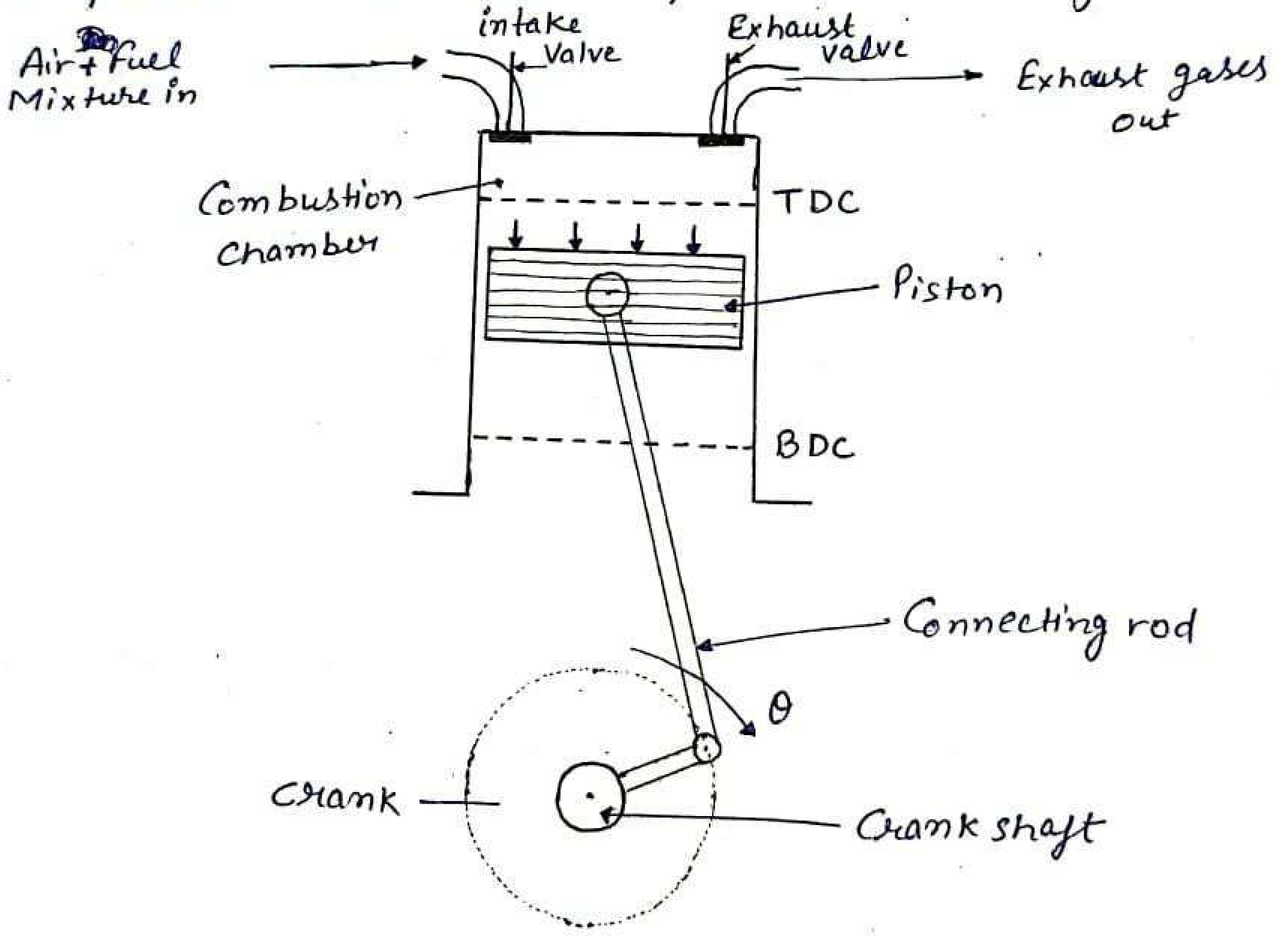
$$\text{So} \quad (COP)_{HP} - (COP)_{Ref} = \frac{Q_1}{Q_1 - Q_2} - \frac{Q_2}{Q_1 - Q_2}$$

$$(COP)_{HP} - (COP)_{Ref} = \frac{Q_1 - Q_2}{Q_1 - Q_2} = 1$$

$$\left\{ (COP)_{HP} = 1 + (COP)_{Ref} \right\}$$

Internal Combustion Engine (IC Engine)

An IC Engine is a type of heat engine that converts the chemical energy stored in fuel into mechanical energy.
Fuel and air are mixed, combusted and burned in an IC engine within a combustion chamber. The resulting high pressure gases exert force on a piston, which translates the pressure into rotational motion through a crank shaft. This rotational mechanical energy is then used to power the vehicle or operate machinery.



The working of an IC engine can be explained in the following steps:

Intake stroke:- In this first stroke, the fuel-air mixture is drawn into the engine cylinder through the open intake valve

Compression stroke:- In this stroke, the piston compresses the fuel-air mixture inside the cylinder by moving upwards.

Power stroke:- In this stroke, the fuel-air mixture is ignited by a spark plug or a high pressure injector, causing an explosion that forces the piston to move downward. This downward motion of the piston is the source of mechanical energy.

Exhaust stroke:- In this final stroke, the exhaust valve opens, and the piston moves upward, pushing the exhaust gases out of the engine through the open exhaust valve.

Classification of IC Engine

① Based on the type of cycle they follow

(i) **Otto cycle:-** Petrol Engine works on otto cycle.
Spark plug is required.

(ii) **Diesel cycle:-** Diesel engine works on diesel cycle
Fuel injector is required.

(iii) **Dual cycle:-** It is a combination of otto and diesel cycle.

② Based on the ~~$~~ Number of strokes per cycle

(i) Four stroke IC engine:- In this type of IC engine, the piston compeletes four stroke (two upstokes and two down strokes) to complete one cycle.

(ii) Two stroke IC engine:- In this type of IC engine, the piston completes Two strokes (one upstroke and one downstroke) to complete ~~the~~ one cycle.

③ Based on fuel type

(i) Spark-ignition IC Engine:- The combustion process in SI engine is initiated by an electric spark.
This engine uses gasoline and Petrol as a fuel.

(ii) Combustion-Ignition IC Engine:- The combustion process in CI engine is initiated by the high temperature and pressure of the compressed air in the cylinder.
This engine uses diesel as a fuel.

Application of IC Engine

- Automobile (cars, buses, trucks and motorcycle)
- Aircraft (small aircraft and Helicopter)
- Marine (ships, boats and submarine)
- Agriculture (tractors, harvestors and irrigation pumps)
- Power generation (Generators)
- Construction (excavators, bulldozers and cranes)
- Military (tanks and air craft)
- Small equipment (lawn movers, chainsaws)

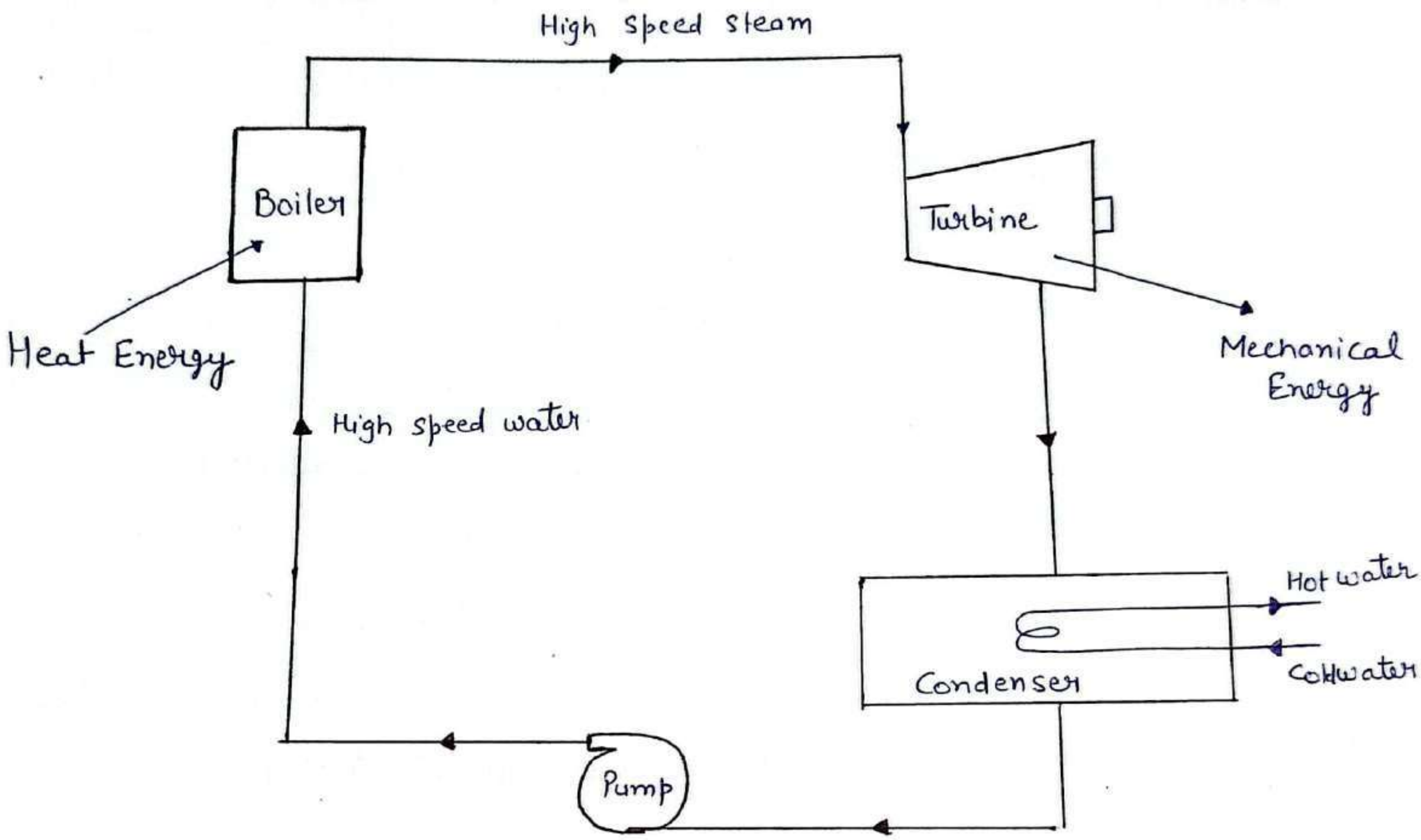
Steam Power Cycle :- Steam Power Cycle is also known as vapour Power cycle.

Those power plants which depend on steam power cycle are called steam power plants.

A steam power plant continuously converts the energy stored in fossil fuels (coal, petroleum, and natural gas) or fissile fuels (uranium, thorium) into mechanical energy and ultimately into electricity.

In steam power cycle, the working fluid, which is water, undergoes a change of phase.

Heat is transferred to water in the boiler from an external source (furnace, where fuel is continuously burnt) to raise steam with high pressure and temperature.


High speed steam
Boiler
Turbine
Heat Energy
Mechanical Energy
High speed water
Hot water
Condenser
Coldwater
Pump

1) Pump (Process 1-2) : Pump pressurized the liquid water to the boiler. For this, the pump has to work. which is denoted by W_P.

2) Boiler (Process 2-3) : Liquid water enters the boiler and is heated to super heated state in the boiler. The heat required for this process can be named as Q_1

3) Turbine (Process 3-4) : steam from the boiler, which has an elevated temperature and pressure, expand through the turbine to produce work (W_T) and then is discharged to the condenser with relatively low pressure.

4) Condenser (Process 4-1) : steam from the turbine is condensed to liquid water in the condenser.

Efficiency: The efficiency of steam power cycle is defined as:

$$\eta_{cycle} = \frac{\text{Net work done}}{\text{Heat supplied to boiler}}$$

$$= \frac{W_{net}}{Q_{in}}$$

$$\left\{ \eta_{cycle} = \frac{W_T - W_P}{Q_{in}} \right\}$$

Where W_T = work obtained from Turbine

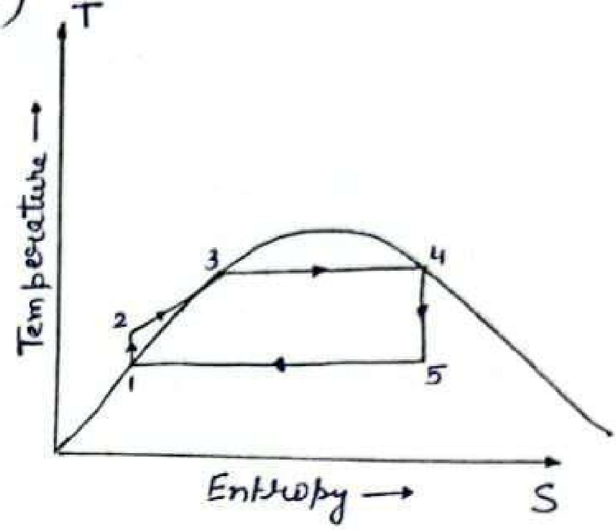
W_P = Work done by the pump

Q_{in} = Heat supplied to the boiler.

Rankine Cycle: Rankine Cycle is an ideal vapour power cycle which is named after William John Macquorn Rankine, a Scottish Professor.

The Rankine Cycle operates in the following steps:

- Isentropic Compression (Process 1-2)
- Isobaric heat transfer (2-3-4)
- Isentropic Expansion (4-5)
- Isobaric heat rejection (5-1)



In Rankine cycle, the work done by the pump is only 1% of the work done obtained from turbine, hence we consider the work done by the pump as negligible.

So the efficiency of Rankine cycle is:

$$\left\{ \eta_{Rankine} = \frac{W_T}{Q_{in}} \right\}$$

where W_T = Work obtained from turbine

Q_{in} = Heat supplied to the boiler.

Gas Power Cycle :- A gas power cycle typically refers to a thermodynamic cycle that converts heat energy into mechanical energy using a working fluid, such as air or gas.

- The most common gas power cycles are otto cycle and diesel cycle, which are used in IC engines.
- Brayton Cycle is used in Jet engines and gas turbine power plants.
- Each gas power cycle involves specific processes: Compression, heating, expansion and cooling that describe how energy is transferred into and out of the gas to produce work.

1) Otto cycle: used in petrol engines, where air-fuel mixture is compressed, ignited by spark plug, and then expands to produce work.

2) Diesel cycle: used in diesel engines, where air is compressed to a high temperature, fuel is injected, combusted by compression heat, and then expands to produce work.

3) Brayton Cycle: used in gas turbine engines and power plants. Air is compressed, heated at constant pressure by burning fuel, expanded through a turbine to produce work.

Physics of Power Plant :- The physics of a power plant revolves around the fundamental principles of thermodynamics and electromagnetism, which govern the conversion of various forms of energy into electrical energy.

Here are the key aspects of the physics involved in a power plants:

1) **Thermodynamics** :- Power plants operate on the principles of thermodynamics, perticularly the conversion of heat into mechanical energy. This involves processes such as combustion (in fossil fuel plants), nuclear reaction (in nuclear plants, or harnessing renewable energy sources like solar or hydrothermal energy.

2) **Electricity and Magnetism** :- Electricity generation relies on electromagnetic induction, where moving a conductor through a magnetic field generates electric current. This principle is used in generators to convert mechanical energy (from turbine) into electrical energy.

3) **Fluid Mechanics** :- Fluid mechanics is crucial for the operation of turbines and the circulation of coolant in power plants. Understanding fluid flow, pressure differentials, and turbulance is essential for optimizing plant efficiency and safety.

4) **Material science** :- Power plants require materials capable of withstanding high temperatures, pressures and corrosive environments. Material science ensures that components like turbine, boilers and pipes are durable and efficient.

5) Control systems and instrumentation:- Physics principles are also applied in designing control systems and instrumentions to monitor and regulate process within power plants. This ensures stable operation and safety.

- Understanding these physics principles allows engineers to design, operate and maintain power plants efficiently

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Solid State phenomena :-

solid state phenomena refer to the properties and behaviors of materials in the solid state. This phenomena is related to the interaction of solids with light (Photo), heat (thermal) and electricity. Here's an overview of these aspects:

1) Photo electric Phenomena:

(a) Photo Conductivity:- some solids, perticulatily semi-conductors exhibit increased electrical conductivity when exposed to light. This occurs because photons from light excite electrons across the band gap, creating electron-hole pairs (excitons) that can conduct electricity.

(b) Photovoltanic effect:- This effect is crucial in solar cells where light (Photons) is absorbed by a semiconductor material, generating electron hole pairs that produce a photovoltanic current. This phenomena converts light energy directly into electrical energy.

2) Thermal Phenomena:

(a) Thermal conductivity :- Thermal Conductivity refers to the ability of a material to conduct heat. it depends on how easily heat can be transferred through the material via atomic vibrations and free electrons.

(b) Thermal expansion :- Thermal expansion is the tendency of materials to change their shape, area and volume in response to change in temperature

③ Electric Phenomena:

(a) Electrical Conductivity :- solids can range from insulators (poor Conductors of electricity) to Conductors (good conductors). Conductivity depends on the availability of free electrons and their mobility within structure.

(b) Dielectric Properties :- Dielectric materials exhibit polarization under the influence of an electric field, storing electrical energy temporarily in an electric field. They are essential in capacitors and as insulators in electronic devices.

(c) Piezoelectric effect :- Some solids (such as quartz, ceramics) exhibit the ability to generate an electric charge in response to applied mechanical stress (direct piezoelectric effect) or undergo mechanical deformation in response to an applied electric field (inverse piezoelectric effect). This property is used in sensors, actuators and ultrasonic devices.

Important Questions and PYQ (AKTU)

1. Define Energy and their important units.
2. Define Kinetic and Potential energy with examples.
3. Explain the conversion between heat & mechanical energy.
4. What is electromagnetic energy?
5. Discuss the concept of Quantum. Also describe how quantization of energy takes place.
6. State Phase change energy conversion.
7. Define Entropy. How it is related with temperature?
8. Illustrate the working of Carnot heat engine with p-V and T-S diagram
9. Describe the different Processes of Rankine cycle with the help of diagram.
10. Define refrigeration and heat pump. State the applications of them.
11. Discuss the working and application of fuel cells.
12. How internal Combustion engines work?
13. Describe in detail about photo, thermal and electrical aspects in solid state.

Que:- Phase change energy Conversion

Ans:- Phase change energy conversion refers to the process of utilizing the energy associated with phase changes of substances (like from solid to liquid or liquid to gas) to perform work or generate electricity.

This concept is often applied in various technologies and applications

1) steam engine and steam power plant

2) Refrigeration and Heat Pump

3) Thermal energy storage systems

4) Cryogenic Energy storage