Power Plant Engineering
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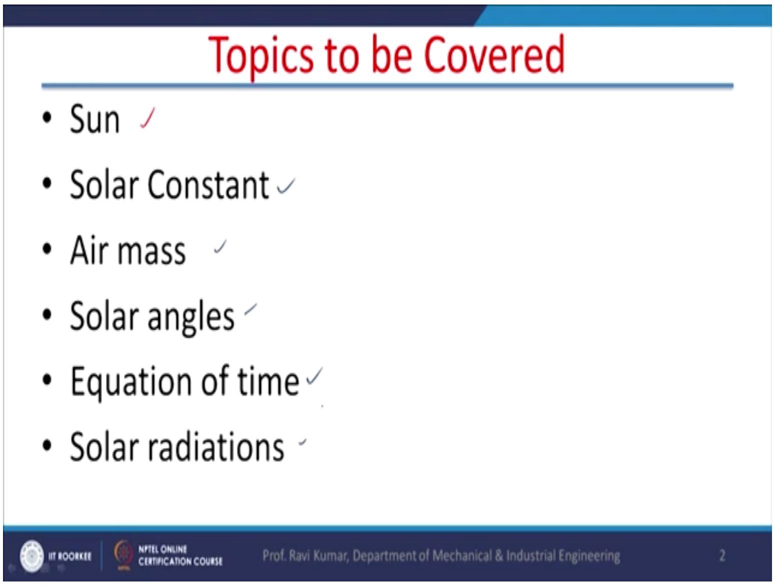
Lecture – 30
Solar Radiations

Hello, I welcome you all in this course on Power Plant Engineering. Now, from this lecture onwards, we will discuss about the direct energy conversion. We have already discussed the hydro power, thermal power and nuclear power as well and the combination of these power generations. And, now we will go in coming lecture we will go for direct energy conversion. So, in direct energy conversion first is solar power right. (Refer Slide Time: 00:59)



Now, before we discuss the solar power I would like to discuss certain facts about the Solar Radiations. Topics to be covered therefore topics to be covered in today's lecture first of all about the sun, then solar constant, air mass, solar angles, equation of time, solar radiations because these information's are required when you design a solar thermal power plants right. So, first of all let us do the sun out of which we are getting the power.

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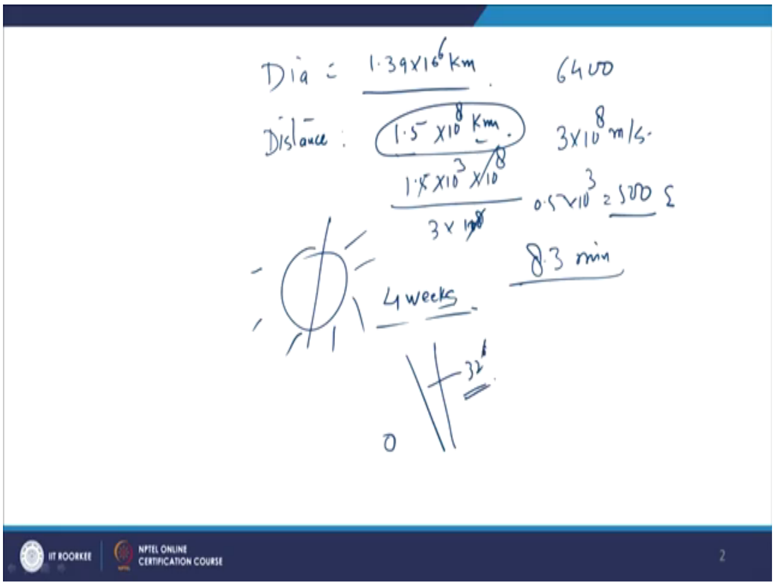

Now, the diameter of the sun let us have some physical idea about the sun. So, diameter of the sun is 1.39 into 10 to the power 6 kilometers. If you compare with the diameter of the Earth diameter of the Earth is 6400 kilometers. So, it is more than the 200 times; the diameter of the sun is more than the 200 times the diameter of the Earth. Distance from the Earth; distance of the Earth is 1.5, it is exactly 1.49 something, but I rounded off to 1.5 into 10 to the power 8 kilometers.

As you know the velocity of the light is 3 into 10 to the power 8 meters per second. If you calculate the time travelled by the light from sun to Earth so, it is going to be 10 to the power 3 meters 10 to the power 8 divided by 3 into 10 to the power 8 0.5 into 10 to the power 3 it is equal to 500 seconds; if you convert this 500 seconds into minutes, it is going to be 8.3 minutes. This is the time the light takes to travel from sun to Earth.

Sun also rotates on an axis as the Earth and the moon they rotate on their axis sun also rotate on it is axis and it takes 4 weeks time. In 28 days it rotates on its own axis the radiations of the sun they go in all directions and at a distance of this much when the Earth is here, the angle rendered by the radiation line is 32 minutes. They are almost parallel when they are coming to the Earth.

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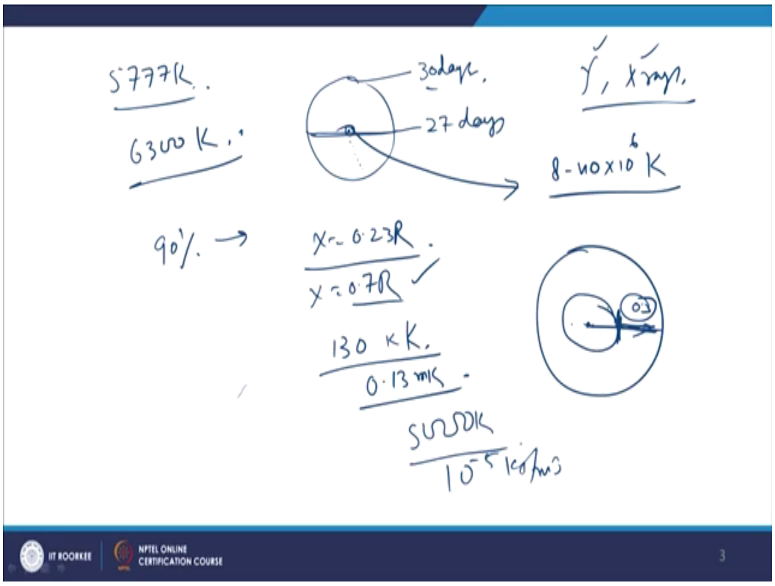

Now, sun does not rotate as a solid body sun is not a solid body. So, it does not rotate as a solid body. This equator it takes 27 days and polar region it takes around 30 days because it is a the sun is like a fire ball it does not have any solid any material in a solid state. All the materials are in a gaseous state; the temperature of interior region of the sun is 8 to 40 into 10 to power 6 Kelvin. So, at this temperature none of the material or the solid material will survive. Now, we will not go in to the details of the of the sun.

Now, sun is a energy source for us. So, what sort of energy we are getting from the sun and what are the what is the magnitude of energy we are getting from the sun that is a important that is important here. So, if you consider sun as a black body, then a black of 5777 Kelvin temperature. So, if you take a black body which is at 5777 Kelvin temperature the same amount of radiations ah which are coming from the sun to Earth.

Now, the maximum the so sun radiations they are also they keep on changing with time. So, the maximum radiation, 6300 Kelvin. So, if you want a maximum radiation from the sun the black body temperature has to be ah sixty 6300 Kelvin. Now, radiations coming from the core of the sun they are in the form of gamma and x-rays; gamma and x-rays. And, their wave length both gamma and x-rays they are smaller wave length. This wave length keep on increasing when we move away from the centre of the sun because when we are moving from the centre to periphery, the wave length of the radiations increases right.

And, 90 percent of the energy in sun is generated X is equal to 0.23R 23 percent of the radius; 23 percent of the radius, 90 percent of the energy is generated. And, if you move a distance 0.7R, if you move 70 percent distance from the centre the temperature drops to 130 130 kilo Kelvin or 0.13 million Kelvin, when you move 70 percent distance from centre to Earth the periphery.

And, this is know this zone which is 0.3 I mean 0.7 we have already moved this 0.3R is known as connective zone and it is it is zone and in this zone also the temperature falls around 5000 Kelvin and density is 10 to the power minus kg per meter density is very low where as the temperature is very very high the density is going to be the very very low right.

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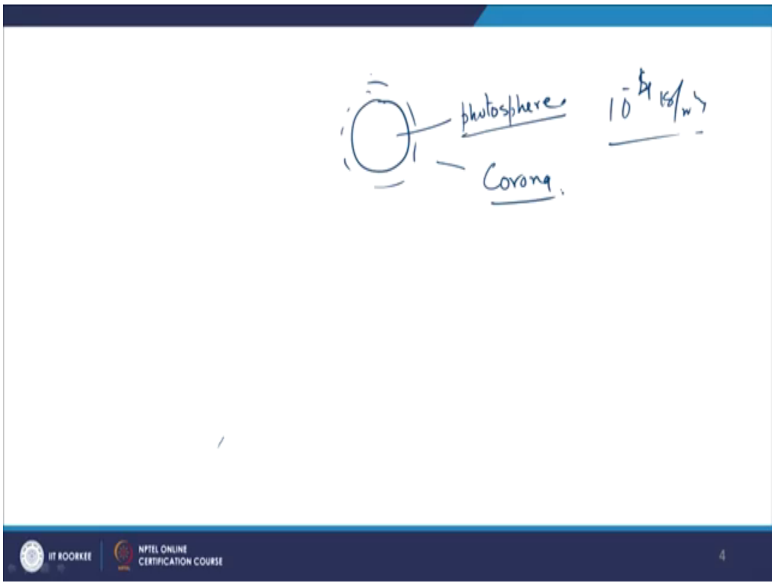

So, the outer convective zone of the sun; outer convective zone of the sun is known as photosphere; photosphere and beyond the photosphere there is a cornia corona, not cornia corona and the density here is 10 to the power 4 kg per meter cube. This is about the sun and what we seen more morally mostly what we seen it is corona only it is corona only.

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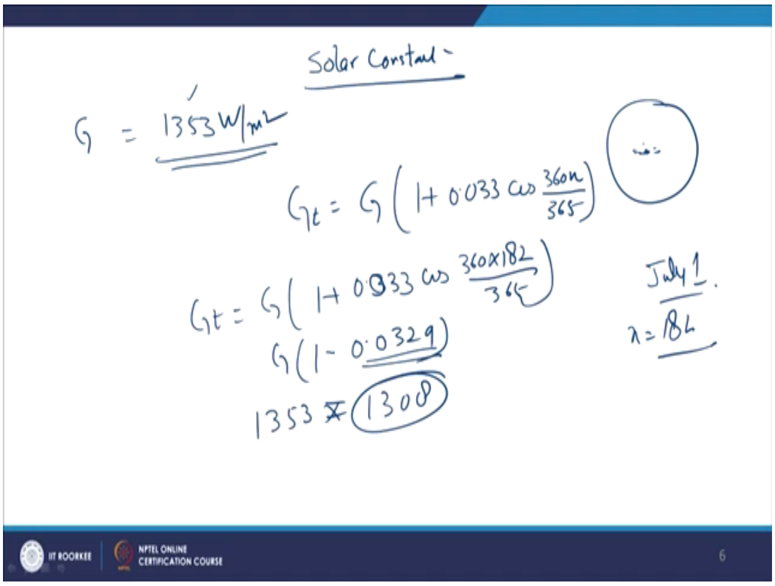

Now, there is a term which is known as solar constant. Solar constant; solar constant is G which has value of 1353 watt per meter square. It is the amount of radiation falling on the Earth's surface right, while this radiation when it is penetrating the Earth's Earth atmosphere. Now, this is the radiation which is falling on the Earth when this radiation penetrates the atmosphere of the Earth it also get reduced, but outside the atmosphere it is 1353 Watts per meter square.

Now, because Earth is not in the centre of the orbit sorry, the sun is not in the centre of the orbit of the Earth there is some eccentricity. That is why there is plus minus 3 percent variation in the value of G; suppose, any day you want have the value of G is equal to G 1 plus 0.033 cos 360n divided by 365. Now, suppose you want have the value of G t on 1st July. So, 1st July is when n is equal to 182. So, G t is equal to G 1 plus 0.033 cos 360 into 182 by 365.

Now, if you take 360 cos of 360 into 182 divided by 365 it is minus point G and it is multiplied by 0.033. So, it is 1 minus 0.0329 right. So, again there is a variation approximately 3 percent. So, G is 1353 multiplied by into 1353, 1308 is equal to 1308 right. So, this is the variation of plus minus 3 percent due to eccentricity of Earth with the sun.

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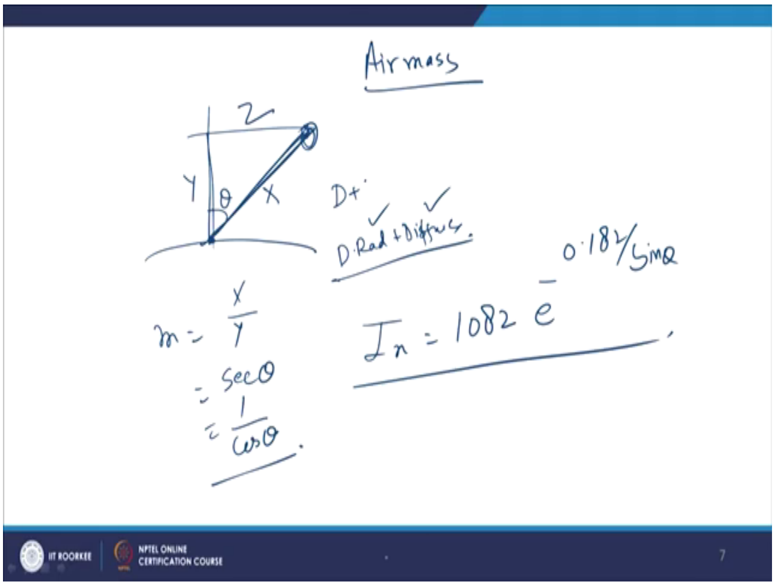

Another term which commonly comes in to the picture while we do the work on the solar energy that is air mass. Air suppose you are standing here on the Earth this is zenith, air is sun is here at an angle theta. So, this distance versus this distance the ratio is air mass.

So, the air mass air mass is the ratio of X Y Z, so it is the ratio of X and Y. Ratio on X and Y is sec theta or one by cos theta right. Second thing is when the sun is here it has to travel more distance when the electromagnetic radiations of the light when the light is travelling or the radiations are travelling we have two types of radiations.

One is direct energy radiation – direct radiation, radiations directly falling on the Earth; another are diffuse radiations – when the radiations that are scattered and when they are discarded they are diffused and then we get this total radiation is direct radiations plus diffused radiations DRI direct radiations plus diffuse radiations. So, the sum of the direct radiations and diffuse radiation is total radiation is total radiation right.

So, due to this angle further attenuation when the radiation takes place and this intensity of the radiation reduces is equal to 1082 e raise to the power minus 0.182 divided by sin theta. This is the formula of attenuation of radiation with the angle of theta.

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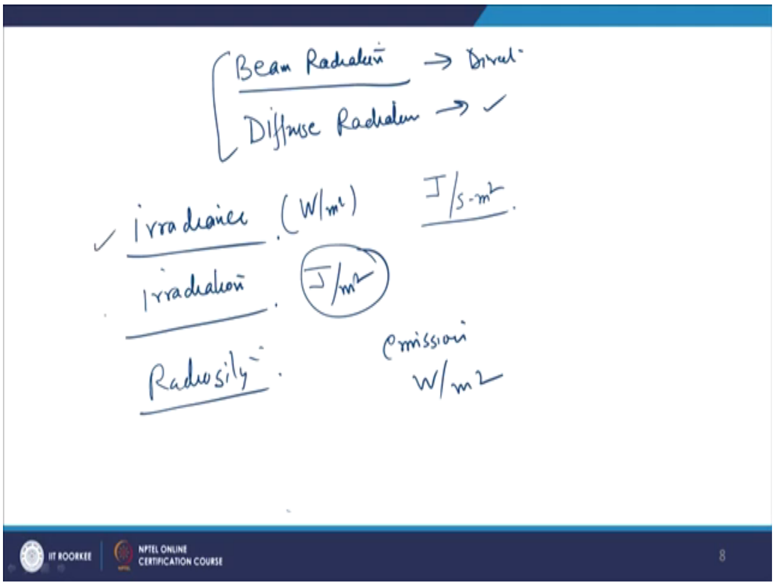

So, as I said direct radiation or beam radiation they are direct right and another is diffuse radiation, they are indirect type of radiation. So, when we are sitting at the room and the windows are open sunlight is coming to the room this is by diffusion, then it is not the direct light it is a light through diffusion. So, the total radiations are the sum of these two radiations.

Or there are certain terms in solar energy; first is irradiance. Irradiance it is expressed in terms of watt per meter square. It means energy falling on the fall surface per second on per meter square area, this is known as irradiance. And, another is irradiation; irradiation is it is not Watt per meter square it is Joules per meter square energy falling on the Earth surface over a period of time right.

So, it is Joules per meter square, this is known as irradiation. Another is radiosity; radiosity rate at which energy leaves the Earth right and that is known as radiosity and it is it is giving the Earth surface by emission and, this also term a watt per meter square. So, there are three things irradiance, irradiation and radoisity.

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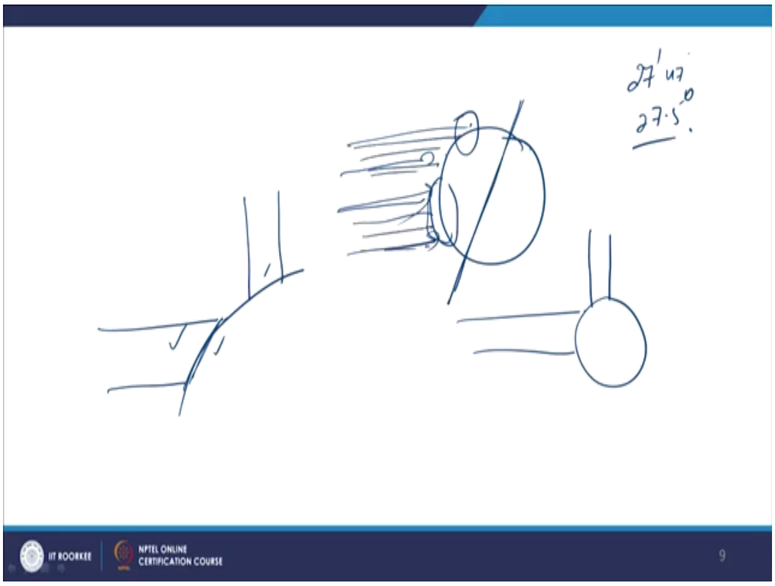

Now, let us talk about the Earth. Earth is inclined on an axis by 27 degree 47 of we say 27.5 degree right because the Earth is inclined on the axis when the sunray fall right. So, more radiations are this we are getting here rather than here.

For example, if you take a torch if a beam of a torch is a lighting this and if beam of a torch is coming from this side right there is a Earth surface. Let us say this is a Earth, surface beam of torch is coming like this and the beam of a torch is coming like this it is covering more area because it is a oblique right, but energy intensity will reduce here energy intensity will be high.

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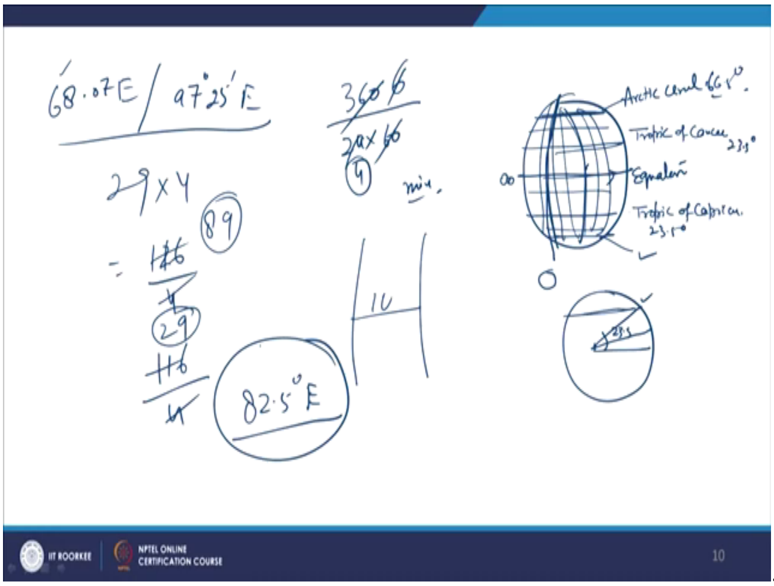

So, the part of the Earth which is inclines towards the sun suppose sunrays are coming from this direction and the axis of the Earth is like this, this part radiation will be high and this part the radiations will be less. Earth has equator right it is 0 00, then it has Tropic of Cancer and there is a Tropic of Capricorn.

It is 23.5 degree; it is 23.5 degree and these parallel lines they are known as latitudes if you look at the side of the Earth in the centre of the Earth they are latitudes at every degree. So, this is 23.5. So, this line 23.5 is latitude of 23.5 ok. Then at 16.5 or 16.5 it is Arctic Circle and here it is Antarctic Circle and they around 66.5 degree, right. So, when we move north or south right. So, there is a change in the latitude.

Now, there are longitudes also on the Earth joining the North Pole and the South Pole. If you move along this longitude the time will not change, but if you move along with the latitude the time will change right. Earth rotates I mean in 24 hours by 360 degree. So, if you take 360 degree by 24 hours and it is multiplied by 60 minutes, 4. So, it means if you move by 1 degree; 1 degree means 4 minutes. If there is the difference in the latitude of two places if it is 10, 10 degree the time between these two places will be is going to be 40 degree. Time reference is going to be the 40 degree.

That is why when we move on and there is a latitude 0 latitude which gives the basic in time which passes through somewhere in England and which has longitude not latitude longitude as 0. And, then we move towards the East and longitude say for example, India is 68.07 East and 97 degree and 25 minutes East that is from East to West longitudes of India. If you take the difference this is 97 simply 97 minus 68, so, it is going to be 29, 29 broadly 29 into 4 116 116; 116 and you divide this by 4 89 18 or 89 116 divided by 4, 29 right. So, there is a time with difference local time difference from extreme east to the extreme west of the India is 29 minutes.

But, we have one standard time and that is the average of the these two 68 plus 97, if you take average of these two 68 plus 97 divided by 2 is 82.5 82.5 degree East that is a longitude which passes through Allahabad near Allahabad right this gives the Indian Standard Time.

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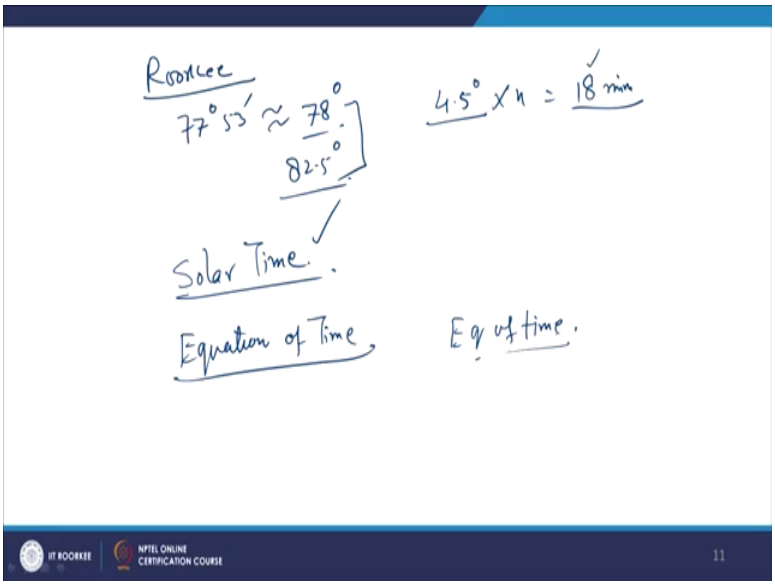

If I want to have local time if I want to have local time for example Roorkee longitude is 77 degree 53 minutes right and let us assume it to be 78 degree for the sake of convenience. Allahabad is 82.5 degree right. So, we are so, the difference between Roorkee and Allahabad is 4.5 degree multiplied by 4, 18 minutes. So, this is the time difference local time difference between Roorkee and Allahabad right and this is the local time which is given by the watch.

There is another time which is known as solar time. Solar time is solar time is different from the local time right. Solar time is it depends upon the sun and there is a equation of time we call an equation of time. Equation of time gives the difference between the local time and the solar time. So, when we are taking time with a solar watch this equation of time has to be taken into the account right. So, as we have calculated local time by changing by taking the difference of the longitude into the account difference in the longitude multiplied by 4, this will give the local time it depends further we are going east or west.

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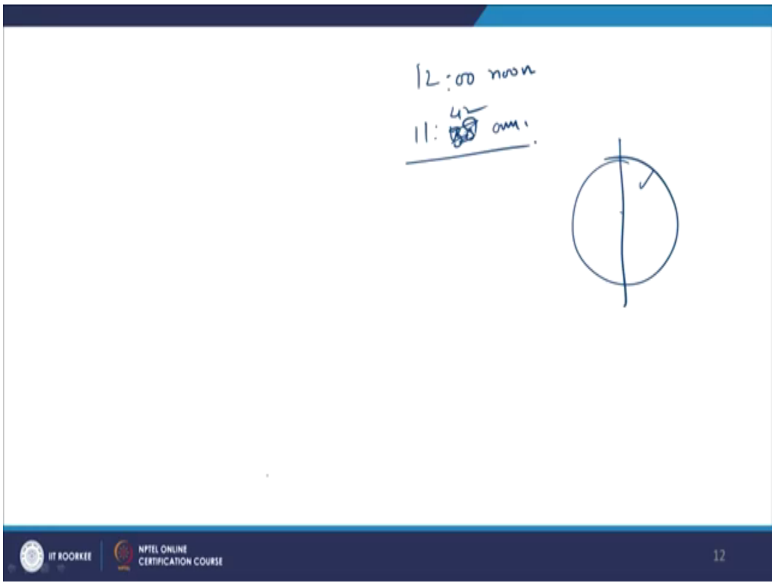

If we are going east to Allahabad the Allahabad it is 12 noon so, for example, 12 noon. So, in Roorkee it is going to be 12 minus 18 11 48 no ah 38 11 38 am, there is a difference of 18 minutes. Sorry, this is 22, 42 not 38, 42; 11 42. So, in Roorkee it is going to be 11 42 am that is a local time and local time by the watch.

But, the local sun time is going to be different. Why local sun time is to going to be different? Because when sun takes at the same level longitude when sun takes 24 hours to come back meanwhile there is a movement in the Earth also position of the Earth also right and if you take into the account we will get there getting an equation of time.

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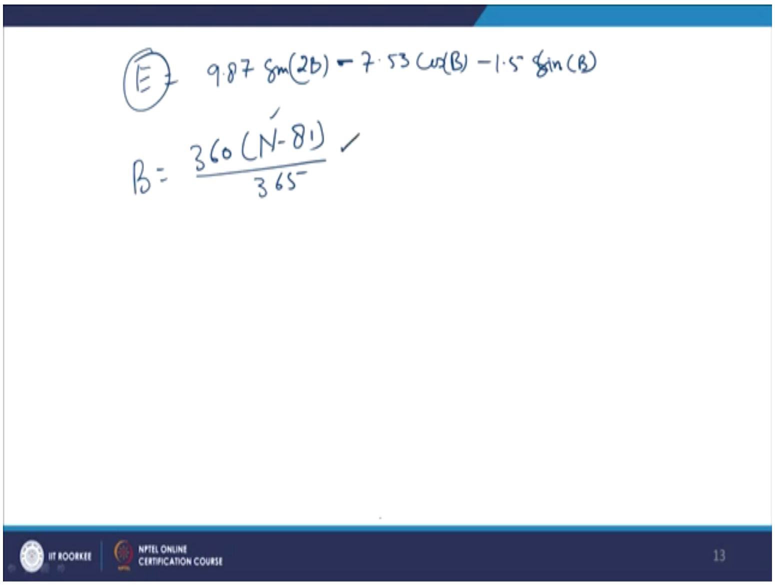

And, equation of time is expressed as E 9.87 sin 2 B minus 7.53 cos B minus 1.5 sin B. This is equation of time right, where B is 360 N minus 81 divided by 365, right. So, once we now we will again if you want to have value of E in July we will take N as 182 and we will put the value of B in this equation we will get the value of E and this E will be; this E will be added in the local time. This E will be added in the local time and this will give us the solar time.

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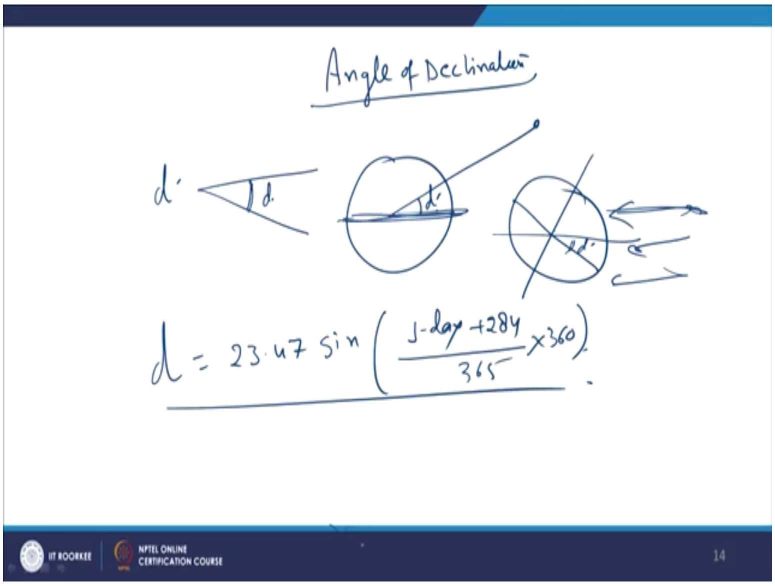

Earth – sun angles also first and the most popular angle is angles of declination. Angle of declination is defined by d and it is the angle of the sun from the Earths Earth plane of the Earth. This is the equatorial plane and this is sun, so, this is angle of declination because Earth is inclined at a certain angle Earth is not it is inclined at an certain angle. So, this angle of declination keeps on changing depending upon the position of the Earth with respect to the sun right.

So, for any day the angle of declination d is 23.47 sin J-day plus 284 divided by 365 into 360. This will give the angle of declination and when it is this is this is angle of declination this. When this is inclined then this is angle of declination because sun rays are coming from here. So, this is the angle of declination. So, angle of declination is also used in calculating in the calculations related with the solar radiation and, it keeps on changing.

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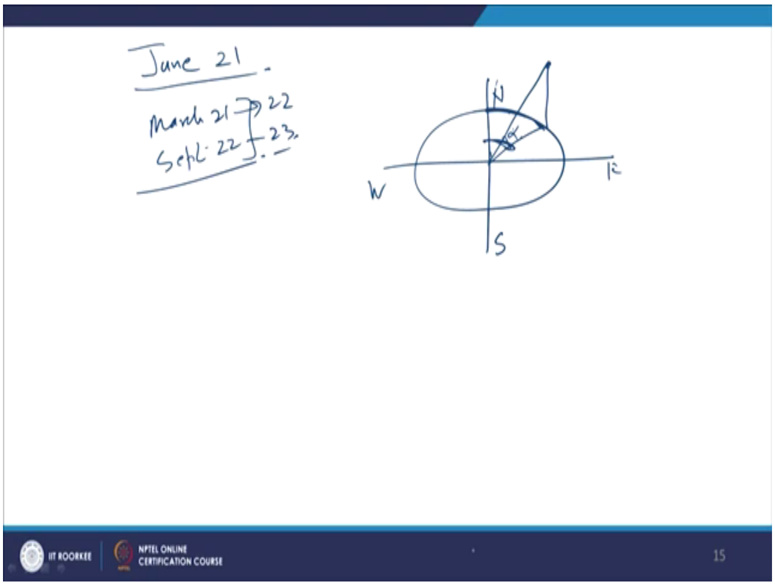

And, June 22nd June 20 for summer solicit it is called summer solicit, the angle of declination is maximum right and angle of declination is minimum on equinoxes. Equinoxes is March; March 21st and September 22nd September right. In India it comes out to be 22nd March and 23rd September right ah.

There is another angle which is known as azimuthal angle. So, if you take the Earth like this, this is north, south, west and east, then sun is here. So, this angle is known as azimuthal angle. Sorry, this angle – movement from the north; movement from the north. So, this angle is known as azimuthal angle ok. So, these angles, the information about these angle is required when we do the calculation related with the solar energy.

Now, in the coming lectures then we will discuss how to trap the solar energy we will be discussing more about the angle solar angles on the Earth. That is all for today.

Thank you very much.