

Solar Energy Engineering and Technology
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Lecture No. 04
Solar Radiation and Sunshine Measuring Instruments

Dear students, today we will discuss about solar radiation and sunshine measuring instruments. So, before we start our topic, let us summarize what we have discussed in the last class.

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Summary of the last lecture

- Propagation of solar radiation from the surface of the Sun to the earth's surface.
- Atmospheric absorption and scattering.
- Sun-earth relationship.
- Different types of radiation .
- Air mass (AM0, AM1, AM2, AM1.5).

In the last class, we are discussing about propagation of solar radiation from the sun surface to the earth surface. So, how solar radiation is propagated? So, there what we have discussed, so we have this earth atmosphere and then earth is here and sun was here. Sun emits the short wave radiation and this is the earth atmosphere, aerosols, H₂O, carbon dioxide, carbon monoxide, oxygen, then we have ozone, all the elements will be here and then particulate matter.

Then some of the radiations which is unaffected by this earth atmosphere and it is directly striking on the earth surface. And then some of the radiations when it travels, then it scatters in the earth atmosphere, and then this radiation is redirected in all the directions and then intensity of this radiation decreases. And then from the earth surface, this long wave radiation is propagated and it is captured in the earth's atmosphere.

So if we draw this spectral emissive power Vs λ for extra-terrestrial region, so the region which is above the earth atmosphere is called extra-terrestrial region, extra-terrestrial region. And just below the earth's atmosphere, we will have terrestrial region, terrestrial region. So here, if we draw this curve, this will be something like this. So, this is maybe 10^8 , then we have $W/m^2-\mu m$.

And this plot is for short wavelength radiation and at 6000 K. So, this is the radiation of spectrum when radiation is coming from the sun surface. And this value is 5 and this is of course in micron and maybe we have 10 here and it goes up to 30. And in this case when we draw this spectrum curve for long wavelength radiation after re-radiating from the earth surface, then we will have something like this kind of profile. So, these peaks will be at $10 \mu m$ and this will be at 288 K.

And this may be at 30, and of course this is spectral emissive power, unit is $W/m^2-\mu m$. So here, solar radiation is propagated what happens in the earth atmosphere? Some of the radiations is unaffected by this earth atmosphere and it is directly striking on the earth surface. So, the kind of radiation what is directly striking on the earth surface is known as normal radiation. And when this radiation is scattered, because of this aerosol present in the earth atmosphere, intensity of the radiation reduces.

So, this radiation intensity is known as diffuse radiation. So, when we add this diffuse radiation plus normal radiation it becomes global radiation or we can represent in capital IG. So, two kinds of radiations we are getting at the earth surface, one is normal radiation and other one is diffuse radiation. If we combine both then what we call is global radiation. So, we will study the kind of instrument used for the measurement of diffuse and global radiation and normal radiation.

Also we have studied in the last class the relationship between sun and earth. So, how solar radiation is propagated from the sun to the earth and we also studied the distance between that means average distance between sun and earth. Also we know the radius of the sun and radius of the earth. So, by utilizing this concept what we can able to calculate is black body temperature of the sun, by utilizing the concept of energy emitted by the sun and then the amount of energy received by the earth surface. So, this has been demonstrated in the last class.

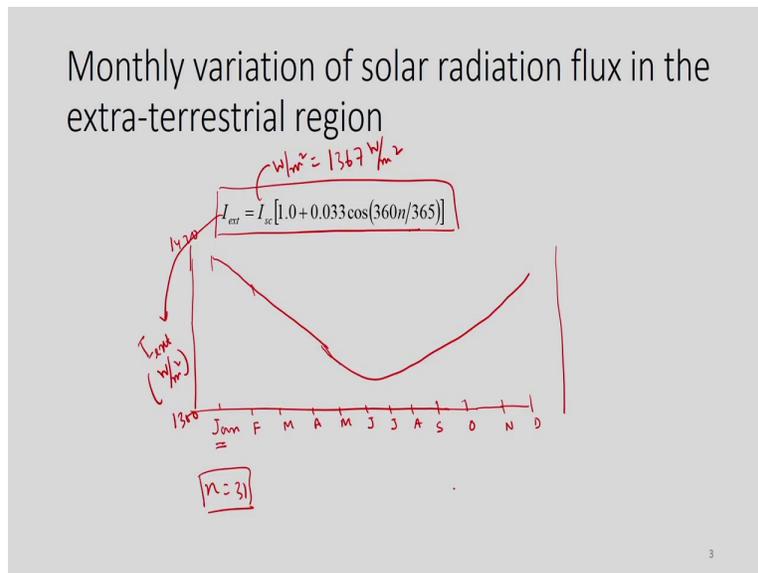
Also we have studied a very important parameter called air mass, so air mass is very, very important and we must know the significance of those AM0, AM1, AM2, AM1.5. So, what does

this AM0 indicates, that means that is the spectrum, the solar energy radiation spectrum above the earth atmosphere that means in extra-terrestrial region where radiation is not affected by the earth atmosphere. So, it is represented by AM0.

So, first let me write the expression for air mass, so this will be something like $1/\cos \theta$, what we have discussed in the last class, for example if we consider this plot and if we represent these as A this point and this is B and this is C, that means AB by BC is $1/\cos \theta$. And this is known as air mass, what is written here. So, if theta is 0° means this angle is 0, this angle is 0, means what will happen then $\cos 0$ is 1, so AM will be 1. That means this spectrum is known as AM1.

And AM0 already we have defined, so in this plot what we can see here, this red colored line is for AM0 which is this spectrum is available in the extra-terrestrial region and blue colored profile is for AM1.5. Why AM1.5 is very important? Because at this air mass normally all the solar devices are tested. Of course we need to consider the radiation, so at what radiations normally this is tested, this is normally tested at 1000 W/m^2 , but AM1.5 need to be maintained for standardizing these solar devices.

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Also let us summarize the monthly variation of solar radiation flux in the extra-terrestrial region, already we have studied this expression and we understand how this extra-terrestrial region or extra-terrestrial intensity is varying with number of days. We can also plot this variation, so for example, say for January, starting from January to December, so here January, maybe I will say

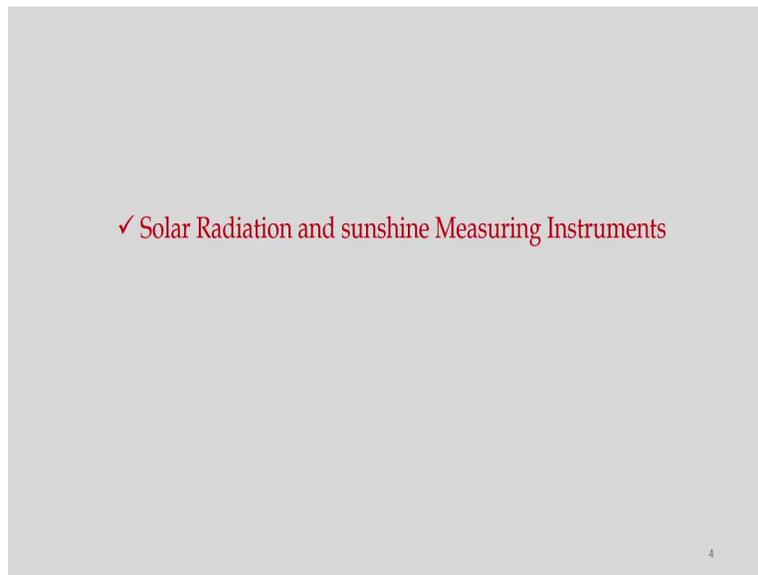
January here, then I will write February F, maybe March here, April, May, then we have June, then we have July, then we have August, I have September, then we have October, then we have November, then we have December.

So, January line maybe here, so this vertical line is for extra-terrestrial region, so I will write I_{ext} this is something like this here. So, if we used January 1 or end of the month, may be $n = 31$, so there are some recommendations, so sometimes what happens, we need to analyze daily, how this addition is varying, what is the extra-terrestrial region, extra-terrestrial radiation on day 1, may be first January for this the extra-terrestrial radiation, second January what is the extra-terrestrial radiation, so that way you can calculate.

But know people have recommended that, if we take a particular day of a particular month as a representative day, so on that day we can calculate what is the extra-terrestrial radiation for the particular month? So, here may be at the end of the month, maybe we can consider, we can see how this extra-terrestrial radiation is varying. So, of course unit will be W/m^2 , because solar constant is also W/m^2 , its value is 1367. It is a modern value normally we use.

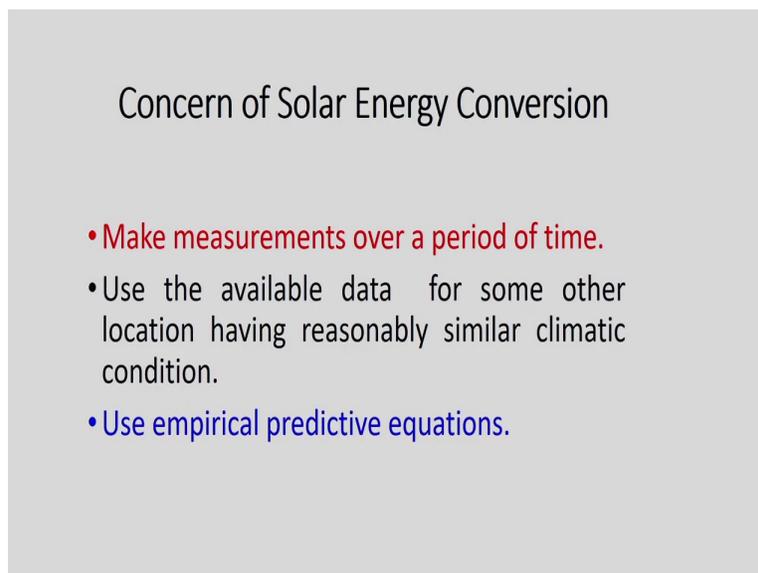
So, these variations already you have understood why the variation is happening, so may be scale I can start from 1300 and we can go up to 1420, so I will just write a qualitative curve here. So, this moves something like June will be June, July, June will be lowest, so June will be lowest, this will be something like this. So, here every point we can get that extra-terrestrial value, so this plot will be something like this. Sometimes we are not bothered about the variations, only we take the I_{sc} value but when we are doing very precise calculation, of course we need to know how this extra-terrestrial radiation is varying with month.

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Now let us discuss our today's topic is solar radiation and sunshine measuring instruments.

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So, here in order to understand the mechanism of absorption, scattering and attenuation coefficients, people have done extensive research, but still it is very difficult to predict the radiation on a particular day at a particular time. So, the designer has decided to do something else, so that they can design their equipment for a particular region.

So there are many options, one of the option is make measurement over a period of time, so we can get long term data, maybe 10 years data, maybe 20 years data, if we extend the duration of

the data, then of course we know our accuracy level will increase. And second option is use the available data for some other locations having reasonably similar climatic conditions.

So, if we know some of the locations, where you know climatic condition is similar to the climatic conditions of where we are planning to design or install some kind of solar equipment. So, we can take those data and we can do the analysis. And the third option is we can use empirical predictive equations. So, there are numerous correlations available to relate metrological data and radiation data.

Metrological data means like what is the sunshine duration, what is the precipitations, so if we get those data we can relate with the radiation data and then we can calculate what is the or we can estimate the kind of global radiations following on a particular location at a particular time. So, these are the considerations normally designers adopt for designing an PV system or maybe solar thermal system.

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Atmosphere at earth's surface

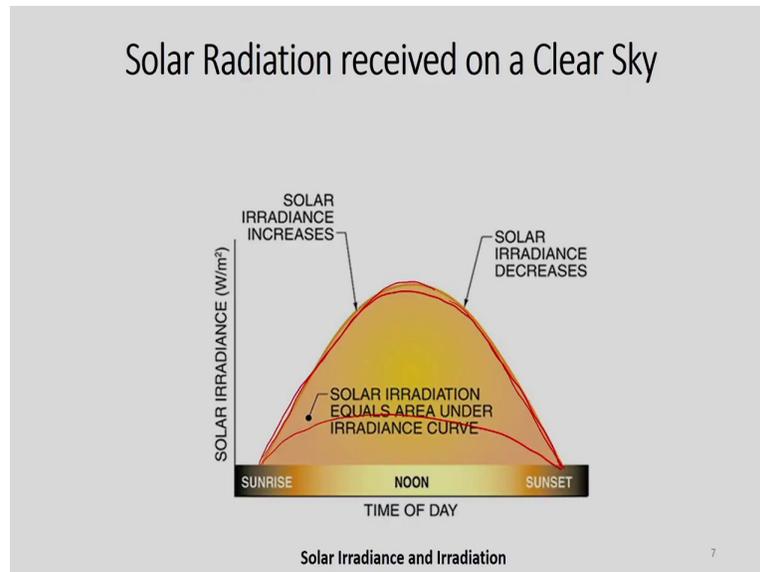
- An atmosphere without clouds (Cloud less)
- An atmosphere with clouds (partially or fully covered by cloud)

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So, as far as atmosphere at the earth surface is concerned, primarily there are two atmospheres. So, an atmosphere without clouds that is cloudless, so sky is very clear. And another category is an atmosphere with clouds, that means partially or fully clouds. But this mechanism of scattering and absorption are same for both the cases, but of course intensity of solar radiation will be higher in case of an atmosphere without clouds that is in clear sky. So, these considerations will

be studied and based on these classifications, there will be many more correlations we will study one by one in the later slides, once we finish this part of the course.

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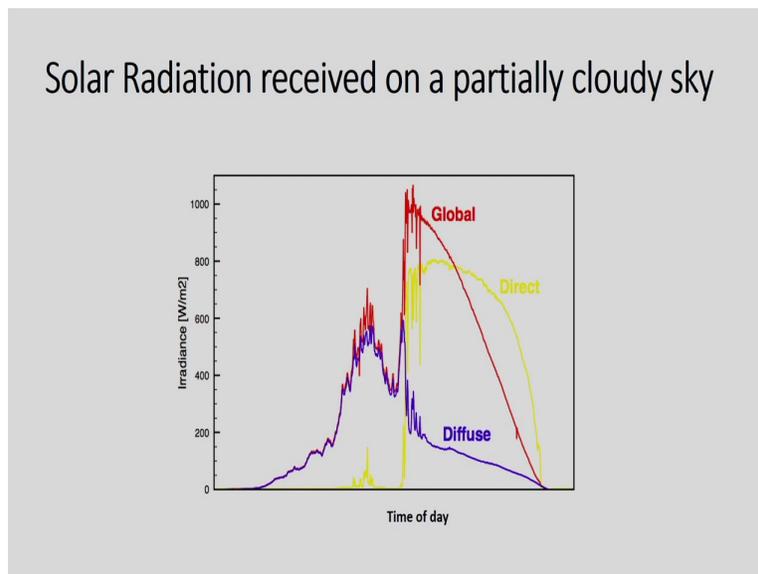
So, now come to the solar radiation received on a clear sky, when sky is clear the way you are expected to get these kind of profiles. So, in the sunrise, radiation will be very very low and then it will slowly, it will increase and will reach a peak at the noon and then it is decreases. When it reaches to 0 when sunset occurs. So, this profile is a very standard profile and this kind of profile if we get that is very good, that is very good for solar installations.

Here what happens, this curve maybe holds good for both diffuse and normal radiation. So, of course, if we consider this is for normal if irradiation, so diffuse component will be something like here. So, there are many things to be studied in this curve. So normally what happens we are sometimes telling like what is a solar radiation? So, solar radiations maybe solar irradiance or solar irradiation.

So, solar irradiance is instantaneous, so what is the value of say normal radiations at this moment? Maybe something like 700 W/m^2 that is instantaneous values. But this instantaneous word is valid for 1 hour. So, since these solar radiations is not varying much in 1 hour duration, so this solar irradiance is hold good for 1 hour variation. And of course we are interested for daily variations, what is the daily sunshine variation or what is the daily global radiation variation? What is the daily diffuse radiation variation?

These informations are of course required when we are doing that kind of calculations. So, now my concern is, so one is solar irradiance and second one is solar irradiation. So, instantaneous value is solar irradiance and when we integrate over the time that becomes solar irradiation. So, this plot is for clear day when no cloud is covered, so sky is clear.

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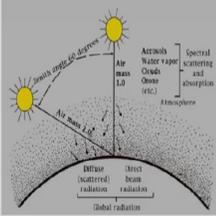


In this case, this is partially cloudy sky, what you can see there are lots of peaks and valleys. So, there is no uniform patterns, so under this condition it is very difficult to design a solar collectors that maybe PV collectors or maybe solar thermal collectors. So, this kind of irruptive behaviors are observed. So, red color indicates global radiation, a sum of diffuse and normal radiation and this yellow color is direct radiation and this blue color is for diffuse radiation. We can see the variations of this irradiance, of the day.

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Types of solar radiation

- 1. Direct radiation (beam radiation or direct beam radiation):** Describes solar radiation traveling on a straight line from the sun down to the surface of the earth.
- 2. Diffuse radiation:** Describes the sunlight that has been scattered by molecules and particles in the atmosphere but that has still made it down to the surface of the earth.
- 3. Reflected radiation:** Describes sunlight that has been reflected off of non-atmospheric things such as the ground. Asphalt reflects about 4% of the light that strikes it and a lawn about 25%.



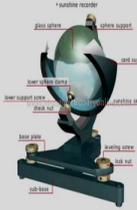
The diagram illustrates the path of solar radiation from the sun to the Earth's surface. It shows direct radiation as a straight line from the sun to the ground. Diffuse radiation is shown as multiple lines from the sun that are scattered by the atmosphere before reaching the ground. Reflected radiation is shown as lines from the sun that hit the ground and are reflected back into the atmosphere. Labels include 'Sun', 'Air mass 1.0', 'Air mass 2.0', 'Atmosphere', 'Spectral scattering and absorption', 'Direct beam radiation', 'Diffuse scattered radiation', and 'Global radiation'.

Now, since we have already accustomed about different kind of radiations, direct radiation then diffuse radiation and then reflected radiation. So, let us learn something details on those radiations and we will learn how those radiations are measured by using different instruments. So, if we have to measure direct radiations then we have to use pyrhelimeter. For diffuse radiation we have to go for pyranometer and of course reflected radiations can be measured by using different instruments.

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SOLAR INSTRUMENTS

- ❖ PYRANOMETERS
- ❖ PYRHELIOMETERS
- ❖ SUNSHINE RECORDER



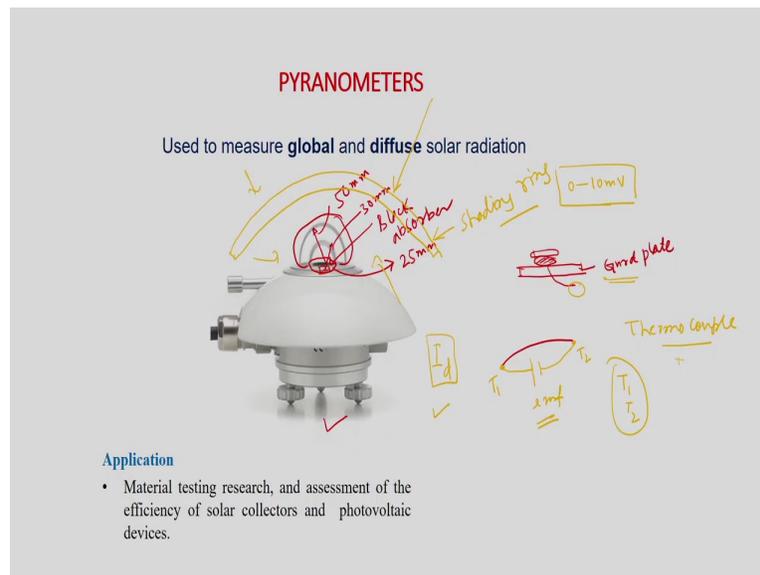
The diagram of a sunshine recorder shows a glass sphere on a vertical support, with a horizontal support and a base. Labels include 'sunshine recorder', 'glass sphere', 'vertical support', 'horizontal support', 'base', 'base plate', 'leveling screw', 'lock nut', and 'top base'.

Direct Normal	Global Horizontal	Diffuse
Measured by a <i>Pyrheliometer</i> on a sun-following tracker	Measured by a <i>Pyranometer</i> with a horizontal sensor	Measured by a shaded <i>Pyranometer</i> under a tracking ball
		

So, these are the different instruments used. This plot is for pyrhelimeter which is very, very costly and it will give normal radiations falling on the earth surface. And this is pyranometer, pyranometer is mostly used in many of the experiments and other applications. And of course same instrument pyranometer can be used for diffuse radiation measurement by using a shading ring.

So, we will discuss this in the next couple of slides. And of course we need a sunshine recorder to know that duration of the sunshine, which is important how long our sun will retain. So, this is a special kind of instrument called sunshine recorder used for measurement of duration of the bright sunshine.

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So, now come to the pyranometer, so which is used for measurement of both global and diffuse radiation. So, here as you can see this is the instrument used for measurement of both global and diffuse radiation. So, here what happens, one black absorber is used here, as you can see here that is a black absorber, it is a black absorber. And these are the glass, semi-hemisphere glass. Normally, if we draw line here, so this diameter is about 50 mm, outer diameter and this is about 30 mm and this is a circular disc kind of absorber, so its about 25 mm diameter.

So, when solar radiation is exposed here in this black absorber, its temperature rise will be will be there. So, this will rate of rise will continue till the heat loss by convection, conduction and reradiations are or reradiations are equal, so this mass transfer has to be there. So, in order to

measure these, thermopiles are used. So at the beneath of this absorber one thermopiles are attached, these are thermopiles.

Then if we write very clearly, so this is a black cover and then there is one and here we have absorber and this is a thermopile or say sensor and this is a gurd plate, one gurd plate will be here, gurd plate. So, here I hope that you know the thermocouple principle, principles of thermocouples, so when we have two dissimilar metals, so this is one maybe one material and we will have, I will use some another color, maybe this one, so we will have two different materials and we maintain at two different temperatures, two different temperatures, maybe I will remove this and maybe I will use this.

And if we connect 1 mV and this is at, this maybe T_1 and this may be T_2 . If maybe T_1 , these two are different, T_1 and T_2 are at different temperatures. And if these two are at different temperatures then EMF will be generated. So, this is a principle of thermocouple, thermo thermocouple. So, how does a thermocouple work? If we have two dissimilar metals, and we keep the junction of both at two different temperatures then EMF will be generated.

So, here what happens same principle is applied here, so thermopiles are used, thermopiles are nothing but if we use many thermocouples in series that becomes thermopile. So, these thermopiles are connected at the beneath of this absorber plate and then when solar radiation is exposed then this part, black end surface will be heated up and then heat will transfer to this sensor that is thermopiles.

And one bit is maintained here or one junction is maintained here and that is some kind of spherical or say circular junction. And other junction is maintained just below this gurd plate and this bit is maintained in such a way that this is not exposed to the solar radiation. So, a value of 0 to 10 mV is generated and this is accumulated with time and then finally that can be converted to W/m^2 by using some kind of fitting coefficient.

So, principle is very simple, so we use the concept of thermocouple that means thermopiles are used to measure the rise in EMF, so this is calibrated and finally we can calculate in terms of W/m^2 . So, the kind of radiations we will get is called global radiations. If we save this, this part, we will not allow a semi-circular strip, we use to save this glass envelope so that direct radiations cannot come and strike on this black surface.

So, only radiation will come from the other side, this is a scattered part or diffuse radiation. The kind of radiations we will get under this condition is called diffuse radiation. So, have to save this glass envelope, so that direct radiations cannot be, cannot strike this glass envelope. And there is a procedure how to install this shading ring, so this is called shading ring, shading ring. So, this shading ring is used for measurement of diffuse radiations. There are many applications of this radiation like material testing research, assessment or efficiency of solar collectors and photovoltaic devices.

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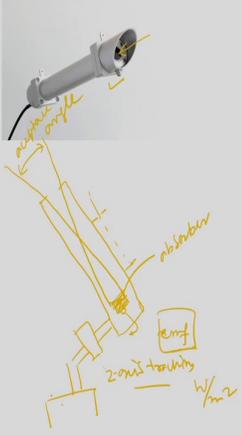
PYRHELIOMETER

- Used to measure beam solar irradiance.
- Sunlight enters the instrument through a window and is directed on thermopile which converts heat to an electrical signal that can be recorded. The signal voltage is converted via a formula to measure watts per square meter.
- It is used with a solar tracking system to keep the instrument aimed at the sun.

Components: Protection cap, Sensor, Thermopile

Application

- Meteorology, material testing research, and assessment of the efficiency of solar collectors and photovoltaic devices.



Now, let us learn something about pyrhelionometer. So, this is a very good instrument and very costly instrument and normally this is used for measurement of beam solar irradiance. So, this sunlight enters as you can see here, sunlight enters through this tube, so I can write or I can make this kind of arrangement how this can be measured, so we will have absorber and then we will have one more, this is absorber and then we will have thermopile. This part is thermopile.

And I will have some kind of support here and then radiation will come and then strike and then this radiation will come and this will be here. And this is absorber and of course we need some kind of arrangement, so to see whether it is aligned or not. So, we can see from here and we need some kind of tracking device here. This kind of tracking device.

And this angle is called acceptance angle, angle. So, what happens if you see this figure, this structure is something like that, solar radiation pass through this and this is a tube through which

solar radiation penetrates and there is an absorber. So, special kind of materials are applied here in order to increase the absorptivity and this thermopile is attached here. So, this one as discussed in the case of pyranometer, so one junction is maintained here and other junction is somewhere here, which should not be exposed with solar radiation, so we can get the mV generator or EMF generation here.

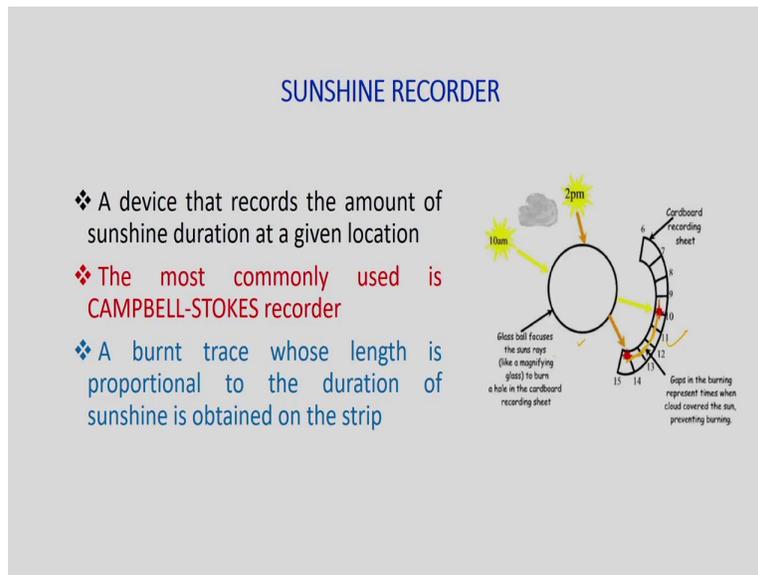
So, once we know the EMF, then we can calibrate and finally we can get in terms of W/m^2 . So, in order to here, what is the difference between pyranometer and pyrheliometer, so here we need to track the normal solar radiations, only normal solar radiation is allowed to enter in this tube and we can measure the intensity of the normal solar radiation.

Of course, some amount of diffuse radiation also penetrates but that's a very negligible amount. So, the kind of radiation what we will get by doing these calculations or measurement we will get normal radiation. So, this is two axis tracking, so two two axis tracking two axis tracking. So, what happens we can access in the 2 dimensions, one is this way, another is this way. So, two ways we can track it in order to capture the normal radiation.

So, this as I have written here, sunlight enters the instrument through a window and is directed on the thermopile which converts the heat to the electric signal that can be recorded. The signal voltage is converted via a formula to measure W/m^2 . And of course we need to use solar tracking devices to track the normal radiations. And already we have explained what are the components, we need the sensors like thermopiles and protecting cap.

And as far as applications are concerned, this kind of instruments can be used in meteorology, material testing research, assessment of the efficiency of the solar collectors and photovoltaic devices.

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Now, let us learn the other instrument which is used for measurement of duration of sunshine hours in a particular day. So, here we used CAMPBELL-STOKES recorder. So, in this measurement we will have one spherical bowl shape structure and we will have some kind of strips, so solar radiation is focused by using this glass sphere to a point on the paper strip which is held concentrically with respect to this glass envelope and there is a groove where we can fix this paper strip.

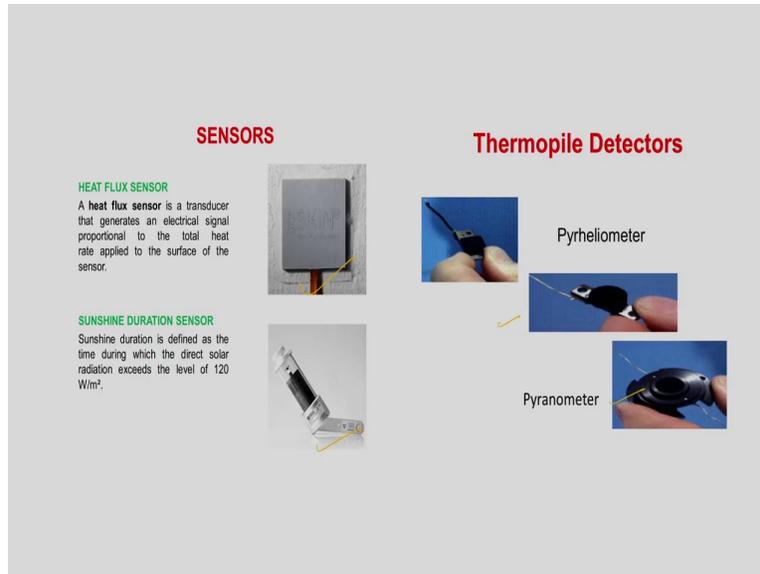
Whenever there is a bright sunshine, so that image form is intense enough to burn the strip, so as the sun is moving in the sky, then these burnt trace will also move from the original focal point or burning point till burning takes place. So this burnt trace, this length of the burnt or burnt trace is directly proportional to the duration of the bright sunshine hours. So, that way we can measure the duration of the bright sunshine hours.

So, this device that records the amount of sunshine durations at a given locations and a burnt trace whose length is proportional to the duration of the sunshine is obtained on the strip. So, once we know this burnt trace then from that we can calculate the duration of the bright sunshine hours.

So, this is very, very good instrument, so basically what it does, though this sphere is used to form a image here and this strip is time specific. So, same strip cannot be used for throughout the years. So, there are many strips, so which can be applied for particular duration, maybe so

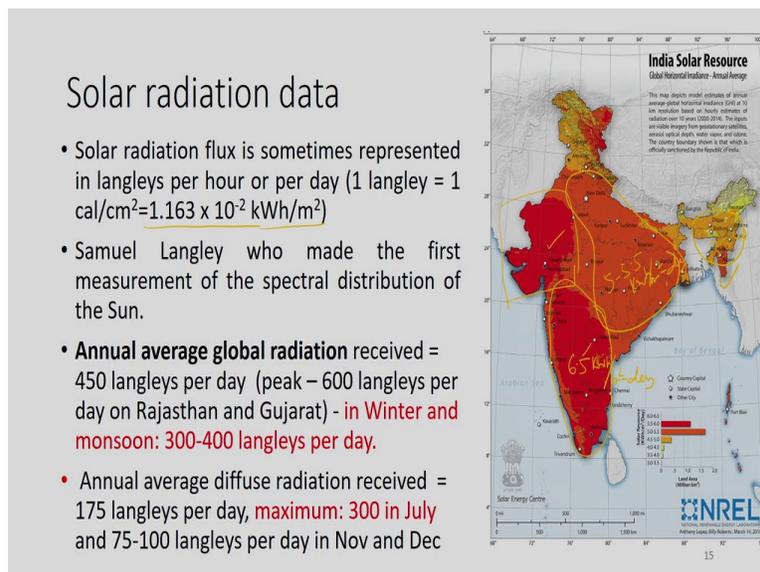
January to February one strip, then February to say April one strip, so that way there are different kind of strips can be used for measurement of brightness of the sun for a particular month.

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So, this slide shows the different kind of sensors used for radiation measurement, so we can have heat flux sensors or thermopile detectors. So, structure of those sensors can be seen, so this is something like that and heat flux sensors are something like that. And there are sunshine duration sensors which is available in the market, these kind of sensors are also used for measurement of brightness of the sun or sunshine duration.

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So, now let us discuss something about solar radiation data because we must know the unit used for measurement of solar radiation and then what is the source of solar radiation data. So, normally we use W/m^2 as a standard unit for solar radiation flux but one very interesting or very renowned scientist Samuel Langley who made the first measurement of the spectral distribution of the sun. To honor his contributions, there is a unit called langleys, which is also used to represent solar radiation or radiation flux, which is also used to represent solar radiation flux.

That is 1 langley is equal to 1 cal/cm^2 and if we convert to kWh/m^2 , it is something like $1.163 \times 10^{-2} \text{ kWh/m}^2$. So, that means $1 \text{ langley} = 1.163 \times 10^{-2} \text{ kWh/m}^2$. So, if we see in terms of langleys, the amount of energy received in Indian context, so this is about 450 langleys/day for summer season, if we consider global radiation.

So, that means that the global radiation received in India is about 450 langleys/day and peak is about 600 langleys/day and this is maybe in the month of May-June and of course the place like Rajasthan and Gujarat are mostly exposed to the sun, so they are receiving more langleys per day compared to rest of the countries. And in winter months this average global radiation is found to be about 300 to 400 langleys/day.

And when we talk about diffuse radiation, so annual average diffuse radiation received in India is about 175 langleys/day and maximum is about 300 langleys/day and this is may be in the month of July and Gujarat is the place where we get maximum solar radiation. And we get minimum of values 75 to 100 in the month of November and December that means 75 to 100 langleys/day.

And of course, there are many sources from where we can get the radiation data. There are institutions where they generate radiations data and they compile it and if we buy it then of course we can get the, all the spectrum radiations. So, as far as Indian map is concerned we can see here so which portion is having higher intense radiations as we can see this portion is very deep or say very highly intense radiation fall in this region.

And of course this locations, this part like southern part and other part as you can see 5 to, 5.5 to 6 $1.163 \times 10^{-2} \text{ kWh/m}^2\text{-day}$ is received in those locations and about 5 to 5.5 is about these locations is about, this is about 5 to 5.5 $\text{kWh/m}^2\text{-day}$. So here, it is somewhat higher, it is about 6.5 is very good for solar $\text{kWh/m}^2\text{-day}$. And we can see these portions are very erratic because of climate is somewhat different and so here about 3.5 to 4 $\text{kWh/m}^2\text{-day}$ is received.

So, that way it's very difficult that same instrument cannot be or same product we can install in all the places but you cannot expect that same efficiency we will get, throughout the locations, so which a radiation specific. So, radiation data we can get from many sources and we can we can do our calculations and we can design our solar components based on the radiation data.

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Solar radiation data

- Instantaneous Global and Diffuse flux (W/m^2), I_g & I_d
- Hourly values of Global and Diffuse flux (kWh/m^2-h or kJ/m^2-h) I_g & I_d (kWh/m^2-h or kJ/m^2-h)
- For daily global and diffuse flux incident over a whole day (in kWh/m^2-day or kJ/m^2-day) H_g & H_d (kWh/m^2-day or kJ/m^2-day)

\bar{I}_g & \bar{I}_d \bar{H}_g & \bar{H}_d

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And one very interesting things we need to discuss about instantaneous and global diffuse flux, so normally we use I_g and I_d . So, this is the instantaneous global flux and this is the instantaneous diffuse flux. And unit is W/m^2 . So, as already we have discussed this instantaneous nomenclature can also be used for hourly variations. So, it is assumed that in 1hour time, this radiation is not varying much, so that's why we can use the same terminology for representing hourly values of global and diffuse flux.

So, these expressions are hold good for both instantaneous global and diffuse flux as well as hourly values of global and diffuse flux, and I_d . Sometimes we are interested to know that daily global and diffuse flux incident over a whole day. So, under that conditions we use this kind of terminology H_g and H_d . So, this all about daily global and diffuse flux incident over a whole day. So, if we see precisely these units, so these two units are something like kWh/m^2-day or kJ/m^2-day .

And here what we can write unit of these hourly values of global and diffuse radiations are something like kWh/m^2-hr or maybe kJ/m^2-hr . On the top of it sometimes maybe researchers are

interested about average values of hourly values of global and diffuse radiations. Under that conditions, what we will use? We will use \bar{I}_g and \bar{I}_d . So this is for average values of hourly global and diffuse radiation flux. Also sometimes researchers are required average values of daily global and diffuse radiation.

If we are concerned about average of daily global and diffuse radiation, then what we will use \bar{H}_g and \bar{H}_d . These two are very, very important because most of the cases we need to use the average values because in a single day data we cannot design a solar system, so we need a long range data and we need average values of those data. So, once we have those average values, then we can use it for calculations, for amount of radiation what is received on a particular locations and which is finally useful for design of collectors.

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What Influences the solar radiation? →

- ❖ Earth-Sun Distance
- ❖ Relative tilt
- ❖ Time of the day

Irradiance (W/m^2): The rate at which radiant energy is incident on a surface per unit area of surface.

Irradiation (J/m^2): The incident energy per unit area on a surface found by integration of irradiance over a specified time, usually an hour or a day.

Insolation: Apply specifically to solar energy irradiation.

So, what influences the solar radiations? That is first thing is earth sun distance, this has been demonstrated, how this is influence this solar radiation. Because we can see the variation of extra-terrestrial radiation with respect to the days. So, it varies with time and relative tilt and time of the day.

So, these are the parameters which influences the solar radiations and of course we define irradiance and irradiation. So, irradiance is rate at which radiant energy is incident on a surface per unit area of the surface. And irradiation is, when we integrate this irradiance over time what we get that is irradiation. And sometimes we use insulation also, the terminology insulation is

used which apply specifically to solar energy irradiation. So, these terminologies are used in most of the cases when we deal with radiation studies.

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Summary

- Concerns of solar equipment designer
- Different instruments used for radiation measurement
- Units of radiation
- Radiation data

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Now, come to the summary of this lecture. So, today what we have learned about different instruments used for measurement of solar radiation. So, pyrheliometer is used for normal radiation or direct radiation and pyranometer is used for diffuse and global radiation. By using shading ring, we can measure diffuse radiation or without using shading ring we can measure global radiation.

And of course we have learned how duration of sunshine is recorded by using a sunshine recorder, so sunshine recorder is very important instrument for understanding or measuring the brightness of the sun or sunshine duration. And also we have studied the concerns of solar equipment designer, so what condition solar designer has to adopt for the analysis because there are options. So, we have to use the appropriate options for designing the system and designing the components.

And also we have studied the units and units of radiation, so this is W/m^2 , so sometimes we have to represent average of hourly, sometimes we have to represent average of daily and sometimes instantaneous values we need to measure. And of course radiation data, how this radiation data are applied and from where this radiation data can be obtained for further analysis. So, thank you for watching this video.