NCES unit-1

Non-Conventional Energy Sources (Jawaharlal Nehru Technological University, Hyderabad)

* NON-CONVENTIONAL SOURCES OF ENERGY *

*CREDITS - 3 *

*SUBJECT CODE :- ME8000E *

* UNIT - I *

* NOTES *

* PRINCIPLES OF SOLAR RADIATION *

NON - CONVENTIONAL SOURCES OF ENERGY ①

* Energy :-

* It is the primary and most universal measure of all kinds of work by humanbeings and Nature.
* Everything what happens in the world is the expression of flow of energy in one of its forms.
* The energy sources available can be divided into Three Types :-

① primary Energy sources :-

It can be defined as sources which provide a Net supply of energy.

ex :- coal, oil, uranium etc.

② Secondary fuels :-

This sources produce no Net energy. though it may be necessary for the economy.

ex :- Intensive agricultural.

③ Supplementary sources :-

This sources are those whose net energy yield is zero.

ex :- Thermal insulation

* DEFINITION OF NON-conventional souce of energy :-

* Non-conventional sources of energy is also known as Renewable sources of energy. are energy sources that are continually renewed by Natural processes
* It includes such as sunlight, wind, the movement of water and geothermal heat.

* Definition of conventional souce of energy :-

* Source of energy that has been in use for centuries are called conventional source of energy.
* It includes wood, coal, petroleum and flowing water.

* UNIT-1 *

* PRINCIPLES OF SOLAR RADIATION *

* Solar Radiation :-

convert sunlight into electricity either through photo voltaic cell (or) through mirror that concentrates solar Radiation.

* Role and potential of New and Renewable source :-

* Attention of scientists and engineers all over the world has been drawn to develop alternative energy technologies, since the oil crisis in 1973.
* With Technological Advancements, people have now become aware of the demerits of burning fossil fuels and thus it is observed that by end of 21^{st} century fossil fuels get exhausted.

* As population Increases, Demand for energy - Increases. ②

* Hence, Non conventional sources of energy must be given much significance, which can fulfill the future power Demand.

* Potential of New and Renewable sources:-

* India Ranks 3rd place in production of electricity through Renewable Sources.

* High potential for generation of renewable energy from - wind, solar, Biomass etc.

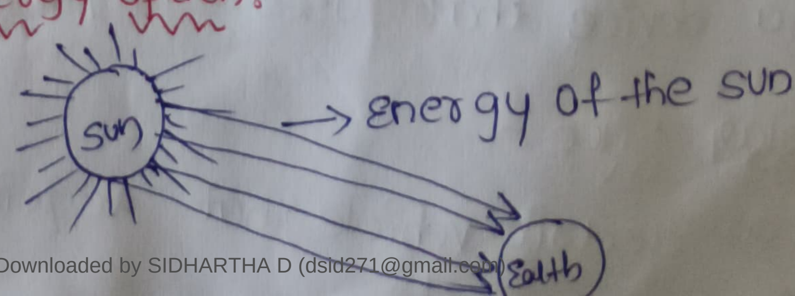
* IN November 2021, India has Renewable energy capacity of 150GW consisting of

  * Solar - 48.55 Gigawatts (GW)
  * Wind - 40.03 GW
  * Small Hydro - 4.83 GW
  * Biomass - 10.62 GW
  * large Hydro - 46.51 GW
  * Nuclear - 6.78 GW

* India has committed for a goal of 450(GW) Renewable energy capacity by 2030

② The Solar Energy Option:-

*



* Solar energy is the sun rays falling to the earth
* Solar energy is converted into electrical energy
↓
Heat energy
↓
Kinetic energy
↓
potential energy

* solar energy is converted into electrical energy due to "photo voltaiccell".
* The solar energy can utilized in.:-

① Solar photovoltaic system:-

It is also called as pv system designed to supply solar power.

② solar water Heatings:-

* conversion of sunlight into heat for water heating using solar thermal collector.

③ solar Thermal power Plant:-

* It is a technology for Harnessing solar energy to generate electricity for industry.

④ solar cooker:-

It is a device that uses sunlight for energy

⑤ solar Bike:-

It is an electric vehicle that requires solar energy to charge the battery.

(6) Solar pump:-

It is a pumping running on electricity generated by photo voltaic panels.

(7) Solar power Tower:-

It is a type of solar furnace using a tower to Receive the focussed light.

(3) Environmental Impact of solar power:-

* The sun provides a Tremendous resource for generating clean and sustainable electricity without toxic pollution.

* The potential environmental impacts associated with solar power - land use and habitat loss, water use and the use of hazardous materials in manufacturing can vary greatly depending on the technology.

* which Includes Two broad categories.

* photovoltaic solar cells (or) concentrating solar Thermal-plants.

* These pv and csp projects also plays a significant role in the level of environmental Impact.

* Land use:-

* 1) It requires the large area of land this Included

In land grabbing in high populated areas.

2) Estimates for utility - scale PV systems range from 3.5 to 10 acres per megawatt.

3) while estimates for CSP facilities are between 4 and 16.5 acres per megawatt

4) There is less opportunity for solar projects to share land with agricultural uses.

5) smaller scale solar pv arrays, which can be built on homes (or) commercial buildings, also have minimal land use Impact.

② water use:-

* solar pv cells do not use water for generating electricity. However as in all manufacturing processes. Some water is used to manufacture solar pv components.

* concentrating solar Thermal plants, like all thermal electric plants, require water for cooling.

* water use depends on the plant design, plant location, and the type of cooling system.

* CSP plants that use wet-recirculating technology with cooling Towers withdraw b/w 600 and 650 gallons of water per megawatt-hour of electricity produced.

* CSP plants with once - through cooling technology have higher levels of water withdrawal, but lower total water consumption.

* Dry - cooling Technology can reduce water use at CSP plants by approximately 90%.

* Many of the regions in the United States that have the highest potential for solar energy also tend to be those with the driest climates, so careful consideration of these water trade-offs is essential.

③ Hazardous materials :-

* The PV cell manufacturing process includes a number of hazardous materials most of which are used to clean and purify the semiconductor surface.

* These chemicals, similar to those used in the general semiconductor industry Include hydrochloric acid, sulfuric acid, nitric acid, hydrogen floride, 1,1,1 - trichlorothane and acetone.

* The amount and type of chemicals used depends on the type of cell.

* Workers also face risks associated with Inhaling silicon dust.

* Thus PV manufacturers must follow U.S law's to ensure that workers are not harmed by

exposure to these chemicals. and that manufacturing waste products are disposed of properly.

* Thin-film PV cells contain a number of more Toxic materials than those used in traditional silicon photovoltaic cells, including gallium arsenide, copper indium-gallium-~~diselenide~~, ~~and~~ arsenide and cadmium-telluride.

* If not handled and disposed properly, these materials could pose serious environmental (or) public health threats.

④ Life-cycle Global warming Emissions:-

* while there are no global warming emissions associated with generating electricity from solar energy, there are emissions associated with other stages of the solar life-cycle. Including manufacturing, materials Transportation, Installation, maintanence and decommissioning and dismantlement

* Most estimates of life-cycle emissions for photovoltaic system are b/w 0.07 and 0.18 pounds of carbondioxide equivalent per kilo-watt hour.

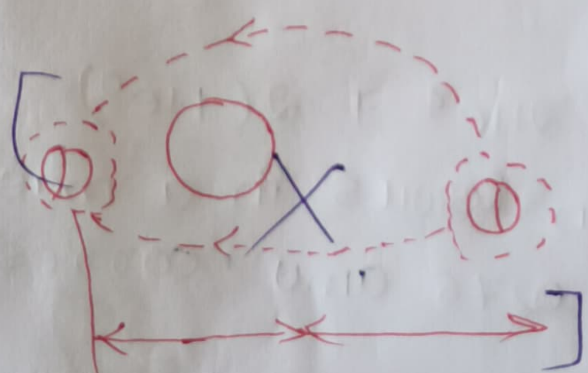
* Most estimates for concentrating solar power Range from 0.08 to 0.2 pounds of carbondioxide equivalent per kilowatt-hour.

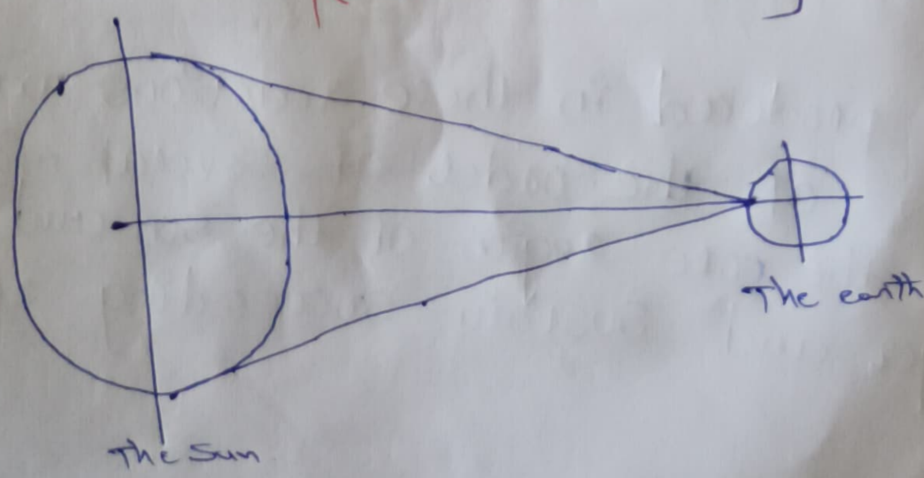
* In both cases, this is far less than the

life cycle emission Rates for Natural gas (0.6-2 lbs of CO_2E/kWh) and coal (1.4-3.6 lbs of CO_2E/kWh)

* physics OF THE SUN :-

* Sun is a medium sized yellow star that may be considered as a sphere of Intensely hot gaseous-matter with an average diameter of 1.39×10^{9} m. at an average distance of 1.495×10^{11} m (or 1 Astronomical unit) from the earth.
* The sun coalesced from a cloud of gas and dust formed 4.5 billion years ago.
* Earth goes round the sun in an elliptic orbit.





* The earth is closest to the sun at 1.47×10^{11}m the perihelion around January 2 each year.
* It is farthest at 1.526×10^{11}m around July 2 each year sun.
* Most important fusion reaction is hydrogen combining to form helium.
* Energy is produced in the sun by continous-fusion in which four nuclei of hydrogen fuse in a series of reactions involving other-particles that continually appear and disappear in the course of the reactions,
* such as He^3, nitrogen, carbon and other nuclei but culminating in one nucleaus of Helium and two positrons. Resulting in a mass decrease.

$$4_1H^1 \longrightarrow 2He^4 + 2(+1e^0)$$

* This reaction results in a mass decrease of about 0.0276 amu, corresponding to 25.7 Mev.
* The heat produced in these reactions maintains Temperatures of the order of several million degrees in the core region of the sun and serves to trigger and sustain succeeding reactions.

⑥

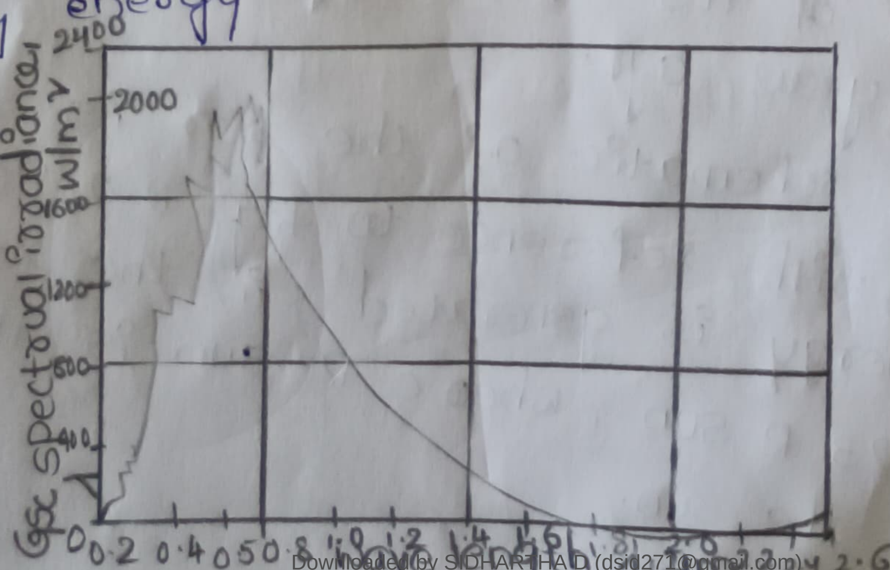
* The Temperature at 0.7 Rsun is the order of 130×10^3 K. from the region $r > R$ sun, convection process begins and is referred to as the convective zone.

* The upper layer of the convective zone is the photosphere.

* which is the source of most solar Radiation. other layers following the reversing layer are, chromosphere and lastly, the corona, of very low density and at a Temperature of 10^6K.

* Solar Radiation is the composite result of several layers which absorb and emit at various wave lengths.

* for Thermal purposes it is adequate to consider the sun to be a black body at an effective temperature of 5762K.
This Information is adequate for many solar energy calculations.

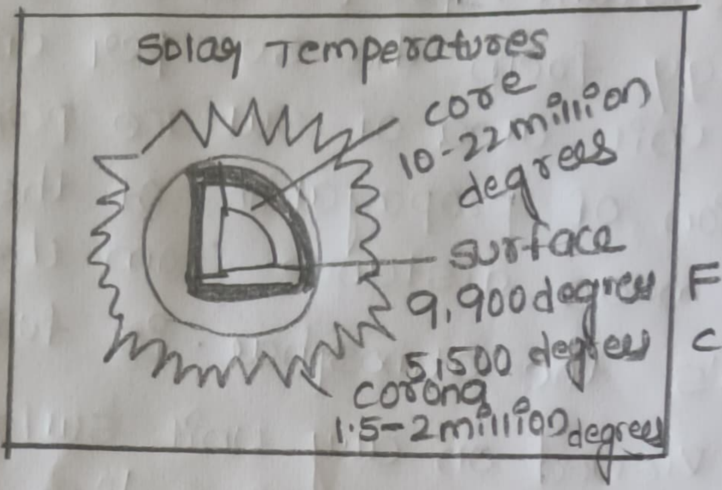


* The sun is made up of about 2×1030 kg of gas. It is composed of about 75% hydrogen and 25% Helium.

* About 0.1% is metals made from hydrogen via nuclear fusion.

* It has been estimated that the sun has used up about half of its initial hydrogen available. 4.5 billion years ago.

* A simple schematic of the sun is shown in fig 2.2 with reference to fig 2.2, 90% of the energy is generated in the region $0 < r < 0.23$ R sun, where R sun is the Radius of the sun.



The details of the sun's temperature are depicted in fig 2.4. the sun's core can reach 5.5×10^{6}°C to 12.5×10^{6}°C. the estimates vary, the higher one going upto 40×10^{6}°C. the surface temperature is approximately 5,500°C, the outer atmosphere of the sun goes up to 1.5×10^{6} to 2×10^{6}°C degrees.

* The effective temperature of the sun is determined by measuring how much energy it emits.

* The Solar constant :-

* The solar constant, I_{sc} [it is the flux density] It is the energy from the sun per unit time, received on a unit area of surface perpendicular to the direction of propagation of the radiation at the earth's mean distance from the sun.
* If the earth's the atmosphere is fully Transpalent
* It may be viewed on any unit surface normal to sun rays on a sphere of radius equal to the sun-earth mean distance.

* The recently reported value of the solar constant is $1367\ W/m^2$
* The physical idea can be obtained by considering the sun to be a sphere of diameter $1.39 \times 10^9 m$. emitting as a black body at an effective temperature of 5762 K.
* The amount of radiation emitted by the sun AS T4 would be σ is the Stefan - Boltzman constant ($= 5.67 \times 10^{-8} W/m^2 \sigma W \cdot K4$)
* AS is the surface area of the sun. the same amount of radiation passes through any sphere surrounding the sun as center.
* Thus, the surface of a sphere of radius equal to the sun-earth mean distance will experience Intensity (W/m^2) Inversely proportional

to the square of the radius of the sphere (8) enclosing the sun. this proportioning leads approximately to 1349 w/m².

* The variation in the total radiation emitted by sun is less than use energy in large spectrum of the entire solar spectrum, and when the Transmittance of atmosphere is a major uncertainty, the emitted energy by the sun may be considered as constant.

* extra-terrestrial solar Radiation :-

* solar Radiation on a surface normal to sun rays kept at a distance of sun-earth.

* Gon, will essentially be the solar constant, modified to take into account the varying distance b/w the sun and the earth. Gon is given by

$$G_{on} = I_{sc}\left(1+0.033\cos\left[\frac{360n}{365}\right]\right)$$

In Eq (3.1) n, is the day of the year, i.e the sequential number of the day counting January 1 as 1.

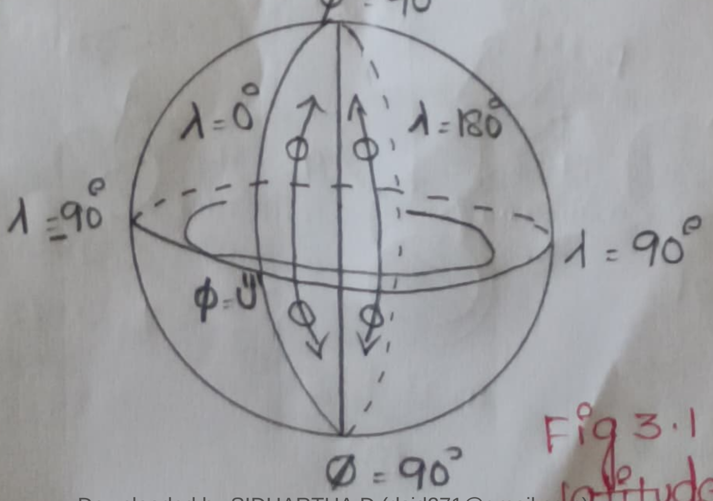
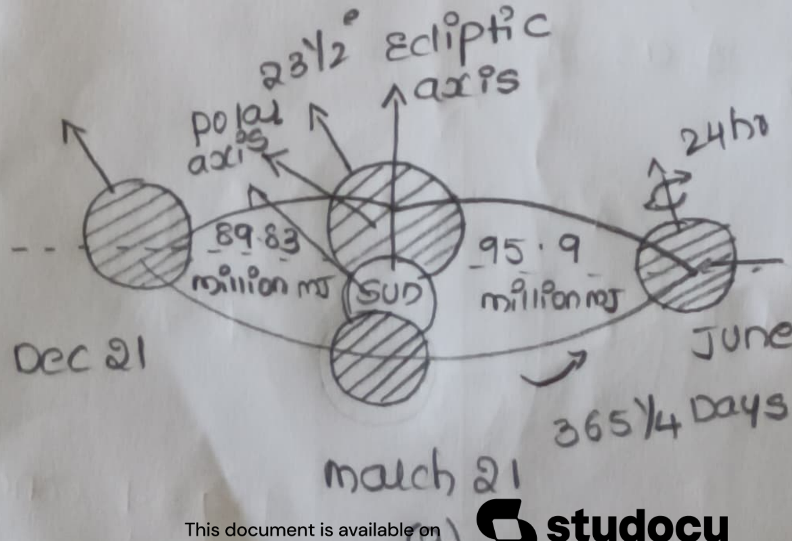


Fig 3.1 concept of latitude, and longitude

* Latitude and longitude are the coordinates of a point on earth's surface.
* A location on the earth surface may be specified by latitude, longitude and elevation.
* Longitudes, λ, is described along with "east" (or) west", meaning that the location is situated to east (or) to west of the Greenwich meridian.
* Thus the latitude varies from -90° to +90° and the longitude varies from 0° to 180°E (or) 0° to 180°W.
* The latitude of a point on the earth's surface is the angle b/w the equatorial plane and a line that pass through that point and is normal to the surface.
* The North pole is 90°N. the south pole is 90°S.
* TERRESTRIAL Solar Radiation:-



(a)

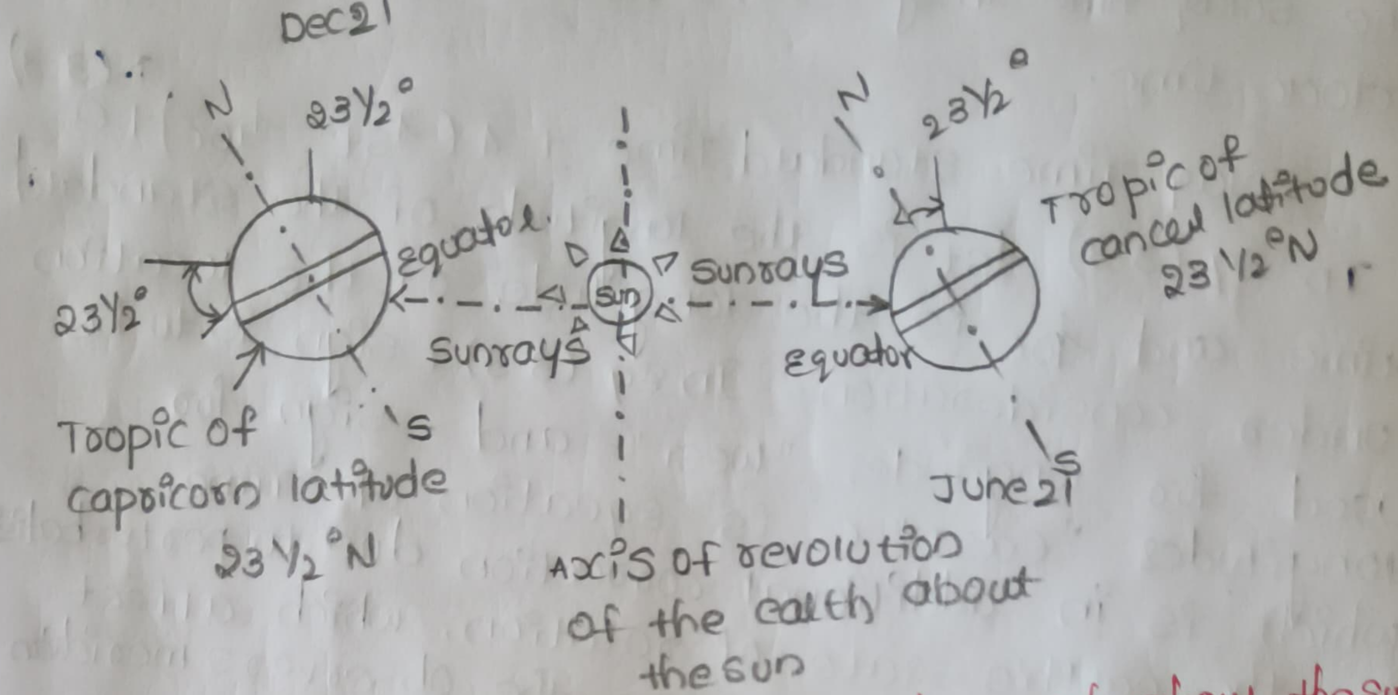


Fig 3.2 motion of the earth about the sun

* Declination, is the angular position of the sun at solar Noon with respect to the place of the equator δ2 Declination, varies from - 23.450 to 23.450 in degrees. , for the day n, of the year, δ can be calculated from.

$$\delta = 23.45 \sin\left(360 \frac{284+n}{365}\right) \quad (3.2)$$

positions of the earth relative to Sun at different times of the year are shown in fig 3.2.

* Solar Time is the time based on the apparent angular motion of the sun across the sky, with solar noon being the time the sun crosses the meridian of the observer.

* Solar Time is used in all sun angle relationships. The solar time in general deviates from the local clock time.

$$\text{Solar Time} = \text{standard Time} \pm 4(\lambda_{st} - \lambda_{loc}) + \epsilon \quad (3.3)$$

* In eq (3.3) λ_{st} is the longitude of the standard time and λ_{loc} is the longitude of the location under consideration. In eq (3.3) + sign is to be used for longitudes "west" and - sign for longitudes "east" ϵ is equation of Time, which is in additional correction due to perturbation in the earth's rate of rotation, which affect the time the sun crosses the observers meridian "ϵ" in minutes can be calculated from

$$\epsilon = 9.87 \sin 2B - 7.53 \cos B - 1.5 \sin B \quad (3.4)$$

* In eq (3.4)

$$B = \frac{360(n-81)}{364}$$, where n is the day of the year, $1 \leq n \leq 365$

* Hour angle, ω, is the angular displacement of the sun east (or) west of the local meridian due to rotation.

* SOLAR RADIATION ON TITLED SURFACE :-

* The solar Radiation Received by a tilted surface comprises of Direct, diffuse and ground reflected components.
* A horizontal surface receives the direct and diffuse components of Radiation.
* while the Titled surface receives in addition, a ground Reflected component if the surface 'sees' the ground.
* The procedure describes to evaluate a factor, Referred to as the Tilt factor for direct radiation,
* which when multiplies the direct radiation available on a horizontal surface yields the direct radiation on the tilted surface.
* The ground Reflected Radiation would be the product of Solar Radiation on the horizontal surface yields the direct radiation on the tilted surface.
* It is conceivable that "G" comprises, of, δ designated by the declination.
* where "Gb and Gd" are the direct and diffuse components of Intensity. the total radiation comprising of the three components at the instant on the tilted surface G_T can be formally expressed as,

$$\boxed{G_T = G_b R_b + F_s G_d + F_g \rho_g G} \quad -[8.2-$$

In Eq (8.2) "G_T" is the Radiation on the tilted surface, "ρ_g" is the ground Reflectivity and "R_b" is the instantaneous tilt factor for direct radiation, Defined as the Ratio of direct Radiation on the surface under consideration and the direct Radiation on a horizontal surface. Thus

$$\boxed{R_b = \frac{G_{bT}}{G_b}}$$

* F_s and F_g are the appropriate factors for sky diffuse and ground Reflected components of Radiation, Assuming an Isotropic distribution of diffuse Radiation, the factor F_s can be obtained as.

$$\boxed{F_s = \frac{(1+\cos\beta)}{2}} \rightarrow (8.4)$$

* The view factor F_g for the ground Reflected component of the Radiation is given by.

$$\boxed{F_g = \frac{(1-\cos\beta)}{2}} \rightarrow (8.5)$$

* **EXPRESSION FOR R_b :-**

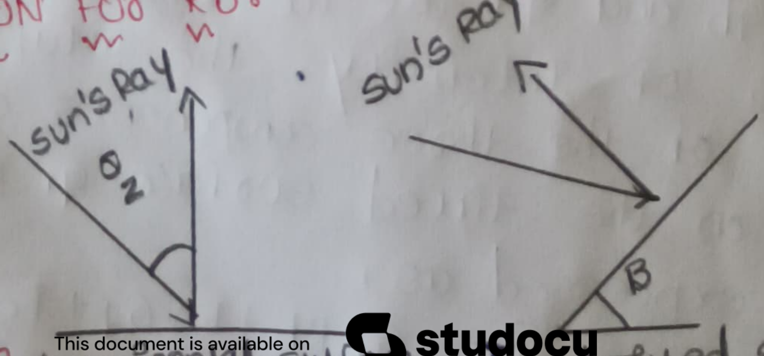


Fig 8.1- Direct radiation on horizontal & tilted surface a) Horizontal surface b) Tilted surface

* consider a horizontal and a tilted surface as shown in fig 8.1. (11)

* Let $G_{b,n}$ be the Intensity of direct radiation "z" with the zenith. θ on a plane perpendicular to the Ray.

* The Ray as shown in Fig 8.1 (a) makes an angle with the outer normal to the tilted surface as "θ" similarly. the Ray makes an angle with the horizontal from the geometry as shown B. shown in fig 8.1(b). The tilted surface makes an angle in Fig 8.1, dt follows.

$$G_b = G_b$$

Thus R_b can be expressed as,

$$R_b = \frac{G_{br}}{G_b} = \frac{\cos\theta}{\cos\theta_z} \longrightarrow (8.6)$$

The expressions for $\cos\theta$ are given by eqs (3.6) (or) (3.7) $\cos\theta$ for south facing surfaces is given by eq (3.12) $\cos\theta_z$ is expressed by eq (3.11). using eqs (3.12) and (3.11) in eq (8.6), R_b for a south facing surface is given by,

$$R_b = \frac{\cos(\phi - B)\cos\delta\cos\omega + \sin(\phi - B)\sin\delta}{\cos\phi\cos\delta\cos\omega + \sin\phi\sin\delta}$$

expression given by eq (8.7), strictly speaking is valid for an instant by the value of the hour angle ω employed. However, eq (8.7) can be used with no significant loss of accuracy for a time period of one hour (ω_1 to ω_2) using $\omega = \frac{(\omega_1+\omega_2)}{2}$.

* INSTRUMENTS FOR SOLAR RADIATION

* There are two types of infrared detectors for solar radiation measurement.
Thermal detectors and photon detectors.
* Thermal detectors
* Heating effect of incident radiation causing a change in some physical property of the detector is the principle underlying the thermal detectors.
* The time constant of the detectors should be small for responding to quick changes in the incident radiation.
* Time constant of several seconds can be accepted in solar radiation measurements.
* Photon detectors converts some of the incident radiation directly into electricity, which is proportional to the incident radiation.
* The detecting capability, in general, of photon

detectors is one (or) Two orders of magnitude (12)
greater.

* However, the penalty associated with photon detectors is that their spectral response is Non-uniform.

* Alternately, Instruments to measure solar radiation broadly fall into three categories.
They are 1) measure global Radiation
2) Diffuse Radiation
3) Direct Radiation

* It is easy to envisage that, it is best to measure normal incident direct Radiation and in order to do this.
* The instrument sensor needs to face the sun Always.
* This calls for a Tracking instrument with consequent inconvenience and additional equipment to follow the sun.

* The instruments used to measure global radiation are referred to as pyranometers.
* The instruments that measure direct radiation are called pyrheliometers.

* pyranometers :-

* Eppley pyranometer designed by Kimball and Hobbs of US. weather Bureau has become the most widely used working pyranometer's.

* The eppley pyranometer's detector (or) the working surface consists of TWO concentric-silver rings.

* The Inner ring is coated with parsons optical-black lacquer and the outer one is coated with white magnesium oxide. the temperature difference between the two is an indication of the incident solar radiation and is measured by a thermopile.

* The sensor is placed inside a hermetically sealed spherical lamp bulb filled with dry air

* The detector is best when used to measure. Horizontal Radiation.

* A Reduction of 5%. output is caused when the instrument is mounted vertically due to convective currents in the glass enclosure.

* The New eppley pyranometer equipped with a Thermister compensated electrical circuit reduced the temperature dependence and improved the cosine Response.

* SUNSHINE RECORDER :-

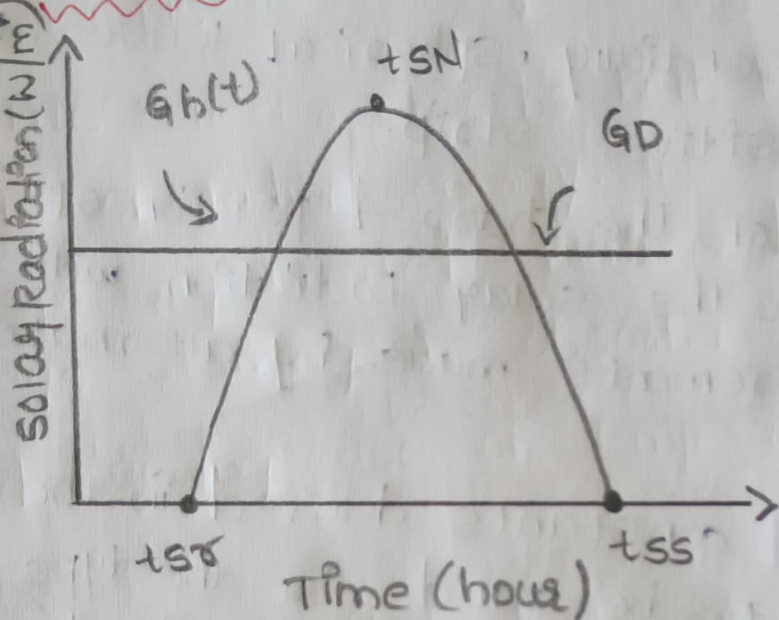
The sunshine recorders essentially static do not require power supply and alleviate the difficulties faced by the recorders where uninterrupted power supply is not available.

* They are esentially, spherical lenses, which blacken a sensitive strip.
* The length of the charred portion of the strip is Related to the solar Radiation with the help of measurements made, by alternate Instruments.
* The empirical constants derived in the relations are expected to be valid for the type of climate for which they are derived.
* They are simple to use.
* Indeed, significant numbers of studies have been made in deriving reliable constants and examining their applicability for different climates.
* camp.bell-stokes Recorder focuses solar-Radiation to burn a trace in a chart.
* Jordan Recorder focuses sunlight on to photographic paper.
* Marvin Recorder makes uses of a Thermoelectric switch to actuate a chronograph to trace the.

sunshine hours.

* The daily global solar Radiation on a horizontal Radiation "H" is related to the number of hours of bright sunshine.

* SOLAR RADIATION DATA :-



* The solar Radiation data is widely used as the source of Renewable energy.
* It is highly required to formulate the estimation model and forecasting the meteorological data.
* However, solar data play a key role in various Domains.
* The application of AI includes modeling hourly, monthly, and Daily solar Radiation Data.

* SOLAR ENERGY COLLECTION:-

* Solar collectors are used to collect the solar energy and convert the Incident radiations into Thermal energy by absorbing them.
* This heat is extracted by flowing fluid in the tube of the collector for further utilization in different applications.

* Types of solar collectors:-

* 1) Non-concentrating collectors
  2) concentrating (focusing) collectors.

1) Non-concentrating collectors:-

* In these type, the collector area is the same as the absorber area.
* It is generally used for low & medium Temperature Requirements.

2) concentrating (focusing) collectors:-

* It have a larger Interceptor than absorber.
* It is generally used for high Temperature Requirements.

* FLAT PLATE COLLECTORS:-

* Flat plate collector is most important part of any solar Thermal energy system.
* It is simplest in design and both direct and

Diffuse components of Radiant energy. (10)
The absorber plate]
diffuse Radiations are absorbed by collector and converted into useful heat. these collectors are suitable for heating to temperature below 100C.

* Flat plate collector absorbs both beam and diffuse components of Radiant energy. The absorber plate. is a specially treated blackened metal surface.

* Sun Rays striking the absorber. plate are absorbed causing rise of Temperature of transport-fluid.

* Thermal insulation behind the absorber plate. and Transparent cover sheets. prevent loss of heat to surroundings.

* The constructional details of flat plate. collector is given below.

1) Insulated Box:-

The Rectangular box is made of thin Galvanised sheet and is insulated from sides and bottom using glass (or) mineral wool of thickness 5 to 8cm reduce losses from conduction to back and side wall.

*.. The box is Tilted at due south and a Tilt

angle depends on the latitude of location. 15

The face area of the collector box is kept between 1 to 2 m^2.

2) Transpalent cover:-

This allows solar energy to pass through and reduces the convective heat losses from the absorber plate through air space.

* The Transpalent tampered glass cover is placed on Top of Rectangular box to trap the solar energy and sealed by Rubber gaskets to prevent the leakage of hot air.

* It is made of plastic/glass but glass is most favorable because of its transmittance and low surface degradation.

* The plastics are available at low cost, light in weight and can be used to make Tubes, plates and cover. but are suitable for low Temperature application 70-120 c with single cover plate (or) upto 150c using double cover plate.

* The thickness of glass cover 3 to 4 mm is commonly used and 1 to 2 covers with spacing 1.5 to 3cm are generally used b/w plates.

* The Temperature of glass cover is lower than the absorber plate. and is a good absorber

of Thermal energy and Reduces convective and Radiative losses of sky.

3)