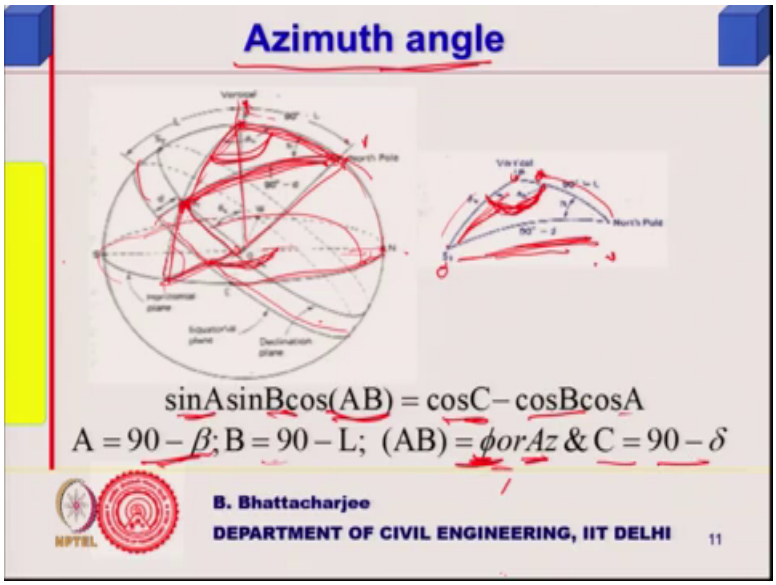
Energy Efficiency, Acoustics & Daylighting in building
Prof. B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Technology, Delhi

Lecture - 06
Introduction & Environmental Factors (contd.)

(Refer Slide Time: 00:20)



Now we will try to look for derive an expression for azimuth angle. For that what we do is, same equatorial plane this vertical equatorial. Sorry not equatorial plane, this horizontal, this is horizontal plane, parallel to what is a circular diameter, parallel to horizontal plane. Equatorial plane is somewhere there, and then this is the vertical, P stands for vertical. The equatorial plane is here, the sun is somewhere there right. This will be North Pole, because this is equatorial plane. So, normal to that would be North Pole. So, this is North Pole, this is North Pole, and sun is somewhere there, sun is somewhere there. You know suns path is, sun path is somewhere there. This is a sun path.

So, somewhere here is a sun path. So, you know this angle, this angle. Therefore, sun is here from the center of earth, this is the horizontal plane, and this is a suns position. So, this represents the altitude angle, this will represents the. This will represent the zenith angle; this represents the zenith angle right. So, this point I am interested in suns point, the vertical and the North Pole, vertical and the North Pole is somewhere there. So, this

is the spherical triangle I am looking at. This is a spherical triangle I am looking at. This is the suns position, these are North Pole. So, what is this angle? This angle is 90 degree minus.

Student: (Refer Time: 01:42).

Delta 90 degree minus delta. So, this angle is 90 North Pole and sun, this is 90 degree minus delta. This is vertical to the sun; that is you know 90 degree minus, vertical to the, sun is, vertical to the sun is basically zenith angle 90 degree minus altitude angle, and pole to, North Pole to the vertical North Pole to the vertical. Basically I am interested in azimuth angle. I am interested in azimuth angle. So, what is the azimuth angle? Azimuth angle is the angle between suns position and.

Student: (Refer Time: 02:20).

Geographical North direction, you know this is my geographical North direction. So, this will be my azimuth angle, this will be my azimuth angle. This is north, this is south, this is east and this is west. So, this is my azimuth angle, actually this is a azimuth angle. So, projection of what is this projection of? This vertical through the North Pole is a North direction, but projection or vertical through the North Pole.

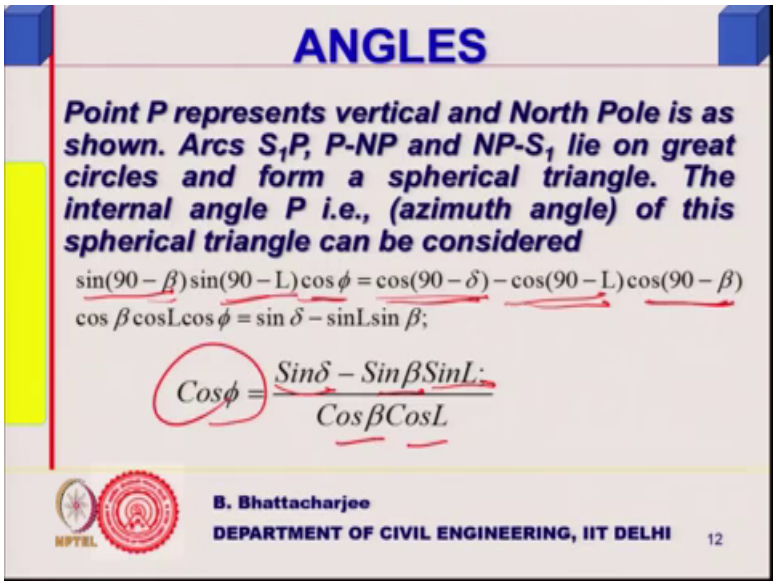
This is nothing, but this line is, this represents this plane, plane along this one and this is nothing, but you know 90 degree minus latitude. No North Pole to the vertical North Pole to the vertical that would be 90 degree minus latitude. So, this is 90 degree minus latitude, this is 90 degree minus delta, this is my zenith angle, and contained angle between this plane and contained angle between this plane. You know this plane is my North direction, and this plane this angle is nothing, but my azimuth angle.

Angle between particle North Pole, you know that arc and vertical. And the sun that would be azimuth angle, because I am taking it from North direction, but anyway it cannot be zero anytime, sun starts from east. So, sun starts from somewhere around this point, but I am measuring the angle from the geographical known. So, like you know the plane joining in the spherical one, plane joining North Pole to the geographical north, that corresponds to my azimuth as 0.

So, contained angle is nothing, but azimuth angle. So, if I use the concept of spherical triangle again. Now this will be, you know this will be, if you remember this is sin A is 90 degree minus beta, because this is my vertical, this is the sun. So, this is 90 degree minus beta sin B, which is 90 degree minus latitude and contained angle is azimuth angle, is equal to cos of C which is 90 degree minus delta and cos of B A.

So, you see A B is azimuth angle, sometime denoted by phi or A Z, the contained angle C is 90 degree minus delta. So, put that in the formula simple as this.

(Refer Slide Time: 04:37)



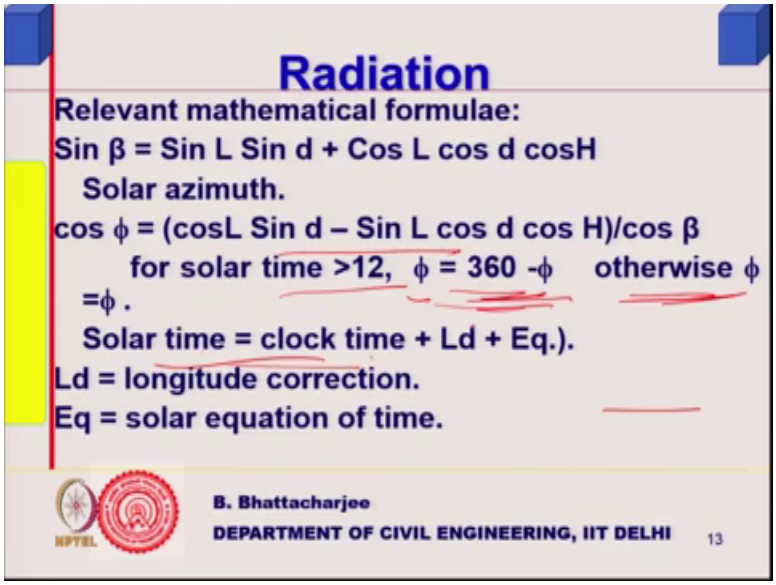
Then you will get it something like, you know point P represents vertical, I am just whatever I stated is written here, P represents vertical North Pole, and North Pole P, point P represents vertical and North Pole N as shown arcs S 1 P P-NP etcetera lie on the great circle, and form a spherical triangle, the internal angle P of this spherical triangle can be considered, and this is the azimuth angle. So, as I said and this was cos 90 my minus delta this angle C, this is called 90 minus S l and 90 minus B. So, this is nothing, but sin latitude sin altitude angle you know, and this is cos of sin of delta this sin of delta.

So, sin of delta minus sin beta sin latitude divided by cos of beta, cos of latitude angle; that is the angle for relationship for azimuth angle. So, azimuth angle is given as sin of declination minus sin of altitude angle, and sin of latitude divided by cos of altitude angle and cos of latitude; that means, first you have to calculate out the altitude angle. To calculate the azimuth angle this is one formula. There are some other formulae derived in

some other manner, or if it is south is the reference things might change someone. So, this is another formula for azimuth angle.

So, I expect that you can really remember this formula is not very difficult.

(Refer Slide Time: 06:04)

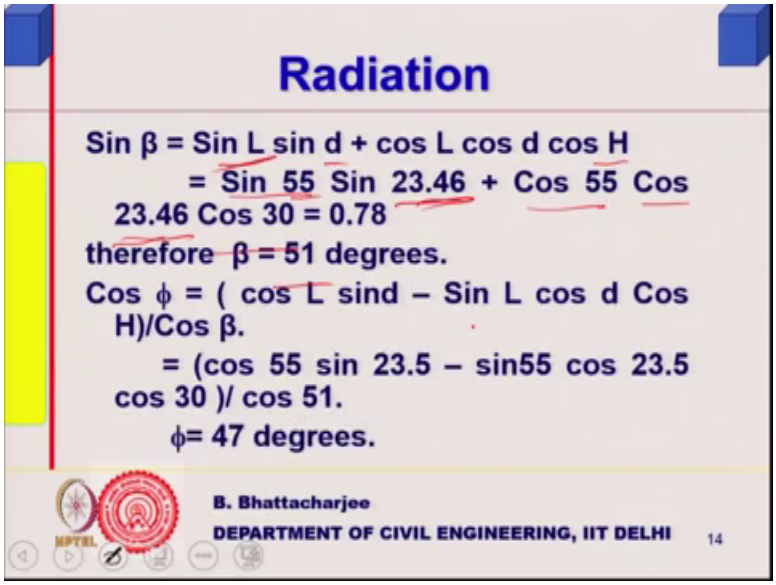


So, now, summing it up sin beta is equals to this. We have seen sin altitude is equals to sin latitude, sin declination cos latitude cos hour angle. I mean cos declination and cos hour angle. So, sin of altitude angle is equals to sin of latitude sin of declination plus cos of latitude cos of declination and cos hour angle, not very difficult to remember, solar azimuth is given by cos latitude, one formula is like that you know one formula is like that, but we are using a different formula which you have derived. They have a different convention. So, this formula you might find in some books, thus I have left it, I did not throw it away.

You know some books you will find this cos latitude sin declination minus sin latitude cos cos, it divided by cos beta, derived it in somewhat other manner, because phi is defined in A. I mean phi is also defined 360 minus phi; otherwise take it from; you know it is depending upon, depending on the type of the day. So, convention of defining the azimuth will dictate which formula you presume. We will be using this formula most of the time, you will be using this formula where we define our altitude angle with respect to geographical North clockwise geographical, you know azimuth angle with respect to geographical North clockwise right.

So, that is what it is all right, time equation of time I have already given you solar time equation of solar time, I have already given you right.

(Refer Slide Time: 07:37)

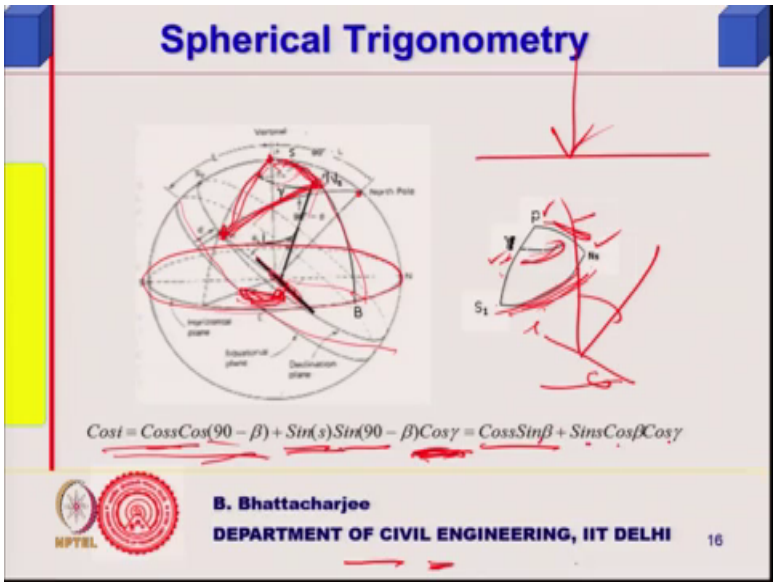


So, now, just small calculations, again supposing declination we calculate out 23.46 other day, they say declination we have calculate out other day right. So, latitude, let us say 55, this is again same problem. This problem you can verify is there in Marcus and Morris book other day; we calculated our declination as 23.46. Let us say I take from 55 degree latitude. So, this will be sin 55 cos 55 cos 23.6 and time of the 2 P m let us say.

So, it is cos 30 comes out to be 78, and therefore, beta is 51 degree beta is 51 degree. So, you can calculate out back from this, just as an example, quick example and from the same from the formula; that is given in that book. If you calculate out, you find it out to be something like you know 47 degree, but the convention is as per that books Marcus and Morris book or this formula, you find the same thing with our, you know this formula if solar time is more than 12 take 5 is equals to 360 minus 5; otherwise phi is equal to phi. So, solar time is clock time etcetera.

But if you calculate from the formula that I have derived will give you same. So, this is this. I have just shown in the calculation.

(Refer Slide Time: 09:01)



Now let us come to incident angle, when I want to do incident angle, same thing I do this is my horizontal, horizontal surface. This is my equatorial plane right, this is my equatorial plane, and this is my surface now, and normal to the surface is this, and it can go to the celestial sphere, normal to the surface or not horizontal anymore right. So, it is at some angle. Therefore, I can define tilt angle here, the angle at which it is there, if it is vertical it will be 90 degree for others. So, this is their, be tilt angle defined here, and this is, this is that, this is going up.

Now, this is, this was vertical, this vertical, this is North Pole. I think I may not need it right now. This is the normal to the surface stretching the celestial sphere NS right, and what is this. this is the suns position. So, I can have NS, this point suns position and the vertical you know suns position this something like this. So, something like this, I can have suns position and the normal to the surface I am considering.

So, what is this angle what is this angle from vertical to the surface, normal to the surface, vertical to the normal, normal to the surface, and it is an inclined surface on to the ground. It is normally somewhere there, and vertical is somewhere there. So, we call tilt angle as this angle. So, this angle also will be normal to the horizontal is vertical normal to the surface. I am trying to find out the angle between the two.

The angle between horizontal and the surface, we call it tilt angle. Therefore, normal to the surface and vertical that angle will be also.

Student: Tilt.

Tilt angle. So, this is tilt angle, this is tilt angle, this is tilt angle. So, one of them will be tilt angle. The other is sun to the North vertical; that is zenith angle this will be zenith angle, and what about this angle, this angle is normal to the surface, and you know suns position actually normal to the surface and sun position. So, normal to the surface and suns position, what is this angle? We call it incident angle. How do you define incident angle. Earlier I did incident angle is the angle between suns ray and normal to the surface right. So, we said normal incidence when it is a horizontal surface, vertical sun ray incident angle is zero at any other. So, that is why I said cos theta formula, when you are talking about the, you know cos angle law.

So, this angle is nothing, but normal to the surface and suns ray this angle is incident angle. So, now, you see this is known sun, the vertical to the sun, this is zenith angle, this angle is, this angle is tilt angle, and this angle is from the sun to the surface is incident angle. This is incident angle, this tilt angle, and this is zenith angle 90 minus beta. What is the contained angle between the two, this two.

This is the surface and this is a line joining vertical to the sun ray, this angle between these two, is nothing, but the it is angle between these two, is what we call wall solar azimuth wall, solar azimuth, because projection of this onto the horizontal plane projection of this onto the horizontal plane and projection of sun onto the horizontal plane. So, angle between these two, I will be calling. So, projection of this is nothing, but this actually projection of, this is my wall solar azimuth.

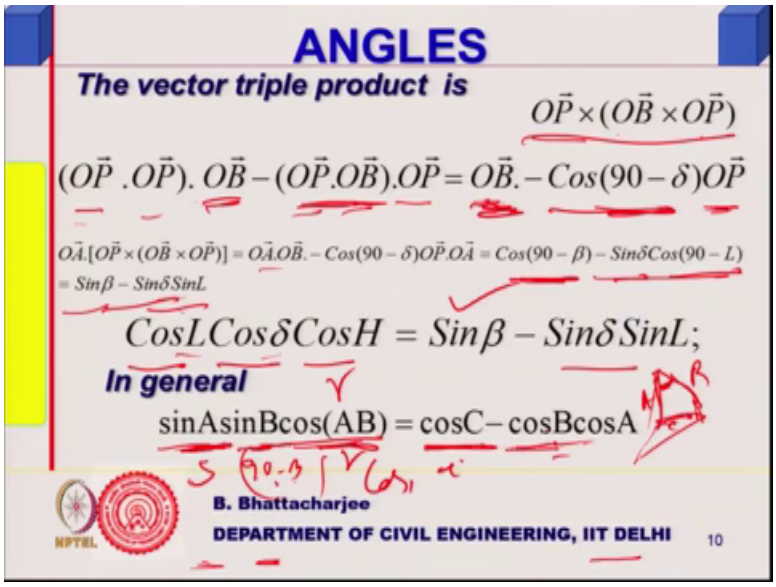
What was wall solar azimuth, solar azimuth minus wall azimuth. So, this is wall solar azimuth. So, contained angle is nothing, but wall solar azimuth. So, I can apply the same rule again right. I can apply the source, same rule again. So, you know I applying the same rule cos of tilt angle, applying the same rule. What was the rule?.

Student: (Refer Time: 13:11).

No I think, there is some slight problem, let us understand this. This is the wall solar azimuth. So, did I write this here cos gamma is very much there, contained angle is right; that is what I said it is cos gamma. So, it is been written straight away, but I think I can write it like this sin tilt angles sin 90 degree minus beta cos contained angle is equals to

cos of that third angle. This is incident angle, you know I think I should write it, write the formula, remove this, remove this you know. So, let me write it in this formula itself, earlier formula straight away. Maybe then I can come back easily, let me go back to the C, let me go back to the general formula here.

(Refer Slide Time: 13:58)



So, this was, you know in that spherical triangle this, this angle was nothing, but incident angle, cos of incident angle, third angle right. This content angle was the wall solar azimuth; one of them was 90 degree minus, 90 degree minus altitude angle, 90 degree minus beta, and the other one was.

Student: (Refer Time: 14:24).

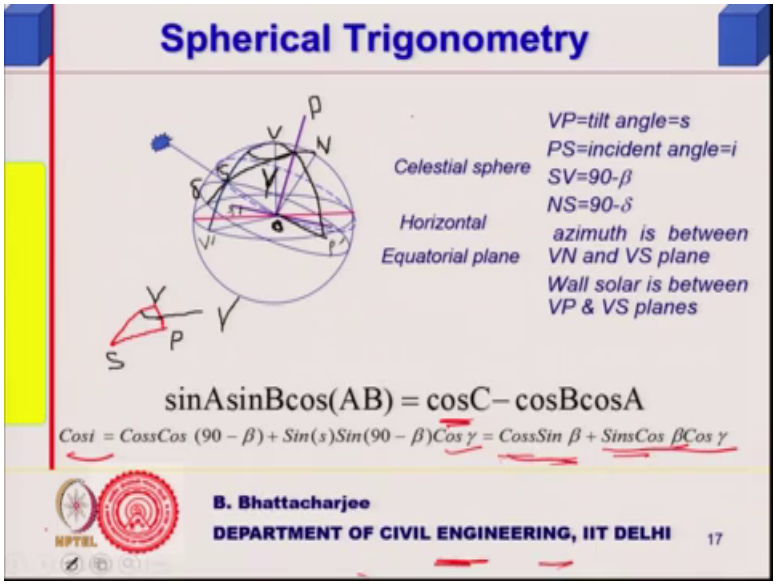
Other ones was.

Student: Tilt angle, tilt angle.

Tilt angle; yes, other one was tilt angle. So, this is S. This tends for 90 minus beta, and this is gamma, and therefore, this you know the formula will come as cos of incident angle will be equals to cos of tilt angle sin of sin of beta, and here again sin of cos of beta sin of tilt angle and cos of gamma. So, that is how if you just do it yourself, maybe we will get it straight forward. I just wanted to go back there. So, cos incident angle is given by cos of tilt angle cos of 90 minus beta, and sin and sin 90 minus is a cos Y; this will

come out to be cos tilt angle sin beta sin tilt angle cos beta cos of wall solar azimuth. So, you can derive this, using concepts of spherical trigonometry.

(Refer Slide Time: 15:21)



This is shown again just for your to recollect, you know I can have horizontal equatorial plane like this. Same thing I am just trying to show you this, the sun ray right, sun position is somewhere there, and this is the suns path diagram. So, this is the vertical, vertical to the ground. So, therefore, this is how it is, it is been you know, it is just shown again. So, the same thing we are trying to. I am just trying to show you that how all these angles; you can represent the same thing. I have explained you already, but a second time I am just showing you so that you can understand this properly right.

So, that is tilt angle incident angle etcetera this is shown, and this is what is contained angle is gamma, and this is I just wrote it. So, there is no detail which I just told you earlier in a minute before this other formula comes in all right. So, this for the incident angle sorry this for the incident angle, this for the incident angle. So, you can derive this principle for incident angle. So, we have done now for all angles. Actually we have derived expression for angles.

We have derived expression for altitude angle azimuth angle and incident angle. These are you know. Now altitude and azimuth angle defines the location of the sun position of the sun, at that point of time on a given location, and declination. It depends upon you know latitude declination and hour angle latitude depends upon the location very simply.

He would know that declination we have to calculate out which you can calculate from a simple formula I have given there are other formulae.

But I have given the simplest of all. So, altitude angle is easily you should be able to calculate out, and so, as the case it azimuth angle, azimuth angle is also related to altitude angle, and latitude angle, and also and what was it other thing.

Student: (Refer Time: 17:25).

And it was related to cos L cos beta and hour angle again. So, from this, you can find it out, and therefore, altitudes azimuth angle you can find out, and once you have found out to altitude angle and azimuth angle, wall solar azimuth angle you can find out, because wall azimuth and solar azimuth. From that you find out wall solar azimuth and which is here right, which is here actually. So, azimuth angle you got to find out to find this. Tilt angle, is for tilt for the surface. Now supposing it is horizontal surface what will be the value of tilt angle S is 0.

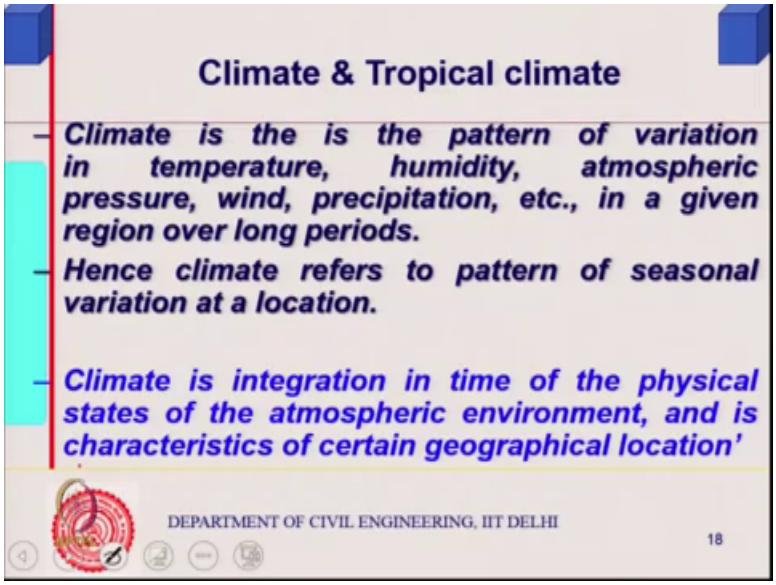
So, therefore, sin term this term goes away, what is remains is simply sin beta. So, for horizontal surface incident angle is simply beta right cos, you know it is sin beta is cos I is equals to sin beta. Sorry cos I is equals to simply sin beta. For vertical surface, S is equals to 90 degree. So, since S is equals to 90 degree, this vanishes, this remains. So, this is nothing, but cos altitude cos of incident angle is equals to cos of altitude angle, and cos of wall solar azimuth so, for horizontal surface and vertical surface equation simplifies.

So, three, this is how you calculate out all this changes. So, once this you have found out incident radiation on any surface, you can find out, because incident radiation on a horizontal surface is known from that beam radiation. You can calculate out to using cosine law, which I have given you earlier in the same lecture, and then you can find out radiation following onto this.

So, detailed radiation calculation, you can calculate out on any surface, if you know radiation on a horizontal surface, which is a meteorological data, and therefore, you are writing a program or something built in your own thing. It will be there, but anyway many of those the software's do the calculation, is you know accordingly. Now we are having. Now knowledge of all these factors a little bit of equations for calculating

radiation and things like that. Now we can look into environment, classify the environment and this classification is environment done in terms of climate.

(Refer Slide Time: 19:42)



How climate is basically, the pattern of variation in temperature, humidity, atmospheric pressure, wind, velocity precipitation, etcetera, in a given region over long periods. That is what is climate? Climate is the pattern of variation ok.

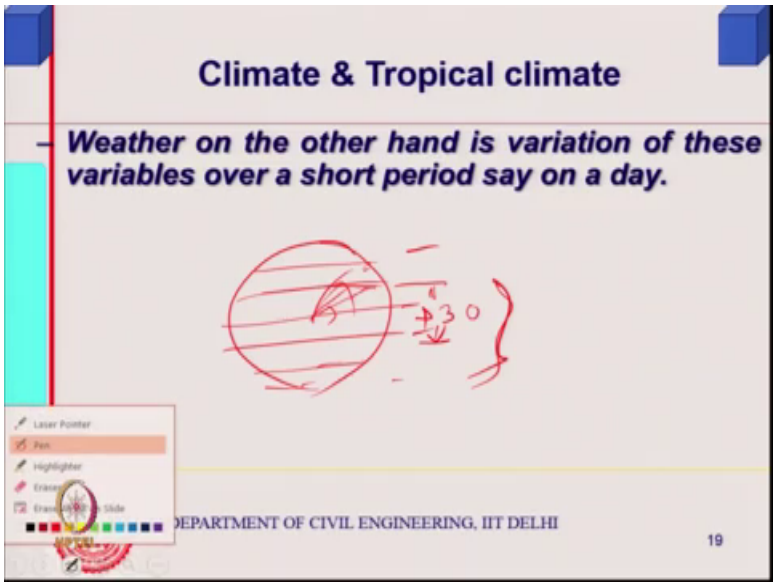
Hence climate refers to present pattern of seasonal variation, at a location as I said it is periodic 365 days, you have looked into sun earth relationship. So, you understand that the earth revolves around the sun in a year around 365, you know period in cities around that much 365 days a year and during this time the radiation received on to the location. It differs from time to time of the year therefore, you have a pattern. So, this pattern varies periodically, varies and this pattern, you can, this pattern of variation of this temperature, because it is variation of temperature, relative humidity, atmospheric pressure, wind, precipitation, everything is governed by solar radiation, received there all right and it is location proximity to of course, water body like C or something of that kind.

So, therefore, I can recognize a pattern and that pattern is called pattern of variation of temperature, etcetera, that is called climate. Hence, climate refers to pattern of seasonal variation, now it will vary when I look at variation day to day, well exactly day to day I may not be interested, because if perturbation for one day to the next day is. So, small I

may not be interested, but I can find out seasons number of days put together. For example, you know there can be winter season, there can be monsoon season, in tropical India, and it can be somewhat dry summer season. So, seasons, which are those ones where pattern of variation is more or less similar so, but season to season variations, are there, because there is a completely early variation. So, every year you will have a summer season, winter season and etcetera. So, refers to seasonal variation at a location.

So, basically if you define it a little bit more formally, climate is the integration in time of the physical states of the atmospheric environment. Climate is a you know integration, in time over the period of time physical states of atmospheric environment and these characteristics of certain g, it is a characteristic of any geographical location, for any location the climate climatic of variation of this pattern of environmental factors, they will vary. So, therefore, this pattern is a function of the geographical location. So, therefore, for the whole globe geographical location, I can look into you know different scenarios or divide them into different zones.

(Refer Slide Time: 22:37)



Weather on the other hand; of course, is a variation daily, variation diurnal, variation daily, variation today's weather, tomorrows weather, because there will be still variation from day to day which is again periodic, but not necessarily absolutely same. Every day you know many things are same, but sometimes they are to do variation and that variation we call it weather. So, I can divide them therefore, whole of the globe, you

know whole of the globe, I can divide, because I have latitudes which I can draw as equatorial plane latitudes right. This is the latitudes, you know if you remember, I can draw it like this, there is a latitude angle. Now, as you remember suns radiation, falls normal only between 23.5 Norths to.

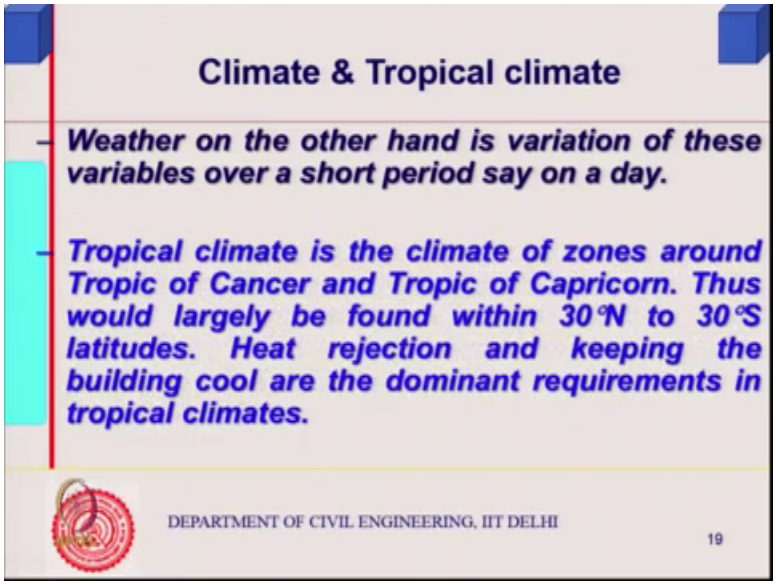
Student: 20.

23.5 South, while somewhere beyond that suns radiation, direct radiation, normally never reaches. Normal radiation never reaches receive. So, therefore, and the temperature will be lower there, because it receives less radiation and correspondingly every other thing will be and we have also seen the wind variation is caused by the suns radiation falling onto Tropic Of Cancer, Tropic Of Capricorn, etcetera. So, we classify three zone actually whole globe. So, up to 30 degree plus 30 to minus 30 plus minus 30, we can consider one zone, which you call as tropical climatic zone, tropical you know broad tropical climate. We call it the climate there is tropical climate.

And 30 to 60 on this side and 30 to 60 on the other time side would be subtropical beyond that is polar right 60 to 96 to 90. I take or entire take whatever it is, we are not at the, in our class we are interested in this plus 30 minus 30, because your, you know like building design is more complex there, because you might have summer, winter, everything put to there, where monotony is relatively less in subtropical climate. Monotony is relatively less is cold. Yes very cold, but then it is cold and cold maybe some places a little bit of summer, but that to the temperature is do not go as high as tropical climate variation in tropical climate in much.

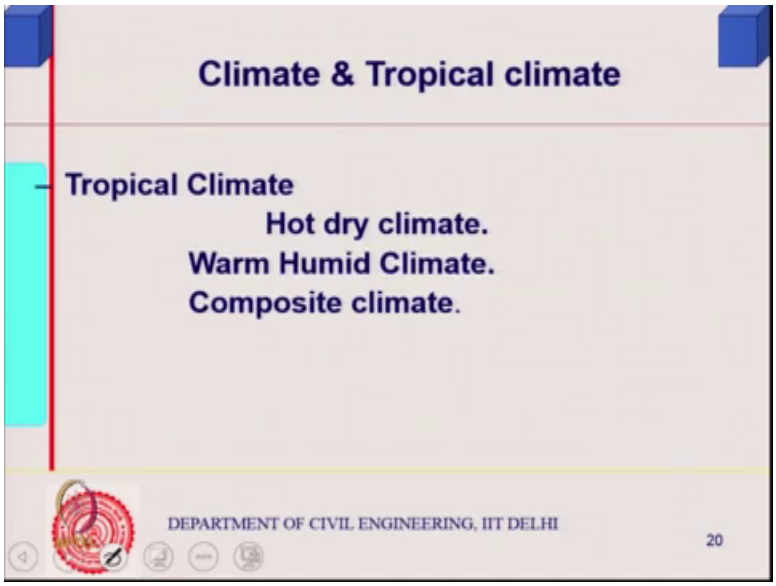
So, it is different kind of a challenge. So, we are trying to look into this. So, tropical climate therefore, we define something like.

(Refer Slide Time: 25:05)



Tropical climate is a climatic zones around Tropic Of Cancer and Tropic Of Capricorn. Thus, would largely be found within 30 degree North to 30 degree South, heat rejection and keeping the building cool are the dominant requirements in this climate right, other places loss of heat is you know their bothered to go to loss of heat, they would not like heat to be lost from the building. Well here would like to keep the heat away as well as sometime we would like to see that it comes right. So, that is the point.

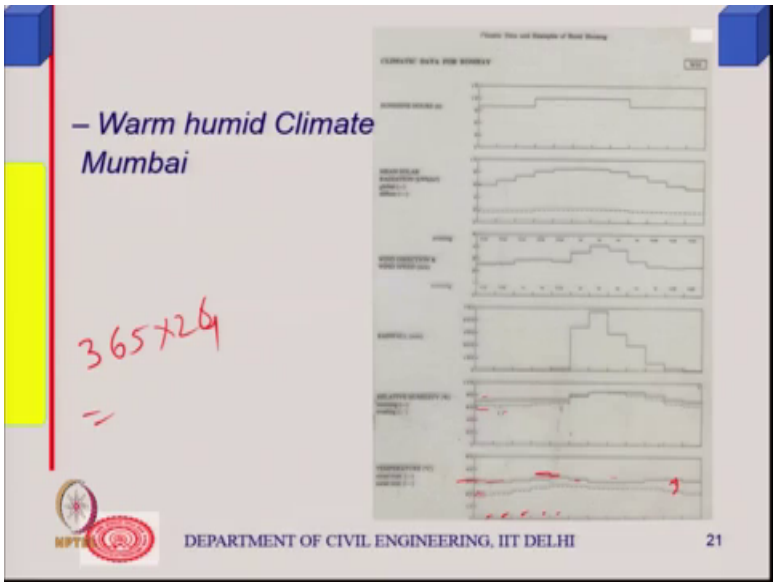
(Refer Slide Time: 25:46)



So, tropical climate again is classified into the climatic zones, and these are hot dry climate, warm humid climate and composite climates. So, these are the main climatic zone in tropical climate. I suppose if you know this like originally, this was given. I do

not remember the name exactly, but it is there in the reference that I have given you or the typed material that I have given you; it would be there in this one. So, hot dry climate, warm humid climate and composite climate. There is the main classification of tropical climate, but there are sub classifications, I will come to that.

(Refer Slide Time: 26:25)



So, let us say what is warm humid climate. The example here is, Mumbai. I am not sure very clearly, you can see that. See the diagram, but does not matter. Main important thing is, you can see the temperature variation. You know this is the mean monthly temperature being shown here.

In fact, we represent temperature. You cannot represent 8760 temperature, you can deal with. If you are, you know if you have program, but you want to get an idea about the climatic zone, and all you do not deal with 8760. What is 8760 365 into 25 24, how much it is. You know it will come to 8760 or some such value right so that, many hourly temperature or if you want to go further, maybe minutes, seconds.

It will be really messy to handle this. So, what we do? We take mean monthly temperature and maybe monthly maximum monthly minimum, but here for climatic understanding monthly mean is good enough. So, if you see monthly mean somewhere around, you know January, February, March, April, May. This shows in Mumbai. This temperature is somewhat higher, but the variation between these two is not very high compared to the next diagram I will show you.

Relative humidity is pretty fairly high 60 90 etcetera. So, one is, one of these, again this measure two times a day. So, you know one can have maximum temperature and monthly minimum temperature, maximum temperature and minimum temperature dotted line shown minimum temperature.

The form line shows maximum temperature, when it comes to relative humidity you can have similarly maximum relative humidity, daily maximum relative humidity and daily minimum humidity. Now which time you will have maximum humidity, early in the morning, when temperature is less, and in the afternoon it will be.

Student: Less.

It will be less, minimum. So, you know it is early in the morning, because it is related to temperature. So, we have now low temperature, relative humidity is higher assuming absolute moisture content, content is same, but if there is a precipitation, if there is a rainfall absolute moisture content will also change. So, we will discuss about this climate thing, just again for a small after a small break all right.