Vikash Polytechnic, Bargarh

Vikash Polytechnic
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Lecture Note on
Renewable Energy Sources

Diploma 6th Semester

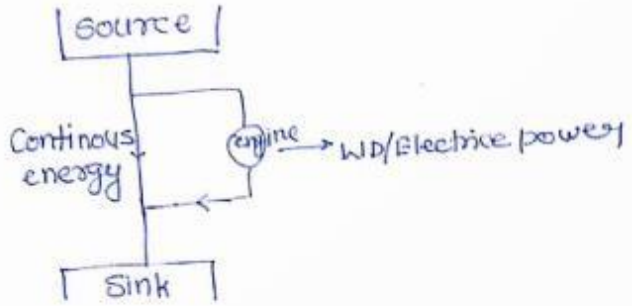
Submitted By:- *SNIGDHA PRIYAMBADA*

* Renewable Sources of Energy *

Objective:- Renewable energy is the form of energy which flows naturaly and reaptedely.

Benefits:-

Renewable energy diagram



① Availibity:- over wide Geographical area.

② Replacible:- Continously over a large time period

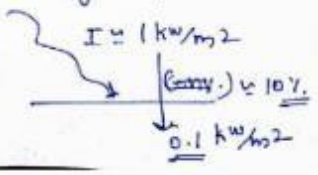
③ Eco Friendly/clean energy :— Pollution free.

④ Running Cost will be minimum:-

Disadvantages:-

① Dilute form of energy

② extraction of energy requires more land area



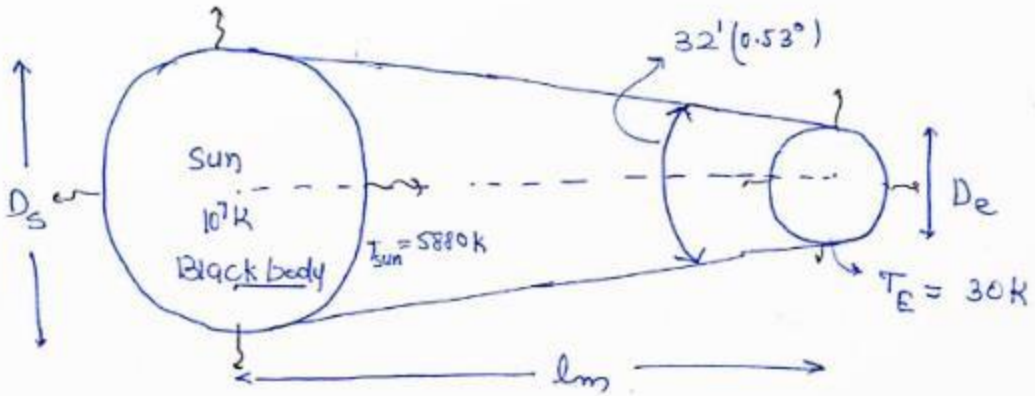
③ Highly Fluctuated → dependend on location and weather condition.

④ Initial investment will be high.

Mode of heat transfer

Physical Contact req
- $q_{cond} \propto (T_1 - T_2)$
- $q_{conv.} \propto (T_1 - T_2)$

E.M.W
- $q_{Rad} \propto (T_1^4 - T_2^4) = (T_1 - T_2)(T_1 + T_2)(T_1^2 + T_2^2)$



$D_s \simeq 10^6$ km $L_m \simeq 10^8$ km

$D_e \simeq 10^4$ km

Solar Radiation :-

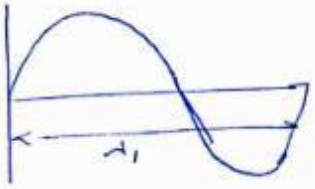
* The power of the sun intercepted by earth is 1.8×10^{11} MW. and if we harness this energy with the 0.01 % efficiency it is sufficient for world power consumption.
* The solar radiation flux having a maximum value of 1 kw/m^2 and over a day it is maximum of 7 kwh/m^2.

Solar energy Quantification :-

D_s = 1.39×10^6 km Diameter of Sun

D_e = 1.27×10^4 km Diameter of earth

L_m = 1.5×10^8 km mean distance between sun & earth

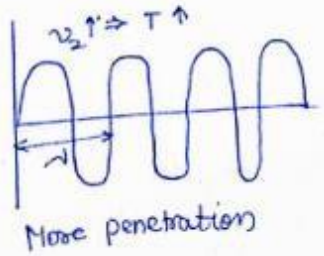


Frequency $\propto$ temp

$\nu \propto T$

$\lambda \propto \frac{1}{\nu}$ $\quad \lambda \cdot \nu = \vec{c}$

$\Rightarrow \nu \propto T \propto \frac{1}{\lambda}$

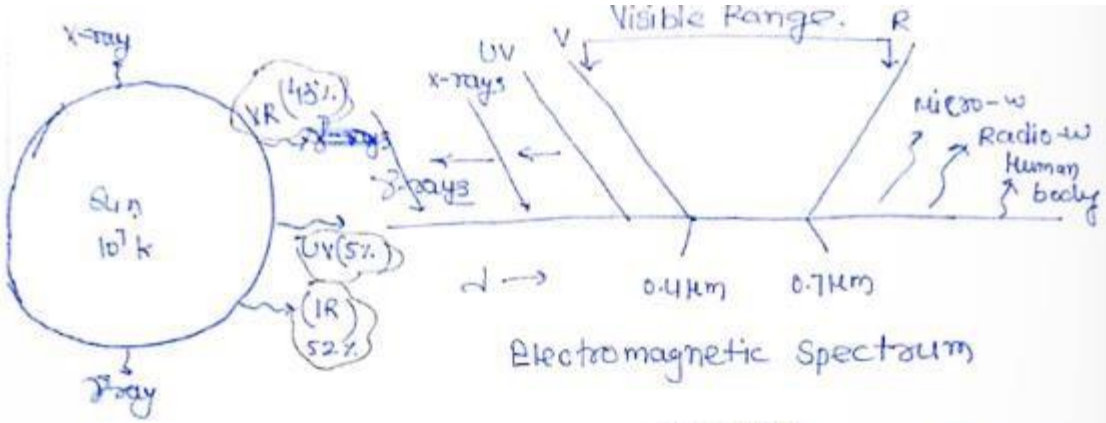


More penetration

$\Rightarrow \lambda \cdot \nu = c\,(3 \times 10^8\ m/s)$

$\lambda \cdot T = \text{Const.}\,(2898\ \mu m\text{-}K)$

$\frac{\nu}{T} = \frac{c}{2898}$



Electromagnetic Spectrum

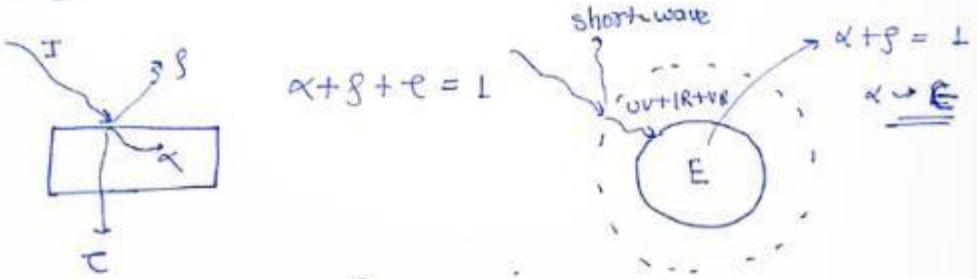
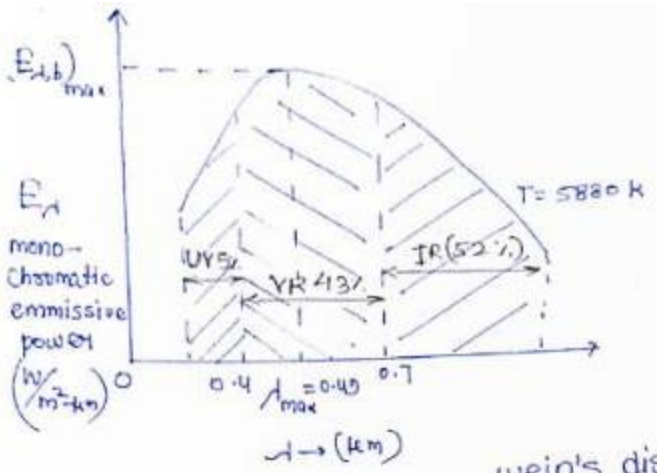


Fig:- Basic surface property

UV – Ultra Violet. (5%)
VR – Visible range (43%)
IR – Infrared (52%)

Electromagnetic Spectrum of Solar Radiation :—

* Solar radiation covers the entire range of visible region and some part of UV & IR waves. Th.
* The maximum emmissive power reaching the earth surface (extraterrestrial solar flux) is in the Infra red region but the maximum monochromatic or spectral emmissive power is in the visible region ($\lambda_{max} = 0.49\,\mu m$)



Plank's law

$$E_{\lambda,b} \propto \frac{1}{e^{\frac{c_2}{\lambda T}}}$$

$$E_{\lambda,b} \propto \frac{1}{e^{\frac{c_2}{\lambda T}}} \rightarrow \lambda_{max} T = 2898 \text{ km-k}$$

(for black & Gray body not valid for real surface)

wein's displacement law

Stefan-Boltzman law

$$E_b = \int_0^\infty E_{\lambda,b}\, d\lambda = \sigma T^4$$

kirchof's law

At thermal eqm

$$\boxed{\alpha = \epsilon}$$

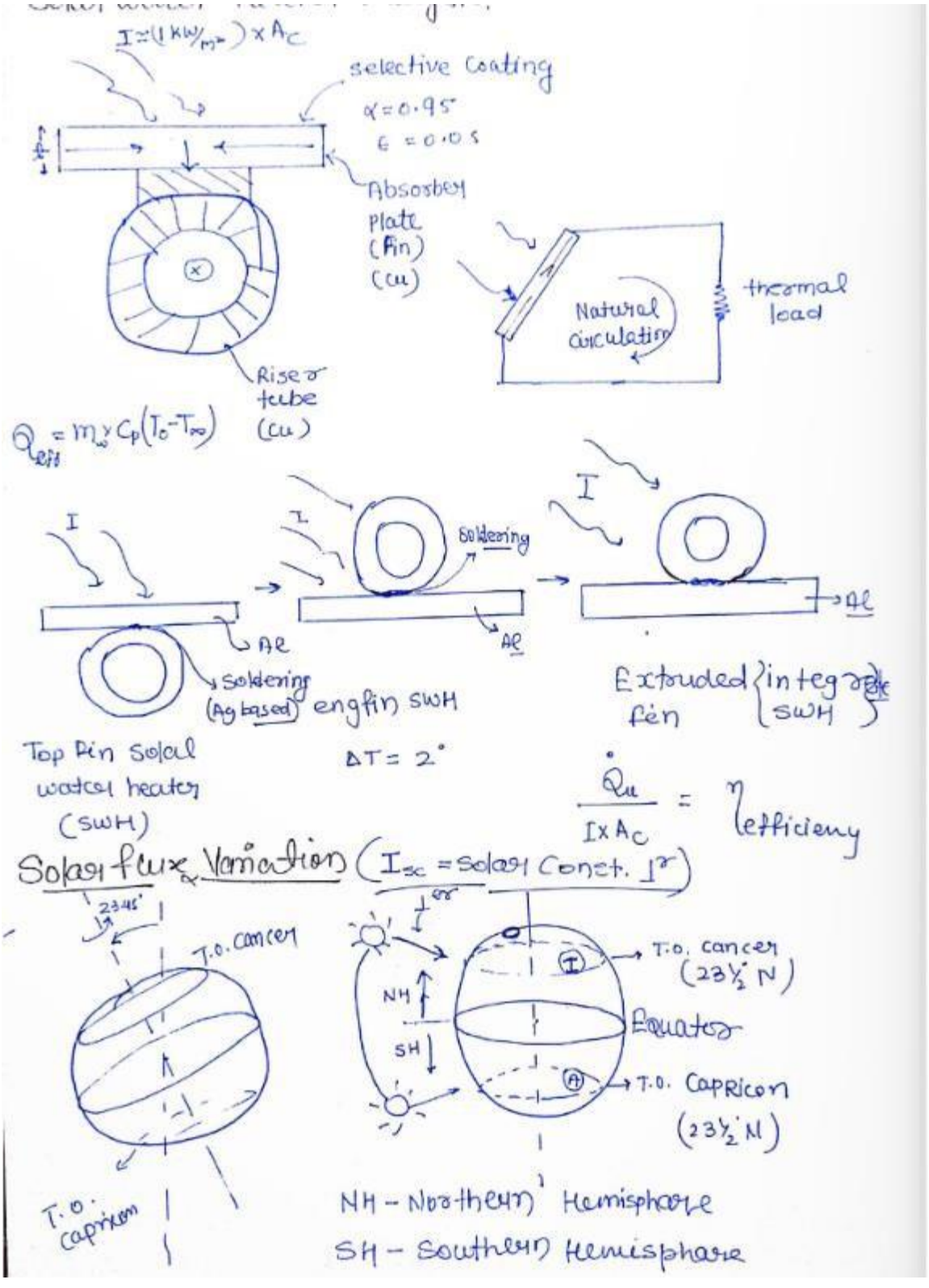
Question Detetmine the range of wavelength for which earth surface is emitting max. spectral emisive power if the earth temp range from 250 to 300 k

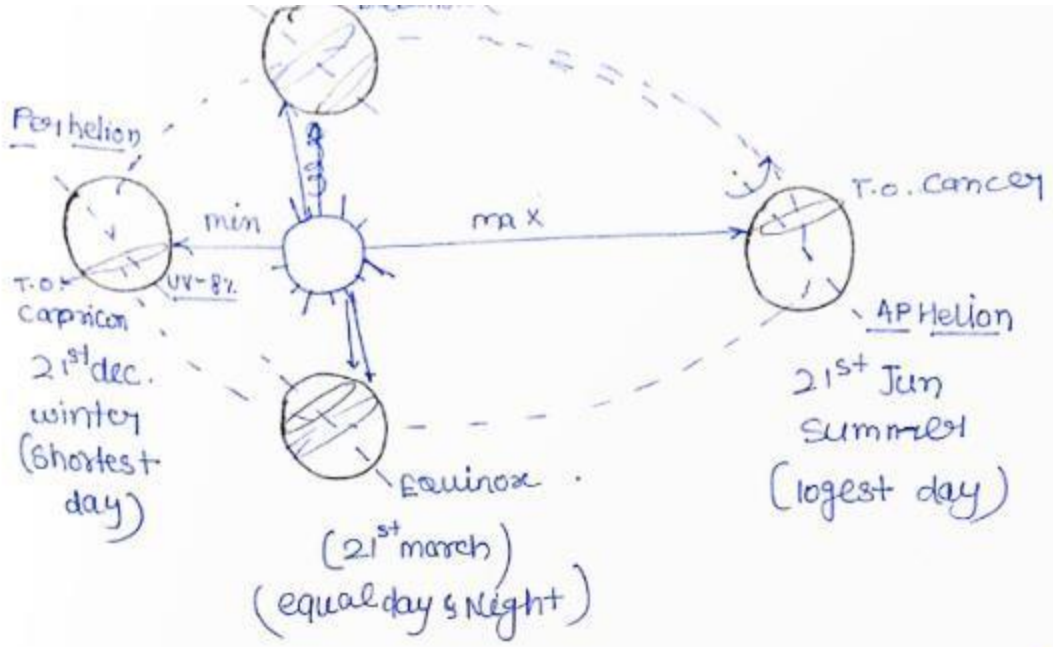
Sol^n

$$\lambda_{m_1} 250 = 2898 \Rightarrow \lambda_{m_1} = 11.592 \text{ km}$$

$$\lambda_{m_2} 300 = 2898 \Rightarrow \lambda_{m_2} = 9.66 \text{ km}$$

So the range of wave length in which earth emit max. spec. emmisive power is $\lambda_m \in (11.59, 966)$ km


I = (1 KW/m²) × Ac
selective coating
α = 0.95
ε = 0.05
Absorber Plate (Fin) (Cu)
Riser tube (Cu)
Natural circulation
thermal load
Qeff = ṁw Cp (To − T∞)
I
Soldering
Al
Al
Soldering (Ag based)
Top Fin Solar water heater (SWH)
ΔT = 2°
engfin SWH
Extruded fin
integ SWH
Qu / (I × Ac) = η efficiency
Solar flux Variation (Isc = Solar Const. I)
23½°
T.O. cancer
T.O. capricon
NH
SH
Equator
T.O. cancer (23½° N)
T.O. Capricon (23½° N)
NH - Northern Hemisphere
SH - Southern Hemisphere

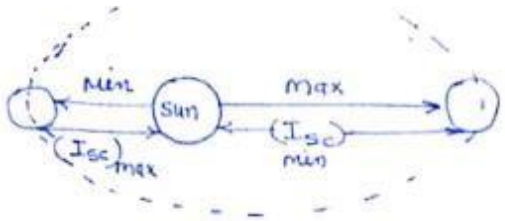


(#) The orbit on which earth revolves around the sun is eliptical hence the distance between the earth and sun varies w.r.t. day.
The maxⁿ Solar flux stoke the earth surface is on 21st Dec. in Southern hemisphare whereas the min on 21st Jun in Northern hemisphare (NH) in 1ᵉʸ direction.

Solar Constant :- The energy flux receive from the flux to the outside surface of earth.

$$I_{sc} = 1367 \text{ W/m}^2 \rightarrow \text{Solar constant.}$$

* The orbit of the earth on which earth revolves around the sun is elipliptical hence the mean distant b/w sun and earth varies and so thus the solar constant also changes.



$I_{sc} = 1367\ W/m^2$

total variation of $I_{sc} = \pm 3.3\%$

for n^{th} day

$$I'_{sc} = I_{sc}\left\{1 + 0.033 \cos\left(360^\circ \times \frac{n}{365}\right)\right\}$$

$\cos\theta$ — Max = +1, Min = −1

$n \longrightarrow n^{th}$ day

$n = 1 \Rightarrow 1$ Jan.

For Jun 21, $n = 31+28+31+30+31+21 = 172$

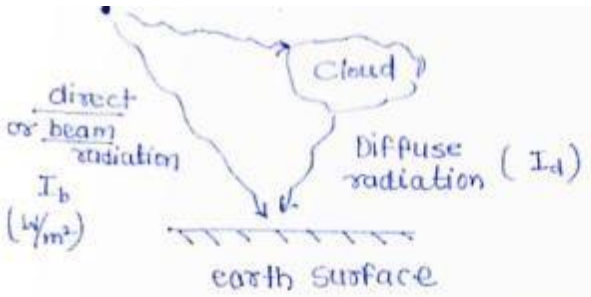
$$I'_{sc} = 1320.6\ W/m^2$$

For Dec 21, $n = 355$

$$I'_{sc} = 1411.4\ W/m^2$$

Effect of Environment on Solar radiation:—

Solar radiation recipive on the earth surface are under gone Absorption, scattering or reflection from the ozone layer and water vapour.



Total Radiation $\boxed{I_g = \text{Global radiation} = I_b + I_d}$

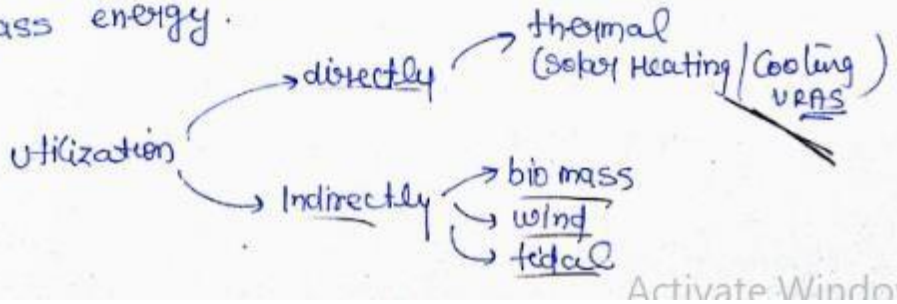
Direct/Beam Radiation:- Solar radiation receive at the surface of earth in line with the sun is know as direct radiation

Diffuse Radiation:- Solar radiation receive on the earth after getting scatter because of the atmosphere of earth.

Utilization Method for solar Energy:-

Solar energy can be utilise directly or indirectly in which directly heat of water or air or Conversation of solar into electricity.

Indirect method of solar energy drives the ecology system. some of the examples are. wind energy and Bio-mass energy.



Directly :-

(A) Thermal -- solar heating or cooling

Solar Power Plant :-

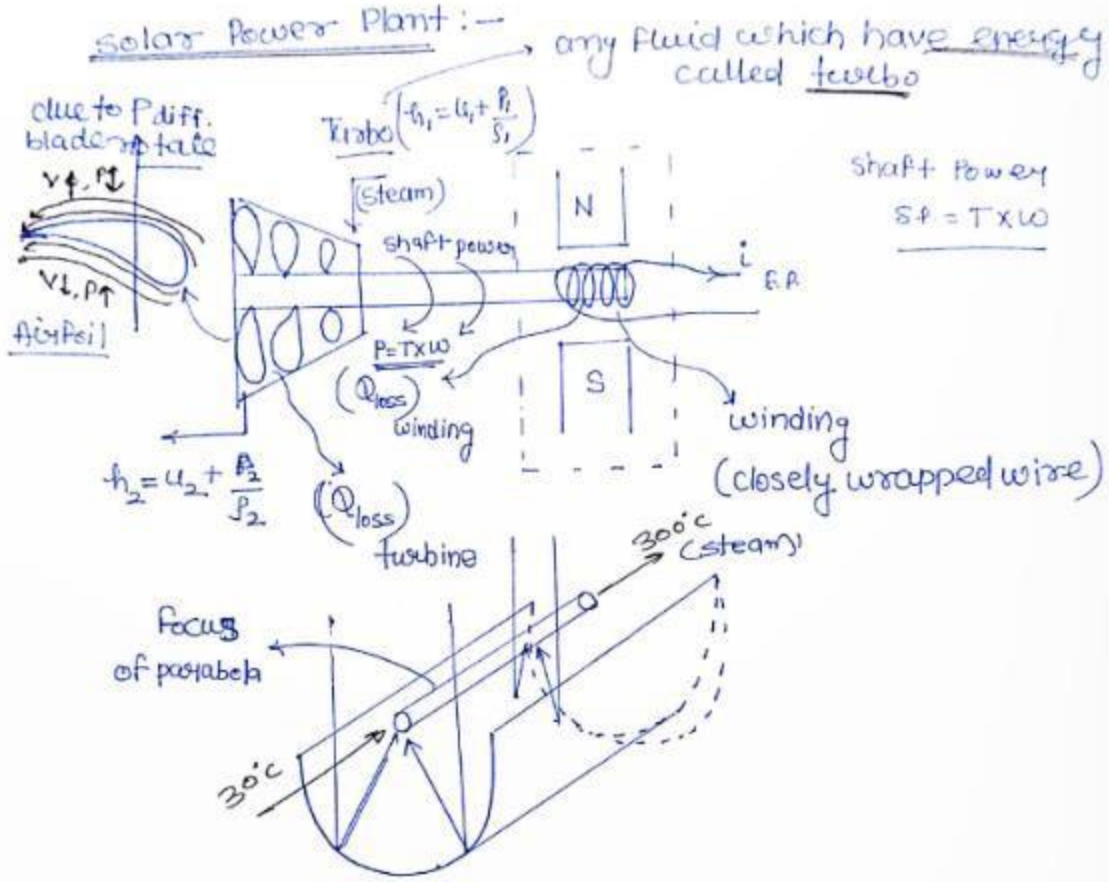


Fig :- Parabalic Collecter

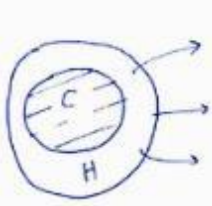
* A high energy containtent fluid (turbo) is entered into the turbine and losses its energy and that energy is given the turbine shaft power
* In order to create high energy fluid like steam) concentrating type solar collertor are used.

(B) Photo-Volatic

{ Solar energy → Directly → Electrical energy }

Indirectly

Bio mass :-



'H' Comb. First

'H' Comb. Rapidly

$\Delta_H >> \Delta_C$

* $CH_4 + 2O_2 \longrightarrow 2 \cdot H_2O + CO_2$

Stiochimetry reaction / Perfect Combustion

* $C_3H_8 + 5O_2 \longrightarrow 4H_2O + 3CO_2$

$C - O - O \rightarrow CO_2$
$C - O - O \rightarrow CO_2$
$C - O \rightarrow CO$

let 10% less O_2

$C_3H_8 + 4.5O_2 \longrightarrow 4H_2O + CO + 2CO_2$

$$\% CO = \frac{1}{4+1+2} = 14.28\%$$

Gate-2016

$C \xrightarrow{O} CO \xrightarrow{O} CO_2$

* First rapidly 'H' Comb. happens and H_2O becomes then rest O_2 make CO and then CO_2

* $C_8H_{18} + 12.5O_2 \longrightarrow 9H_2O + 8.CO_2$ Complate combustion

* Stub let $10O_2$

$C_8H_{18} + 10O_2 \longrightarrow 9H_2O + 5CO_2 + 3CO_2$

$\%CO = \frac{5}{9+5+3} = 29.4\%$

पहले H_2O बनेगा $11 \to 0$ left

फिर CO ⇒ एक एक O से और फिर CO_2

C−O−O ⇒ CO_2
C−O−O ⇒ CO_2
C−O−O ⇒ CO_2
C−O ⇒ CO

C−O ⇒ CO
C−O ⇒ CO
C−O ⇒ CO
C−O ⇒ CO

⇒ $5CO + 3CO_2$

* $C_{10}H_{22} + 15.5\left\{O_2 + \frac{79}{21}N_2\right\} \longrightarrow 11.H_2O + 10CO_2 + 15.5 \times \frac{79}{21} N_2$

Air

$\left\{\begin{array}{l} 21\% \to O_2 \\ 79\% \to N_2 \\ \text{for } 1\ O_2 \\ \frac{79}{21} N_2 \end{array}\right\}$

11 + 20 = 31 O_2 require

So $15.2O_2$

let $10.5O_2$ then

$C_{10}H_{22} + 10.5\left\{O_2 + \frac{79}{21}N_2\right\} \longrightarrow \underbrace{11H_2O}_{10 \to 0 \text{ left}} + 10CO + 10 \times \frac{79}{21} \times N_2$

So. $\%CO = \frac{10}{10+11+10 \times \frac{79}{21}} = 17.05\%$

let $2OO_2$ $+4.5O_2$

$$N_2 \xrightarrow[\text{High temp.}]{\text{oxidation}} NO_x$$

Latitude and longitute :- Definition of Angle

Lattitude Angle(ϕ) :- The lattitude of a location P is the Angle made by the redial line Joining the location to the center of earth with the projection of line on equitorial plane.

Sign Convention :-

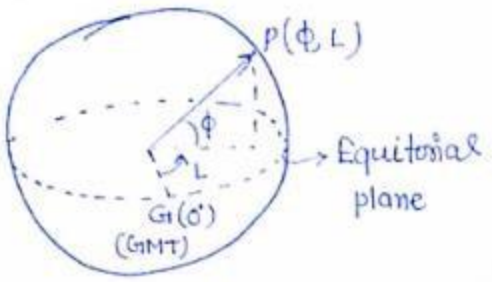
ϕ → Lattitude → ϕ° N
Lattitude → ϕ° S

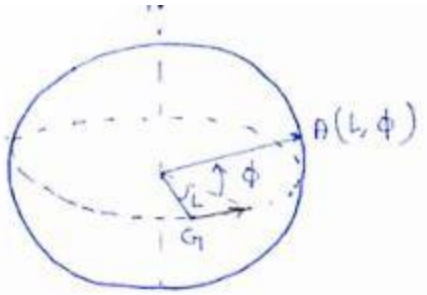
Longitude (L) :- longitude is measured from the refrance point Greenwhich, England and it is the angle between the projection of line of any point P on equitorial plane the projection of line having lattitude of Greenwhich.

Sign Convention

L → θ° E
L → θ° W

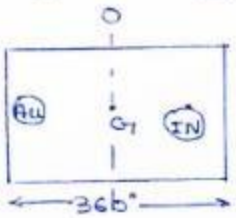
From Greenwhich england





G - Greenwhich

GMT - Global Meridian time (Greenwhich)



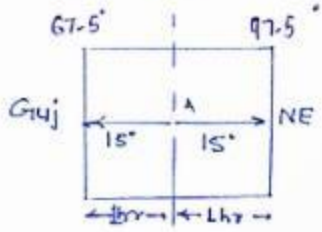
one day = 360°

1 hr = $\frac{360}{24}$ = 15°/hr

Solar Noon = 12:00

S

82½° E



A - Allahabad Mirzapur

Diff b/w Allahabad & Green which

= $\frac{82\frac{1}{2}^\circ}{15^\circ}$ = 5.5 hrs

(depend only one longitute)

$$\text{Solar time} = \text{Watch time} - 4(L_{ST} - L_{lo})$$

$$ST = WT - 4(L_{st} - L_{lo})$$

L_{st} = longitude of Standard Meridian (Country)

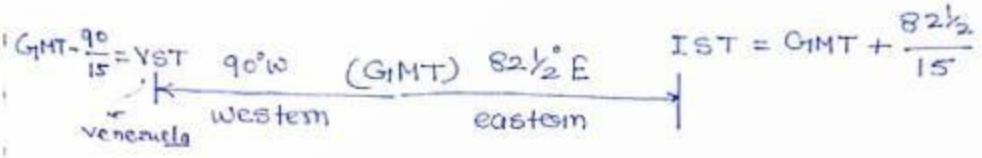
L_{lo} = local longitude

$(ST)_{NE} = 12 - 4(-15) = 1300$ hrs

$(ST)_{GMT} = 12 - 4(15) = 1100$ hrs

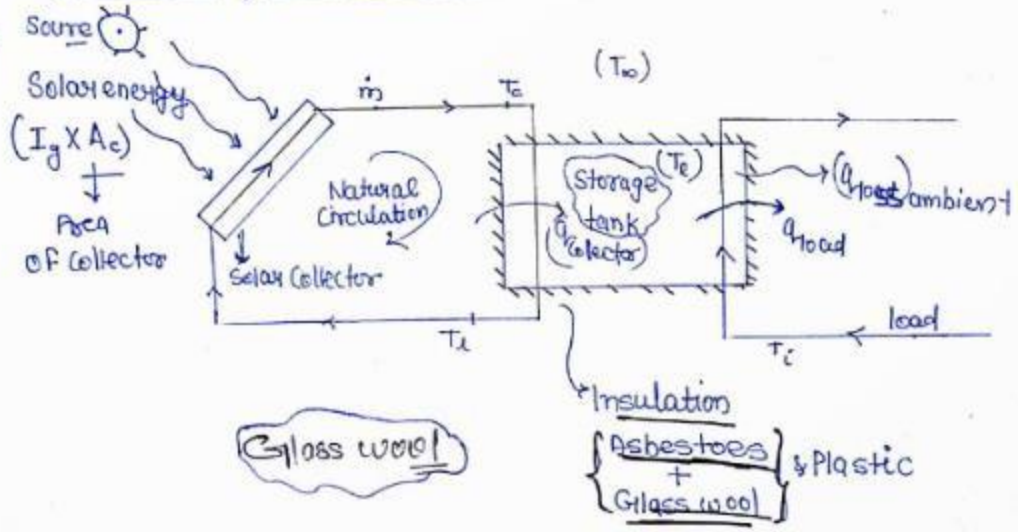
Solar thermal Energy storage system:—

The availability of solar radiation at any particular location is intermitant, variable, and unpredictable



In order to overcome this disadvantage solar energy storage system require to ensure the smooth supply of power over a desired period of time.

Basic configration of thermal storage system:-



In solar thermal energy storage system energy in the form of heat is added to the collecter system to the storage System

Type-1 (Sensible Storage Devices)

↳ Heating a liquid or solid without phase change.

$$E_{storage} = m\int C_p \cdot dT$$

These are sensible storage device and the amount of store (E) is a function of temp change

$$E = m\int C_p \, dT$$

Ques A Thermal heat storage device contains a organic liquid R-11a which is having variable specific heat C_p Given by $C_p = (0.05T + 0.2)\ ^{KJ}/_{kg-K}$. The rise in temprature in the liquid from 20°c to 50°c. Then determine the amount thermal energy stored for the unit mass System.

Soln

$T_1 = 20°c = 293\,K$

$T_2 = 50°c = 323\,K$

$$E_{(storage)} = m\int_{T_1}^{T_2} C_p \cdot dT$$

$$E = 1\int_{T_1}^{T_2} (0.05T + 0.2)\cdot dT$$

$$E = \left[0.05\frac{T^2}{2} + 0.2T\right]\Bigg|_{293}^{323}$$

$$E = 0.05\frac{(323-293)^2}{2} + 0.2(323-293)$$

$$E = 46.8\ KJ$$

↳ Heating a material which undergone change of phase

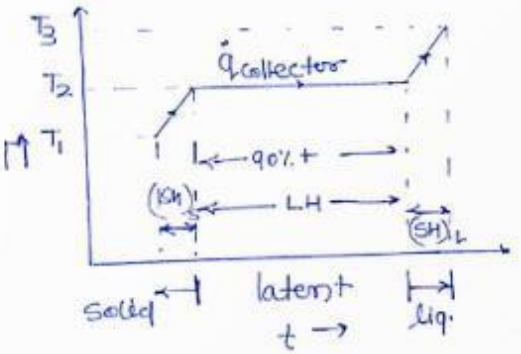
→ These devices are called as latent heat storage devices and these devices energy stored in the form of latent heat.

P.C.M. (phase change material) → Solid $\underset{\dot{q}_{load}}{\overset{\dot{q}_{collector}}{\rightleftharpoons}}$ Liquid

$$E_{stored} = m \times (L.H)$$

LH - latent heat

In case of practical application there is a chances that some heat may be stored as sensible heat



Practically

$$E_{Stored} = m\int_{T_1}^{T_2} C_p \cdot dT + m(LH) + m\int_{T_2}^{T_3} C_p dT$$

Solid — latent — liquid

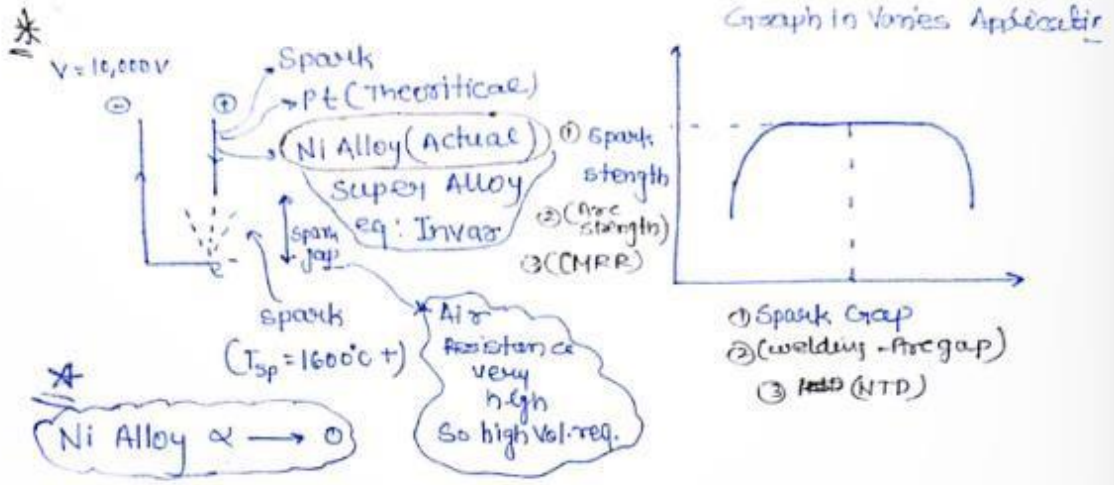
Note!- It is best suited for constant temp. load application.

P.C.M. :- The material use for heat storage at constant temp. when a material undergoes the phase change.

Imp. Properties:- (i) Melting point should be in the temp. range of application.

(ii) High value of latent heat of fusion

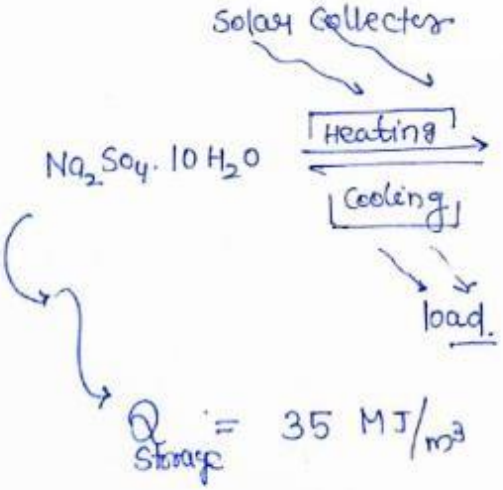
(iii) $\alpha \rightarrow$ low



(iii) Very low value of coefficient of thermal expansion

Example's of PCM :-

Hydrated salt like Sodium Sulphate has very Volumetric storage capacity which overcome the problem of unpredictable nature of solar energy availability.



Type-3 (Thermochemical Storage)

→ In thermo chemical storage system, solar energy which is to be use stored in induced Endothermic chemical reaction and the product stored in storage tank.

→ Whenever energy is required (Load), reverse Exothermic reaction is made and it release huge amount of energy.

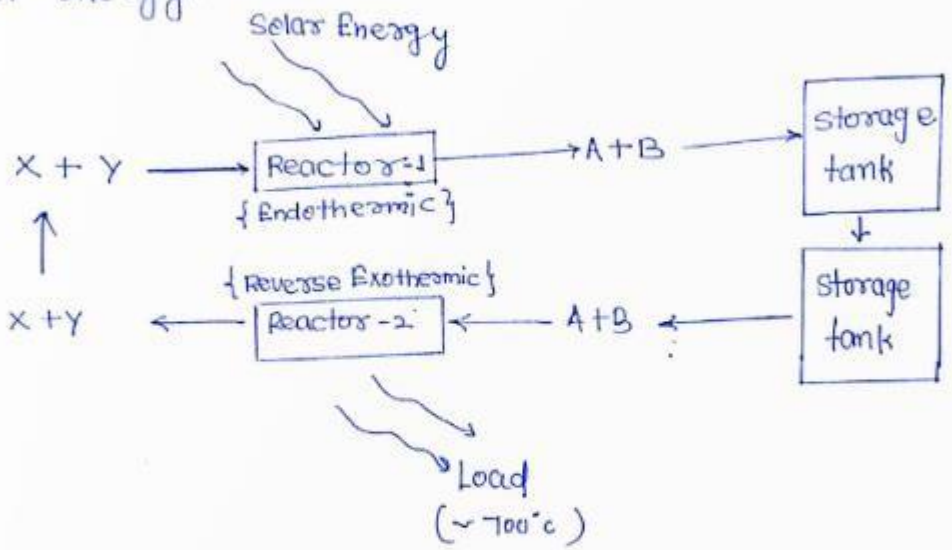


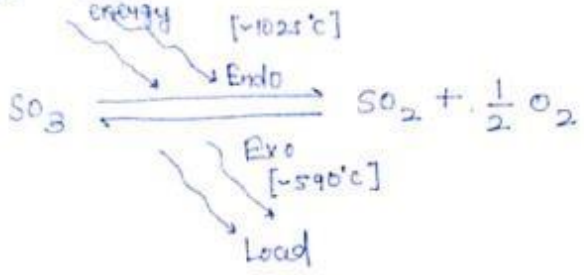
Fig:- Basic thermo chemical storage system

Note: (i) It is applicable for high temp. applications

(ii) The forward endothermic reaction (solar collector) and the reverse exothermic reaction (Load) is always occurs at different temp.

$$T_{ENDO} > T_{EXO} \quad \text{Always}$$

Example:- Solar energy [~1025°C]

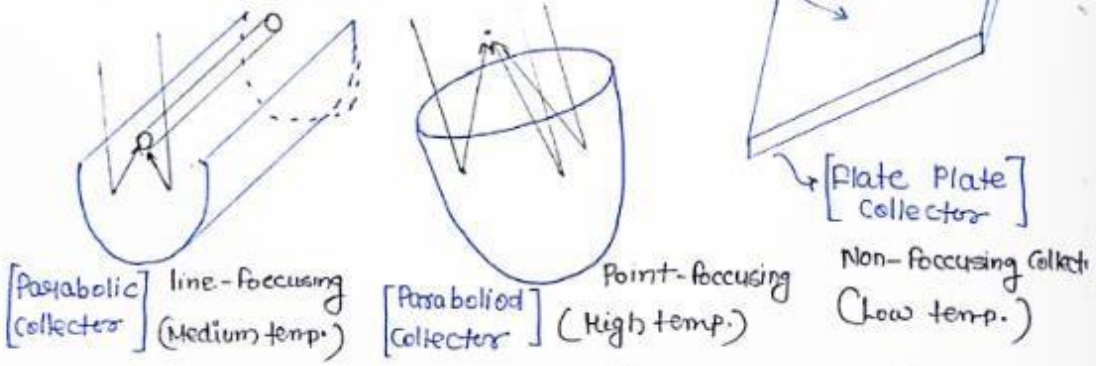


The max. storage capacity is

$$\left(Q_{max}\right)_{Storage} \simeq 2.5 \text{ GJ/m}^3$$

* High storage capacity

* Types of Collectors



Note:- for the high temp. application Solar Collector is should be focusing or concentrating type

Declination Angle:-(δ)

It is the angle made by the line joining the centre of sun and earth with the projection on equitorial plane and it relation Given by Cooper's Relation

Cooper's Relation :-

$$\delta = 23.45^\circ \sin\left\{\frac{360}{365}(284+n)\right\}$$

$\delta \simeq +23.45^\circ \rightarrow$ Jun'21 $\Rightarrow$ $n = 172$ (longest day)

$\delta \simeq -23.45^\circ \rightarrow$ Dec'21 $\Rightarrow$ $n = 355$ (shortest day)

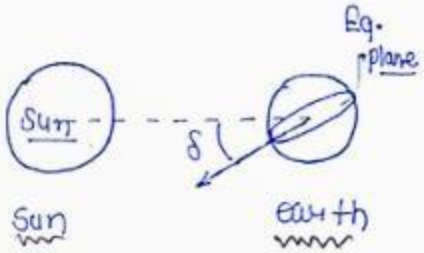
$\delta \simeq 0^\circ \rightarrow$ Sept'21 $\Rightarrow$ $n = 265$ } equinox

$\delta \simeq 0^\circ \rightarrow$ Mar'21 $\Rightarrow$ $n = 80$ }

$\delta \in [+23.45^\circ, -23.45^\circ]$

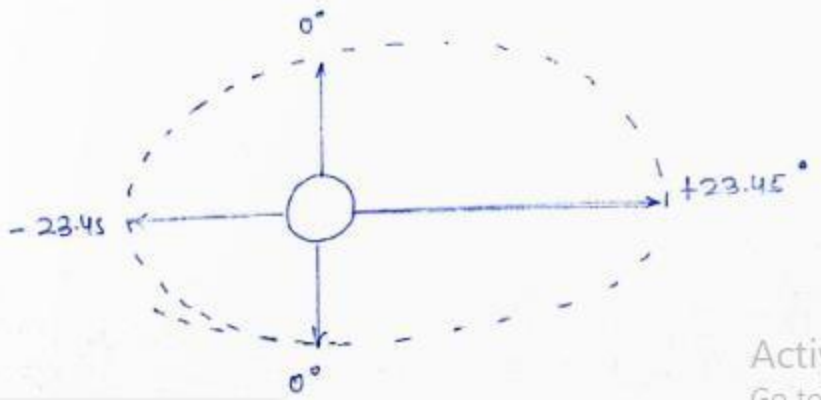
↑ Northern hemisphere

↑ Southern hemisphere

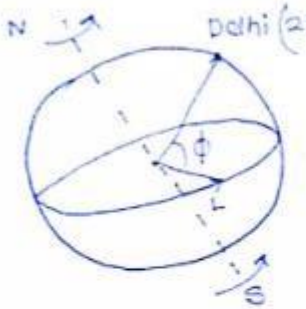


Sun

Earth



Question:- On 21st Aug for the flat plate collector laying in Delhi (28°35' North, 77°22' East) what is the solar time at watch time 12:30



$$L = 77 + \frac{12}{60} = 77.2^\circ$$

$$ST = WT - 4\left(T_{s_0} - T_{l_0}\right)$$

$$ST = 1230 - 4(82.5 - 77.2)$$

$$= 1230 - 21.2 \text{ min}$$

$$= 12:08:48$$

$(1-0.2)\times 60$

$\Rightarrow 30 \quad \Rightarrow 0.8 \times 60$

$-22 \quad \Rightarrow 48$

08

21st Aug $n = 233$

$$\delta = 23.45 \sin\left\{\frac{360^\circ}{365}(284+233)\right\}$$

$$\delta = 11.75^\circ$$

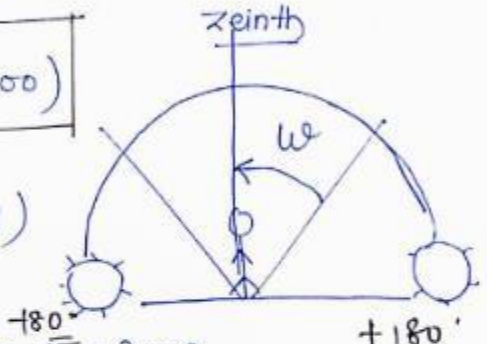
The earth revolves about it's axis and complete revolution in 24 hrs it means

$$\frac{360}{24} = 15^\circ/hr$$

Hence hour angle (ω) for any location is the angle through which earth is rotated since Solar Noon.

$$\omega = \frac{360^\circ}{24}(ST - 1200)$$

$\Rightarrow \omega$: -ve (Morning), +ve (evening)



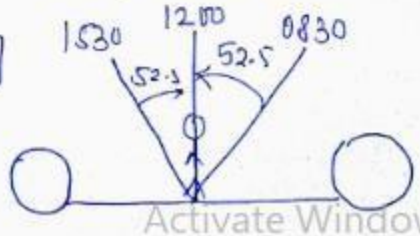
* Hour angle at Solar time = Solar noon $\Rightarrow \omega = 0$

Question :- In order to design a sun tracking m an engineer wants to calculate hour angle from 08:30 to 15:30 Local apparent time (LAT) or Solar time. Find out the range of hour angle to help the engineer. 3 hr 30 min = 3.5 hr

Soln $ST_1 = 0830$ $\omega_1 = 15(0830 - 1200) = -52.5^\circ$

$ST_2 = 1530$ $\omega_2 = 15(1530 - 1200) = +52.5^\circ$

$\omega \in [-52.5^\circ, 52.5^\circ]$



3hr 30 min = 210 min
= 210/60 = 3.5 hr

☆ Imp

Photo - Volatic

Photo - Volatic

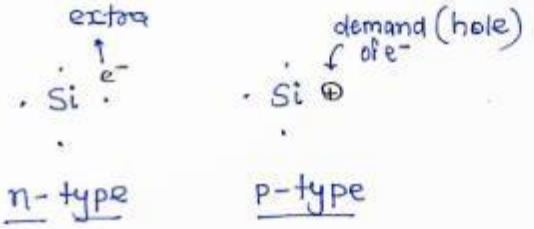
↓

Photon

↳ Solar energy —P.V. cell→ Electrical Energy

The conversion of solar energy directly in to electricity is known as solar photo volatic conversion and the device use for the same is know as solar cells.

Solar cells are made of semiconductor material Generally of crystal silicon. n and p type semi-conductor fuse toghether by diffussion process



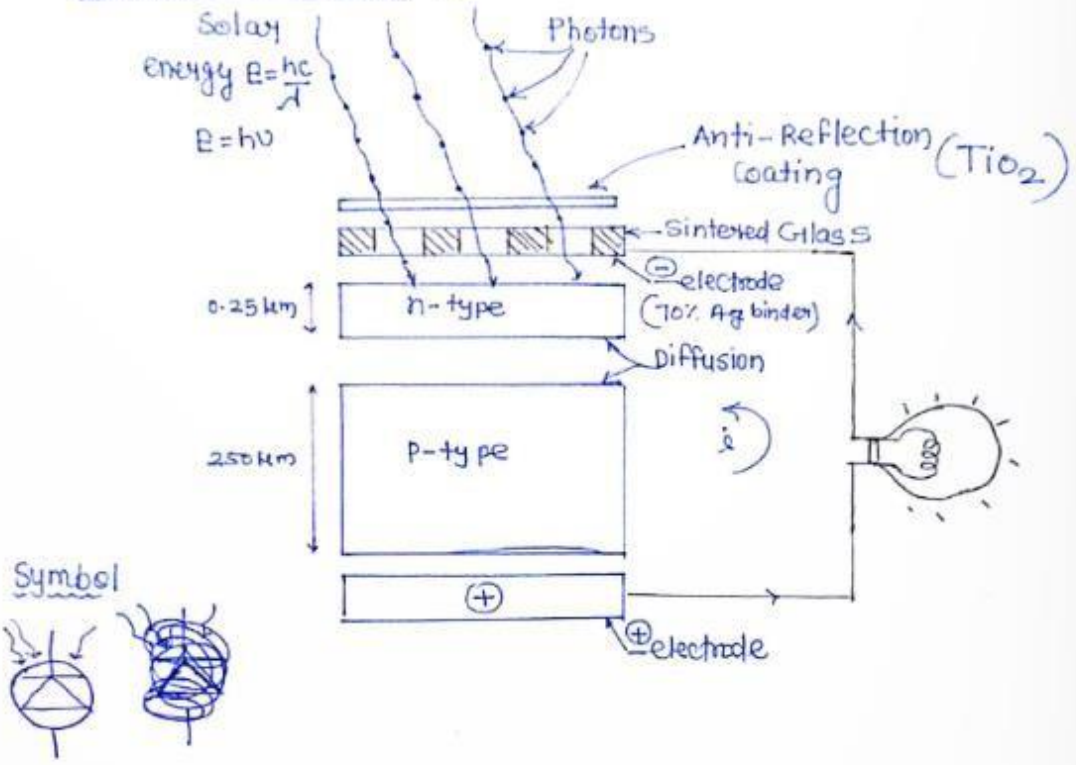
n-type p-type

☆

A Thin layer of n-type semiconductor (0.25 μm) is by diffusion place over a thick layer of p-type semiconductor (250 μm)

Generally the front contact is made of sintered Glass electrode consist of 70% Ag (silver) as organic binder and also an anti reflecting coating (TiO_2) is place over the top of the surface to increase absorption

Construction details :-



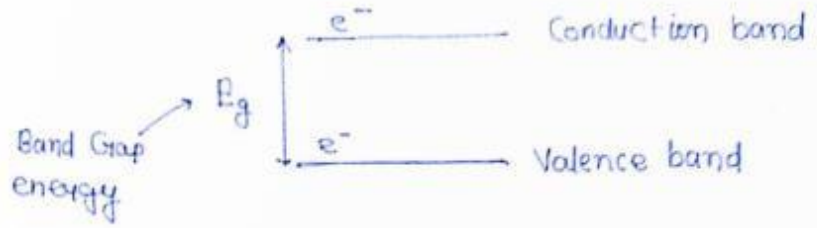
Symbol

In case of semiconductor electron occupies either of this two energy band

(a) Valence-band :- It is a low energy leved and fully occupies.

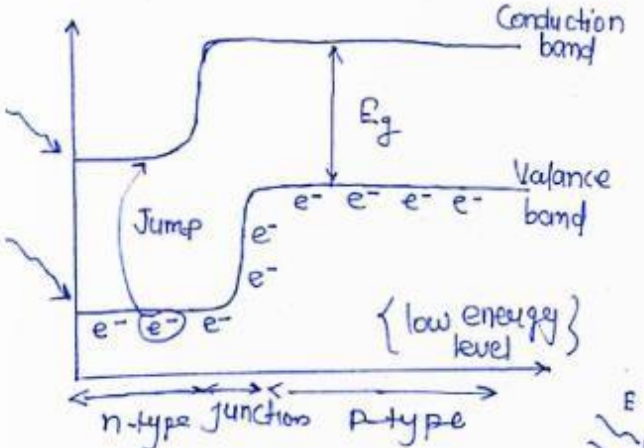
(b) Conduction band :- high energy band and partically occupies

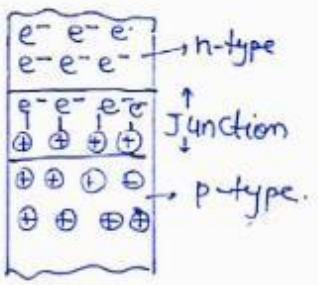
The differance between the minimum energy of the electron in the Conduction band and the maximum energy of electron in Valance band is known as band Gap energy (E_g)



* When the cells are expose to solar radiation then the photons of the sun light contains energy $E\left(E=\frac{hc}{\lambda}\right)$ if it is greater than the band Gap energy E_g then it excite same of the e^- which made to flow through an external circuit

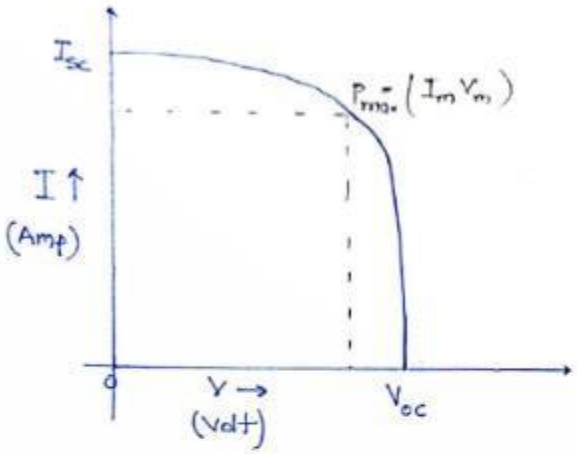
if $\left(E=\frac{hc}{\lambda}\right) > E_g \Rightarrow e^-$ Jump. $\Rightarrow$ i-flow



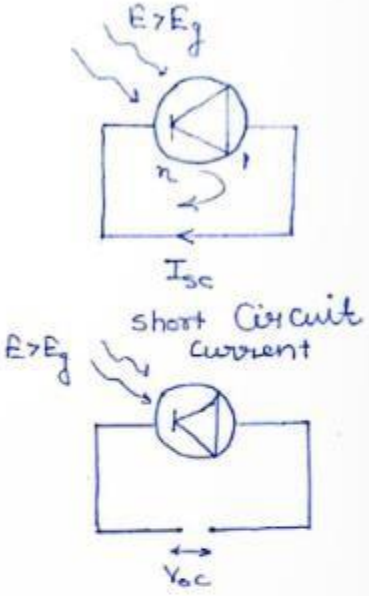


Performance characteristic Curve :-

Performance of solar is analyse by floting it current Voltage characteristic.



$P = V \times I$



* V_{oc} and I_{sc} are opencircuit Voltage (Max^m possible potential drop) and short circuit current (Max^m possible current) across diode.

Fill factor, $\boxed{FF = \frac{P_{max}}{I_{sc} V_{oc}} = \frac{V_m I_m}{V_{oc} \cdot I_{sc}}}$

$\eta_{conversion} = \frac{(P = V \times I)}{I_t \times A_c}$

$$\boxed{(\eta_{Conv.})_{max} = \frac{P_{max}}{I_t \times A_c} = \frac{V_m \times I_m}{I_t \times A_c} = \frac{FF \times V_{oc} \cdot I_{sc}}{I_t \times A_c}}$$

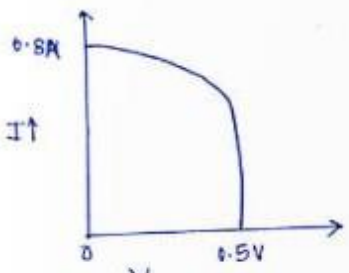
* I_m and V_m are current and voltage corresponding to max^m power.

* The maximum conversion efficiency of a solar cell is the ratio of max useful electrical power developed by P-V cell to the incident solar radiation.

→ It is normally in between 15 to 25%.

$\{\eta_{max} \simeq 15 \text{ to } 20\%\}$ $\{\eta_{max} \simeq 47\%\}$

Question A P-V cell which is operating at cell temp. 40°C it's performance curve is given below. determine the max^m power from the solar cell if the fill factor (FF) = 0.8



$I_{sc} = 0.8\,A$, $V_{oc} = 0.5\,V$

$FF = \frac{P_{max}}{V_{oc} I_{sc}}$ → $P_{max} = (FF)(V_{oc} I_{sc})$

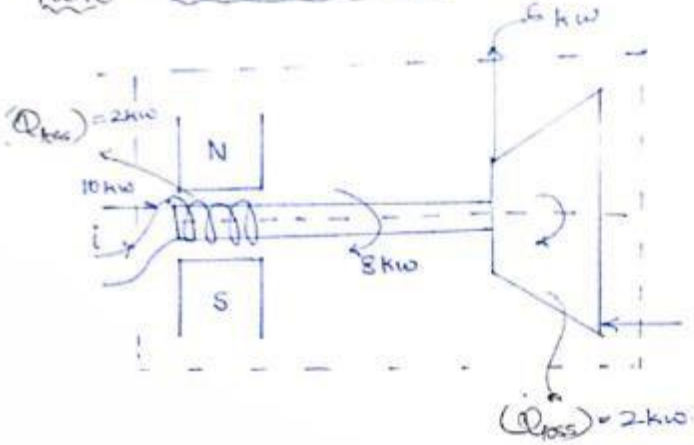
$P_{max} = 0.8 \times 0.5 \times 0.8 = 0.32\,W$

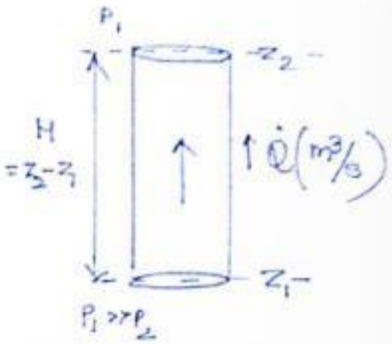
Q In above problem if the voltage at max power is 0.45 V then determine the current for max. power condition

$P_{max} = V_m \cdot I_m$

$0.32 = 0.45\, I_m \Rightarrow I_m = 0.71\,A$

Note pump motor set





$$P_{pump} = mgH = (\rho \cdot Q)\, gH$$

Power requisite to

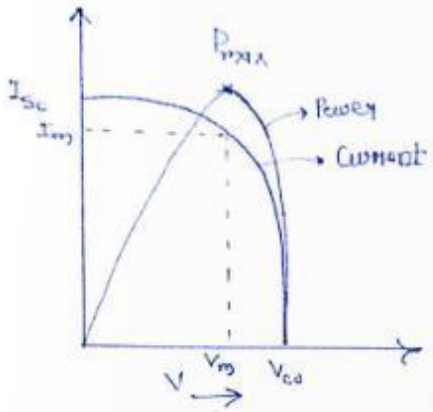
Types of Solar Cell

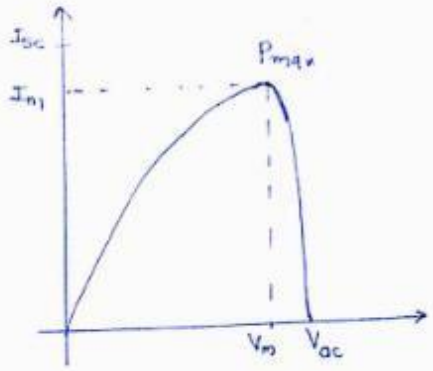
- Solar Cell
  - Silicon Semi Conductor
    - Crystalline
      - Single Crystal (10-17)% (costely)
      - poly Crystal (10-13)% ← Most widely use (less cost)
    - Non Crystalline
      - ↓ Amorphous (7-10 %)
  - Compound Semi Conductor
    - Gallium Arsenade (GaAs) (18-30 %) (Highly Cost)
  - organic Semiconductor
    - Die Sentisized (7-8 %)
    - organic thin layer type (2-3 %)

Decrease order of efficiency (conversion)

Gallium Arsenade > Single Crystal > poly Crystal > Amorphous

Power characteristic:- $P = V \times I$





Question:- A photo volatic system is used to supply drinking water. is installed in a village. The water is pumped from a borwell, from a depth of 48 m. Solar cell are made from Single crystal Silicon and the array consists 24 Module The are total 36 cell en a Module and each cell area is $(12.5 \times 12.5\ cm^2)$. The global radiation incident normal on the cell is 945 W/m^2 Solar cell conversion efficiency is 12.5 %. The inverter efficiency is 85 % (DC → AC) and the motor pump set efficiency is 45 %. Determine $\dot{Q}$ in (lit/hr)

Sol^n $A_c = \frac{12.5}{100} \times \frac{12.5}{100} \times 24 \times 36 = 13.5\ m^2$.

$I_t = 945\ W/m^2$

Solar radiante $I_t A_c = 12757.5\ W$

$\eta_{conversion} = 12.5\ \%$

$\eta_{conv.} = \dfrac{P}{I_t \times A_c}$ $\quad \therefore P = (0.125)(12757.5)$

$P = 1594.68\ W$

$P_{cell} = 1594.68\ W$

$\eta_{inverter} = \dfrac{P_{cell(AC)}}{P_{cell(DC)}} = 85\ \%$

$P_{cell(AC)} = (0.85)(1594.68)\ W$

$P_{cell(AC)} = 1355.47\ W$

$\eta_{\substack{motor \\ pump}} = \dfrac{P_{pump}}{P_{cell(AC)}} = 45\ \%$

$P_{pump} = (0.45)(1355.47)$

$P_{pump} = 609.96\ W$

$\rho = 1000\ kg/m^3$

$g = 9.81\ m/sec^2$

$H = 48\ m$

$P_{pump} = \dot{m} g H = \rho Q g H$

$609.96 = (1000)\dot{Q} \times 9.81 \times 48$

$1 m^3 = 1000\ lit$

$\dot{Q} = 1.295 \times 10^{-3}\ m^3/sec.$

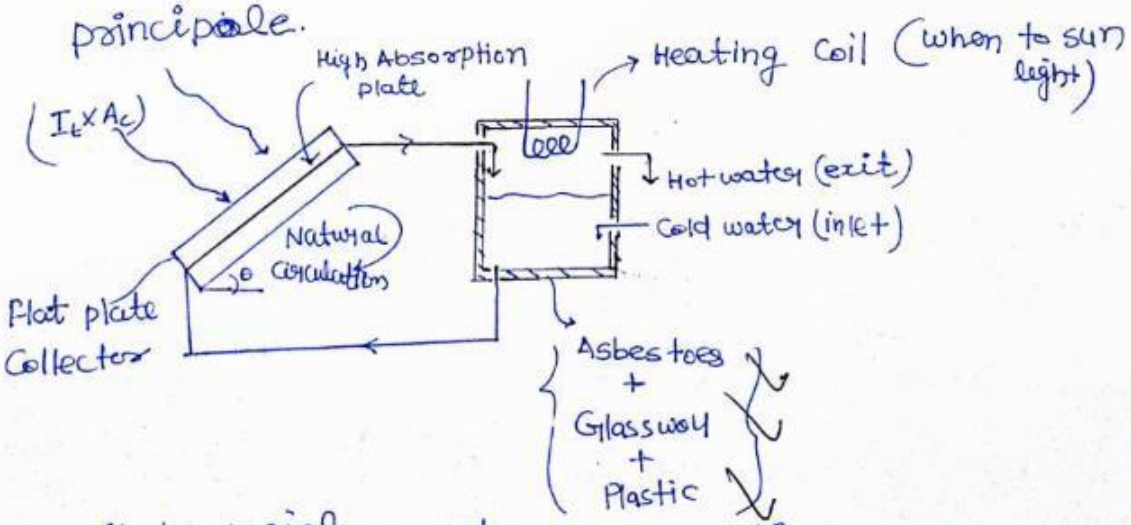
$\dot{Q} = 1.295 \times 3600\ lit/hr$

$\dot{Q} = 4663\ lit/hr$

Solar thermal Energy Applications

1. Solar water Heating :- solar water heating is classified as

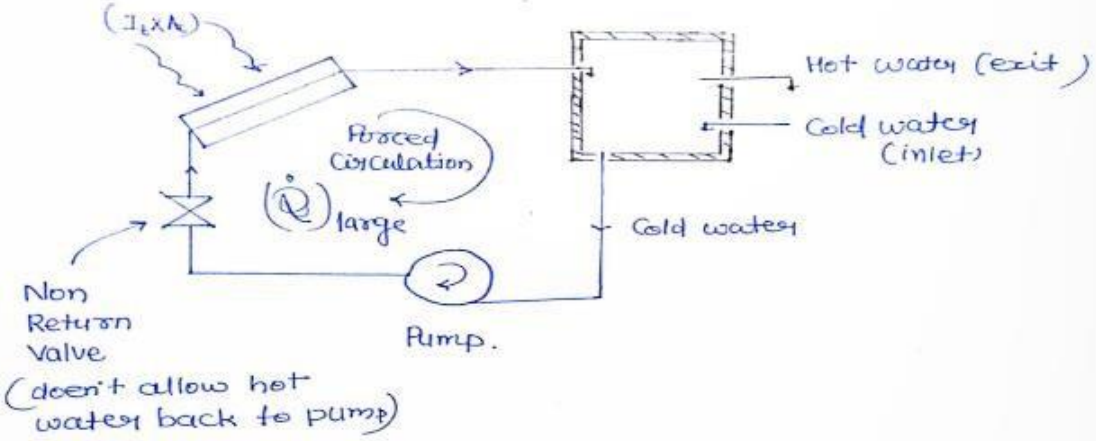
(a) Natural convection :- In natural circulation solar water heater the temp. of fluid at the exit is around 40 - 45°c (low temp. application) and it is based on buoyancy principale.



* it is mainly used in domestic cases

(b) Forced Circulation System :-

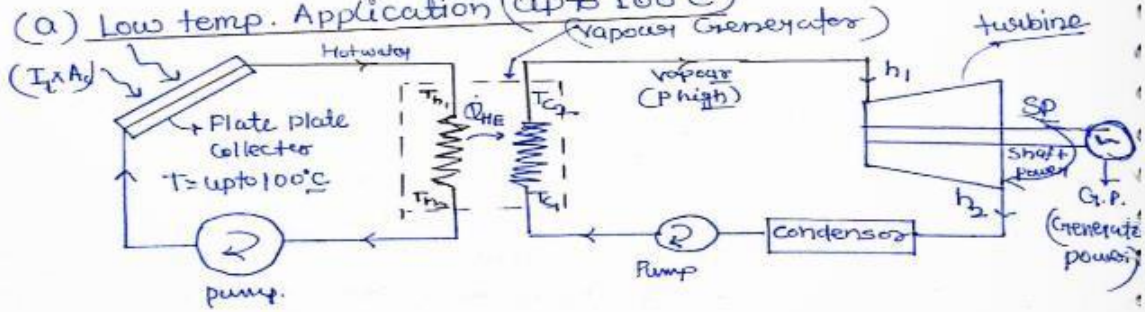
→ It has dedicated pump for circulation
→ It is mainly used for industrial purpose and high discharge rate application purpose.



2. Power Generation :-

The Generation of electrical energy from solar energy is further classified into three categories.

(a) Low temp. Application (upto 100°C)



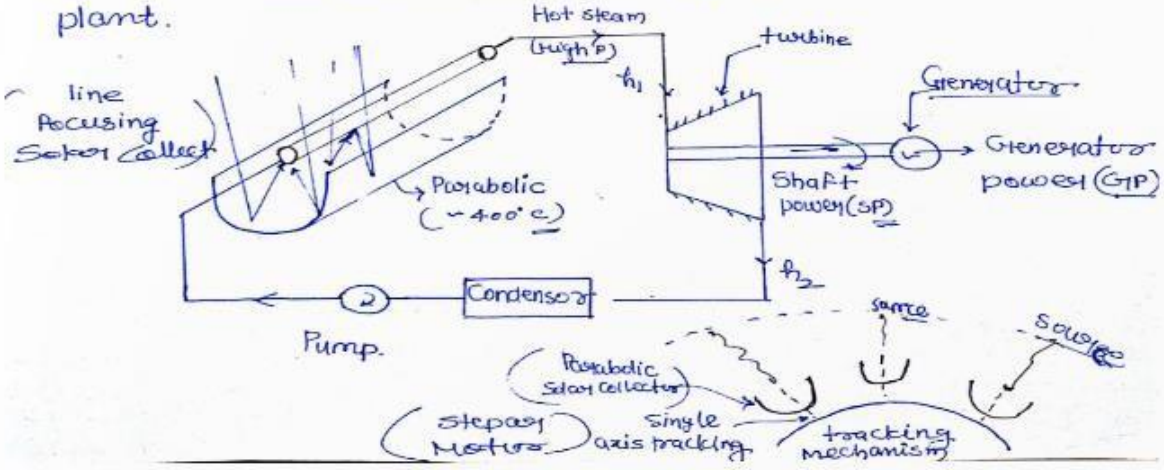
$$\epsilon_{HE} = \frac{(Q_{loss})_{Hot} \text{ or } (Q_{gain})_{Cold}}{(\dot{m}C_p)_{Small}\,(T_{hi} - T_{ci})}$$

low temp. system utilizes the Flat plate collector to heat fluid upto boiling point and delivers this heat to the working fluid of rankine cycle through vapour generator.

Disadvantages:- Not economical because it require large collector area.

(b) Medium temp. System:- Medium temp. power plant require line focusing parabolic concentrator which can achieve the temp. upto 400°C

It is the most effective category of solar power plant.



Note:- Tracking Mechanism:-

line focusing Solar Collector requires single axis tracking mechanism so that the incident radiation direction always coinside with the focal point of the parabolic Collector.

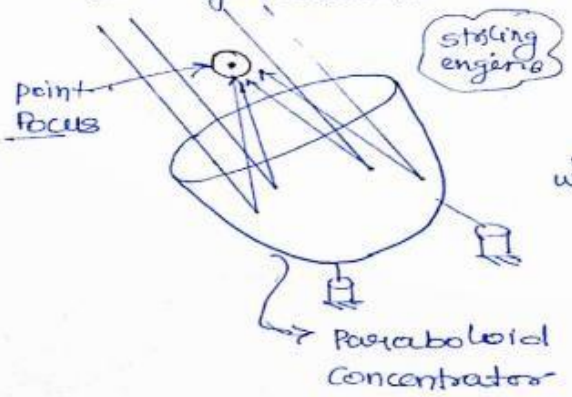
(C) High temprature Application :-

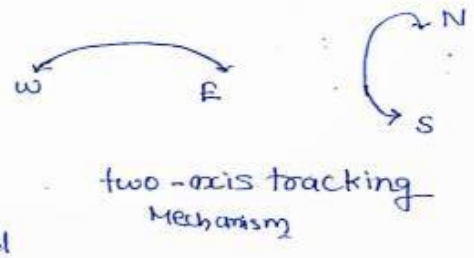
It is further devided into two categories for the temp range upto 1200°C.

(i) Paraboloid disk Concentrator:-

→ In such concentrator motion or direction of sun rays are track by two axis tracking mechanism to bring them to a point of focus.

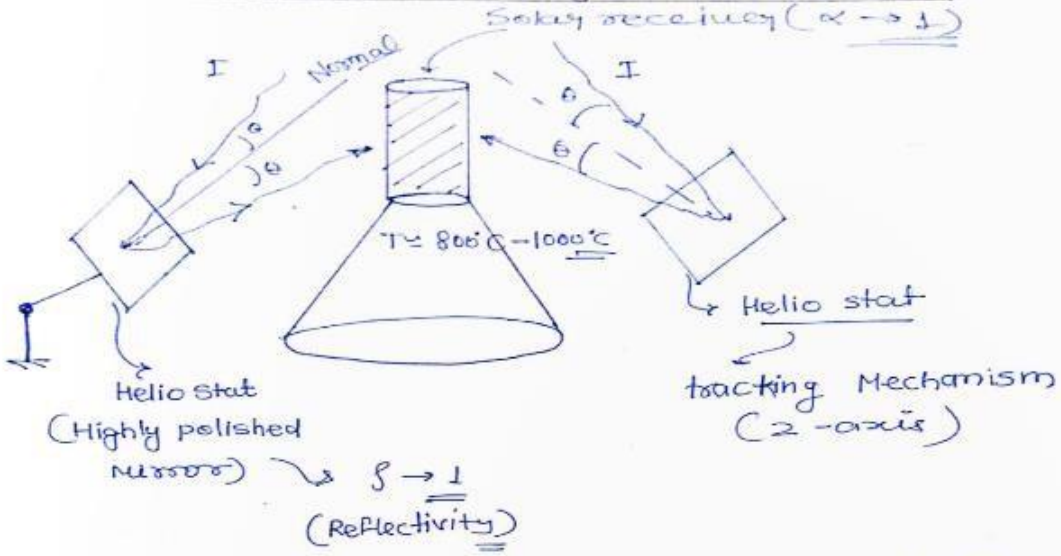
→ This system require highly complex and costly tracking mechanism





two-axis tracking Mechanism

(ii) Central receiver system (Solar tower)



The temp around 800°C and it's concentration ratio is 1000.

Note #

$$\eta_{relative} = \frac{\eta_{engine}}{\eta_{carnot}}$$

Very Imp

decreasing order

1) Paraboloid (point focusing) $\eta_{relative} \simeq 80\%$.
   → dual axis tracking → concentration ratio = 10000
2) Solar tower (point focus) $\eta_{rel.} \simeq 70\%$.
   → dual axis traction → C.R. = 1000
3) Parabolic (line focus) through one axis $\eta_{rel.} \simeq 60\%$. CR = 100
4) Flat-Plate → No tracking → CR = 1 $\eta \simeq 25\%$.

Bio Mass Energy

→ Bio mass is an organic matter which include all plant, tree, animals and micro-organism Grown on land and water and their derivative.

→ Plant matter is created by process of photosynthesis is called bio mass and photosynthesis process drives energy from solar radiation hence it is a indirect form of solar energy.

→

$$CO_2 + H_2O \xrightarrow{E = h\upsilon = \frac{hc}{\lambda}} CH_2O + O_2$$

* The varies resources of bio mass is classified as.

1. Concentrated waste/Residue (High energy content)
   eg.- Municipal residue
2. Dispersed waste
   eg. → Crop Residue
3. Harvested Residue
   eg.- standing Residue.

Methods to obtain Bio mass energy :-

1.) Thermochemical Methos -(a) Combustion Method
(b) Grasification Method.

(a) Combustion Method :- wood is the one of primary biomass which is directly burnt to obtain thermal energy from its chemical energy.

→ Very less efficiency $\eta_{eff} \approx 10\%$.

→ High level of pollution

(b) Bio-mass Gasification Method :-

→ Bio mass gasification is the process of partial combustion in which solid biomass usually in form of residue is converted into combustible gases.

→ It passes through the following process in the gasifier.

(i) Drying :- The biomass is first dried and its moisture is removed and its temp is about 120°C

(ii) Pyrolysis zone :- Biomass in this zone is heated upto 600°C for the exothermic reaction by which it's structure will be broke down.

(iii) Oxidation :- During this process a predetermined air is supplied through the nozzel for the combustion reaction of the bio mass.

→ As a result of combustion reaction the

resultant product is CO_2 and H_2O vapour are formed and temp. reaches to 1200°C.

(iv) Reduction :- The product of Combustion is further passed and it's temp. will decrease as a result of endothermic reaction because of Reduction of biomass and produces gas as form, which calorific value is 1700 KJ/Kg. Producer gas can be use as fuel in ic engine, insi-engine may be directly but in CI engine it is used as dual fuel.

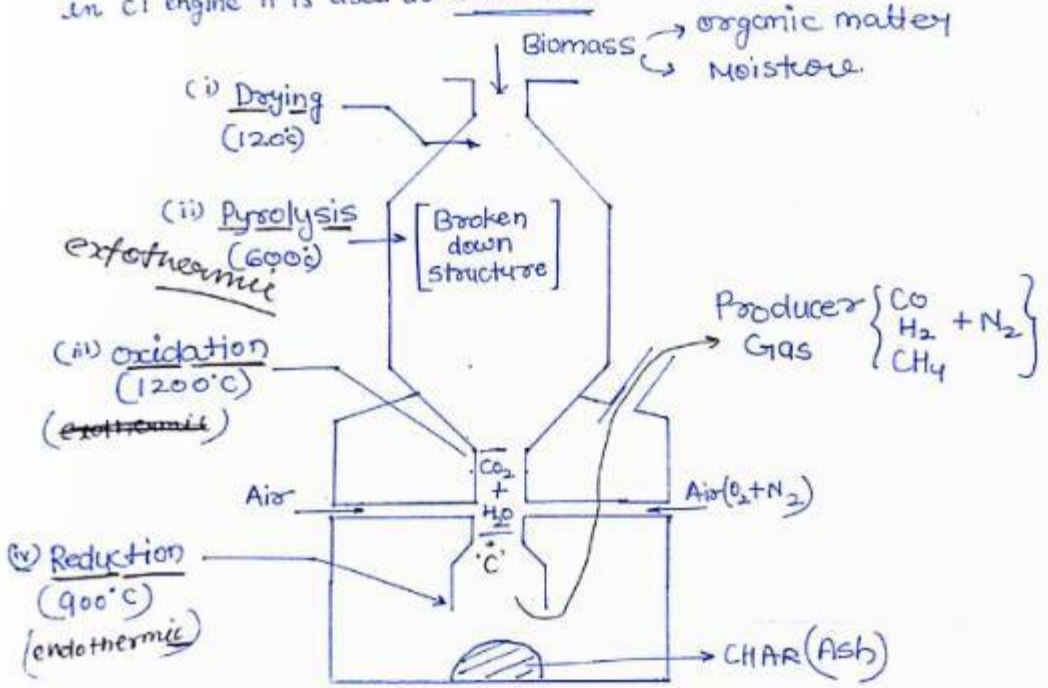


Fig:- Bio Mass Gasifier

Note:- At the end of reduction zone biomass is fully consumed and it gives produced Gases.

$$C_{O_2} + C \longrightarrow 2CO$$

$$H_2O + C \longrightarrow CO + H_2$$

$$2.H_2 + C \longrightarrow CH_4$$

Imp temp. order:-

Oxidation > Reduction > Pyrolysis > Drying

(1200°C) (900°C) (600°C) (120°C)

Note:- $C \xrightarrow[\Delta C_1]{O_2} CO \xrightarrow[\Delta C_2]{O_2} CO_2$ $(\Delta C_2 >> \Delta C_1)$

$$\boxed{\Delta C_1 + \Delta C_2 = \Delta C}$$

Problem:-
A biomass gasifier is used to run a CI engine based diesel cycle. The engine operates in dual fuel mode with 80% diesel replacement. The Gasifier engine system produces 200 kW of power If the overall engine efficiency is 35% if the calorific value of the producer gas is 16800 kJ/kg. and the efficiency of Gasifier is 75%, then determine the rate of producer gas requirment in (kg/hr) and also bio mass feeding rate in (kg/hr)

Soln B.P. = 200 kW

$$\eta_{overall} = 35\% = \frac{B.P.}{(HA)}$$

$$HA = \frac{(200)}{0.35} \times \quad = 571.42 \text{ kW}$$

HA = 571.42 kW

80% diesel replacement. (Biomass).

$(HA)_{producer} = (571.42)(0.80) = 457.14$ kW

$(HA)_{producer} = \dot{m}_p \times (CV)_f$

$457.14 = \dot{m}_p \times (16,800)$

$(\dot{m}_p)_{producer\ Gas} = 0.027$ kg/sec. $= 97.95$ kg/hr.

$\eta_{gasifier} = 75\% = \dfrac{(\dot{m}_f)_{producer}}{\dot{m}_{biomass}}$

$(\dot{m})_{biomass} = \dfrac{97.95}{0.75} \Rightarrow (\dot{m})_{biomass} = 130.7$ kg/hr.

Also determine the compression ratio if cut off ratio is 2.5 & relative efficiency 60%.

$\eta_{relative} = \dfrac{\eta_{brakethermal}}{\eta_{diesel}} = 60\%$ ($\eta_{brakethermal} \rightarrow 35\%$)

$\eta_{diesel} = 0.5833 = 1 - \left(\frac{1}{r}\right)^{r-1} \cdot \dfrac{(\rho^r - 1)}{r(\rho - 1)}$

$= 0.5833 = 1 - \left(\frac{1}{r}\right)^{1.4-1} \dfrac{(2.5^{1.4} - 1)}{1.4(2.5 - 1)}$

$\gamma = 15.31$

If the clearance volume is $V_c = 300\ cm^3$ then determine the cylinder dimension if the engine ratio is 1.5.

$$\frac{V_s}{V_c} = \gamma - 1 \Rightarrow \frac{V_s}{300} = (15.31 - 1)$$

$$V_s = 4,293\ cm^3$$

Engine Ratio $\frac{L}{D} = 1.5 \Rightarrow L = 1.5\,D$

$$V_s = \frac{\pi}{4} D^2 L = 4293$$

$$\frac{\pi}{4} \times D^2 \times 1.5\,D = 4293$$

$$D = 15.39\ cm$$

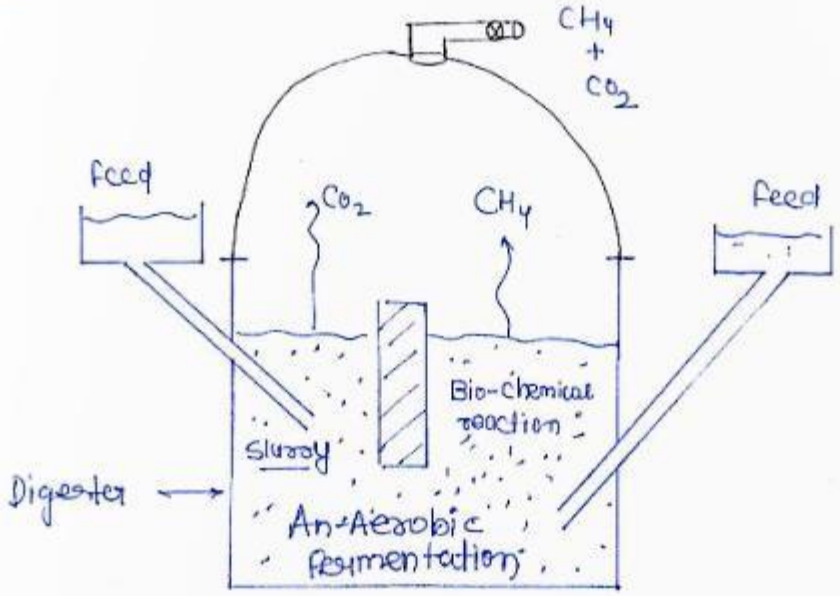
$$L = 1.5D \Rightarrow L = 23.09\ cm.$$

2 Bio-chemical Method:-

Fermentation and digestion:- Bio gas is produce by anaerobic (No O_2)

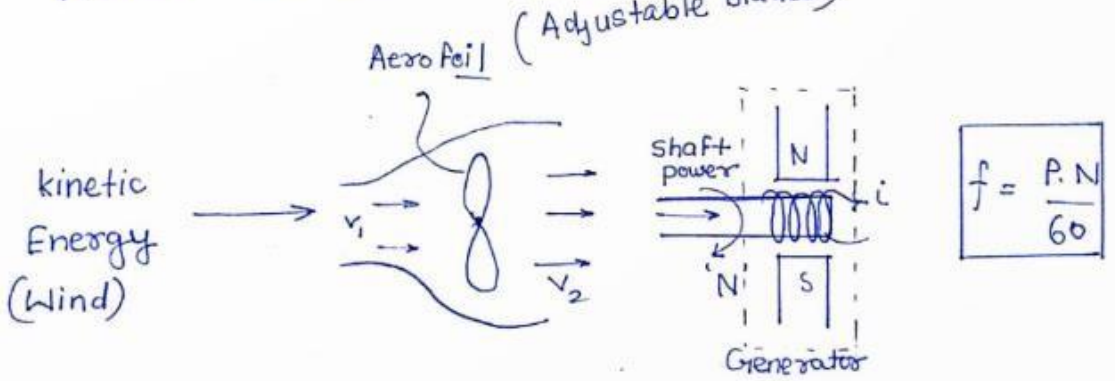
Fermentation of wet-life stock and the plant use for bio-Gas production is known as biogas plant.

→ It contains two major part one is digester in which gas generation takes place because of fermentation and the Gas is collected in the second part which is known as dome.

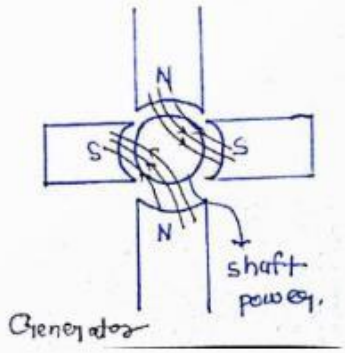


Note:- The Biogas by Biochemical reaction is having 4 to 5 times the Colorific value as compare to producer gas.

Wind Energy:- The wind has energy in the form of kinetic energy which can be harness to produce electrical energy.



Eelectric power (E.P.) $= V.I = I^2R = \frac{V^2}{R}$



Origins of Wind :- (i) local Wind (ii) Planetary Wind.

(i) Local Wind :- local wind are cause by unequal heating and cooling of the ground surface of sea, ocean, hills during day and night.

→ Costal Areas, Hills

(ii) Planetary Wind :- These wind are cause by rotation of earth around it polar axis and also due to unequal temp. between polar region and equitorial region.
The strength and direction changes with the season.

Note :- For the pridiction and the statics of wind data analysis "weisbull distribution" is used.

$$P(\vec{V}) = 1 - e^{-\left(\frac{V}{c}\right)^k}$$

-ve exponential.

V = Wind speed
k = weisbull factor
c = weisbull constant

Variation of wind Speed with elevation : (Height)

$$V \propto H^{\alpha}$$

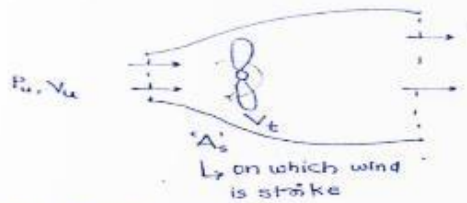
$$\frac{V_1}{V_2} = \left(\frac{H_1}{H_2}\right)^{\alpha}$$

α - power factor
H - Height
V - Velocity

$\alpha = 1/7$ (Generally)

$\alpha \rightarrow (0.1 - 0.2)$

Energy Extraction From the wind :-



$$E = \frac{1}{2} m V^2$$

$$(P)_{max} = \frac{1}{2} \dot{m} V^2 = \frac{1}{2} (\rho A V) \cdot V^2$$

$$\boxed{(P)_{max} = \frac{1}{2} \rho A V_u^3 \quad \text{(theoretically)}}$$

Betz Analysis

Assumption :- Incompressible flow (ρ = constant)

Bernullieq^n

$$\frac{P_u}{\rho g} - \frac{P_d}{\rho g} = \frac{V_u^2}{2g} - \frac{V_d^2}{2g}$$

$$(P_u - P_d) = \frac{1}{2} \rho (V_u^2 - V_d^2)$$

Force $F = (P_u - P_d) \cdot A_s$ — ① due to pressure diff

Momentum eqn $F = \dot{m} (V_u - V_d)$ — ②

① = ②

$$\dot{m} (V_u - V_d) = (P_u - P_d) A_s$$

$$(\rho A_s V_t)(V_u - V_d) = A_s \times \frac{1}{2} \times \rho (V_u^2 - V_d^2)$$

$$\boxed{V_t = \frac{V_u + V_d}{2}}$$ Turbine velocity

Power of turbine = (K.E.) diff

$$P_t = \frac{1}{2}\dot{m}\left(V_u^2 - V_d^2\right)$$

$$P_t = \frac{1}{2}\left(\rho A_s V_t\right)\left(V_u^2 - V_d^2\right)$$

$$P_t = \frac{1}{2}\left(\rho A_s\right)\left(\frac{V_u + V_d}{2}\right)\left(V_u^2 - V_d^2\right)$$

$$\boxed{P_t = \frac{1}{4}\rho A_s\left(V_u^3 - V_u V_d^2 + V_d V_u^2 - V_d^3\right)}$$

V_u – constant only V_d can variable

to find $(P_t)_{max}$

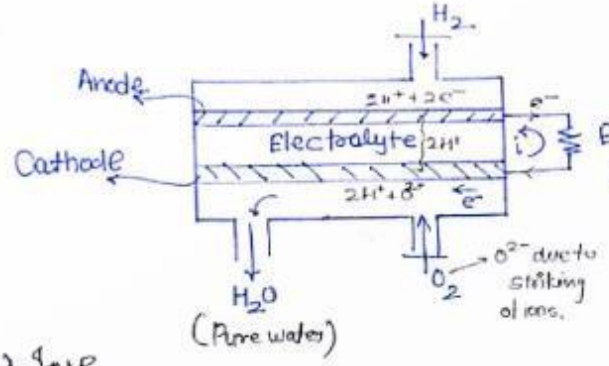
$\left(\frac{dP_t}{dV_d}\right) = 0$ it gives $\boxed{V_d = \frac{V_u}{3}}$

So $\boxed{(P_{turb})_{max} = 0.593\left(P_{max\ possible}\right)}$

0.593 → Betz limit (59.3%)

$(P_{max\ possible}) = \frac{1}{2}\dot{m}V_u^2$ → theoretically

Fuel- Cell :- A fuel cell is a electrochemical device which convert chemical energy of fuel directly into electrical energy without undergoing combustion cycle (Fuel → Comb. → Heat → w.d. → E.E.



$H_2 \rightarrow 2H^+ + 2e^-$

$O_2 + e^- \rightarrow O^{2-}$

$2H^+ + O^{2-} \rightarrow H_2O$.

Hence the efficiency of fuel cell is not limited by the carnot cycle efficiency. Theoretically a fuel cell may be 100% efficient.

$$\left\{ \eta_{\text{fuel cell}} \simeq 60\% \right\} >> \left\{ \eta_{\text{engine}} \simeq 30 \right\}$$

Desriable properties :- (i) Electrolyte :- it should be conductive to ions and it should not be conductive to electricity or e^-.
→ it should not get charge during operation

(ii) Electrode :- It should highly conductive to electricity
→ It should withstand very high temp