

unit-II SOLAR THERMAL COLLECTORS

Solar thermal Collector:

- 1) Solar thermal collector is a device which collects solar radiation absorbing by emitted sun light.
 - 2) → The solar thermal collector commonly refers to device which converts solar energy to electrical energy. It is a one type of generating electrical energy. solar thermal collectors are non-concentrating and non-concentrating types.
 - 3) A common example of such a system is a metal plate which is coated with black colour.
 - 4) The metal plate which is coated with sun reflection material with curved shape.
 - 5) The energy is cooled by the cooling the plate with working fluids, like as water (or) glycol is running in pipes attached to the plates.
 - 6) The apertures is typically in the form of a mirror that is focused at a particular point to attached the absorber plates.
 - 7) The momentum of the sun during the day concentrating collectors to receive some energy gains from the sun.
- Solar thermal collectors are available in five types they are:
- ① Flat-plate collectors. ② Evacuated tube collectors
 - ③ evacuated plate collectors ④ polymer plate collectors
 - ⑤ Bowl collectors.

① Flat-plate collectors:-

- 1) The flat plate collector consists of enclosure containing
- 2) Dark coloured Absorb plate, with fluids circulation

3) Transparent Cover:-

- 4) this flat plate collector one side is back of the enclosure is insulated to reduce the heat loss.
- 5) the circulation of fluids in tropical and sub-tropical climates.
- 6) this flat plate collector is used in mostly industrial purpose.

② Evacuated tube collectors:-

- 1) In this type of collectors are most commonly solar thermal technology.
- 2) They are surrounded a large area metal sheets.
- 3) They offer the highest energy conversion efficiency.
- 4) This solar thermal collectors are required to reflect materials.
- 5) In this type of collectors Both glass and metals.
- 6) These metals are used to prevent the pressures and vapour pressures.

③ Evacuated plate collectors:-

- 1) this solar thermal collectors provide all the advantages of both flat plate and evacuated tube collectors.
- 2) these are more expensive.
- 3) these are also new modern thermal technologies.
- 4) the glass metal seal metal technology can be used.
- 5) these are also used in low atmosphere pressures.

④ polymer plate collectors:-

- 1) These are also designed include metal plate in front of freezings. Torrent water channels.

- 2) These are also made up of silicon, rubber materials.
- 3) polymers are flexible and therefore freezing tolerant and can employ more sufficients of absorbed energy.
- 4) These are also Heat Exchangers that low efficiency.
- 5) These polymers high melting point 160°C to 320°C .

⑤ Bowl-Collectors:-

- ① A Solar bowl is a type of solar thermal collectors. These are operates parabolic mirrors.
- ② It has fixed spherical mirror with tracking receivers.
- ③ A fixed parabolic mirror creates various shape of the sun and receives the solar energy.
- ④ The receiving of the solar energy is independent of the sun's position.

* Explain construction and working of flat plate Collectors

Flat-plate Collectors:-

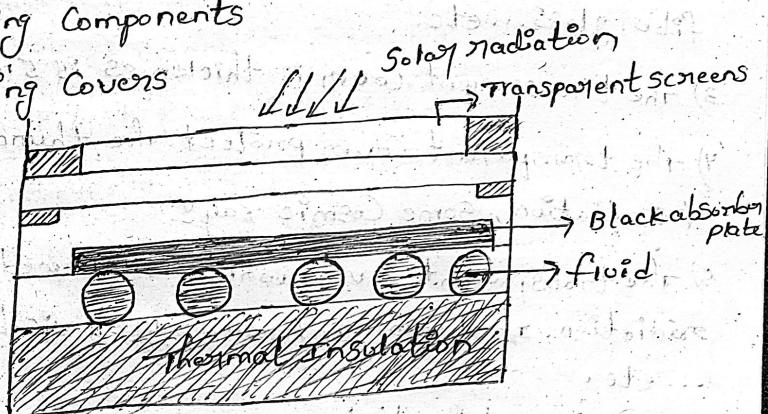
- ① Flat plate solar Thermal Collectors is a device which is solar radiation converts electrical energy.
 - ② This type of device is called Concentrating Collectors.
 - ③ this devices are used in mostly domestic hot water system.
 - ④ The main components of this type of flat plate collectors
- ① Black surface absorbent of the incident radiation
- ② Glazing Cover - Transparent layer
- This transparent layer transmitts the radiation to the absorber and it is prevents the radiation

and heat loss of the surface

- ④ Tubes containing heat fluid to transfer the heat from the collector

- ⑤ Supporting Components

- ⑥ Insulating Covers



Principle:

- 1) when a solar radiation falls on the earth surface
- 2) the basic principle of flat plate collector is green house effect.

Construction:

The flat plate collector consists of mainly four important components

1) Absorber plates:

- 1) Absorber plate is a black metallic plate of high thermal conductivity
- 2) It is mostly made up of metals like as Copper, aluminium, Ironous etc.

- 3) In generally the absorber plates is serves as copper.

- 4) the absorber plate is absorption of solar radiation and it is convert heat energy is easily

- 5) the thickness of absorber plate is 0.5mm to 1mm.

- 6) Recently the absorber plates is used to plastic materials and fiber materials also.

② transparent Cover :-

- 1) A flat plate contains a transparent Cover.
- 2) The transparent Cover is serves as glass, teflon glass, fiber glass...etc.
- 3) The transparent Cover is thickness is 5mm.
- 4) The transparent Cover protect the thunders high intensity of radiation, some Cosmic rays.
- 5) The transparent Covers which is allowed only for Solar radiation. including Infrared rays, visible rays, u.v rays...etc.

③ Tubes (or) channels :-

- 1) Tubes or channels is made up of metals like as Copper, aluminium, forums...etc.
- 2) These tubes having diameter is 1mm to 1.5mm
- 3) These tubes containing working fluid
- 4) These tubes bottom of the Surface is containing thermal insulators.

④ Fiber glass Insulation:- (Thermal Insulations)

- 1) Fiber glass Insulation of a thickness is 2.5cm to 8cm minimize the Heat energy.

Explanation:-

- 1) A flat plate Solar thermal Collectors is the fundamental Solar technology.
- 2) The Solar radiation is absorbed by the black plate and transfers the heat energy to the fluids in the tubes.
- 3) This tubes in the contains working fluids like as water, and mixing of Glycol.

4) Here the water is a common option as a fluid. It is accessibility, and good thermal property

5) The ~~maximum~~ flat plate collector design or maximum absorption minimizing reflection and radiation losses and effective heat transfer from the collectors

Advantages of flat plate Collector:-

* The advantages of flat plate collector are:-

① It is easy to manufacturing

② It is very low cost

③ It is catches the diffusion and direct radiation

④ It is very low little maintenance

⑤ It is the best tracking sun positions.

Disadvantages:-

The flat plate collector of disadvantages are:-

1) It is very low power consumption

2) It's operates from wide range of voltage supply

5m
* Explain energy-Balance equation and efficiency of solar thermal collectors?

Energy Balance in a flat plate Collector:-

1) A fundamental concept of thermal analysis of any thermal system is conversion of energy

2) the flat plate collector converts the solar energy into heat energy and the entire heat energy is transfers to working fluid.

3) The transferred of heat energy to the fluid after the thermal losses is defined as the useful heat

energy is converts the electrical energy.

- (4) The useful energy output of the solar thermal radiation collector is the difference between absorbed solar radiation and the total thermal losses from the collector.

$$\text{useful energy} = \text{Absorbed energy} - \text{thermal losses}$$

- (5) The higher energy useful output from a particular design of solar thermal collectors.

- (6) Here the thermal efficiency of the collector is an important parameter.

- (7) This parameter is used to analysis of the solar thermal collector systems.

$$\text{Now, thermal efficiency } (\eta) = \frac{\Phi_U}{A_c G_T}$$

Here Φ_U = The useful energy output from the collector.

G_T = The incident solar radiation flux

A_c = The area of the solar collector.

- (8) The total energy input for the collector. The collector area a set of technical characteristic the solar radiation area of the collector and absorption of used metals.

- (9) The energy balance equation can be express as follows.

$$\Phi_U = A_c [S - U_L (T_{plate} - T_{ambient})]$$

Here S is the absorbed solar radiation

U_L = is the total heat losses.

T_{plate} = is temperature of the absorber plate

$T_{ambient}$ = is temperature of the air

A_c = is the area of the collector plate

when we measured the incident solar radiation (I_t) are available.

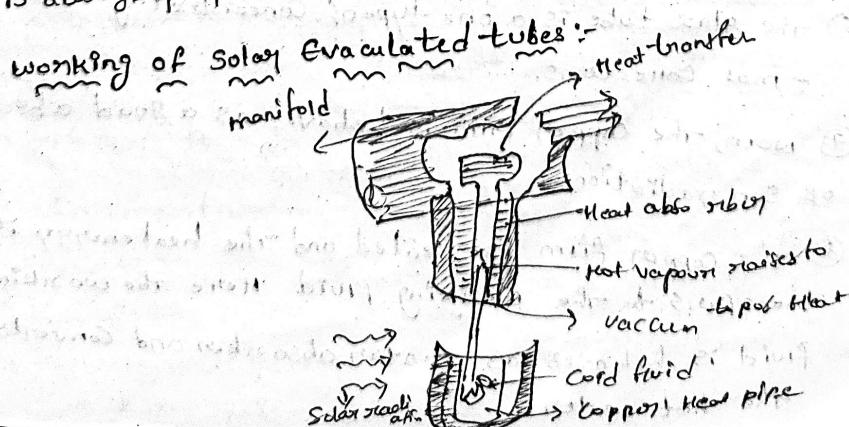
The convenient approximation for the absorbed energy plate is given by

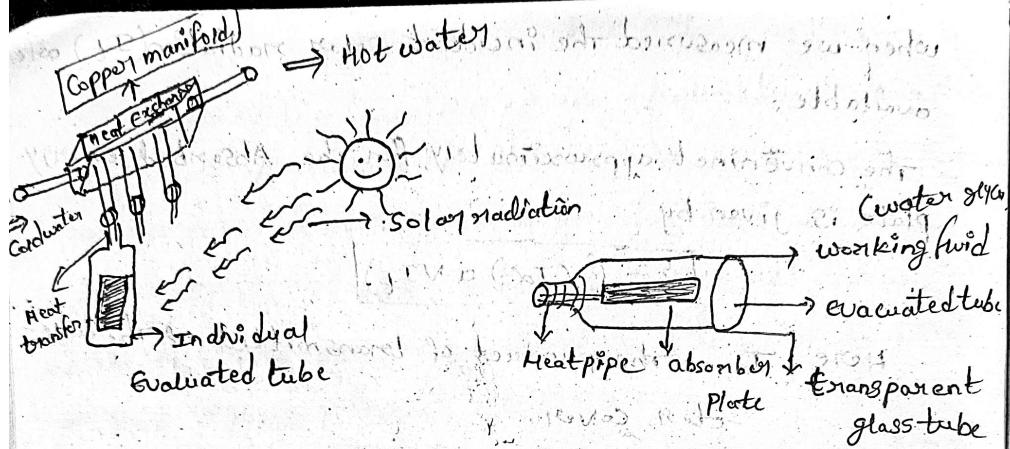
$$S = (T_\alpha) \alpha N I_t$$

Here, T_α = the product of transmitted of the collector cover.

Ques. Explain Evacuated Solar Thermal Collectors (or) Explain and working Construction of Evacuated Solar Thermal collectors?

- ① Evacuated (or) vacuum tubes collection consists of no. of rows of parallel transparent glass tubes is connected in one head pipe in series combination.
- ② In this transparent glass tube consists of working fluids.
- ③ These working fluid circulates and absorb heat energy and transfers the heat energy and converts the electrical energy.
- ④ These tubes are arrangement the angle of the Sunlight is always perpendicular to the Heat absorption tubes.





- ① Evacuated tube of collector is made up of a single or multiple rows of parallel.
- ② These tubes is made up of a glass (fiberglass) tubes. Supported on a frame.
- ③ The individual of each tube is consists of diameter is 25mm to 35mm, and length of the glass tube is 1500mm to 2400mm. It depends upon the manufacturer.
- ④ Each tube is consists of a thick glass outer tube and very thin glass in the inner tube, and consists of a thin film of copper.
- ⑤ This glass tube is consists of working fluid with contact of copper film.
- ⑥ The glass tube is a one type of Concentrating Solar thermal collectors.
- ⑦ Now, the copper film is behaves as a good absorber of sun radiation.
- ⑧ The copper film is heated and the heat energy is transferred to the working fluid. Here the working fluid is behaves as water absorber and converts the hot water.

- ⑨ The evacuated water heaters can perform well and can heat water to fairly high temperatures even in cold weather.
- ⑩ It is working better than the flat plate collector and performs very less heat losses hence energy.

Advantages:-

- ① These evacuated solar thermal collectors have high efficiency.
- ② These evacuated solar thermal collectors have low weight systems.
- ③ These evacuated solar thermal collection achieves high temperatures with a small time interval.
- ④ These instruments are more used in industrial purpose, sometimes used in domestic also.
- ⑤ These solar thermal collector occupies the less space and working very cloudy in air also.
- ⑥ It is working in rainy and humidity very dull atmosphere also.

Dis-advantages:-

- ① These solar thermal collectors have high expensive system.
- ② These solar thermal collectors have susceptible to breaking.
- ③ It's can't be mounted to house vertically.
- ④ These maintenance are very cost.

Q Explain working, construction of solar water heating system?

Ans) Solar water heaters sometimes called solar domestic hot water system.

- 2) this system can be used in hot water in your home
- 3) this water system can be used in any climate without purchasing of electricity bill.

Working of solar water heating system:

① Solar water heating system include storage tanks, and solar collectors

② There are two types of solar water heating system

① Active Solar System

② Passive Solar System

① Active solar water heating system :-

There are two types :-

① Direct circulation system

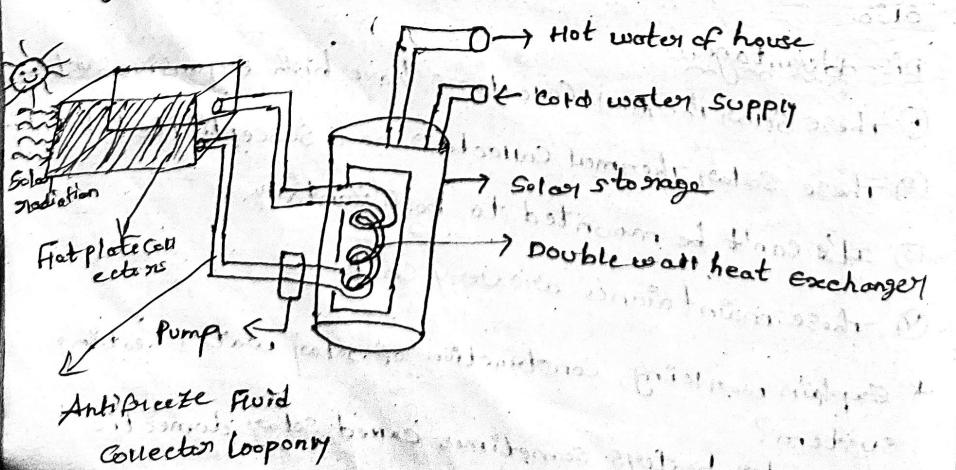
② Indirect circulation system.

① Direct circulation system :-

Pumps circulates the house hold water through the collectors in homes.

② Indirect circulation system :-

Pumps circulates a non-freezing heat transfer fluid through the collectors and heat exchangers.



② passive solar water heating system

① passive solar water heating system it is one type of less expensive system than Active system.

② The passive solar water system can be more reliable and may last longer system.

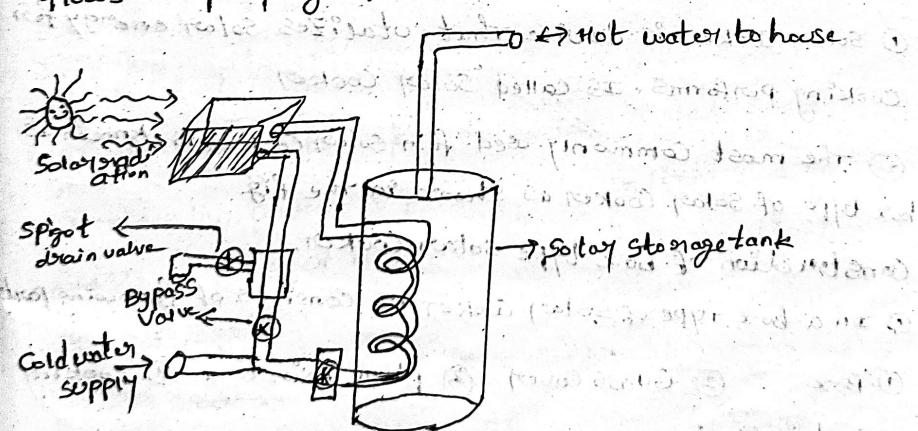
③ there are two types of the system:

① integral collector storage passive system:-

① this consists of a storage tank covered with transparent material to allow the sun to heat the water

② thermo siphon system:-

the water is heated in the collector of roof and then flows the pumping system. when a hot water is open.



storage tank and collectors:-

① the most solar water heating system is required to storage tank

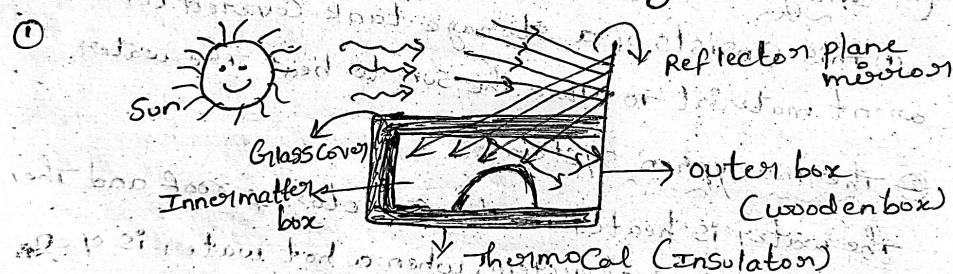
② this storage tank is consists of one inlet and one outlet

③ this storage tank system is series combination one tank to another tank process

Solar Collectors:

- ① The flat plate collectors consists of Enclosure containing dark Coloured Absorber plate with Fluids circulation
- ② These are more expensive
- ④ The glass metal seal metal technology can be used.

Ques:- Give the Construction and working of Solar Cookers?



① Solar Cooker is device that utilizes solar energy for cooking purposes. Is called Solar Cooker

② The most commonly used for Solar Cooker is known as box type of Solar Cooker as shown in the fig

Construction of box type solar Cooker.

① In a box type of solar Cooker is, Consists of following parts

① Box ② Glass Cover ③ Plane mirror ④ Cooking container.

Box:
① This is an insulated metal (or) wooden box
② It is coated with a black colour inside the box
③ It is behaves as good Absorber

Glass Cover:

① A cover is made of two sheets

② These sheets are made up of transparent materials

- ③ These transparent materials transfers the light rays.
- ④ Plane mirror:-

- ① A plane mirror reflector fixed in a frame is fixed to the box.
- ② This plane mirror is highly polished.
- ③ Which is reflection of light.

Cooking Container:-

- ① The cooking container consists of Al and black Coated from the outside is kept in inside the box.
- ② This container contains of cooking material like as Rice, potato, biryani, water, etc.

Working:-

- ① The food is cooked in a container of the box Solar Cooked
- ② The box has transparent ^{century} carrying of glass sheet
- ③ The solar cooker is placed in a sunlight and the reflection is adjusted in a strong beam of sun light enters through the box.
- ④ The black end sheet is observation of the infrared radiation (IR-Ray) from the beam of sunlight.
- ⑤ Then the metal surface is heated to above 100°C .
- Then the food is cooked at the container.

* Explain the working and Construction of Solar dryers

- ① The process of solar energy for during process is known as solar dryers.
- ② In this process Ambient Air which is heated

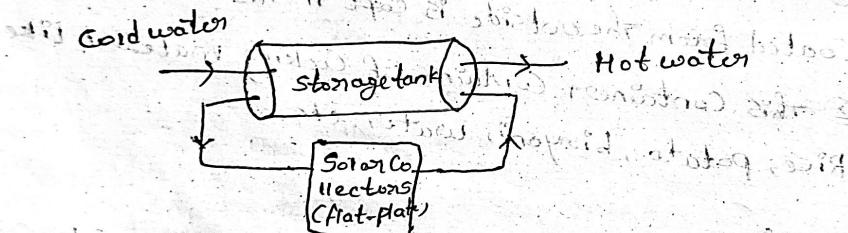
due to Solar radiation

③ The Heat air removes the moisture from the products in the drying chamber

④ for the large scale drying, forced circulation of air is used by solar dryer's

⑤ the direct sunlight is sufficient for drying The No. of Solar air Heaters are used for producing temperature

② Natural water Heating System



① Solar water Heating system is a device which is conversion of solar energy into electrical energy

② The electrical energy is converted into heat energy is transferred to water storage tank system

③ The natural circulation of solar water heating system consists of four

① Storage tank ② Solar Collector's

③ Electrical input is connected to a Heater

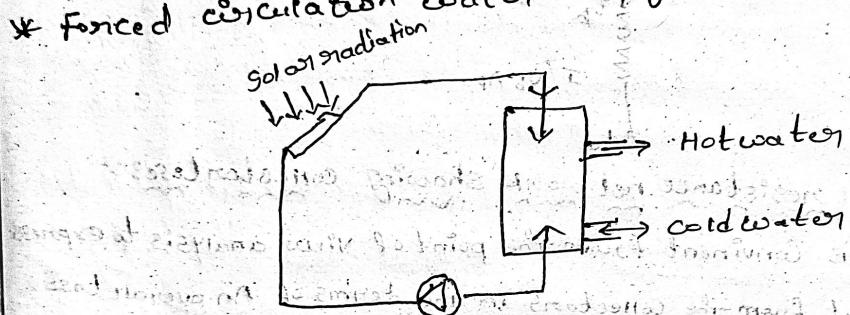
④ The water is heated its density is decreased and hot water rises and flows into the top of the storage tank

⑤ Cold water from the bottom tank. The cold water having higher density, comparison to the hot water molecules.

⑥ Natural circulation of water Heater system the Heater water system using only the energy of the system

⑦ The efficiency of Natural circulation of Solar water Heating system is 30% to 50%.

* forced circulation water Heating system



Ans: the above following 7th question answer
① Solar water heating system is a device which is conversion

of Solar energy into electrical energy

② the electrical energy is converted into Heat energy is transferred to water storage tank system

③ the Natural forced circulation of Solar water Heating system consists of
① storage tank ② Solar Collectors

④ electrical input is connected to a heater

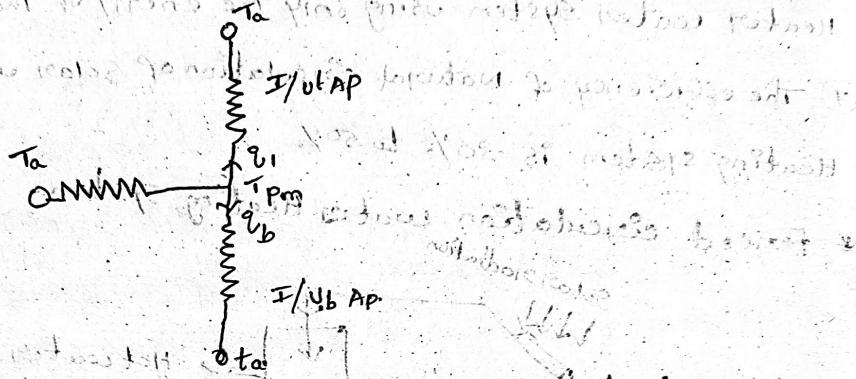
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⑦ forced circulation of water Heater system the Heater water system using only the energy of the system

⑧ The efficiency of forced circulation of Solar water Heating System is 30% to 50%

* Solar Collection over all heat loss Coefficient:



thermal resistance network showing collector losses:

- ① It is convenient from the point of view analysis to express the heat from the collectors in the terms of An overall Loss Heat Coefficient

$$q_i = u_i A_p (T_m - T_a)$$

u_i = overall heat loss Coefficient

A_p = Area of the observer plate

T_m = average temperature of the observer plate

T_a = temperature of the surrounding in air.

The heat loss from the collector is the sum of the heat lost from the top, the same and the sides.

$$q_L = q_i + q_b + q_s$$

q_i = Rate at which heat is lost from the top

q_b = Rate at which heat is lost from the bottom

q_s = Rate at which heat is lost from the sides

q_L = Rate at which heat is lost in the circuit

The bottom loss Coefficient and The side loss Coefficient and heat loss Coefficient can be expressed by the equation

$$q_t = U_t A_p (T_m - T_a) \text{ (Watt)} \quad \text{ANSWER}$$

$$q_b = U_b A_p (T_m - T_a)$$

$$q_s = U_s A_s (T_m - T_a)$$

3. FUNDAMENTAL OF SOLAR CELLS

* Explain semiconductor interfaces?

Semi Conductors:-

- ① Semi conductors are materials which is the conduction of electrons in partially are semi
- ② these semi conductors less conductivity comparison to the good conductors of electricity
- ③ the electric conductors are mostly used in metals like as Silver, Aluminium, Copper, lead, steel, gold...etc.
- ④ some examples of semi conductor materials Silicon, germanium, Gallium, Arsenic, Selenium, ..etc.
- ⑤ solar cells are made up of these semi conductor materials
- ⑥ the solar cells capture the solar energy when the light is absorbed near the cells surface
- ⑦ the surface of the cell represents a major of charge carriers
- ⑧ the efficiency in the Advanced SiIicon solar cells by recombination of electron hole pair.
- ⑨ these electron hole pairs formation at the surface of the solar thermal collectors and interfaces.
- ⑩ solar cells are a strong technology and over while the drawback is very high doping of P type and N type semi conductor materials.
- ⑪ semi conductor interfaces are two types.
 - ① Homojunction interfaces
 - ② Heterojunction interfaces.

① Homojunction interfaces:-

- ① Homojunction is a semi conductor interfaces between the two layers of similar semi conductor materials like as silicon, is the two layers, to form a Homojunction interfaces.
- ② These materials have equal band gaps, but in different doping.
- ③ In most practical cases the Homojunction semi conductor interfaces between the N-type of semi conductor materials it behaves as a donor, and P-type of semi conductor materials is a acceptors.
- ④ In Homojunction semi conductor interfaces it serves as the commonly used in p-n junction Diode is connected in forward bias.

15 Bias:-
⑤ The different doping levels in p-n junction diode which is causes to the increasing the band gap and depletion layer will be formed in the interfaces.

② Heterojunction interfaces:-

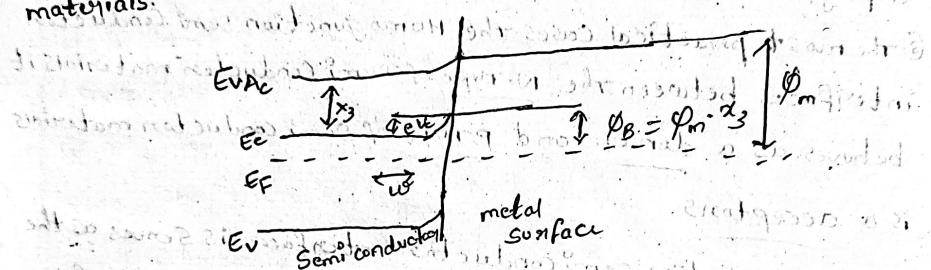
- ① A Heterojunction interface is an interface between the two layers of two regions of non-similar of semi conductor materials.
- ② The non-similars of semi conductor materials like as silicon is designed P-type, and germanium is designed N-type. Both these materials to form Heterojunction interface.
- ③ In Heterojunction semi conductor interface, consists of different band gaps and different doping.
- ④ It is the advanced technology in semi conductor interface the electronic energy band gaps in solid state device appi-cations.

③ the requirement of those materials with unequal bond gap
which is more electron available in conduction stage

10m what is schottky barrier?

① Schottky barrier is a potential energy barrier for electrons formed at Semiconductor materials and metal surface

materials.



② Schottky Barrier is a highly rectifying characteristics and they are used in P-N junction Diode it is also called Junction Diode characteristics

③ one of the basic characteristics of schottky barrier is its high regular Electron vibrating periodic it is denoted by "ΦB."

④ The value of Φ_B depends upon the metal and semiconductor of contains free electrons.

⑤ The barrier between the metal and semiconductor has been predicted schottky-mott rule

⑥ The schottky mott rule is the difference of the metal surface in vacuum and it's work function.

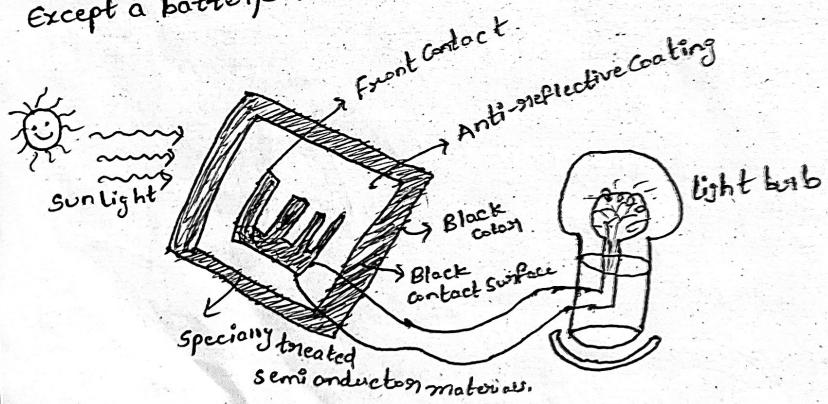
⑦ Hence the schottky mott rule the semiconductor vacuum the electron having affinity values is also always possible

⑧ the shape of the potential barrier is depends upon the charge distribution in semiconductor and metal surface

⑨ the electron density is reduce to exponentially with "Ee"

- ⑩ The shape of the barrier mostly calculated by the spatial distribution of donors of electrons in semiconductors materials.
- ⑪ the constant doping up to the contact with the metal surface uniformly space charge in the region
- ⑫ the electric field in this region the electric field increases linearly from the edge of the depletion region and in the interface the potential barrier is parabolic shape
- ⑬ this resulting potential is regularly referred to schottky barrier.

- ~~* How does photovoltaic cell work?~~
- ~~Photo voltaic cell :-~~
- ① Photo voltaic cell is a device which is the generates electrical energy by absorbing Sunlight and using that light energy to create an electrical circuit.
 - ② They are many applications of photo voltaic cell within a single solar construction.
 - ③ Some few applications to help power your schools, home, business, ... etc
 - ④ In a Solar panel we designed to generate electricity except a battery's make electricity from chemicals.



- ⑤ The Sunlight consists of photons (or) small amount of particles of Solar radiation of energy.
- ⑥ These photons contain a maximum amount of energy.
- ⑦ These energy depends upon the wavelength of solar spectrum.

$$\text{The energy } E = h\nu d$$

$$E = \frac{h \cdot c}{\lambda}$$

$$E \cdot \lambda = h \cdot c$$

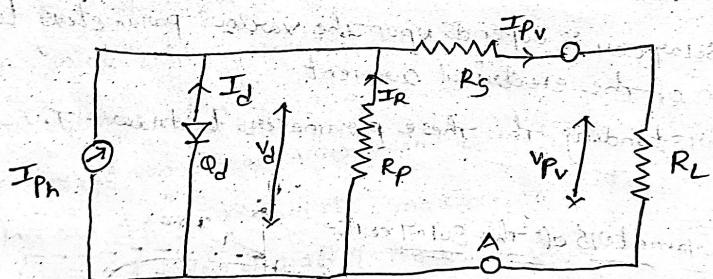
$$\lambda = \frac{h \cdot c}{E}$$

③ These photons hit the solar cells. Some amount of solar radiation is absorbed and remaining amount of solar radiation is reflected.

④ The solar material absorbs the sufficient energy and releases the more no. of free electrons on this surface of the materials.

⑤ These electrons migrated to the surface of the solar cells. Each electron carrying the negative energy travel towards the photovoltaic cells and creates the electrical energy at the battery of positive and negative terminals.

* Give an equivalent circuit for photo voltaic cell?



$$I_{PV} = I_{Ph} - I_d = I_{Ph} - I_0 \left(\frac{V_{PV} + R_s I_{PV}}{e^{n_s v_t / (R_p + R_s)}} - \frac{V_{PV} + R_s I_{PV}}{R_p} \right)$$

V_{PV} = PV module voltage (V)

I_{PV} = PV module current (A)

I_{Ph} = light current (A)

α_d = diode ideality factor

n_s = number of cells in series

R_s = series resistance

R_p = shunt resistance

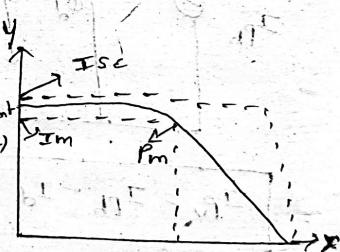
v_t = thermal voltage

$$\therefore v_t = kT_c / e$$

- ① A simple equivalent circuit in photovoltaic cell is consists of a Real diode (pn junction diode) in parallel to the an ideal current sources.
- ② The ideal current source devices is used to flow of current in the circuit is directly proportional to the solar flux
- ③ there are two conditions of interest for the actual PV and for its equivalent circuits
- ① The current flows to the terminals (I_{SC})
 - ② The voltage across the terminals when the circuit is opened.
- * Explain Solar Cell output parameters.

Solar cell: ① The conversion of Sun light into electrical energy
By using Solar cell

- ② These Solar cell is depends upon the various parameters to determination of the electrical current
- ③ we understanding the these parameters to draw a J-V curve
- ④ Output parameters of the Solar cell
- ① (I_{SC}) \rightarrow Short circuit current is the maximum is produced by the solar cell
 - ② It is measured in amperes and milliamperes
 - ③ The value of short circuit is depends upon the area of the solar cell.



- ④ The solar radiation is incident on the used in cell technology.
- ⑤ These short circuit current is depends upon the make up of the material and current density also.

⑥ Open circuit Voltage E_{oc} (V_{oc})

open circuit voltage is maximum produced by solar

cell in open circuit conditions.

② The voltage is measured by voltmeter in volts or millivolts.

③ Open circuit voltage is depends upon the made up of the semi

Conductor materials.

④ Maximum power point (P_m)

⑤ Maximum power point is the maximum value produced by

① maximum power point depends upon the solar technologies

② maximum power point depends upon the solar technologies

③ maximum power point depends upon the temperature

of the solar cells.

④ Current maximum power point (I_m)

Current at maximum power point which is depends upon the solar cell we produce the maximum current at maximum power point when operating the solar system

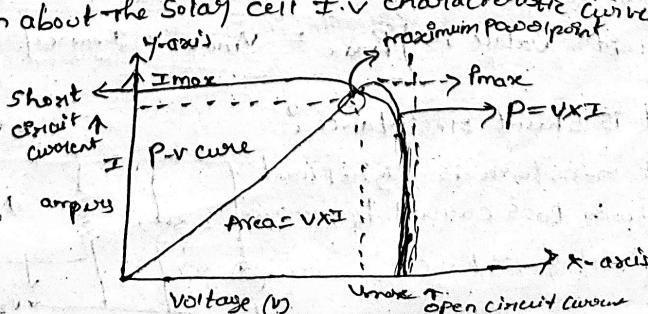
⑤ Voltage at maximum power point (V_m)

Voltage at maximum power point which is depends upon the solar cell we produce the maximum voltage at maximum power point when operating the solar system.

Fill Factor = $\frac{P_m}{I_m V_m}$

It is represents the area of the $I_m - V_m$ rectangle with area covered by the $I_{SC} - V_{OC}$ rectangle by dotted lines is called fill factor. Now Fill Factor = $\frac{P_m}{I_m V_m}$

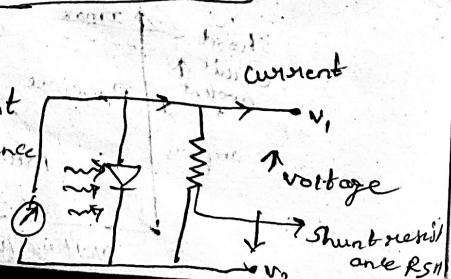
& Explain about the Solar Cell I-V characteristic curve



- ① Solar cell is one of the electrical device which is used to convert solar energy into electrical energy.
- ② The solar cell IV characteristic curves as shown in the fig.
- ③ It gives the detailed information about the solar energy conversion ability and efficiency of the particular photovoltaic cells.
- ④ The photovoltaic cells converts the sun radiation in light directly into electrical energy.
- ⑤ With increasing the energy of the source the electrical energy is also increases.
- ⑥ The above graph shows that the current and voltage characteristics of silicon PV cell operating at normal condition.
- ⑦ The power generation by a single solar panel is the product of its output current and voltage multiplication.
- ⑧ The power curve will be at minimum the voltage across the cell is maximum. This condition is known as open circuit voltage.
- ⑨ The positive and negative terminals of the cell is connected to the circuit the voltage is minimum and the current is maximum. This condition of solar cell is called short circuit condition.
- ⑩ One particular condition of the solar cell is generates the maximum current is depends upon the generated maximum power its value is $P_{max} = V_{max} \times I_{max}$

Q What is shunt resistance?

Q Shunt resistance is significant the power loss caused by presence of shunt resistance.



② shunt resistance is a one type of two control the flow of current in the circuit to protect the sensitivity of electronic component.

③ the solar cell junction reduce the voltage from the solar cell.

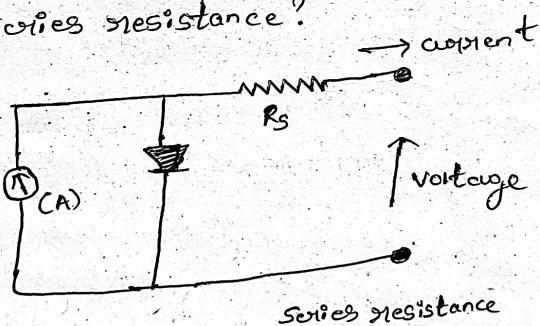
④ the effect of shunt resistance particularly serves the at low sun radiation.

⑤ At lower voltage the effective resistance of the solar cell is high. the impact of resistance in parallel.

⑥ the equation of solar cell in presence of shunt resistance is given

$$\text{By } I = I_L - I_0 e^{\frac{q(V+I \cdot R_s)}{nKT}}$$

what is series resistance?



series resistance:

① In a Solar cell Resistance is Connected to series combination of PV cell mode.

② the series resistance is combined to the resistance of to prevent the loss of power caused by the presence of series resistance.

③ The resistance of the Semiconductor material and metallic plates to contact with the Semiconductor and metal plates

④ The series resistance to reduce the fill factor and short circuit current in the circuit.

⑤ the series resistance in a Solar cell

$$I = I_L - I_0 e^{\left[\frac{q(V+I \cdot R_s)}{nKT} \right]}$$

- I is the cell output current
- I_L is the light generated current
- V is the voltage across the cell terminals
- T is temperature
- q and k are constants
- n is the ideality factor
- R_s is the cell series resistance

UNIT-4 TYPES OF SOLAR CELLS

* what type of solar cells are available?

Solar cell :- Solar cell is a device which is converts solar radiation into electrical energy of light directly incident on the photovoltaic effect.

- 2) The photovoltaic cell consists of two different types of semi conductor materials
- 3) one is P-type semi conductors another one is N-type semi conductor material and both P and N-type materials are connected to each other.
- 4) These two types of semi conductor materials and creates an electric field in the junction.

5) The electron moves to positive P-side and positive holes moves N-type side.

6) When the sunlight is absorbed by P-N junction the electron hole pairs are generated flows through the external circuit producing the current in the circuit.

7) Solar cells can be classified into three types. They are:

- ① Mono crystalline silicon type solar cells
- ② Poly silicon crystalline solar cells
- ③ Thin film solar cells

① Mono crystalline silicon solar cells :-

- 1) It is designed by pure form of Silicon atoms.
- 2) The available of Silicon in crystal nature.
- 3) 90% of the silicon is made up of solar panels, and system use the crystalline silicon cells.

4) In a monocrystalline silicon is pure, and efficiency of the cell is higher than the other cells. This type of solar cells are used in commercial purposes.

Advantages:-

- 1) It is renewable solar energy sources.
- 2) It is clean and non-pollution solar sources.
- 3) Low energy consumptions.
- 4) It is very cheap cost.

Dis-advantages:-

- 1) These are less efficiency.
- 2) These are most expensive in market.
- 3) There is a lot of waste materials when design the monocrystalline silicon solar cells.

② Poly silicon crystalline solar cells-

- 1) It is liquid silicon materials are used.
- 2) Poly silicon crystal was designed by solid state of process.
- 3) The material contains various crystal sizes.
- 4) The poly crystalline solar cells was introduced in 1981.
- 5) These cells are designed in square modules and rectangular modules only.

Advantages:-

- 1) The manufacturing process is very cheap cost.
- 2) The manufacturing very easy to installation.
- 3) It avoids silicon wastage.
- 4) The poly crystalline cells are more attracted to the people.

Dis-advantages:-

- 1) The efficiency is 13 to 15% only.

2) these are low levels of silicon purity

3) they have lower output rates

4) these are occupies more spaces

③ Thin film Solar cells:-

1) thin film Solar cells are manufacturing by several thin layers of photovoltaic cells. to create the electrical energy from solar energy.

2) they are actually few different types of thin solar silicon cells. They are:-

① Amorphous Silicon Solar cells

② Cadmium telluride Silicon Solar cells

③ Copper Indium gallium Silicon Solar cells

④ organic Solar cells

3) these are depends upon the technology Based. They have been more efficiency than other solar cells.

4) this type of Solar cells are used in since, 2002

5) these type of Solar cells having efficiency above 25%.

Advantages:-

① they can be manufactured to be flexible

② this arrangement mass production ea is easy to installation.

③ these are very cheap cost and produce more energy

④ these are effectively working at low sunlight also

Dis-advantages:-

1) they are not ideal for domestic purpose. They have short life span.

2) shorter warranty period.

* what is multi junction solar cells? (or) Explain about single and multi junction solar cells? how do the multi junction solar cell works?

① the solar cell which contains two (or) more than junction

to formation of a solar cell is called "multi junction solar cell"

② In a multi junction solar cells having two (or) more than semi.

conductors energy band gaps.

Conductors energy band gaps can absorption of Sunlight and its Convert

③ these Band gaps can absorption of Sunlight and its Convert the electrical energy

④ multi junction solar cell

* what is multi junction? How it is working?

Read and write front page multi junction question

* what is Bi-pass Diode? How it is working?

① Bi-pass diode is a special type of Diode, that is designed to the current around the solar modules.

② when a cell or panel becomes shaded or faulty (Faulty)

③ the diode which is enables current to flow in a single direction.

working:-

① the solar cell panels are connected in series combination to form a string.

② Each string the current flows from the cell to cell in a single direction.

③ It means the positive terminal of the one cell through the negative terminal of that same cell into the negative terminal of the next successive cell

④ A Bi-pass Diode is inserted across the every string as to flow of current. If any one or more cells connected in series combination.

⑤ A Bi-pass Diode function by allowing the current to flow in the direction that will allow the maximum voltage possible.

* what is Blocking diode? How it is working?

⑥ A blocking diode prevents from current from flowing in the reverse direction.

⑦ It is an essential component in solar panels that stops your solar array from discharging at night or when battery are full.

⑧ Blocking diode are also one type of rectify which is used to stop the current in solar power system.

⑨ Blocking diode is used in solar power system because they

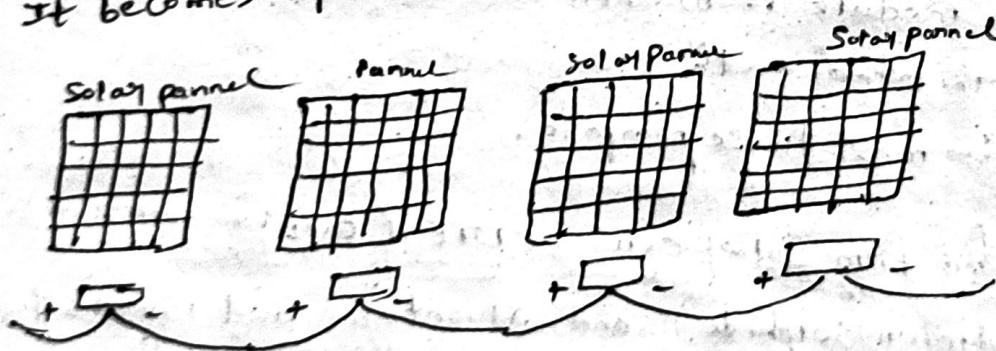
protecting batteries from over charge

Working:-

- ① Blocking diodes are connected in parallel with solar panel (or) another charging source.
- ② they are working correctly to prevent the flow of current in backward direction.
- ③ these blocking diodes are used in strings, one connected in parallel to voltage resistors to resistance of the circuit.

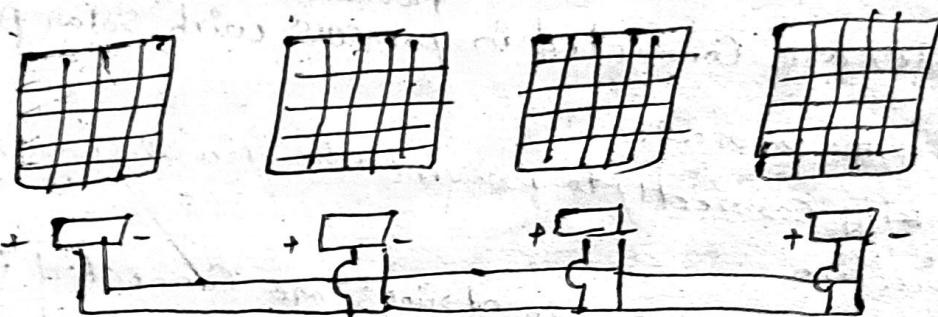
* Explain Series Combination of Solar panels? In series?

- ① When we connect the positive terminal of one panel to the negative terminal of another panel we create a series connection.
- ② when you connect two (or) more solar panels like this way, it becomes a p.v source circuit.



- ③ The solar panels are wired in series the voltage of the panels are added together.
- ④ In this series combination the flow of current is constant.
- ⑤ The panels are in series the makes it increase the voltage of solar panel system.
- ⑥ The most important the solar power system it is need to operate at a certain voltage increase.
- ⑦ You connect solar panels in series to meet operating voltage window requirements of your inverter.

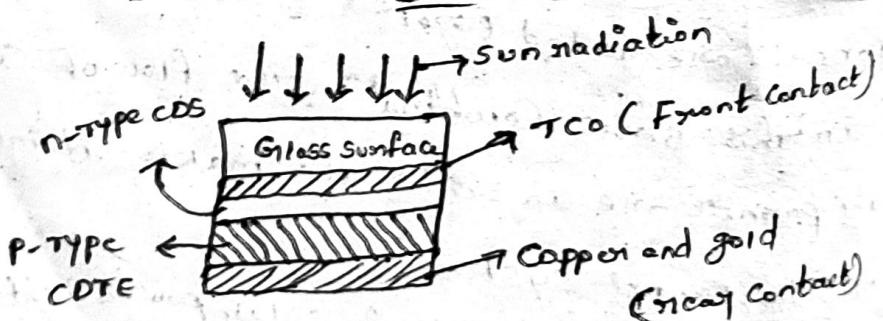
* Explain about solar panels in parallel Combination



- ① Solar modules have two terminals one is positive terminal and second one is negative terminal
- ② the positive terminal of one module to the positive terminal of another module and negative terminal of one module to the negative terminal of another module is connected to the common terminal to create a parallel connection as shown in the fig.
- ③ In this circuit have multiple path for the current to move along if any module is broken the current will continue to move along the other path.
- ④ It is used for most house purpose.

* What are thin film solar cells CdTe (Cadmium Telluride) and CdS (Cadmium Sulphide) and Advantages and Disadvantages

CdTe/CdS of thin film solar cells Configuration:-



- ① this system is water based crystal silicon solar cells are the most widely used solar cell. Due to their high efficiency and high abundant availability of silicon cells. Hence these are called first generation solar cells. But recently the production and use of solar cell based on thin film technology

② Cadmium Telluride is a Compound of semi conductor material. It has an ideal band gap 1.45 electron volt to maximum efficiency hence the material of small thickness is sufficient.

③ The efficiency of CdTe solar cell is 16.7%.

④ A layer of p-type Cadmium Telluride with thickness of 1.5 mm to 8 micrometer (mm) is contact with n-type Cadmium Sulfide of thickness 0.05 mm.

⑤ A thin layer of transparent conducting oxide is used for front contact surface.

⑥ Advantages:-

- ① It is easily handle
- ② more flexible than other solar cells.
- ③ Is Available as a thin layers.
- ④ It is a cheap cost

Dis-advantages:-

- ① less efficiency
- ② complex structure
- ③ Need to be very carefully handling.
- ④ They have very short life span

5. Solar Photovoltaic System

- ① Explain Available energy storage in p.v system?

Energy storage: the solar energy is converted into electrical energy. Due to solar cell, this electrical energy can't be supplied by 24 hours in a day.

- ② Solar energy is depends upon the weather.

- ③ The solution for this problem we need some energy storage system like as Batteries.

- ④ We have some available of energy storage systems

- ① Compressed air storage:-

In this Compressed air energy storage system, creating high pressure system in series of large underground chambers.

- ② Pumped stored Hydro electric system:-

① In this system a popular form energy storage system

② Hydro electric system is a type of design to store excess from the power grid

- ⑤ Electricity from the grid is used to pump water into a reservoir.

- ③ Advanced Rail energy storage System:-

Advanced Rail energy storage system uses to reverse of electricity.

- ④ Fly wheel energy storage System:-

The Fly wheel storage energy system is converting electrical energy into kinetic energy in the form of spinning of wheel.

⑤ Electrochemical storage energy system:-

- ① Electrochemical energy is defined as the energy which is converts electrical energy into chemical energy.
- ② Battery is the example of Electrochemical storage system.
- ③ A Battery is a group of cells that generates energy from Internal chemical reaction
- ④ The cell consists of two different materials as the electrode, conducting as immersed as electrolyte solution.
- ⑤ The chemical reaction between the two electrodes and electrolyte results in separation of electric charge on ions and free electrons.
- ⑥ These two electrodes has different potentials is created potential difference between the two electrodes.

⑥ Mechanical energy storage system:-

- ① In the form of electrical energy converted into mechanical energy.
- ② In this storage system contains large momentum of friction less flywheel.
- ③ The solar radiation into mechanical energy by using a rotating wheel.
- ④ The rotating wheel to reverse the mechanical energy into electrical energy.
- ⑤ The rotating wheels are alternative for lead acid batteries for storage of electrical energy systems.

⑦ Super capacitors energy storage system:-

- ① Super capacitor is the example of energy storage system
- ② A super capacitor is also called ultra capacitors
- ③ It means the electrical energy storage is high capacitance

- ④ If the capacitance value is increases the energy storage is also increases.
- ⑤ It is a one type of Storage 10 to 100 times more than energy per unit volume or mass than electrolytic cells.
- ⑥ It can Accept the charging and dis-charging faster than the Batteries.

* Explain mechanical storage of flywheel energy storage Construction and working?

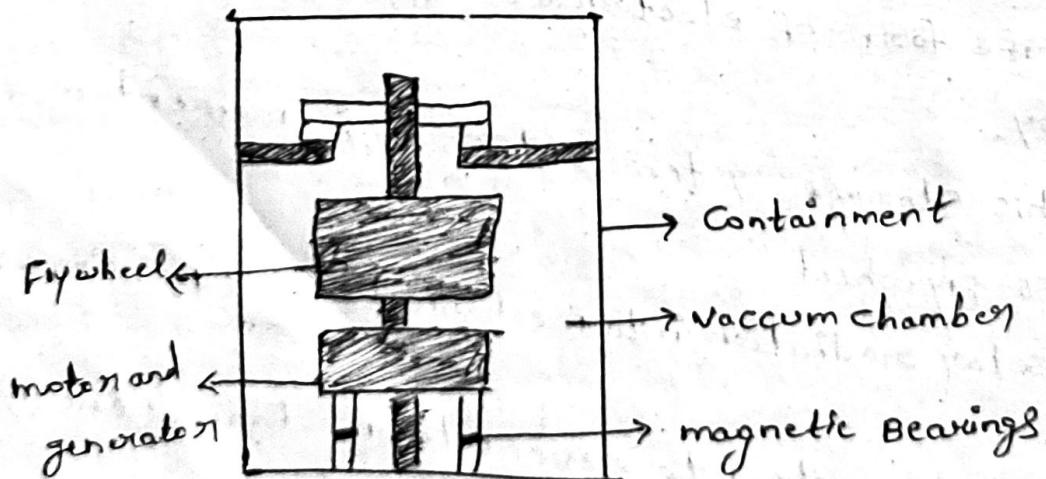
Mechanical energy storage:-

- ① Fly wheel is a device which stores energy in the form of mechanical energy.

- ② It converts the electrical energy which produced some solar radiation into mechanical energy using rotating wheel.
- ③ It is used the same rotating wheel in reverse direction the mechanical energy into electrical energy

- ④ Flywheel are alternative used for lead acid Batteries.

Construction and working of flywheel:-



Flywheel:

- ① the Flywheel is a solid cylinder with a large mass.
- ② It is designed by non-magnetic materials.
- ③ It's spins at high speed making several thousands of rotation per minute.

Containment :-

- ① Mechanical failure can be catastrophic because of the huge forces involved.
- ② The flywheel is encased within a strong casing motor and generator
- ① When the energy is being stored, the electrical devices drives the motor to spin of Flywheel
- ② When the stored energy is being recovered, the motor acts as a generator to convert the spinning motion back to electricity

Magnetic Bearings :-

- ① The Flywheel is supported using magnetic levitations to reduce mechanical energy

Vacuum chamber :-

A Vacuum pump removes the air from the chamber to reduce the air resistances of the flywheel

Advantages of flywheel :-

- ① Short recharge time
- ② Fast power response
- ③ High cycle and calendar life.
- ④ ~~cheaper~~ write about the electrical storage and construction and working of super capacitors?

Electrical Storage :-

- Super capacitor is the example of energy storage system
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Construction and working of Super capacitors

- ① the super capacitor has two parallel plates with large area. The distance between the two plates are very small.
- ② The plates are made up of metal plates and electrolyte.
- ③ The plates are separated by a thin layer of suitable and dielectric constants.
- ④ The opposite charges are formed on both side of the dielectric constant material.
- ⑤ An electric double layer is formed between the two conductive charged plates.
- ⑥ The super capacitor is charged and as higher capacitance.
- ⑦ These capacitors are used to provide high power and low resistance.

Applications:-

- ① To deliver high power and bridge power gaps.
- ② Industrial and electronic applications.
- ③ Used in wind turbines.
- ④ Used in electrical and hybrid vehicles.
- ⑤ To start power in start-stop system.
- ⑥ Regulate voltage in the energy grid.
- ⑦ The Backup power systems in a quick discharge system.

primary Batteries

Battery :- A Battery is a group of cell. that generate energy from an internal chemical reactions.

2. the cell consists of two electrodes these electrodes immer-

sed, solution of electrolyte

3. The chemical reaction between two electrodes and the electrolyte results in separation of electric charges as ions and free electrons.

ns. There are two types of Batteries.

1. primary Batteries

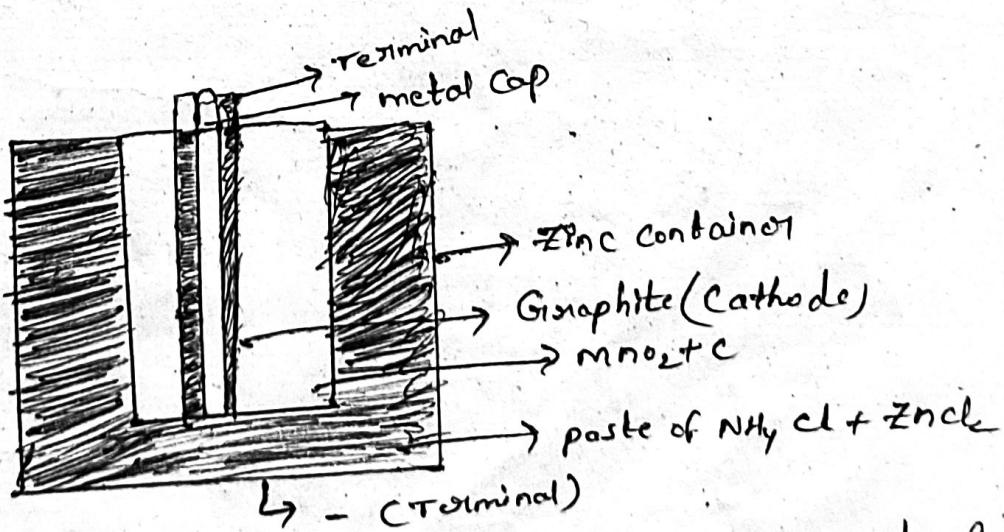
2. Secondary batteries.

1. primary Batteries :-

1. It is designed to used is ones used, and not recharge with electricity. primary Batteries have high density and get discharge slowly.

2. The internal resistance in primary Batteries is very high. And chemical reaction. The primary Batteries are the example of lacrance of shell of normal shells.

construction and working of primary Batteries :-



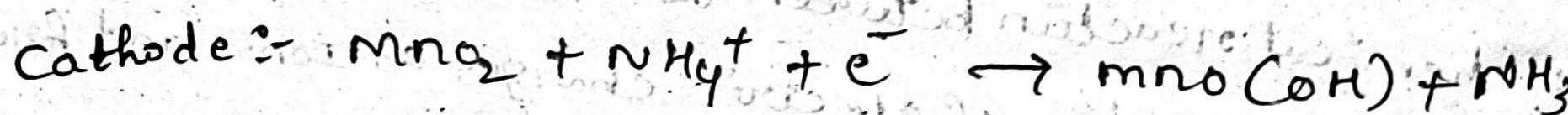
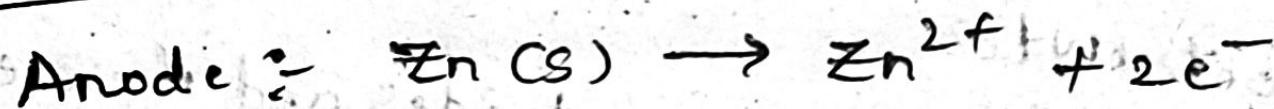
① this liquid state electrolytes are replaced by paste of electrolytes

② the cylinder of Zinc Container is covered with card board

③ this is sealed with metal cap is behaves as a negative terminal

- ④ A carbon rod is surrounded with $MnO_2 + C$ paste
- ⑤ The remaining space is filled with the $NH_4Cl + ZnCl_2$ of paste. These two plates are separated by plastic cover

Electrode reaction:



Applications:-

① Radios, watches, toys low expansive

② It is used very easy

③ High energy density.