Energy Efficiency, Acoustics & Daylighting in building
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Lecture – 03
Introduction & Environmental Factors (contd.)

So, what we look into is basically as I was telling you earth energy balance, because you know whatever energy is received by the earth it comes mainly from the sun. So, whatever is received annually is also dissipated out annually, daytime it receives radiation night it actually.

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Back to the cosmos.

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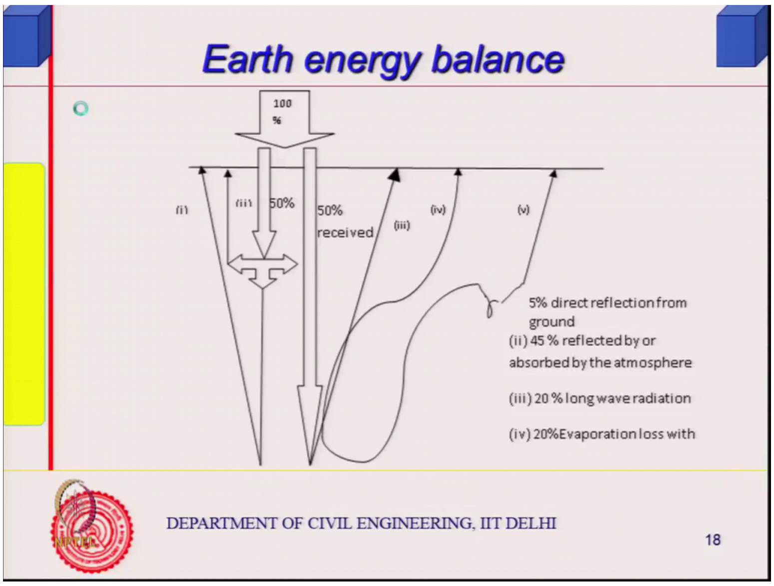

Besides that you know the seasonal variations are there. So, this shows a kind of a bookkeeping or accounting of the earth energy scenario and that is what the diagram was that is what I was looking at in the last class. So, what we said is 100 percent is what is received out of its 50 percent goes right to that atmosphere, absorbed by the particles in the atmosphere. And some of it comes as diffused radiation to the ground, and it is reflected back. So, some of it is reflected back, some directly reflected from the diffused you know particles itself, the sky I mean particle atmospheric particle itself. And then 50 percent is received onto the ground out of which some percentage goes directly to reflection from the ground itself.

So, if you look at that you know 50 percent 5 percent gets direct reflection from the ground. 40 percent reflected by absorbed by the atmosphere or reflected back. 20 percent goes as long wave radiation to the sky like you know as you can see this, this one long wave radiation. And 20 percent would be evaporation from the sea moisture etcetera.

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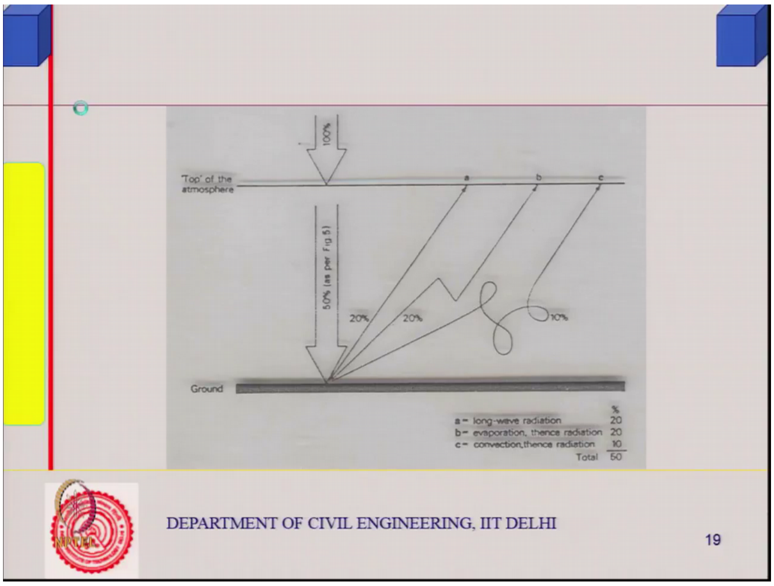

So, this is again now 50 percent what is received on the right, this is what is a breakup. Basically, long wave radiation about 20 percent evaporation from the moisture front sea and such things another 20 percent; and convection radiation you know back from the surface of the earth another 10 percent or so, so that is what it is. Anyway this is not true really, but it we need not go into further details of it, but we understand that.

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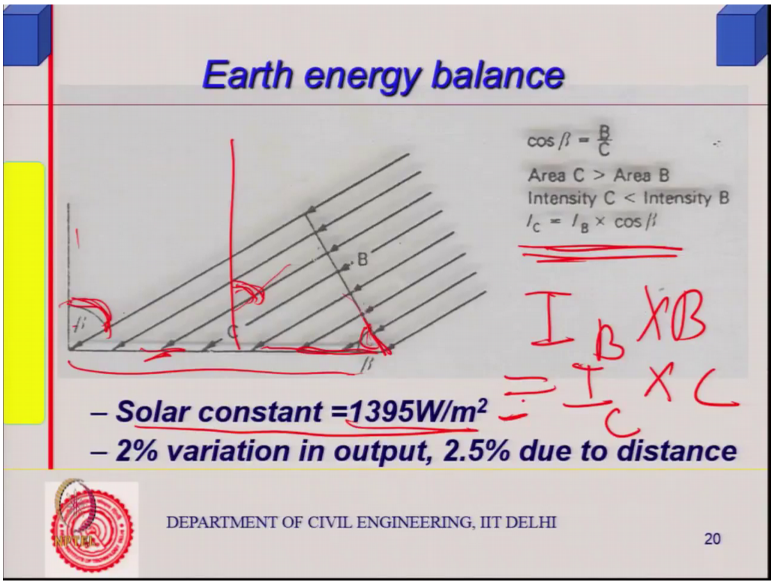

Now, the radiation that falls onto this ground, basically if it is coming directly normal to the surface, normal to the ground surface the intensity will be highest. But if it is coming inclined, same amount of energy is falling on larger surface area. And as you can see for example, the normal surface is B C is the surface area which is on to the horizontal plane or to the ground, then C if I have incident angle is cos theta or cos beta as we are calling it. So, B is equal to you know B will be basically I C or I can write it in this manner there is a pen available.

So, for example, I B is a beam radiation that is falling into an area of B, and I C is the radiation on the horizontal surface on the sea surface multiplied by C area. Area C is the lets say C is this area, C is this area I mean width is one I can take, so C into 1, similarly this is B into 1. So, this should be same because energy is same intensity of radiation is defining watt per meter squared that is what I told you other day. So, watt per meter square multiplied by the meter square, there should be same. Now, what is B by C, B by C is cos beta if this is you know the incident angle is defined normal to the surface this rays makes that is what we call as incident angle normal you know. So, this is incident angle actually which is same as this right, this is incident angle. So, this is same as this. So, basically it is I B cos beta.

So, because the area on which it is falling, it is flat. So, this is you know so normal incident radiation is higher intensity will be higher than inclined any time if there is incident angle is more than 0, this would be less radiation to this will be less. Now, how do you define incident angle normal to the surface and the ray angle between normal to the surface and ray that is your incident angle, right normal to the surface and ray. Now, since this is normal to this, this is normal to this, and this one is normal to the ray. So, this is normal to the this one this one is normal to the ray. So, angle between this will be again beta that is what I was just telling.

Now, solar constant is the amount of radiation that is available on top of the atmosphere, because atmosphere absorbs so amount of radiation that comes on top of the atmosphere that we call as solar constant. This varies a little bit, this varies a little bit because suns position distance of the sun from the earth is not same, it is elliptic orbit. So, perigee, epigee and all those. So, there is the slight variation besides that sun itself it is you know quantity of radiation emitted by the sun that also varies somewhat, but approximately one can take is something of the order of around 1395 watt per meter square. Some other book you might find slightly different and so on, so that is called solar constant that is received on top of the atmosphere. Now, that is what I was saying 2 percent variation in output of the suns output is itself varies and 2.5 percent due to distance, but we do not care about it really, we are not interested in this we are trying to understand only so that is that is what it is.

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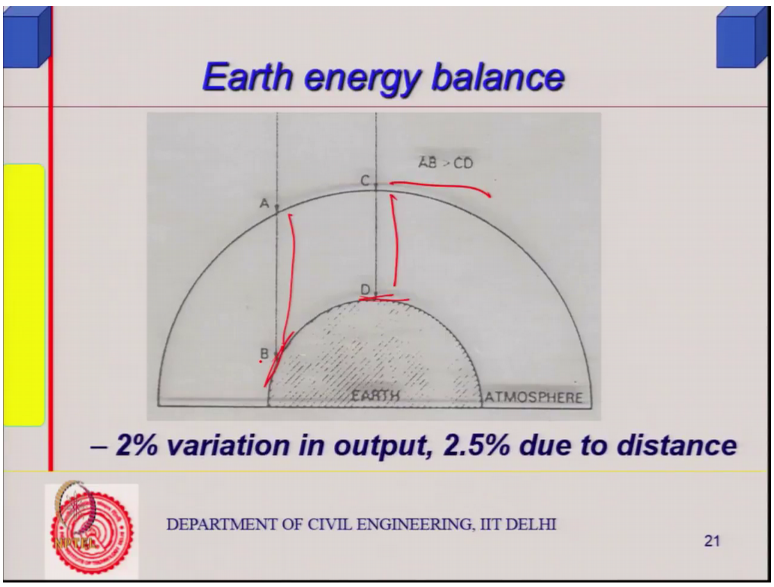

And that is what is you know top of the atmosphere it is more, and distance traveled here is less compared to distance travel in this position so obviously, absorbed will be more. So, it would depend upon and normal surface; obviously, intensity will be higher compared to inclined surface. So, these are the issues at atmosphere etcetera, these are the issues so that is what it is. So, 2 percent variation that is what I said I already said that.

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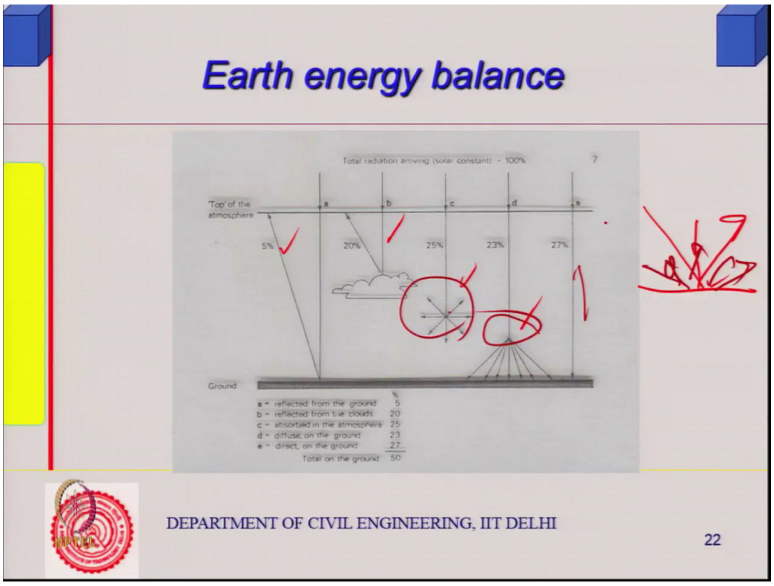

So, that is again the similar kind of diagram 50 percent you know 5 percent straightaway goes out, 20 percent is radiated from the diffuse atmosphere diffuse radiation goes back cloud etcetera, 25 percent absorbed there. 23 percent comes to the ground diffused radiation, you know the radiation what is diffuse radiation, what is specular and diffuse, you see if I have a mirror then rays will be reflected back, so beam and reflected beam. Now, angle of incident is equals to angle of reflection that is specular on a polished surface, but if I have a mat surface something like paper or you know your wood etcetera, etcetera, it will actually it will not be radiating you know it will not be reflecting the way that is written there is shown here.

The pen color I should change actually try to change the pen color over maybe it is changed somewhat. It will be actually reflecting in all direction you do not see your image and you know you mirror you see your image back, but on table or something like that you would not see your image. So, that is what is happening all getting scattered in all direction I mean it diffuses in all direction there is a completely diffused surface right. So, diffused radiation here it gets absorbed by atmosphere and diffused in all direction; 23 percent comes as diffused radiation from the atmosphere 27 is a direct radiation and this is what actually it also dissipate over the year, so that was related to the you know initial discussion of hours.

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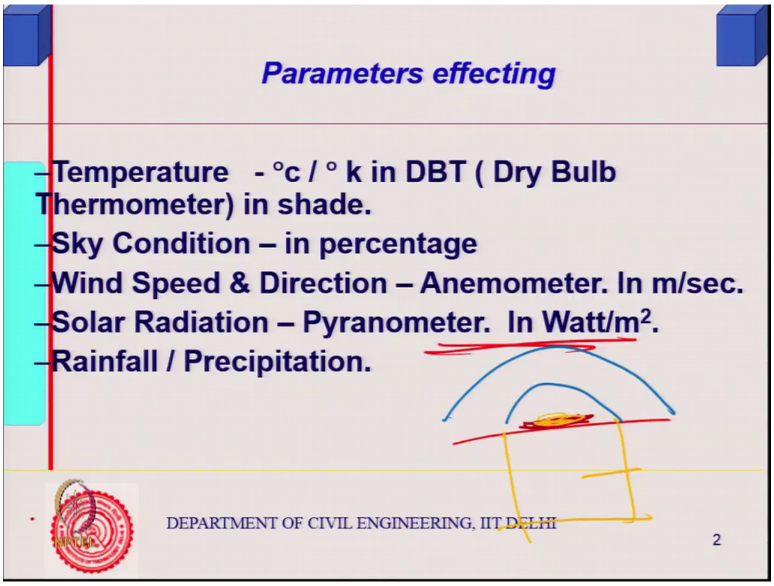

And then we will follow continue with from here itself. So, temperature we have already talked about this effects you know dry bulb thermometer in shade, we talked about sky condition. So, wind speed and direction this we have already looked into the factors which affect the environment surrounding the building you know solar radiation. Now, how do you measure also we talked about I just did not mention about this one. This is called pyranometer, which measures radiation a pyranometer measure measures radiation. Now, there are varieties of type. The one conventionally been used is we will have a blackened you know blackened oh this color is not black anyway, blackened sensing device right blackened surface. There is a dome, there is a dome - concentric dome, there is one dome glass dome here, there is another dome there.

And it has got a heavy base just a small you know quick understanding there is a heavy base, base is heavy, heavy mass. This is blackened actually my color is not showing really black properly it should be black or let me see if I can come close to the black or.

So, go to all erase anyway. So, this is blackened surface around this which I will have maybe this was better black does not matter.

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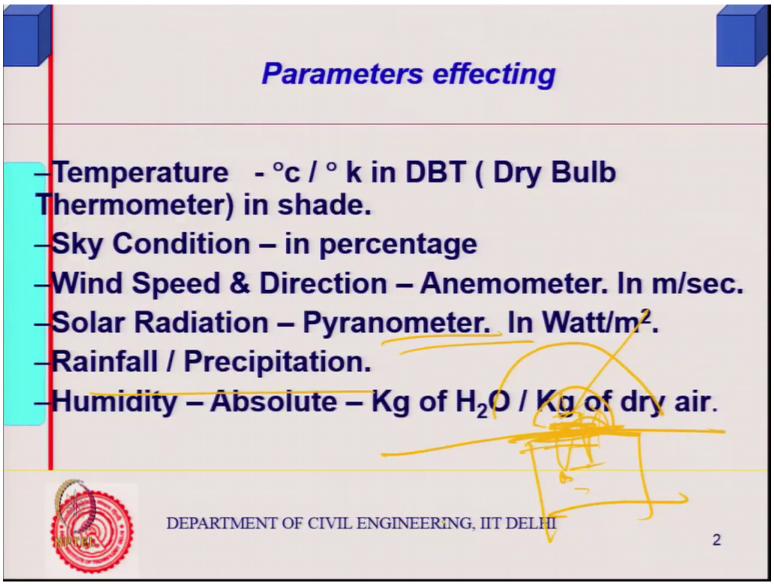

So, it is something like this there are two concentric domes there is a sensing device here and a heavy mass there. And you have actually what is called thermocouples in series. So, basically the hot junction is here cold junction is somewhere in the heavy mass, and there will be number of them together series of them. Such that temperature difference between these two can easily be sensed. So, when radiation comes in, it is absorbed in that blackened portion and temperature rise occurs there, this is a heavy mass heavy thermal mass. So, its temperature would not change besides that is also covered by a disk, so that it does not reciprocate radiation. So, base does not receive radiation it has got a heavy mass its temperature will remain same, but the blackened sensing area it receives radiation.

So, the difference in temperature which is actually kind of magnified or summed up because there are number of hot junctions and cold junctions that is dependent upon intensity of radiation, so it can be calibrated. These two glass domes are put in to reduce down the convective heat transfer also glass traps the radiation. So, no radiation back can go. So, two of them we will ensure that there is no formation of ad or current flow you know air moment etcetera is minimal, so that is a pyranometer. Anyway again the instruments are not really of our. And rainfall gauges are there so that you know. So, we talked about this sometime earlier. So, this is the parameter. And humidity of course, as I said absolute terms moisture vapor per unit kg of dry air that is how we do.

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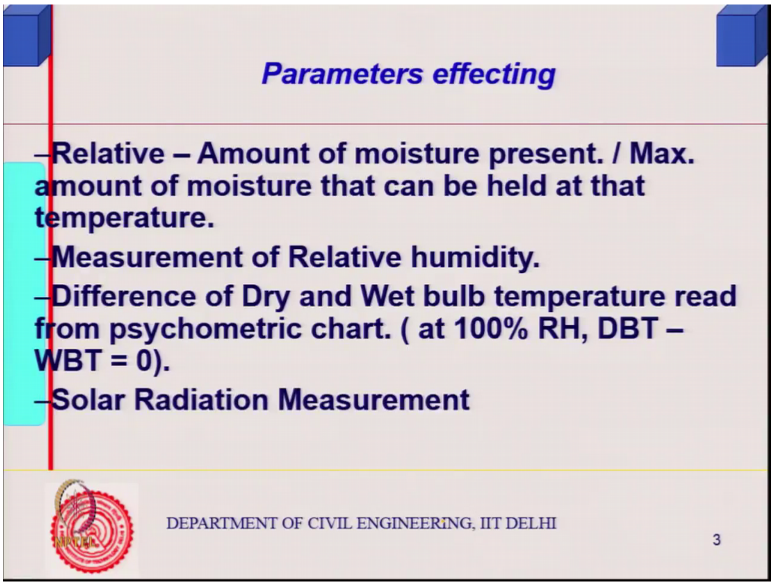

So, that is what we said amount of moisture that can be held in temperature, relative humidity, measurements of relative humidity I already talked about that hygrometer last class or difference in dry and wet bulb temperature. You know in saturated condition BDT minus WBT is equal to 0, this is just a repetition solar radiation measurement I already talked about. So, now this is the environment around right, but this environment is not constant. These environment changes from what we call season to season, location to location as well as season to season, because the environment is mainly governs by the suns radiation that is what we are talking about, the energy that comes from the sun.

So, sensible heat is actually measured by temperature changes which you can sense. Latent heat is one, which occurs because of phase change; latent heat occurs where moisture is vaporizing, there is latent heat. So, since we you see it is receives energy sensible temperature change you would occur you know suns energy. So, temperature surrounding temperature or environmental temperature around the building is a function of the energy received from the sun besides that we have seen the moisture will evaporate. So, moisture content relative humidity etcetera. So, all are related to that. And it varies from therefore, since suns radiation is not constant every day, whatever I get over a period of time let us say month of July and August to December, if there is a you know there will be difference of suns radiation. Because sun is I mean the earth is revolving around the sun, so therefore, its position of this particular location with respect to sun it will go on changing.

Similarly, depending upon not pole for example, it receives radiation indirect radiation also not direct beam radiation never it receives there, because beyond 23.5 beyond certain latitude it does not. So, it is important to look into sun-earth relationship to understand this temperature and relative humidity on those parameter and amount of factor variation of those factors right that causes what we call seasonal variation right seasonal variation, and rotation of the earth about its own axis causes what is called diurnal variation daily diurnal variation. So, we are trying to look into that sun-earth relationship then we will understand then we can come to the climate.

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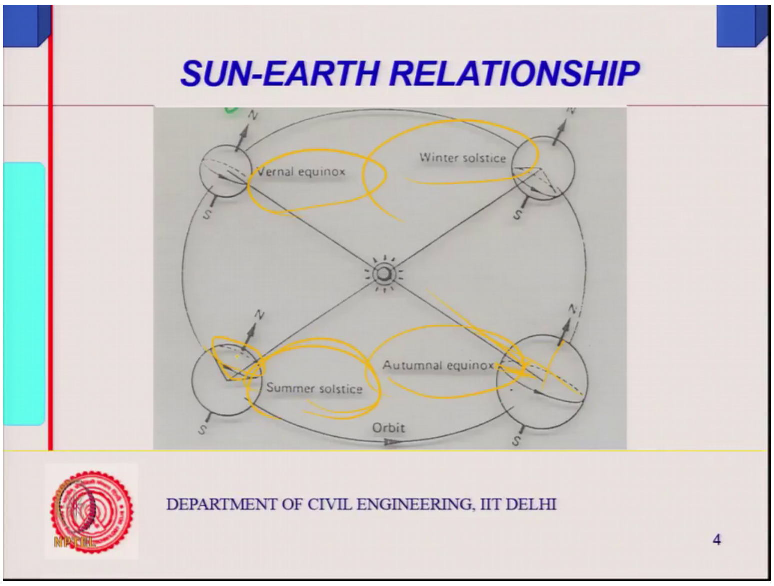

So, see if you look at sun-earth relationship, basically earth has got a banking, it is inclined to this plane of revolution right plane of its revolution under the sun that is got a banking. And that is constant all the time, approximately sixty six point you know 23.5 is the equal you know this angle can be 23.5. So, it is got a banking, I think it is written somewhere exact some (Refer Time: 15:17), it will be there.

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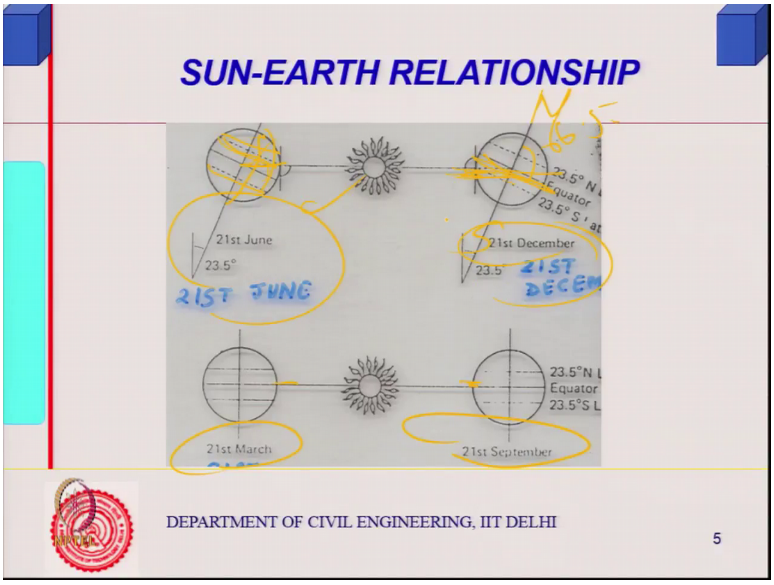

So, it has got a banking. Now, it is revolving like, this revolving all the time like this. So, some point, it will be normal some of you know and this plane on which it is normal I will keep on varying. So, we can find out an angle between the equatorial plane which is equator, this one diameter equatorial diameter the center, this is north, this is south pole. So, normal to that is a diameter diametrical circle which is equatorial circle and sun's rays on particular day falls normal to this point. And as it revolves around only a two point of time there is normal to the equatorial diameter.

So, this is around 21st December, you find that it is normal to 23.5 southern latitude. Now, what is latitude, latitude is the angle at a given location. So, you know I have a chord circle I have a chord circle, I have a chord circle here. So, from the center of the earth, if I join a line the angle that will make with the chord circle that we call as latitude. So, latitude of north pole is 90 degree, latitude of north pole is 90 degree, latitude of equator is 0, so that is how we vary this latitude angle. So, latitude angle vary. So, location of the place you know or point you know the I mean location on the surface of the earth any geographical location, I can express it in terms of its.

Student: latitude (Refer Time: 16:58)

Latitude, longitude these are the one which is this kind of you know I can divide the whole approximately spherical earth into 360 degrees or 180 in each direction and 180 west direction right, so 360 degree. And divide them into equal angles this 360 complete circle. So, these are longitude actually.

And if you travel from little bit of digression have you, any one of you read a book Around the World in 80 days by AG Wells, Phileas Fogg. Well, just digression, basically he had a bet and you know some club in England, here a bet that I will complete the world, go around the world, and come back to London in 80 days. And he managed his way through a long story is a book is a novel sort of scientific you know science fiction sort of thing. So, he moves around even India comes in there. So, he moves around and then finally, reaches there and according to his watch, he found that he is one day late. Then he suddenly realized as he was traveling he should have changed his time you know he should have changed his time he did not do that. So, he counted one day more.

So, if you are moving, you know moving from east to west, you have to adjust your clock, because when it is 12 noon here let us say in Delhi, it will be morning somewhere in Europe and so on. So, you got to adjust. He did not do that adjustment, and then suddenly realize at home he saw the calendar and he is you know servant or somebody has marked it the previously rent to the club of course, won the bet that is a there is a story.

So, anyway coming back to this. So, longitude relates to time. What do you call solar time and standard time. Standard time is Indian standard time is with respect to 82.5 there is the longitude of Allahabad so far it is like that. So, coming back to this as you are saying longitude, we will have a little bit talk about that sometime later and also. So, latitude defines a position of a location on the surface of the earth with respect to equatorial diameter in terms of the angle. So, sun's rays falls normal to because it has got a banking this is 90 minus 23.5 is how much.

Student: 66.5

0.5. So, this banking is 66.5, since it is got banking with this plane of revolution 66.5. Therefore, it falls normal here sometime, normal here some you know normal to this equatorial plane only in two times there is 21 September around 21 March, this is around 21 June summer solstice and winter solstice and so on equinoxes these are equinoxes. So, sun's you know I think this is yeah this is this diagram also shows you vernal equinox, winter solstice or autumnal equinox and summer solstice. So, it falls normal to this circle which is 23.5 latitude north; on summer solstice they are somewhere around June. This is winter somewhere in Australia you will have summer during that period of time, so suns radiation falls normal here and during this autumnal and vernal equinox its normal to the equatorial plane.

So, normal winds radiation can be received only from 23.5 to 23.5, I mean north to 23.5 south, so that is why these places who will have relatively warm environment. So, what you do is we classify all the latitude into three groups say 0 to 30, 30 to 60 and then 30 to again 30, north to 30 south right, and 30 south to 60 south and 60 to 90 that would be right. So, the one from 60 to 90, they are polar, polar climate subtropical; and 30 north to 30 south we call it tropical climate, because the environment is warm and I have not possibly defined climate. Climate is a pattern of temperature, relative humidity etcetera at a given location. And weather is a daily data, daily changes. So, weather change in weather relates to daily temperature relative humidity etcetera. So, when you say today's weather is likely to be rainy we mean, but then we talk of monsoon season. So, seasonal variation depends on the climate and everything is related to a sun, so that is what it is so that is what we looked into.

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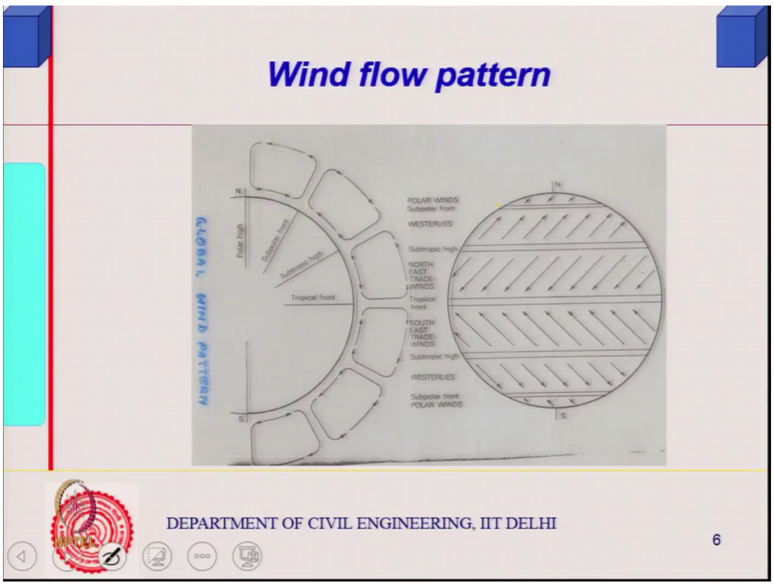

Even wind flow pattern is because of sun's radiation, because during the summer solid states the suns radiation will be normal to tropic of cancer that is 23.5 north that we call as tropic of cancer. And see around 23.5, it passes through India by the way Ahmadabad close to Ahmadabad and I think Agartala, we draw a line from Ahmadabad to Agartala 23.5. Indian latitude varies from 8 degree north Thiruvananthapuram somewhere around that place is 8 to about Delhi's 29, it is 29 you know and 33 or so something like that J and K that place, so it will be Ladakh on those areas would be of this order. So, this is you know by enlarge India's tropical.

Now, even the wind movement is dependent upon the sun's radiation, because we are in summer solstice around that period of time it will be heating of the sea around the tropic of cancer. So, the hot you know hot tropical front will start moving up the hot air, air gets heated up water vapor you know so air gets heated up. And basically as it heats up the cool air from the subtropical region will tend to move to fill in this gap. And then it will move you know it will it the circulation this circulation pattern actually circulation pattern starts. So, this is tropical front, subtropic high, subtropic front etcetera, etcetera and polar high.

So, this also is because of the wind movement is because of this, but there is a model there is slight modification will be there if you moving upward, but the earth is is rotating so what you call coriolis forces. So, you find the patterns are something like this. You know this is the direction shown as seen from vertically from the top, so that is what it is. So, they you know they are called trade winds actually because the trade straits man in sea they are the first one to recognize this pattern of this wind anyway. So, wind variation or air movement, air wind velocity is at a given location is also related to the climatic scenario or its location, but kind of ready is solar radiation it receives, it latitude and so on.

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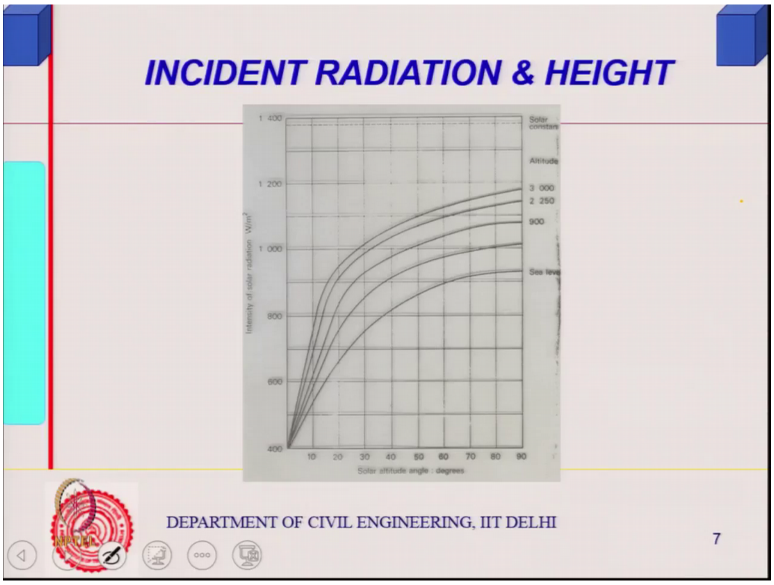

Altitude is another factor at higher or tier at sea level the radiation is less. At higher altitude, it can be somewhat higher because of the distance that we talked about absorption by the atmosphere etcetera. And this is solar altitude angle that means, when it is falling normal this is the maximum, you know when it is normal so depending upon the solar altitude angle will define what is altitude angle of the sun little bit later on so that is what it is. So, height also varies. So, therefore, you know at higher altitude you are likely to receive somewhat higher radiation, but does not mean this will be warmer because there are other factors which makes it cooler.

One of the ways of finding out of course, all this data are available from meteorological department, there are stations and they measure this, all data could be available. But one can even do a little bit of for understanding purpose one can look into some sorts of equation and try to look at how you can calculate it out from solar constant. We know the solar constant value.

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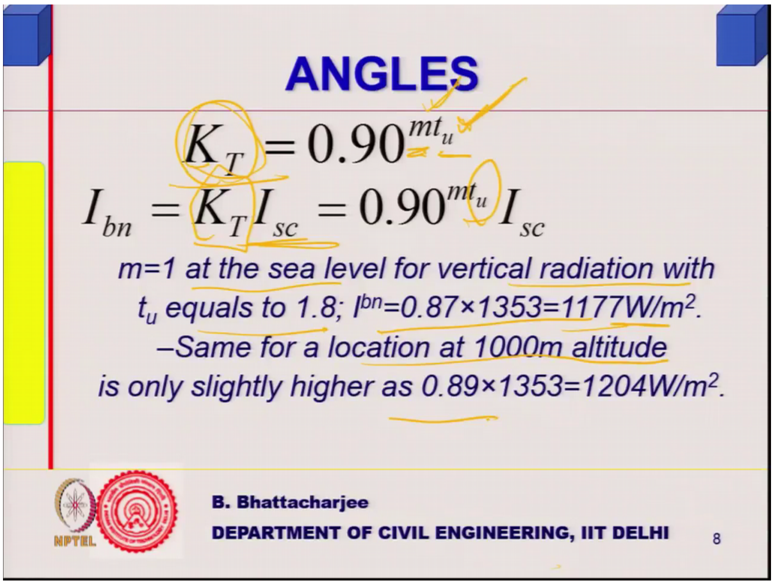

So, you see its like this beam radiation beam radiation I sc stands for solar constant multiplied by a factor K T. K T is given as this is more for understanding, but if data is available let us say for New Delhi data is available, design data is available then you do not bother to look into this, but we understand how it is. For example, K T is this factor which is a function of t u is the turbidity factor, m depends upon you know m is equals to one at sea level for vertical radiation. And this you know this depends upon altitude, this is a turbidity factor depends upon whether it is industrial or non industrial how much pollution etcetera.

So, m is one at sea level for vertical radiation with t u equals to let us say 1.8 which is big depending upon turbidity can go to 8 value of around 8 or so one can find out how much the radiation would be. Same for a location of 1000 meter altitude, this m value would change m value will depend upon the distance, altitude of the location and this is depends upon turbidity. So, if you know solar constant, this kind of an empirical formula 0.9 into m which is a function of the altitude; t u is the function of atmospheric pollution or turbidity there it. The tabular values are given, for industrial situation, this value is higher. What it means is 0.9 into fraction to the power some value. So, if you increase that value what will happen to K T value, it will reduce 0.9 into some power 0.9 to the power 2 is 0.81. If it is three that much multiply, so the value is high for polluted environment industrial situation. And this again depends upon distance, this depends upon distance so that is how it is. So, one can these typical calculations are shown here, these typical calculations are so shown here. This m values you know like these values are all tabulated, so one can actually find it out.

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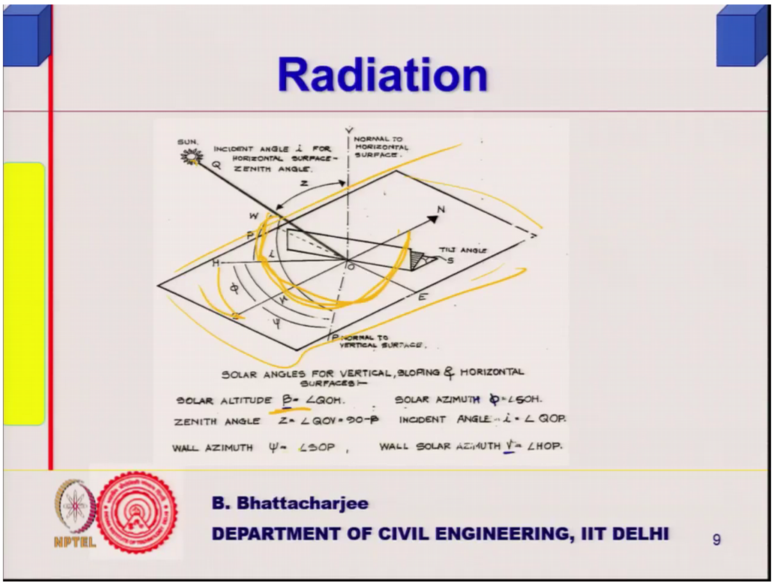

Now, this if I want to find out the radiation, so what we have seen is let us look at this parameters a little bit more and lets quantify them then we will define the climate classification of tropical climate and so on. Let us understand. We define certain angles suppose you want to find out how much radiation is falling onto a vertical surface or a horizontal surface wall of the building or you know roof or inclined wall or whatever it is. Then two things I go to know current suns position, its intensity of radiation, suns position relative to the surface I am interested in, and all these are done in angular measurements or extension into spherical trigonometry.

So, we define certain angles. For example, suns position can be defined, I can define the position of the sun in the sky volt by two angles, one is called an azimuth angle, other is the altitude angle. Now, what is an altitude angle I think this diagram gives you. For example, this is the sun let us say this is my vertical surface, but this is my horizontal plane this is the horizontal plane. This angle is a altitude angle of the sun. If I take sun’s projection onto the horizontal plane, the angle the sun rays makes with this projection we call it altitude angle. I am denoting here by beta right I hope I will be following the same notation if there is a change let me just correct me. So, this is called altitude angle of the sun.

Now that you know that that is that has nothing to do the wall so far. Now, I also want to define the position of the sun in the sky volt, so what I do I take a reference plane in the horizontal plane I take a reference direction. So, let us say I can take north direction. So, if I take north direction, then the angle the sun's ray, projection of the sunray projection of the sun ray on the horizontal plane, the angle that projection makes with the geographical norm, it could be I can call it azimuth angle, and measure it clockwise. Well, this is one convention.

I can start from south and measure clockwise. So, I can you know I have to follow the same convention throughout, equations changes when you because some books for example, maybe people in southern hemisphere would like to follow a different convention than people in northern hemisphere. So, some book you will find that they are actually taking from north, some might take from the south, but whatever it is azimuth angle is the angle between reference direction and.

Student: projection.

Projection of the sunray onto the ground. In this case. it is shown as phi with respect to south. So, phi is SOH. So, SOH is taken with respect to south clockwise, it could be with respect to north also. So, the formula we use one has to be you know you must know what are you using, so that is what it is. So, these are two angles which defines the suns position. Now, I must define the position of my surface. So, what I do I draw a normal to the surface, I draw normal to the surface. Let me erase out the previous one. So, I think this is other a certain thing. So, this is normal to the surface.

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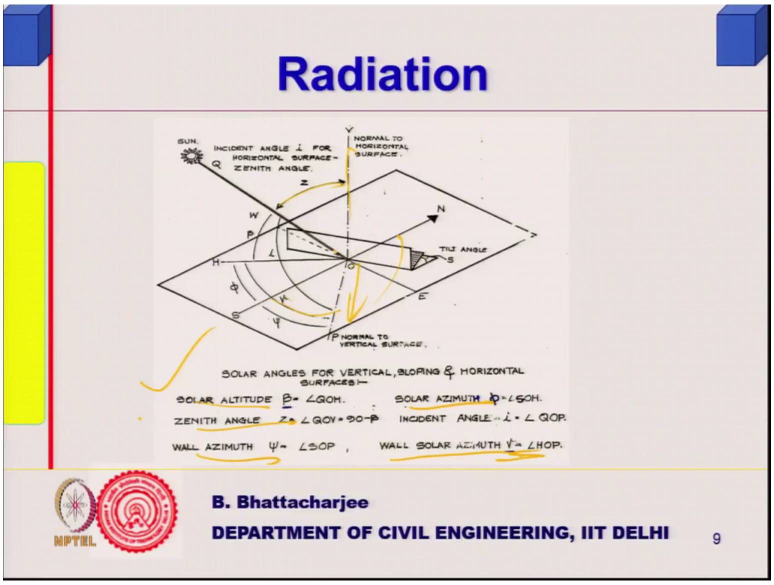

Now, I can find out you know wall azimuth from the same reference or if it is from the south going clockwise, anti clockwise then it will be minus. So, wall azimuth, wall azimuth means I draw it normal to the surface and angle between my reference direction and this normal in horizontal plane. If it is an inclined surface I will take the projection of the normal onto the horizontal plane. For example, if this tilted if it is somewhat tilted, I take the normal take its projection onto the horizontal plane and its angle from a reference direction angle between this projection and the reference direction that is the.

Student: wall azimuth.

Wall azimuth that is wall azimuth, so wall azimuth. And angle between this normal and the suns projection sun's rays projection onto the ground that we call as wall solar azimuth. What is wall solar azimuth. The difference between the angle between the wall azimuth and

Student: solar

Solar azimuth. The angle between the normal right to the surface or its projection onto the ground, and you know projection of the sun straight onto the ground that is we call as wall solar azimuth. So, wall solar azimuth is calling it is gamma which is of course, whatever convention you follow it will remain same because you will start from same reference both the times. So, this is how we define wall, but I have another angle for the wall or surface to be defined called tilt angle. If it is vertical, wall solar azimuth and wall azimuth defines its position wall cell or azimuth defines its position with respect to sun. But if it is an inclined surface then I have something called tilt angle tilt angle is the angle that surface makes from the with the horizontal tilt angle right, so that is tilt angle. So, surface that is how it is defined.

So, these are solar altitude zenith angle is 90 degree minus altitude angle of the sun, zenith angle is with the vertical you know the sun's rays making angle sun's rays the angle the suns ray is making the vertical that we call as zenith angle. So, solar altitudes, zenith angle, wall azimuth I have defined, solar azimuth I have defined and wall azimuth I have defined. Now, one more angle I should define relationship with respect to vertical surfaces and suns ray incident angle.

What is the incident angle, incident angle is the angle between the sunray and normal to the surface. So, incident angle will be you see if the normal if it is inclined surface inclined surface, suppose the surface is inclined its normal with something like this suns ray is something like this angle between this two we call it incident angle. So, for as tilted surface incident angle will mean vertical plane, it will not touch the horizontal ground, but for vertical surface you know that incident angle is basically the normal to the surface that is my this to this ray, this is what is incident angle right. So, these are the definition of certain angles which are important for our discussion and I think that that would be record.

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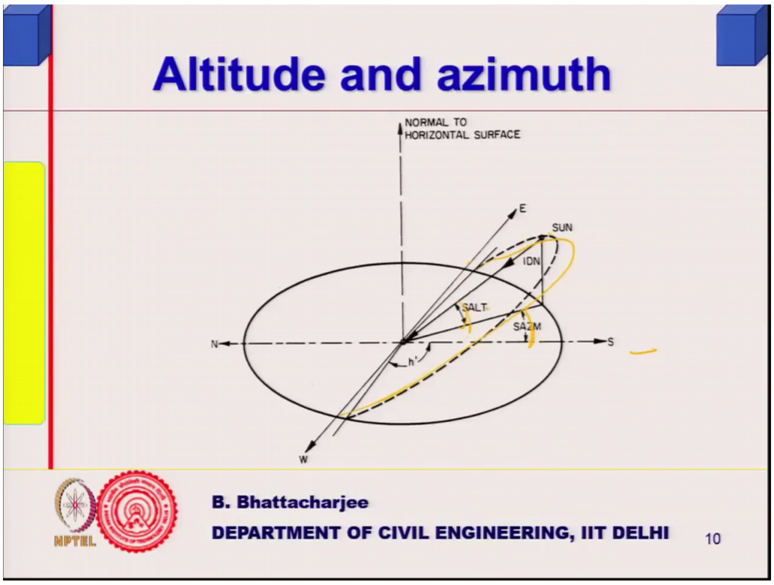

So, this is shown again just to make it clear no confusion should be there. So, this is the sun, this is the solar altitude angle, this is the solar azimuth angle. Again taken from the south here right and you know sun moves from east to west, so it will change from time to time of the day both azimuth angle and.

Student: altitude.

Altitude angle of the sun, it will change from time to time of the day. And obviously, it will vary from day to day also, we will see that. Because for example, you consider 23.5 on you know north latitude on 21st June around that June date whatever I showed you earlier 23rd June or whatever it is the suns ray is normal; that means, that twelve noon it will be sharp right at the head, but in December it will be somewhat inclined. So, you see this angles will keep on varying day to day and as well as time of the day.

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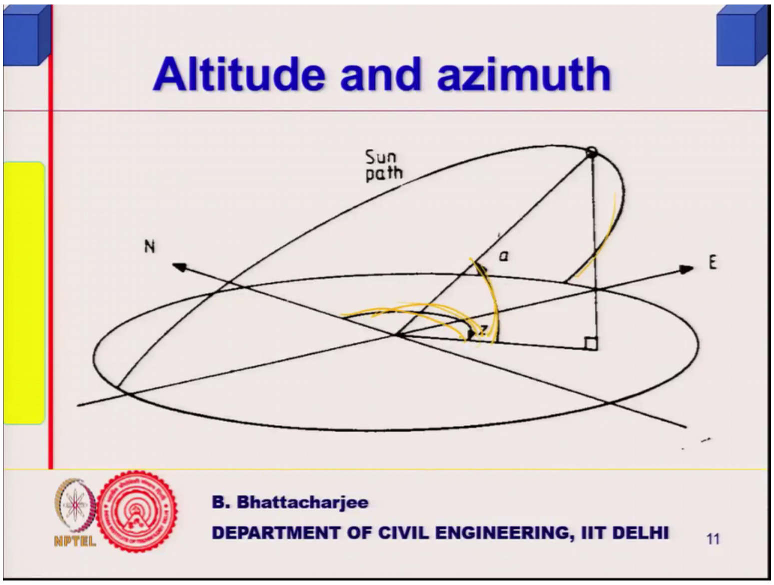

So, we will see that how we take count for this I think I have another diagram showing the same thing. This time this is from the north. This time you see the reference is north this is the azimuth angle of the sun, sun moves from east to the west, and sun moves from east to west, you know and it is inclined towards the south actually northern hemisphere. And altitude angle is this, azimuth angle is this.

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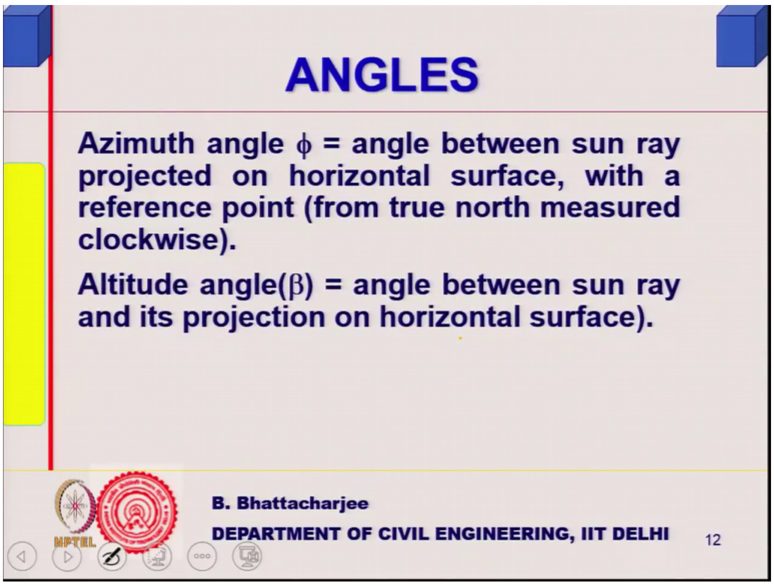

So, I think this concept should be clear now, there should be no confusion of this. So, azimuth angle is the angle between sun ray projected on horizontal surface with a reference direction true north measured clockwise could be what will be using; most of the time in our equations that we will be using true north clockwise. Altitude angle, angle between sun ray and we will be using a notation phi and altitude angle, angle between sun ray and projection to the horizontal surface. And then wall azimuth I have already defined angle between reference and projection of normal to the wall on horizontal surface.

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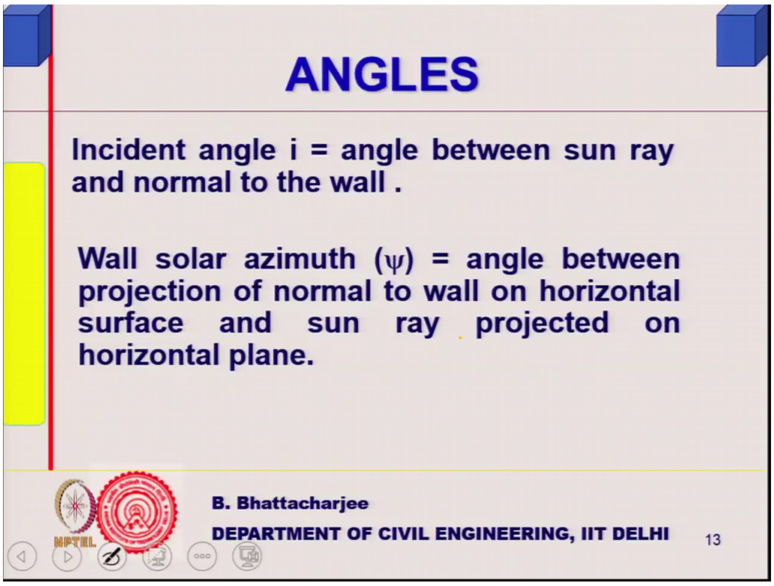

And incident angle, angle between suns ray and normal to the wall. Wall solar azimuth as I said angle between projection of the normal to the wall on horizontal surface and sun ray projected in the horizontal plane. So, I think this should be clear, this angle should be clear. So, incident angle is angle between suns ray normal to the wall. So, at this point, I think I have defined this all. So, angles we have defined. Now, next we can follow how do we calculate out this angle, how do you estimate this angles for any point, we will do that.