Electron Diffraction and Imaging
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Lecture – 02
Stereographic projection-1

Welcome you all to this course on Electron Diffraction and Imaging. In today's class we will start about Stereographic Projections. In fact, you might have heard of various types of projections which we use to represent figures in crystallography or in everyday in the textbook when you look at in various ways in which we gets and drawn. Is it just drawn randomly or is there, there is some method in the way in which it has been done. Yes, in fact there is a method the way in which it has been done.

Before we go into stereographic projections which is used in a crystallography and analysis of diffraction patterns we will talk about what all the different types of projections which are available. One of the projections which we can think of which is used very extensively in engineering is orthogonal projections. In orthogonal projection what we do it is when we look an object, like when we look at this object what we do essentially is that we draw a plan that is the front view, side view, and the top if all the three are taken.

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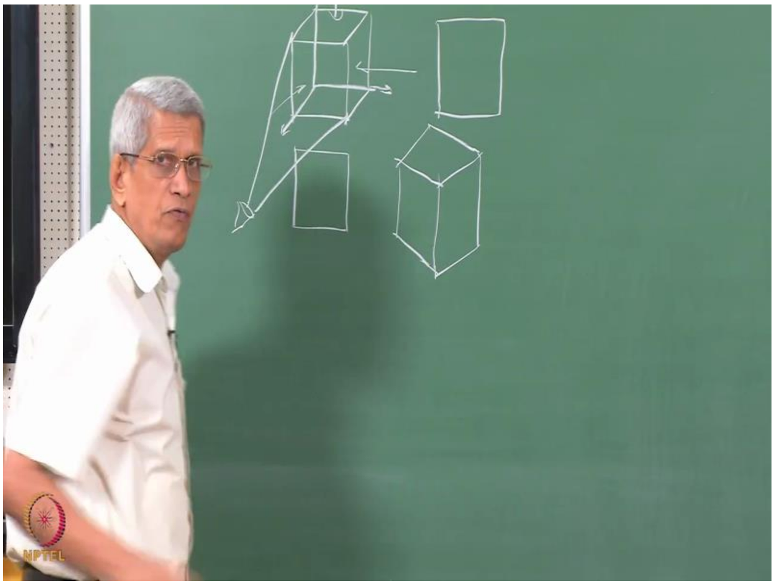

And this is a parallel view of the sample, essentially for example, if we have a cube like this. Is the simplest case which one can think of it could be a cube it could be a tetragonal any structure. When is view is from this direction? A view from this direction view from this direction you try to draw it this view will look like this, this view will look like this and the other view will also be looking like it straight different ones

So, if these information as there we can put them together and get how the object is, this is what it is being; what is used in engineering drawing to describe complex machines, and this is being used by different people that is somebody makes the drawing and then another person constructs the machine based on that drawing. So, we should be able to understand what the person wants it to be done. So, that can be done using this sort of a drawing. These drawing itself these are parallel view we can have a different view in which it could be taken. Then there are many ways in which these cube could be that is oblique views also we could take it in this orthogonal projection, then we look you might have seen that these are all the various ways in which cubes are represented in textbook each is can it taking some particular projection into account.

What is the other way in which we view it? Normally when we view most of our projections are perspective projections. When I look at this room at the light rays from various directions are coming on to the my eye; it is at a particular point it is reaching and the rays which are coming like this same cubic’s like viewing it from keeping an eye here and then trying to view it, then this is the way the rays will be going. So, this if you try to look at it how will this room look like. So, the perspective projection gives not a true representation of that picture. This is one example which I have taken.

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This is taken with a camera, because camera also when photographs are being taken it is nothing but a perspective projection which comes in the picture. Here if you see the region which is close to us, the distances the separation appears with this height appears to be quite this is very tall. As we go away from the camera we can see that the height decreases essentially this is moving in this direction. This is essentially because the angle which it substance to our eye or to the camera gradually is changing.

So, all the images which we get is essentially related by the angle which it substance to the imaging system ok.

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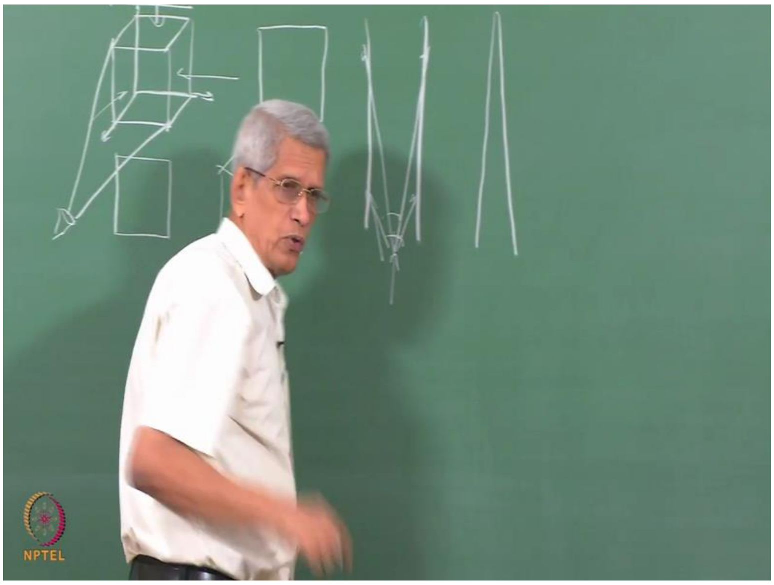

This way if you look at two parallel lines, like railway track when we take photography finally it is going to join at a particular place. This is what in a perspective view, because from here it will be making an angle like this, the one from here if you consider it to the eye the angle which this makes its large this makes it small, so still further. So, that is what it decides. In fact, when an object is very far away; like for example, when you look at a plane which is going in that sky after beyond a particular distance we find that it vanishes from our eye sight, because that angle becomes almost just 0.

This is what a perspective view is. And most of the sketches and drawing which we did is essentially of this type. Especially, when you look at many of this animated pictures and computers there they wanted to make it real like, there the perspective view has to be taken and that is how all the figures are drawn. Stereographic projection what is being done is that we use a perspective view and projections from some regions are being taken into account so that the angular relationships between the different points in that object are being preserved in.

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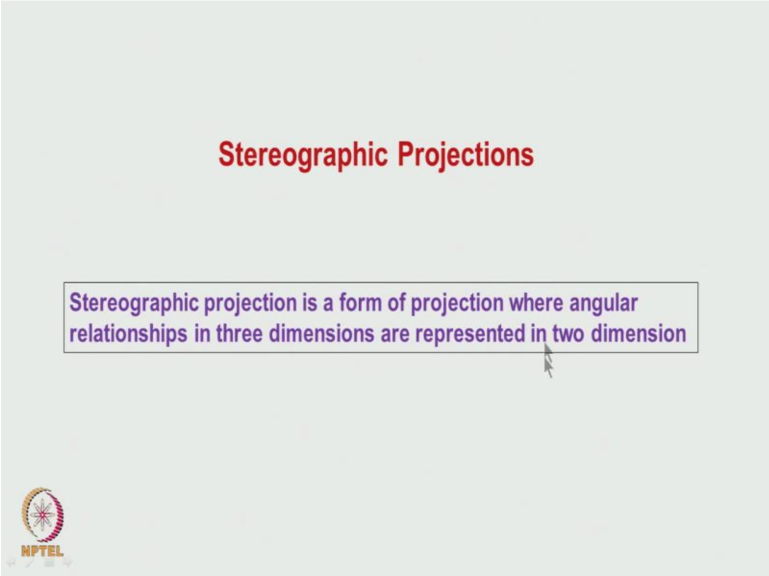

The two dimensional projection, because photograph also when we look at it. For example, this is nothing but a two dimensional projection of a three dimensional image, but when we look at it when in our eye gives an impression of that this is a three dimensional one because of the stereographic vision.

Stereographic projection is another form of a perspective projection where angular relationship in three dimensions in three dimension are represented in two dimensions and in the two dimension that angular relationship is preserved.

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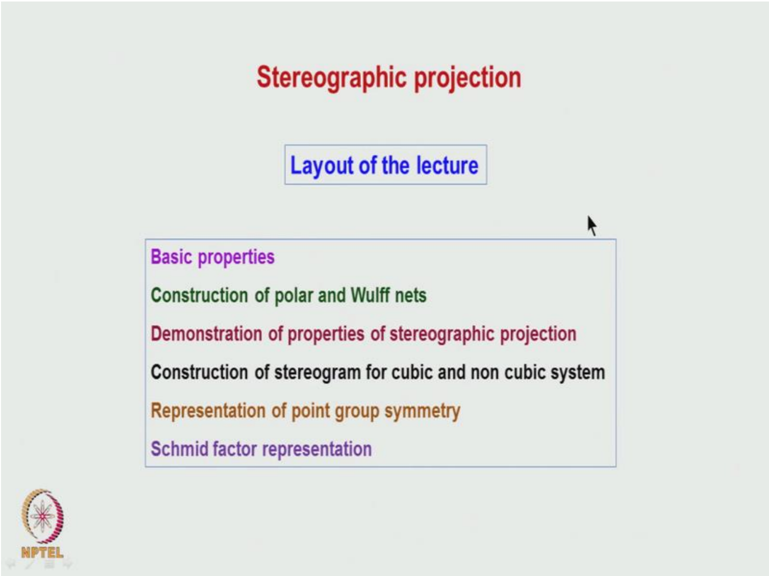

What is the layout of this talked essentially will be; that I will talk about the basic properties of this projection, the construction of different types of nets which can be used to get a information about angle of relationship between different planes. Some of the properties of this stereograms will be demonstrated. Then how to construct a stereogram for a cubic and non cubic system; this I will talk about it because this is very important in analysis of electron diffraction patterns. Then we have representation of a how point group symmetry is represented in stereogram that I will talk about it. These are all the aspects which will be cover in this lecture.

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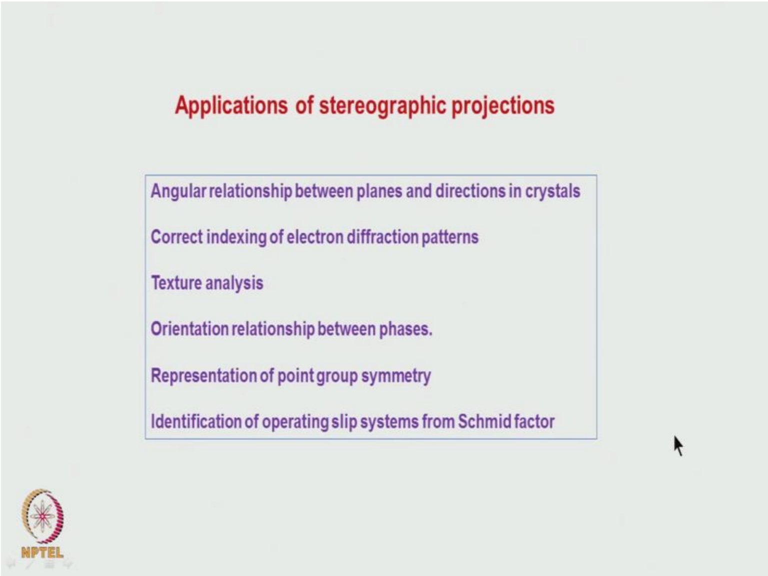

Some of the applications which one can think of; I mention the angular relationship between planes and directions in crystals. In that is any of diffraction patterns correctly we will be requiring this stereographic projection which we will be covering in a separate lecture; how to index a diffraction pattern. In texture analysis because essentially when many samples to get it to differentiate we deform it. During a deformation preferred a texture comes in the material preferred orientation of gains occur which is called as a texture and that can also be analyzed. And a strengthening between phases when we talk about difference phases form in a material.

Look at the strength essentially depends upon how different phases are oriented in the crystal in the matrix and that is the number density and the distribution, especially that how they are oriented, what is the habit plane all these information we could obtain using stereographic analysis. So, this also I had mentioned all these aspects.

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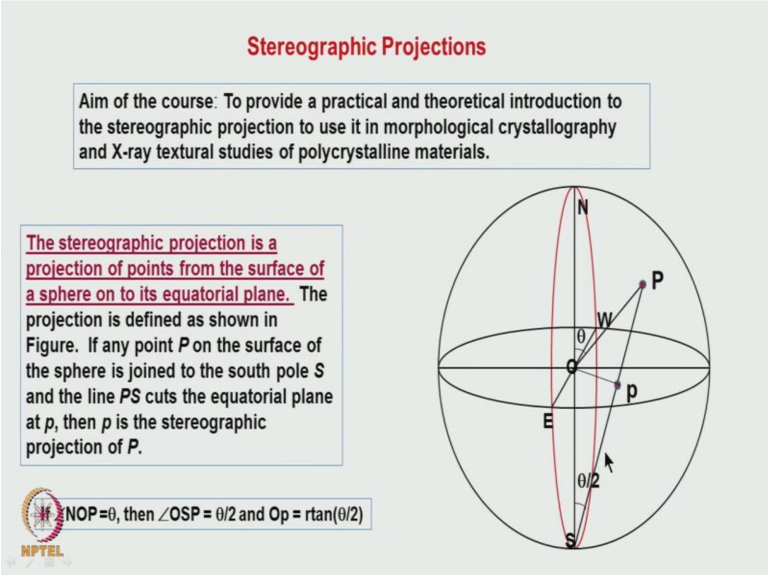

Let us got to what is a stereographic projection. Stereographic projection is nothing but is a projection of points from the surface of a sphere on to one particular plane; it could be an equatorial plane. In this particular case it could be an equatorial plane.

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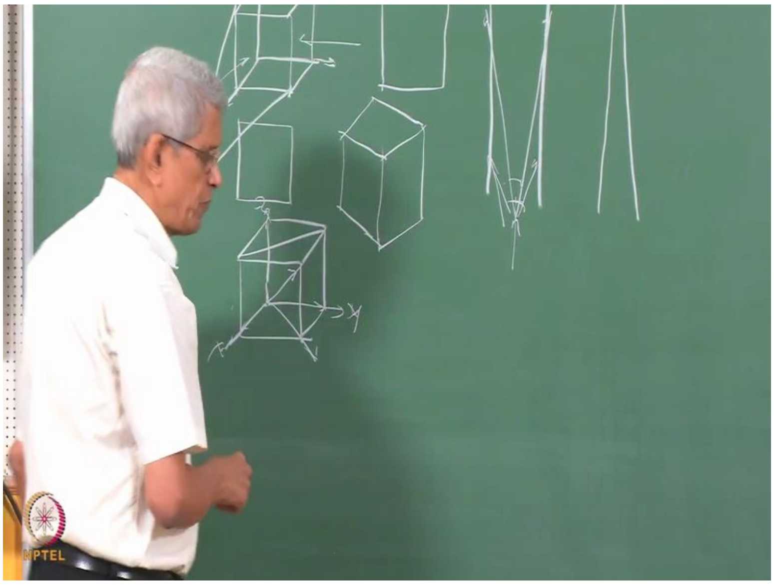

What is essentially done is that if we take a three dimensional object a cube x y and the z axis. In this the plane normal here will be this one, this is the plane normal; the plane normal to this particular one will be coming like this, plane normal in one one one direction will be coming like this. So, if you find out angle between the different planes they are lying in three dimensional spaces. So, measuring angle between different planes which are lying in different directions in space it is extremely difficult. So, if they all can be represented in a two dimensional figure then it is easy to do this measurement that is what essentially is done using a stereographic projection.

So, what is done in a stereographic projection is essentially is that suppose we keep an (Refer Time: 10:05) or be draw lines from the center of the cube to various points on that sphere. These lines as you can make out they will be cutting the sphere on the surface at some different points. We have taken one such line which is cutting at a point P. And this sphere we require a reference axis. So, normally we use in geography as we have studied we use a (Refer Time: 10:38) a spherical system, and we consider the north south poles and east west that same concept is being used here. This is the x axis where north south east west and this is x and this is y and this z axis is coming perpendicular. We view this pole from the southern pole that is if we keep our eye and view it from here then this is equivalent to the rays from different points on the sphere come and makes our eye.

So, for this particular pole the ray comes like this and when it meets. During the process it cuts the equatorial plane as a particular point. This is represented by small p. If the angle this P makes with the north south axis is theta from simple geometry one can work out that this angle will be theta by 2 and this distance o P from the center to this one on this equatorial plane it turns out to be r tan theta by 2. That means that every pole on the surface of the sphere is represented on the equatorial plane by a vector r tan theta by 2. So, there is an angular relationship is maintained in this way.

Now what we have considered here that is all the poles which are there we are viewing it from the south pole, then we view from the south pole; essentially the poles which are on the northern hemisphere only will be cutting through this a equatorial plane, whereas all others will be coming outside of this plane.

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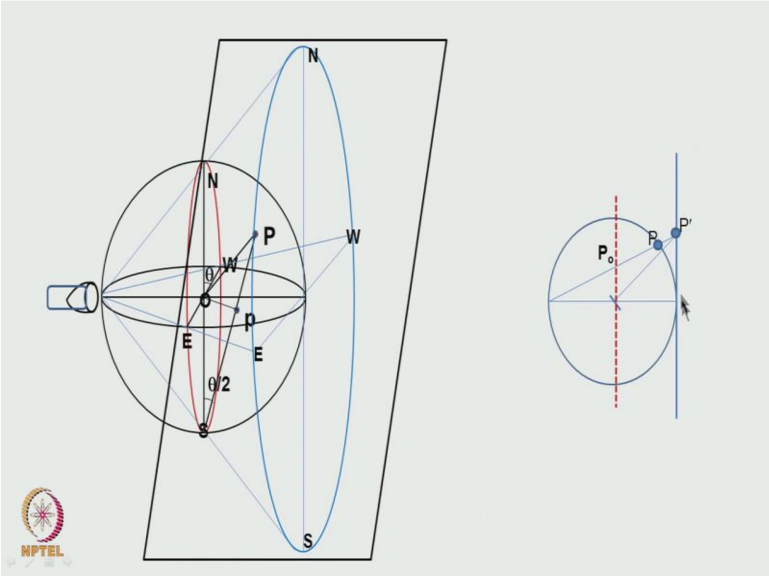

So, we can have this plane either the equatorial plane or there is another method in which we can do it is that. We can view from this direction and then we can keep a sheet of paper on a tangent to it on the other side of it, and then the same thing which happens. Essentially the rays will be coming and for the equatorial plane the rays which are passing through them there will be projecting it and generating a circle. This is called as their primitive circle. And then this projection P it will be a projected on to it that is what essentially is being done one section of it which we are trying to do it. These are point P which is on a the pole on the sphere. This is the direction from which we are viewing. On the opposite direction we have kept a screen, then the projection is essentially going to come here.

And then, if we keep on the equatorial plane this particular plane at the middle then this is going to be the projection, but if you considers the angular relationship depend upon what the radius it is going to be; this will be that if its r tan theta by 2. Here also this will be some r dash tan theta by 2. That is essentially only a slight change in magnification which occurs; otherwise the angular relationship is maintained here.

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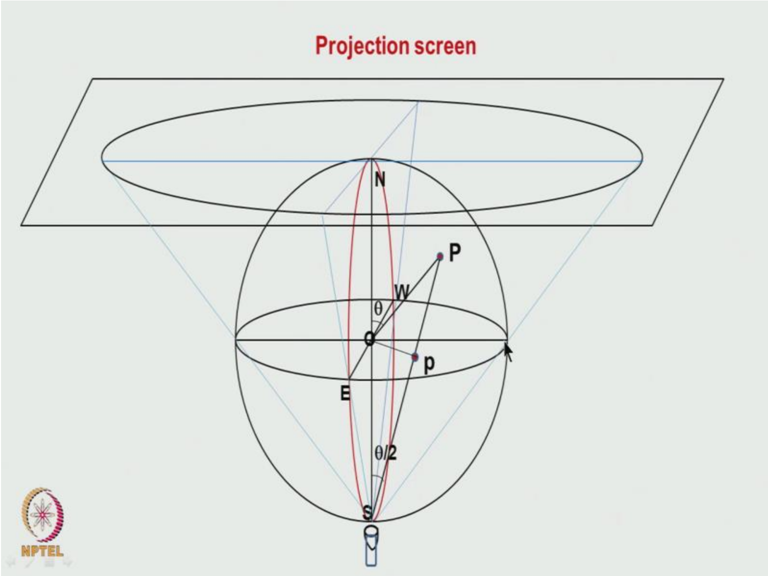

So, there are two ways in which we can view it, for the sphere with a north south axis. Either we can view from the south pole and get a projection, or we can view from this side also perpendicular to it and then get a view of this particular plane; that this planes normally which are passing through the surface of the spheres and passing through the cutting the center we call them as great circles longitudes or meridians. This is one way and this is the other way in which we can view it.

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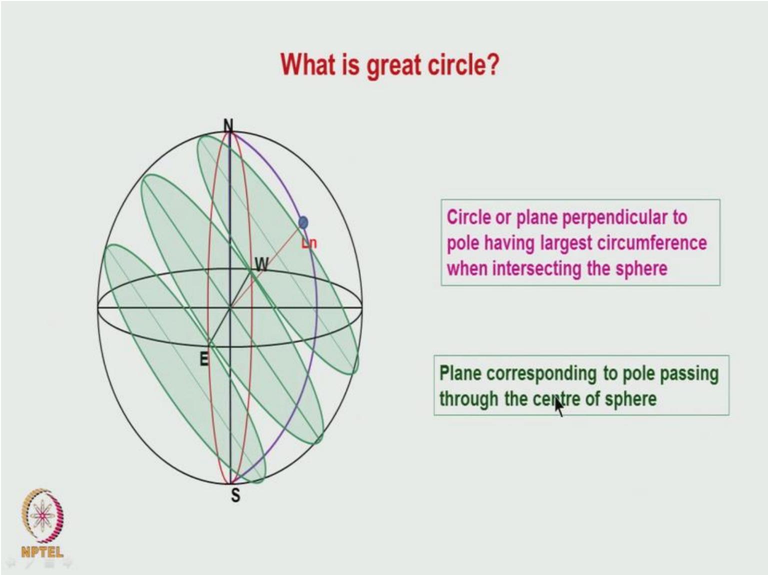

I just mention the term great circle; what is a great circle? This is a pole; this is what we consider this pole I had just drawn it lying on some longitude. Suppose, I am keeping a crystal at the center there can be some plane which is perpendicular to this pole, that is the line joining from the center to this pole. I can have many planes at different points perpendicular to it, but if I extend that plane it will come and meet the sphere on some surface. The locus of that point is essentially going to be a circle. If we draw so many planes like this from one end to the other end we will find that the plane which is passing through the center that is the one we has got the greatest circumference. That plane is normally called as the great circle ok.

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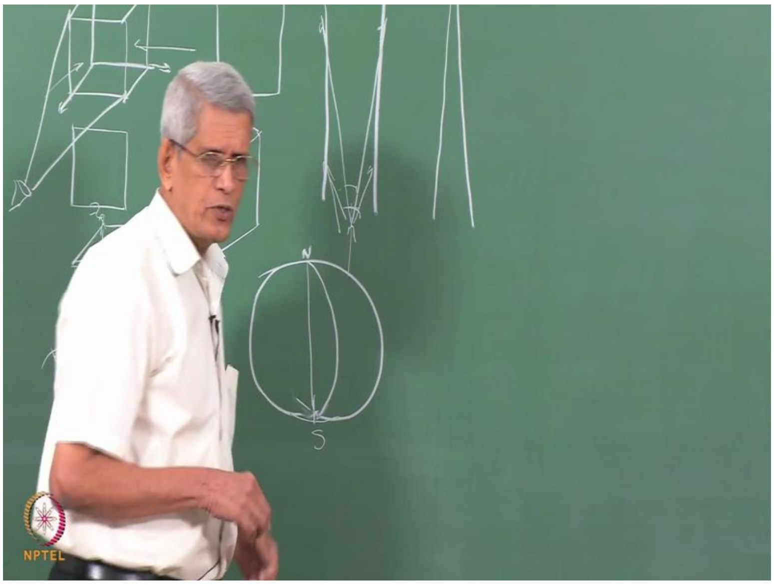

This is what essentially in the earth the globe when we draw it the north south called the longitudes are essentially circles on the surface of the sphere passing through the center. That is what essentially it means. So, this is called in crystallography or in stereographic projection we call them as great circle.

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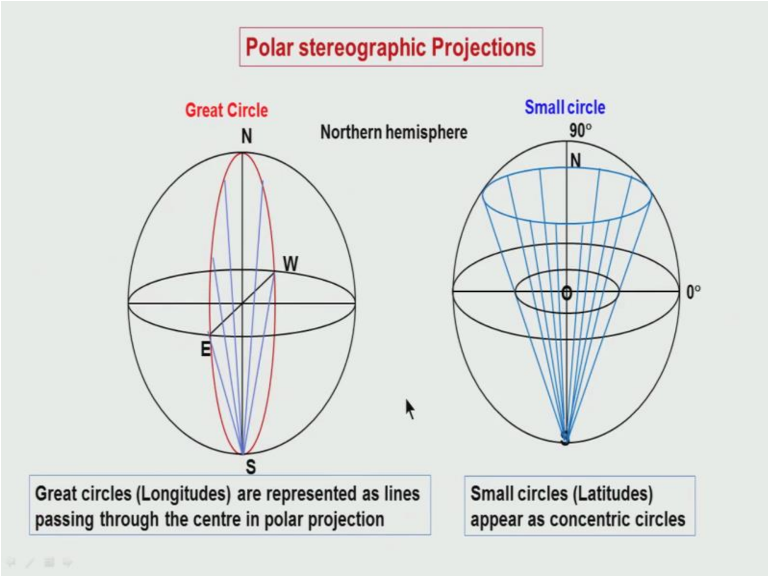

Now, we will look at some of these properties. We have consider it one particular point, look at its projection here what a projection what we are doing it is from the South Pole we are looking at a projection, There is one point is. There are many points can be there on the surface of this sphere and all of them, if you look at make an equal angle with respect to the north south axis; if that is the case the locus joining all these points is going to be a circle on the surface of the sphere concentric with the equatorial plane. These circles we call them as latitudes in geography. And these latitudes are parallel to a equatorial plane, but if you look at the diameters the diameter was given to be smaller this has got the maximum diameter equivalent to that of that sphere.

Now, if you look at the projection of it on to the equatorial plane the projection is essentially going to be a circle. That is for all the latitudes if we take a perspective view projection from the South Pole on the equatorial plane or if you keep a sheet here; it does not matter now which plane we consider it here also it is going to be essentially a circle. That is only in this projection that is in stereographic projection what we have done is essentially the various points on the surface of a sphere are projected on to an equatorial plane and that projection if you look at it retains that shape. That means, a circle on the surface of that sphere looks like a circle here.

Now, let us look at a plane here their north south east (Refer Time: 18:38) plane. When we look from here how will it look like in this equatorial plane? Now you can make out that the rays which are coming from the different points on the northern hemisphere that is cutting into at some different points. And the locus we turn out to be in this particular case is a line. Similarly, we can look at this great circle which is lying on the screen. Then here again if you look at the projections line, this is essentially a line; just let me see from here this is a line. This projection if you consider it all the lines which are going to come from here like this way they will be coming from here that will give rise to this particular line that is right.

That is what essentially is being shown in the projection of the equatorial plane which is being shown.

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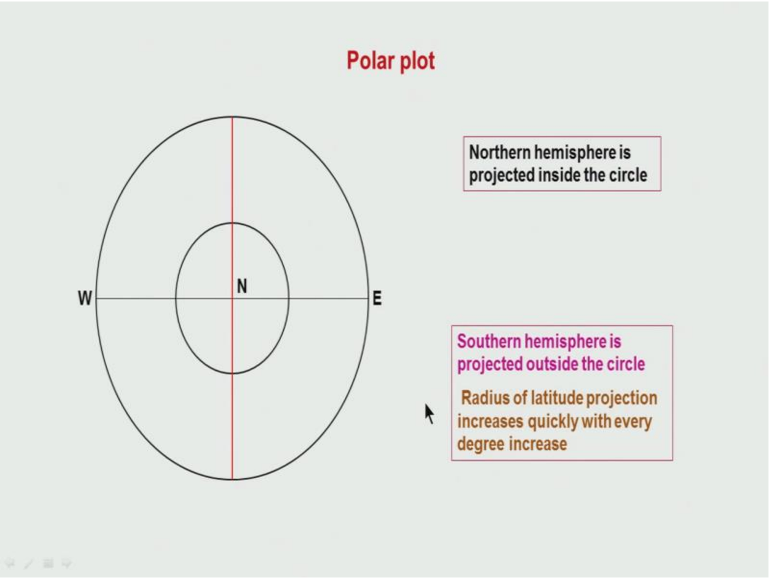

Now, we can see that all the latitudes come as concentric circles all the longitudes come as diameters which are passing through the center. And if you view from the southern hemisphere that is from the South Pole we essentially get only the information on the northern hemisphere which is coming into this picture. And another is that from here to here the away from this that is closer towards the equator when we comes different latitudes which have got where the angle of the latitudes makes with the equator is very small. The angular separation is large this is because of the fact that is r tan theta by 2, the factor which comes into the picture.

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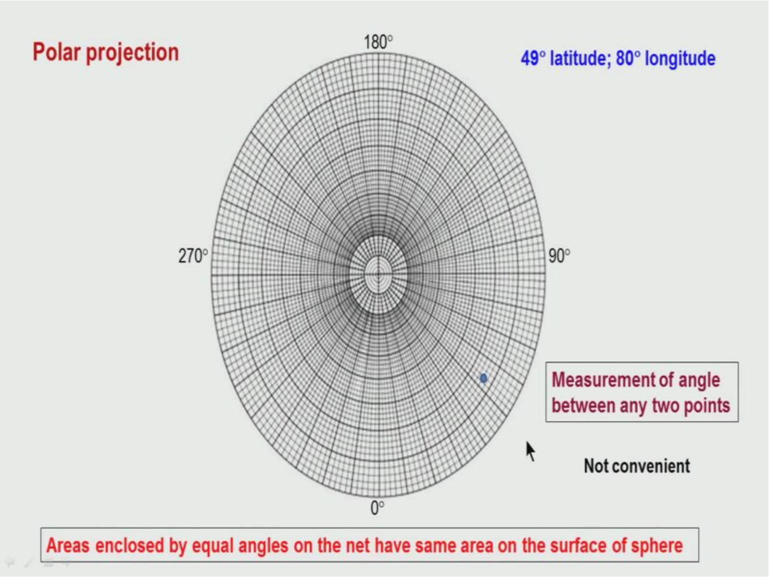

The take as sphere like this we have different latitudes and longitudes which are marked every 1 or 2 degrees the globe. And we look at a projection from the South Pole then what we will be getting it is concentric circles like this. In this particular case it said by every 2 degree. And the then all these diameters which we look at it the angular separation between them is every 2 degree. So, this is a sort of a calibration plot which is available which can be used to measure angle between different points. And if you look here the area wise if you see it this looks as if it is a larger area, but angular separation if you look at it here as well as here the angular separation is that same.

So, essentially the angles are preserved but if you look at that actual area, area is not preserved. But on the surface of the sphere if you look at it angles have been that same area will have angles describe in the same area on this polar projection, will have the same surface area on the surface of the sphere. Suppose you wanted to measure angle between two different points then what is going to happen; here is that it is not a very convenient method by which it could be done. For which another type of projection we said that from any direction we can have the projection instead of the North Pole. There is another projection which is being used and there it is easier to get information.

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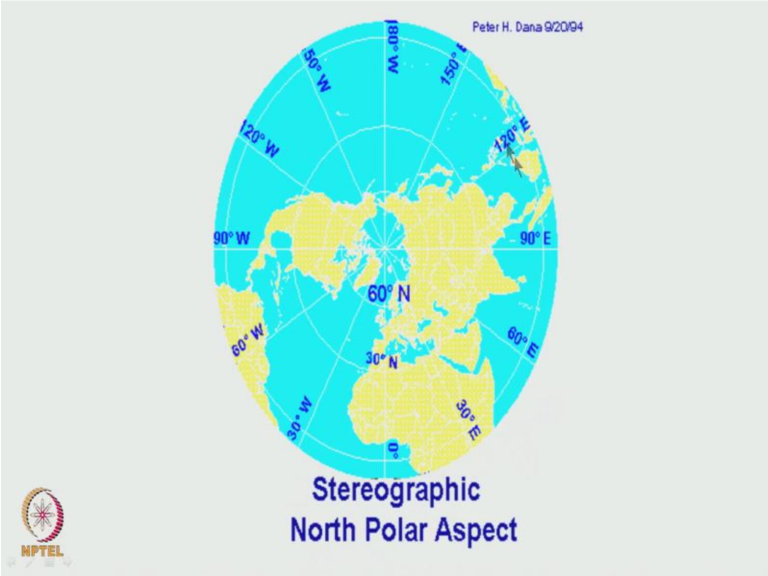

Here essentially I am showing a polar projection of the earth which is shown; this is of the northern hemisphere. And the areas here that is angular area if you consider between the different angles if you consider angular area. And here angular area will be the same, but it looks in the figure that actually this area is large. So, this is not true.

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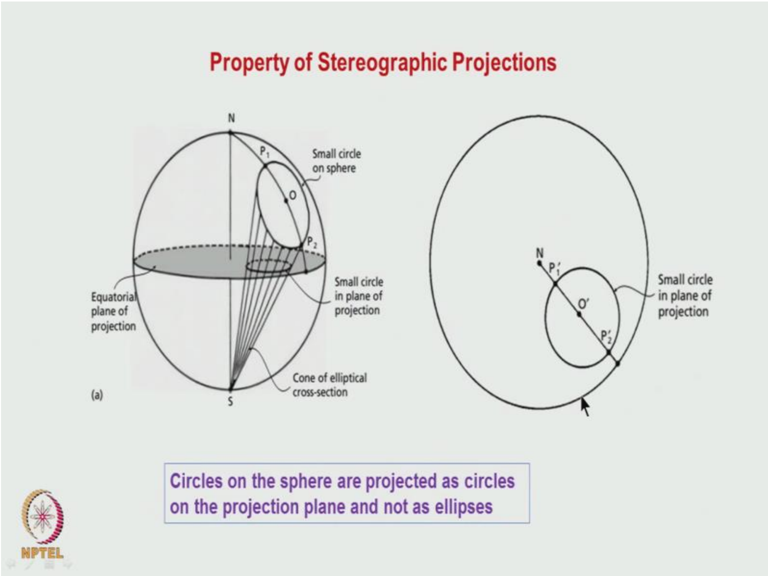

What all the other properties? Suppose it is not a circle which is concentric with the North Pole, even when we view from the South Pole around a point there is locus there is a circle is there on the surface of the sphere. This circle when we look at the projection that will always turn out to be a circle in the equatorial plane projection. That is an important aspect of stereographic projection. In all other projections the circle on this shape, if you take a parallel projection that will be projected as an ellipse. Here the projection retains that a shape.

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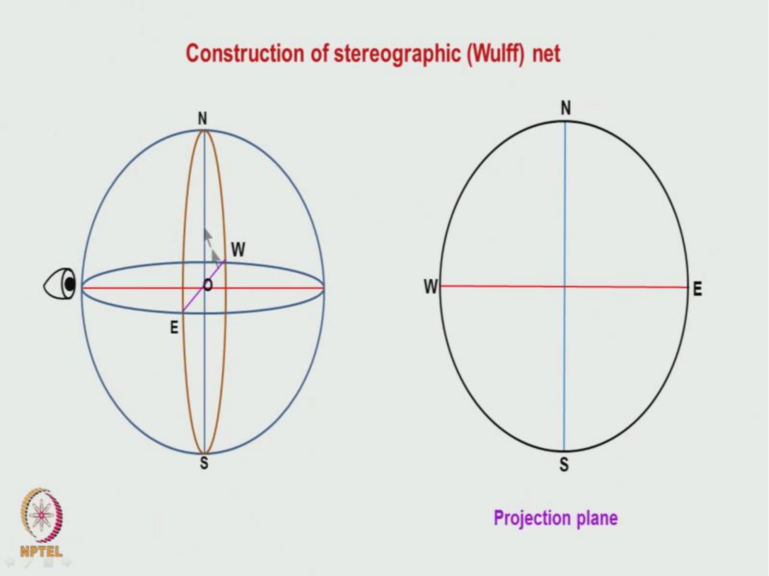

Earlier what we did is; this is now we will talk about polar projection we have talk we have to put another projection which is called as a Wulff net. In the polar projection when we viewed from the South Pole these are all the longitudes, when we viewed from here how we got it. And instead of viewing it from here we can keep an eye here and view it from this. So, we are essentially using a great circle or a projection plane which as perpendicular to this equatorial plane.

This plane if you look at it this is how it will be in the projection plane it will appear east west north south. And the projection of this plane will appear as the equatorial plane projection will appear as an east to west the equatorial line. The other one this projection north to one there is the projection of this circle itself will appear as north along the north south axis projection.

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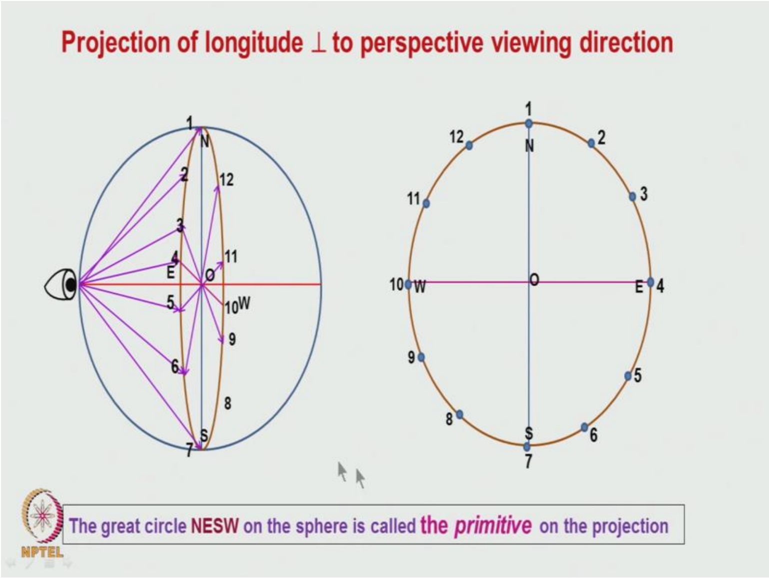

So, if any point on this projection plane if you consider it all of them will be; the rays will be coming from this is the three dimensional projection which we are showing it. Each of this point how will it appear on the projection this is how there will be all lying on this circle. This circle we call it as the primitive circle as I had explained earlier. And equal angle on the surface of the sphere will appear as equal angle on the primitive circle. That means that this can be graduated, here a point if you consider two points it makes some angle. And this distance also if you look at it you will correspond to the same distance which the arc makes it on the surface of the sphere.

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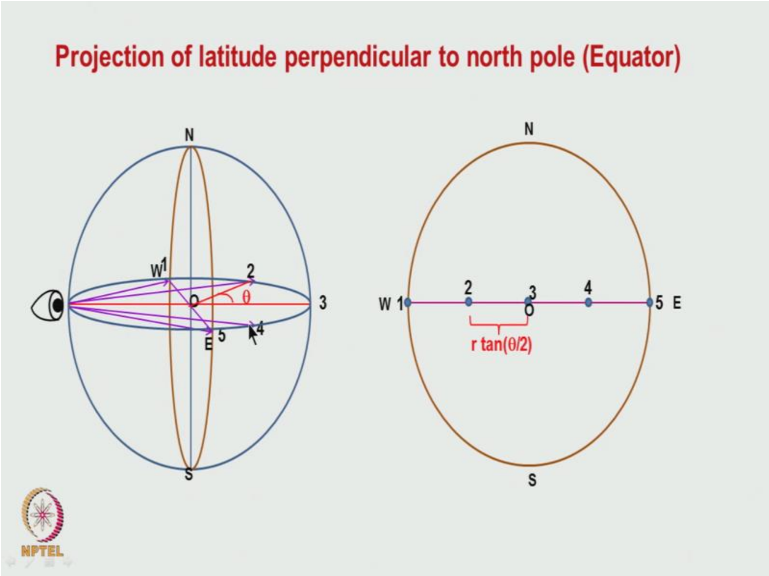

Now, suppose we view only this equatorial plane; how it will appear the equatorial plane will appears line, but what is essentially important is that different points on that equatorial plane if you look at it. Having that same arc the distance which is going to be there depending upon where from we are measuring it. With respect to the center if we consider it the distances are going to be r tan theta by 2; that is on the circumference they are equal angle, here when you go and different angle away from the center, then the angle is going to be given by the distances are going to be given by r tan theta by 2. This is what one should remember.

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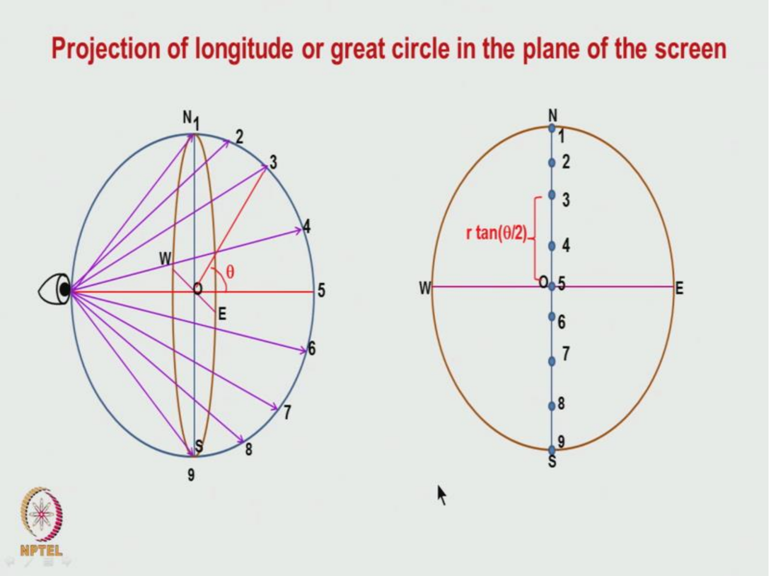

Similarly, the projection of the great circle lying on that plane; if you look at it on this projection plane, here again the various points which have that same angle when we try to look at it, the separation if you try to see it that we gradually increasing as we go away from it.

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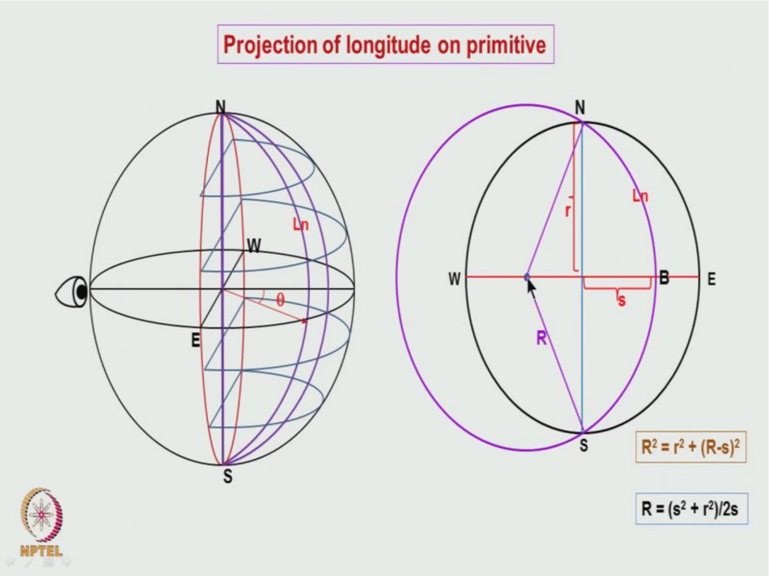

Now, what we have considering it is projection of; so far what we have considered the three planes: equatorial plane, the plane of projection, and the another great circle which is lying on that screen. These are all the three projections which we have consider on this plane of projection. Suppose we have an longitude like this which is lying there and this longitude meets that equatorial plane at this particular point making an angle theta with respect to this axis. Then, how will this plane be projected. This is only one part of it which we achieving in the other part of it will be coming on the other side of the sphere.

This projection if we try to look at it these angles since we know it is going to be theta. What is the point at which it should come that will be given by r tan theta by 2 that is what essentially this distance which is going to be there. And as I mentioned all the circles on the; that is all the great circles are smaller circles on the surface of the sphere on the projection plane they appear as only the circle. That is what essentially, but the radius could be larger or smaller, but the shape is being retains.

This is what it happens in the stereographic projection. If you remember that now we can see that this circle also has to be projected as a circle. Only thing which will happen is that part of the circle which is there in the northern hemisphere is within this projection plane. The other part of it outside in the projection plane that is where it is outside of the primitive circle; if you want this projection if you look at it this is like a perspective view we have just seen that logically we try to understand this is how it will appear.

But when we have to construct calibration nut we cannot take photograph and go about turn do it. So, there should be a method to calculate it for which what we can do it is that from here if we know; what is the angle which it makes from this particular one every angle which it makes. The distance at which the point will appear on the projection is given by a r tan and theta by 2 that information is there and it as to be and arc which as to cut. So, if that this the case this distance the card length is always going to be r, only this distance is going to vary, depending upon that angle.

Now we can using this simple formula we can find out what is going to be this card length we know, and from here to here this length is R minus s. Now we can immediately find out what is going to be the radius. Then from this particular point we can measure a distance and find out where this radius of this circle will be. With this as the center on this primitive we can draw a circle, the part which is lying within this; this is the projection of this longitude on to this projection plane.

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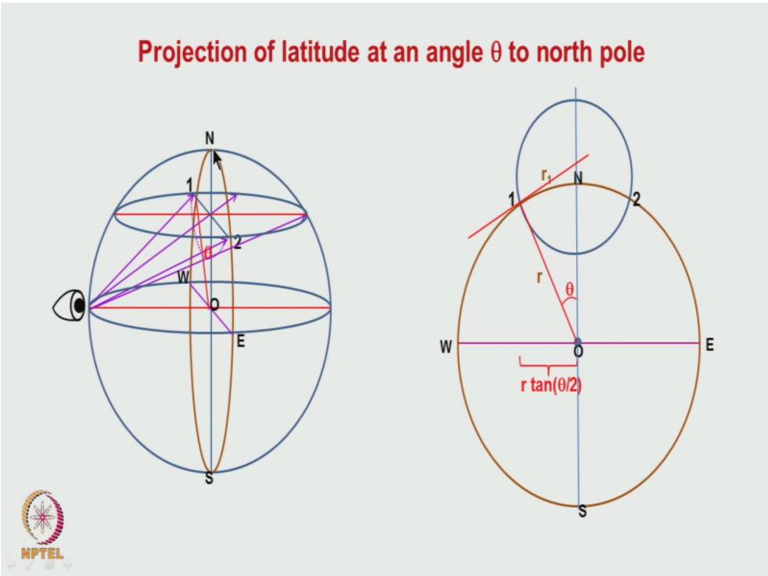

So, what we considered was essentially respect to longitude. Let us take the case of latitude. In the case of latitude also; this is also a circle on the surface of this sphere so the projection plane it has to be some arc of a circle which it as to come. That is what we achieving from the specific being, this is how it is going to be in the projection plane; that is what is being. But this is a essentially they way we view it, but if we have to generate it then what we have to do essentially is that what is that angle which they make as a mention earlier then we can do that.

And then we can find out depending upon that angle at what procession that is from with respect to a center if you take it this is making a particular angle theta with respect to this. Then we can, we will be cutting the primitive and this particular point. Draw a tangent where that tangent will be meeting this north south axis at different places depending upon suppose a draw a tangent here it will be meting it some, and this is going to be there radius. From here to here this distance is the radius, you measure this radius and draw different circle. The arc which is cutting within that is essentially going to be the projection of the latitude.

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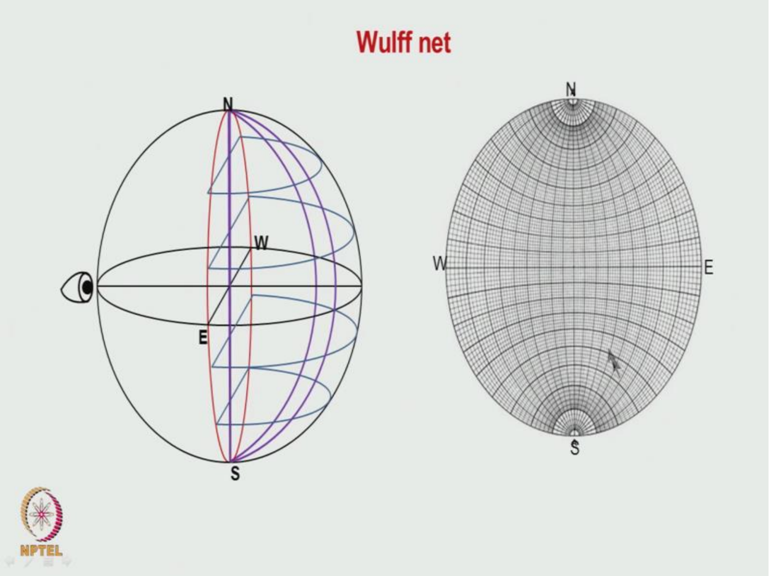

This we can do it for every degree; are very 1 degree are every 2 degree and generated calibration chart. That is essentially is a shown here. This is called that the Wulff net. Here this is the projection of all the longitudes at different angles from the equator which are meeting on the equator some different angles, and that we can make out that these are all arcs of some circle and the then all the latitudes are also arcs of some circle this is with appears. We can calibrate this because this angle can be calibrate from 0 to 90, from here also 0 to 90 degree, here as well as here and here also it is being calibrator that angle 0 to 90 degree.

If you look here the angle of separation domains that same, but if you go from here to the center the angle of separation decreases, as I had mentioned earlier. This Wulff net is the one which is use as a calibration net to do various analysis of the result which have obtunded t e m. But what we will talk about it is a first how to use this.

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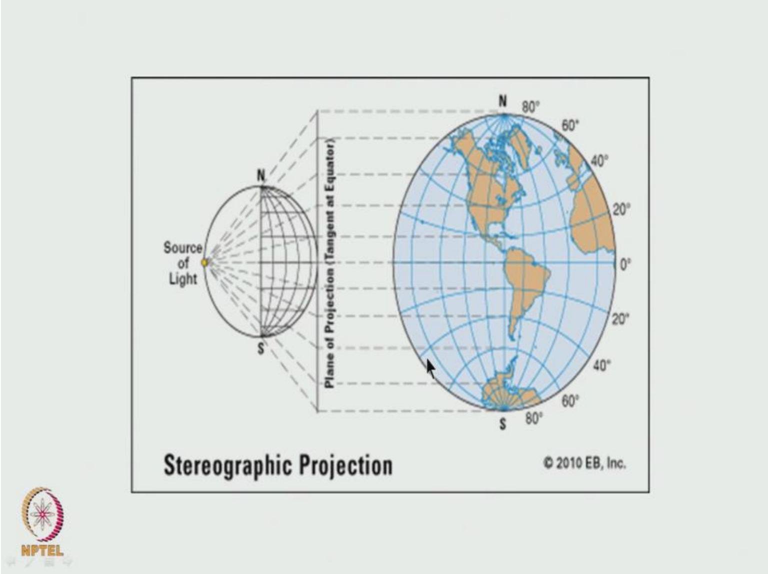

So, the normal projection of the earth which we see is nothing but a stereographic projection. This is how we have studied in a forth standard or fifth standard hold the earth looks like.

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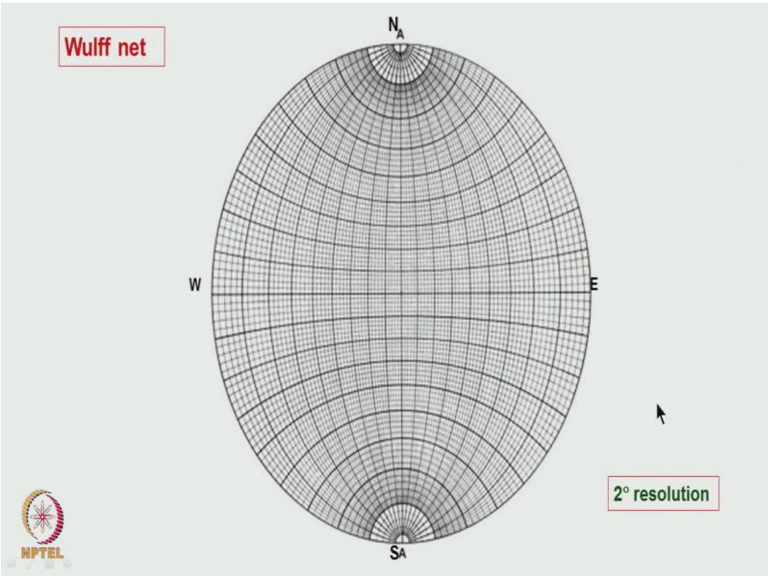

And in this particular on case it is 2 degrees a solution. There are many stereographic project Wulff nets are available with 18 centimeter, they give and 1 degree resolution. Using this generally the angular measurement could be carried out with accuracy about two to three degrees. If you wondered then accuracy better than this we have to do excite computations.

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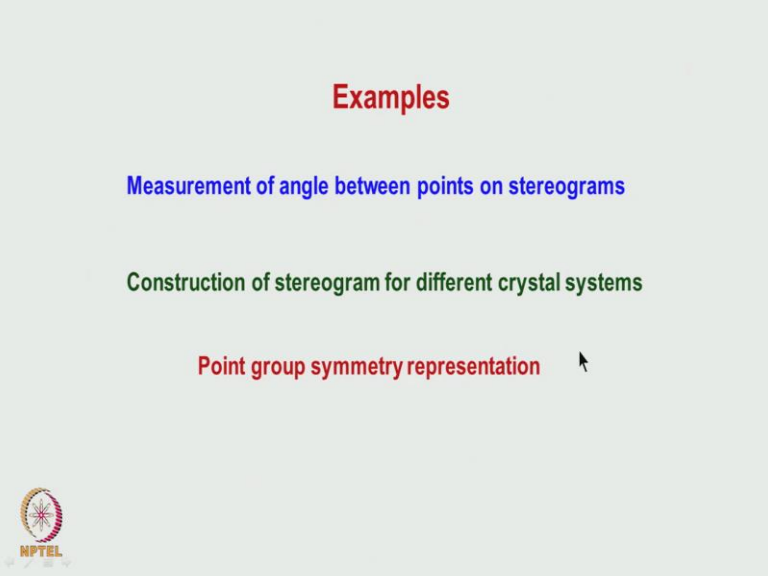

Let us take some examples how to use this to measure some angles. The cases which will you considered one is measurement of angle between points on the stereogram; that is one. Another is construction of stereogram for different crystal structures; this is very important, this accepts I will discuss it. And as mention point group symmetry is also represented in a using stereographic projection; this also how it is done we will talk about only just three.

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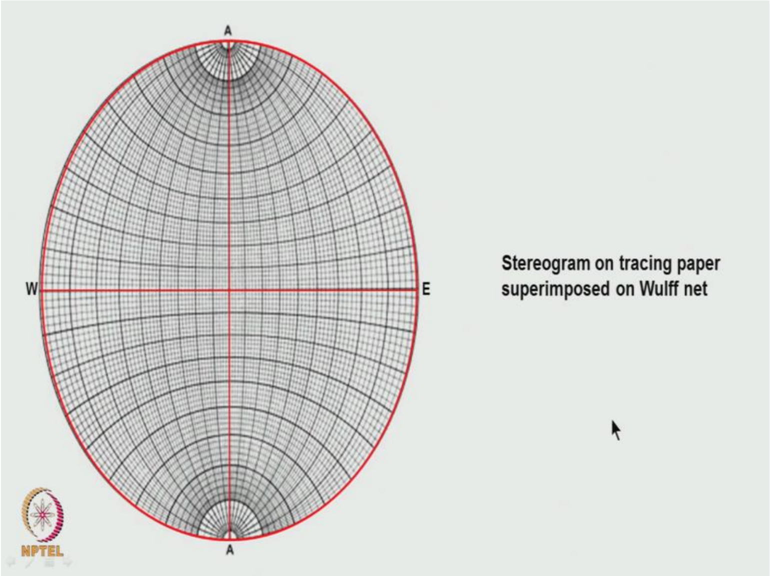

What is first which you have to do? On the stereographic net Wulff net which is available keep at tracing paper, draw the primitive circle, and also draw the east west axis and the north south axis so that we have the reference axis which are there. Generally as a convention if you follow from here to here this is used to x axis, this is as the y axis, is z axis is one which is coming from this particular point. Then what we do it is that if you wanted to do very measurement this Wulff net is kept constant, we pin them together at this center and by rotating this tracing sheet whatever the operation which we wanted to do so that all the angular relationship could be measured. That is what exactly is done in a stereographic projection.

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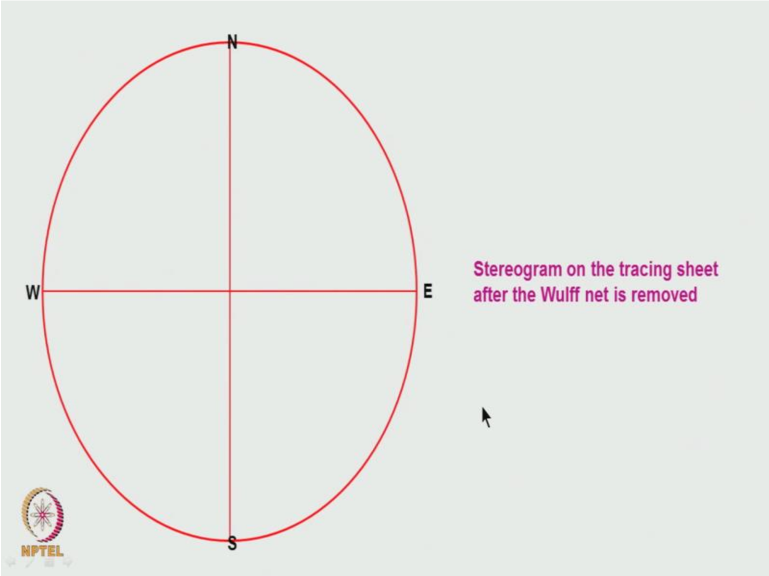

Now, what is done is I had just removed that Wulff net. So, this is how it appears. Let us take one example.

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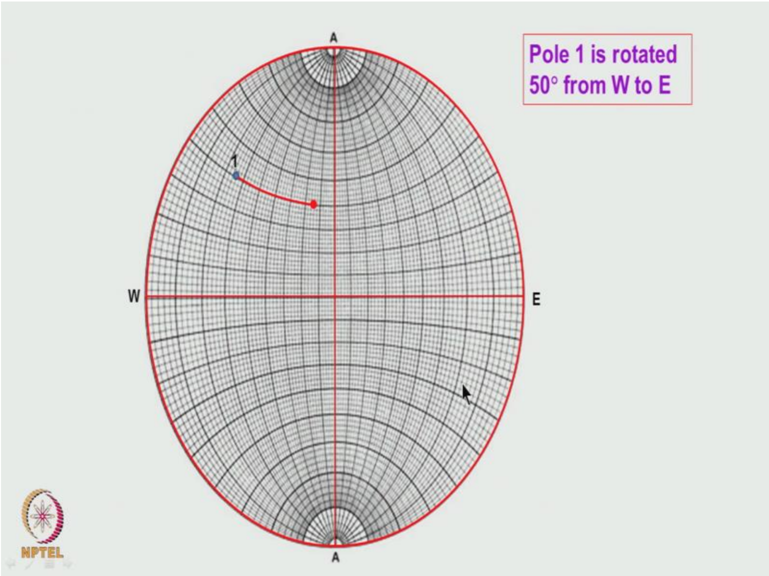

We wondered a point is there on the surface, these are pole and the surface of this sphere, on the same latitude it is rotated 50 degrees from west to east. So, from this point it is rotated and it is coming here. Generally if they are lying on that same latitude, if we measure the angle directly on this latitude that gives what is it going to the angle. So, essentially what we have to do it on the same latitude which we move measure 50 degrees m r this is going to the new point.

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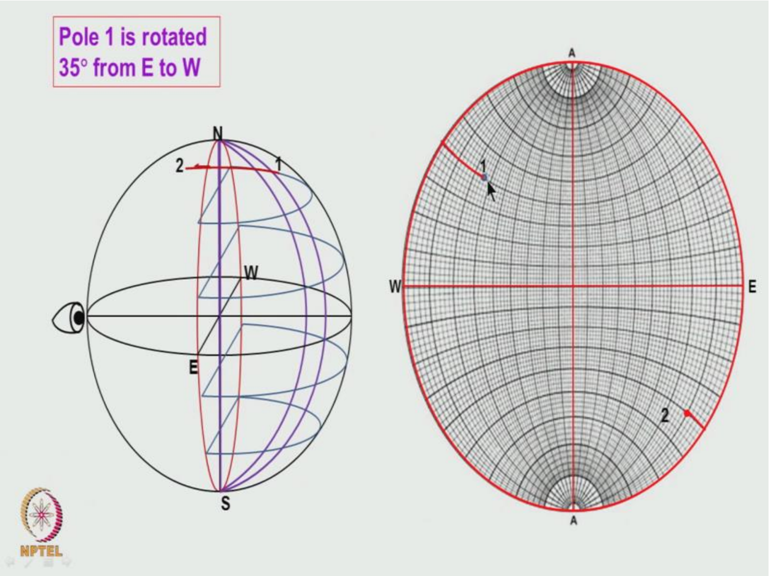

Another is example which I am showing it with a sphere itself, and this attitude it is being more 35 degree from a point 1 and it is to reach a point. But if a look at it after some angle of movement it is coming on to the southern hemisphere. When we comes on to the southern hemisphere what is essentially is going to take place is that; the point which are going to there and this way if you take a perspective view of it they will not be coming within this primitive circle; that is exactly what happens here.

As I mention when they are one the same latitude in the stereographic projection also we have to move on the latitude; that is what is essentially being make. Here is about 25 degrees, then the other 10 degree when it has to move it is going to be outside of this or on the other side of the sphere which is going to be there. That how exactly we can representative is that. We have seen with the eye from this side suppose we keep the eye from here and try to look at it and then what it will happen; there is all the point which are going to be there on the other side, this part of the hemisphere that is the left side of the hemisphere they will all be getting projector on to this point. But since a coordinate system is fix, if we make the correction for it then what it appear is that equivalent latitude on the other side we have to move another 10 degree entries. So, this is how the rotation will be effected.

This is one a important thing which you should always remember that whatever is the moment which is within this which it is going out of it and that angle is larger angle rotational as should be done. Then it is not projected on this side, it will be coming on to the other half. This is how this projection will be.

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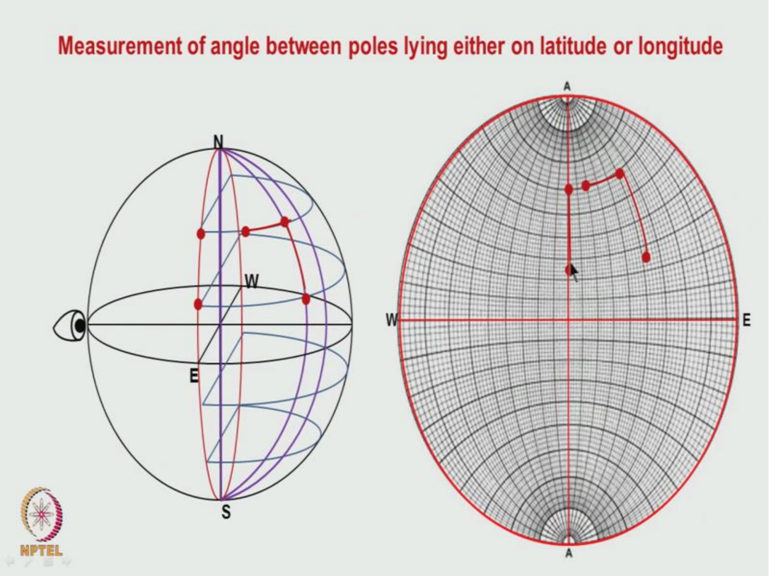

And here, what I can on the globe itself are that is sphere there are some poles are lying: one pole here, another pole, another one, another one, this poles. If we look at this poles are lying on this same latitude this also this two. These are lying on the same longitude, this also lying on the same longitude. How it will appear on the stereographic projection, in the stereographic projection? One is appearing it like this that is from here to here, I think this some mistake if these which is going to be there on the surface should appear somewhere here from this. This projection is appearing it in this way, the one which is lying on the latitude this is the way to appear with the maintaining that same angle. The one which is lying like this in the equator that is essentially going to be the projection nothing but from here to here on the plane that is the great circle which is lying on this screen.

So, the direction measurement are easy when there is lying on a latitude and the longitude; angular measurement can be measure with a easily that is very important.

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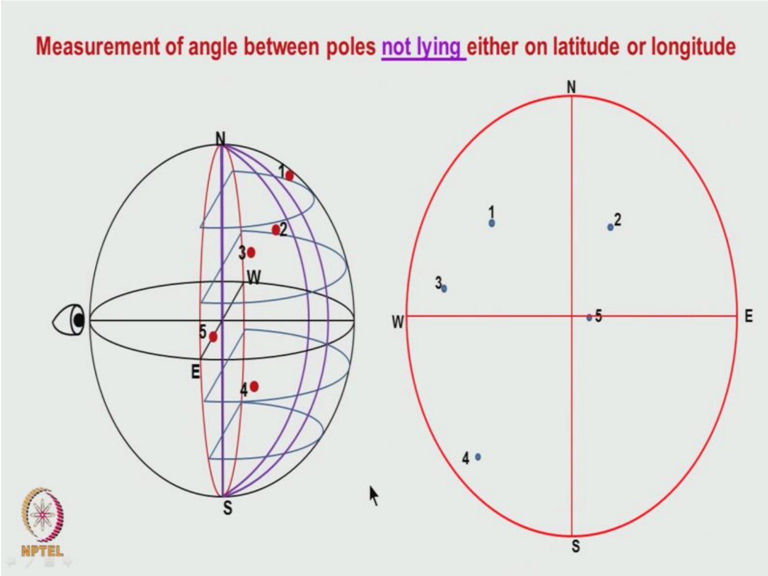

Now, let us look at a case: that there is one point here above this latitude, another point below this latitude, there is the third point somewhere else, there is another point which is somewhere else and this spheres. So, various point is there. This points if you try to represent it on the two dimensional projection this is how it appears that is one the pole one is here, pole two is here, three is here; we wanted to find out angle between all these poles how do we go about. To do that we keep this on top of a Wluff net.

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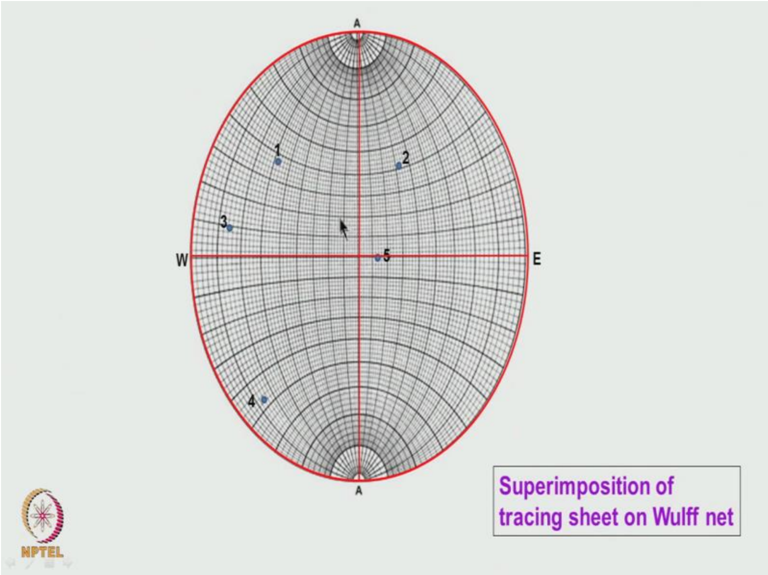

Then if now we try to see it 1 and 2 is not the lying on a longitude and latitude, 1 and 5 there not lying, not 2 and 5, not 1 and 3, only 3 and 4 if lying on a longitude then what we do is that suppose we take the case angle between poles 1 and 2 you wanted know it. Then what we do it is the super imposed one.

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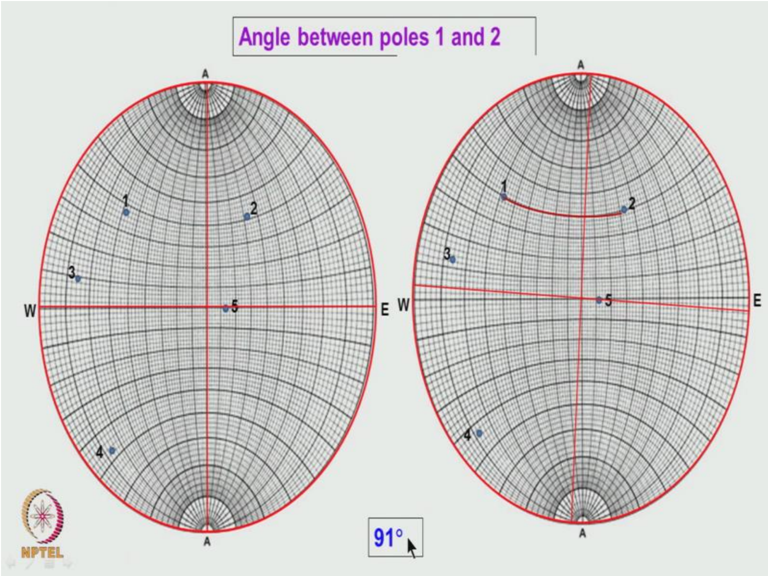

Now we rotates this at the center at the center by a small angle when we rotate its likely rotated then you find it 1 and 2 are coming on the same latitude. Now we can measure that angle between these two points, and this angle turns out to be 91 degrees between 1 and 2.

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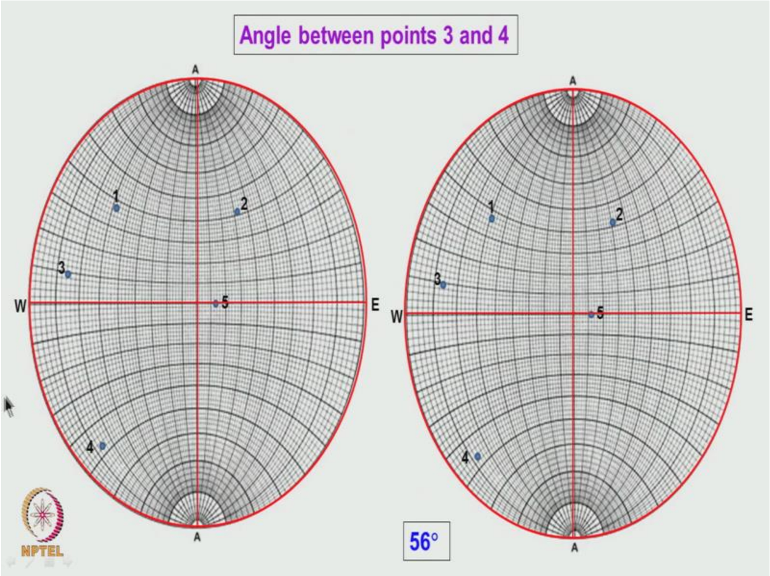

Now, in this case we wanted to measure angle between 3 and 4. The 3 and 4 since there lying on the same longitude we can measure this angle directly keeping at in the same position no rotation is required that angle turns out to be 56 degree.

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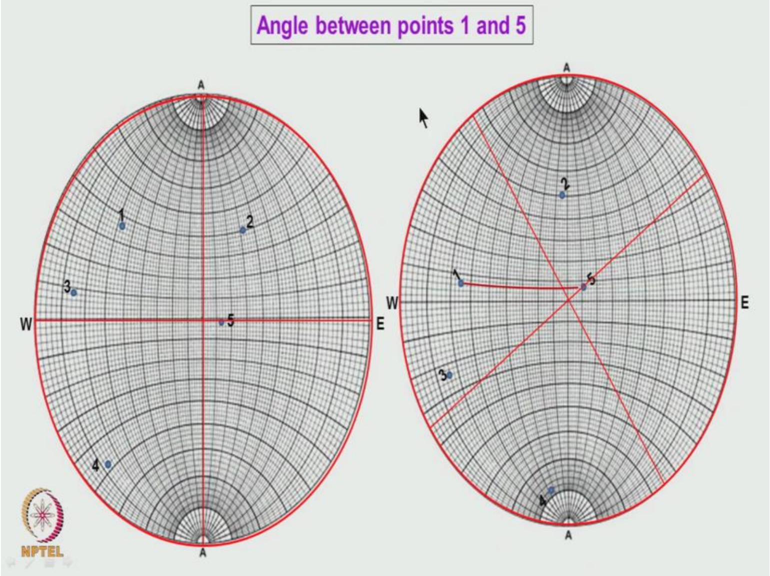

Suppose between angle 1 and 5; if you wanted to measure it what we have to do it now we have to rotate this tracing sheet around this center that is essentially what is being done. The axis been rotated so that 1 and 5 that is you rotate it like this in this way. So, this axis comes here and this axis comes that why essentially it is being done 1 and 5 is lying on the same latitude. Now we can measure that angle separation from here to here if you measure this turns out to be 86 degree. This is how we have to find out angle between different points on that surface of the sphere.

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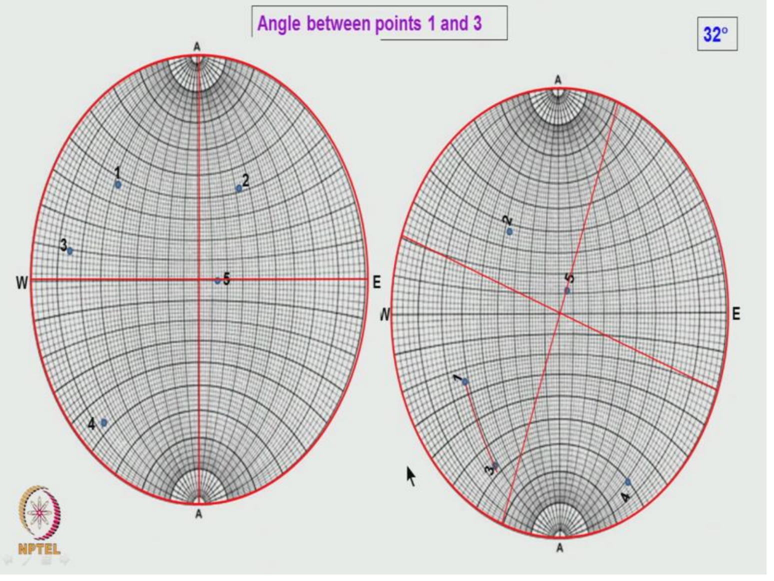

In two dimensions in is using as stereographic net we can measure it. Here what will angle between 1 and 3 the same way a rotation has to be done so that these to lie on a latitude other longitude. Here that it has been rotated it is lying on longitude and then this angle is being measured. This angle in this case turns out to be 32 degree.

So, with this various examples what a have try to demonstrate is that how to use stereogram to find out angle between different poles which are lying on the stereographic projection.

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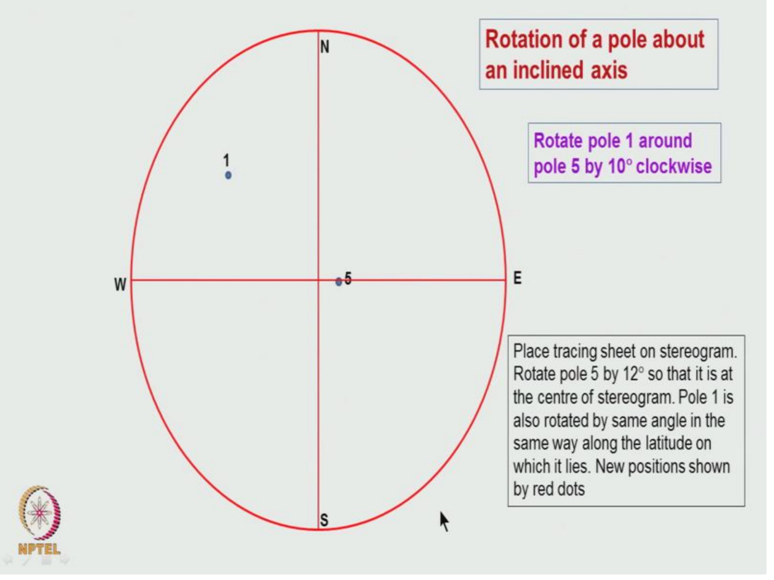

This is a another case where what we are construing it is there is one pole and when view wonder to measure between a two points what we did is we rotated with respect to center. Now I wonder to rotate this pole around another pole which is not lying at this center, then what will we do. These is what it is rotate around pole 5 by 10 degrees clockwise we have rotate it.

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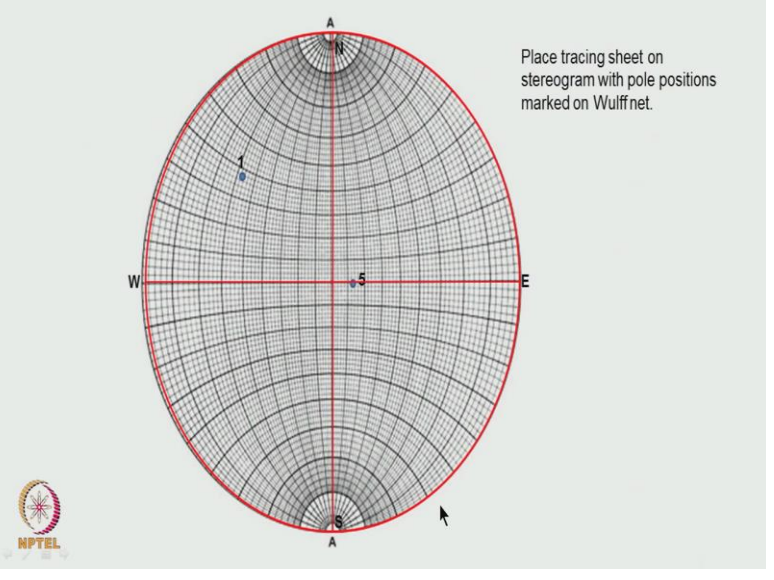

Further the methodology which has be done if that first; keep this on to the stereogram. In this particular case the pole 5 is lying on the equatorial plane. Then what we do it is we rotate this pole first then it will be coming here. So, when we rotate this pole, this also will automatically get rotated. So, that is what it I this rotation essentially required if measure it is about 12 degrees.

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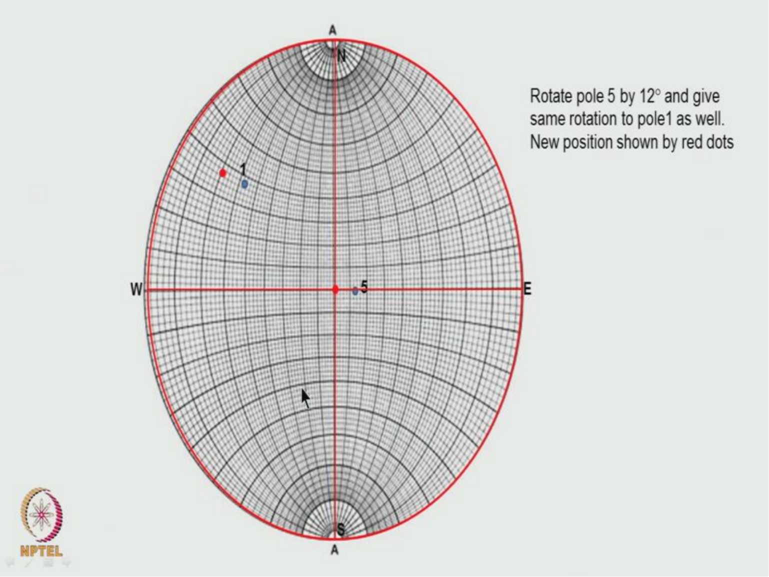

So, 12 degrees if we rotate it a being to the center on this latitude it will also be rotate it 12 degrees and brought it this point. These new positions are essentially these new positions. Once now this pole as been brought to the center and a one has been moved here, now since it see the center going in siding with the Wulff net now we can make a rotation around this poled by just rotating this tracing sheet by 10 degrees then it will be moved from here to here.

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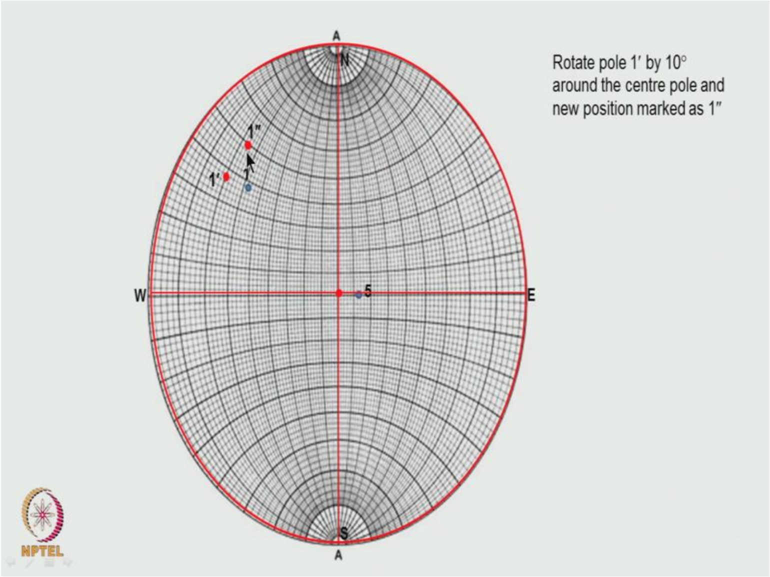

That is what essentially is being done degrees we have rotated. This is the point which it comes. And when this is reach here, but actually the rotation is effected from point. Now after it has been reached now what we do it is, now we go back to original position the move it from here to here find back then this will have to move along this latitude from here this decision and reach a new position.

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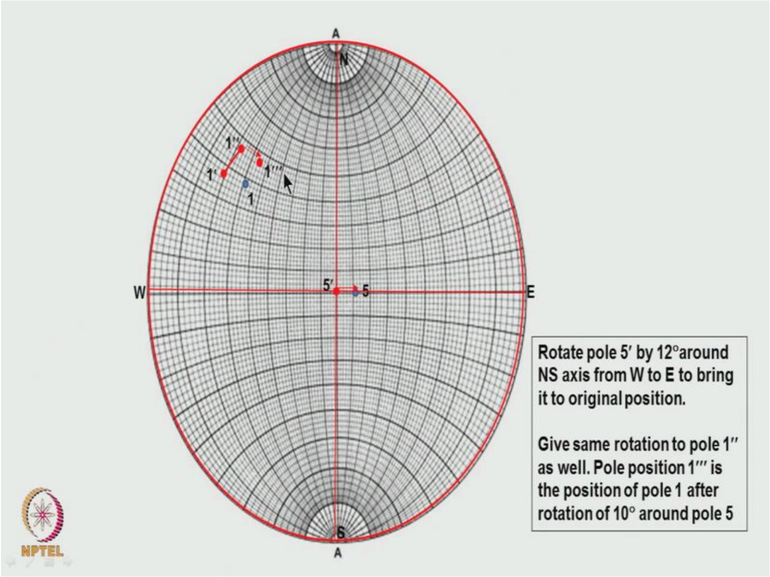

This new position this is what these are the position 1 to 1 dash 2 1 2 dash and a final position is and comes back to the original position. So, effectively these are all intermediate positions that is how when we rotated one around 5 in a clockwise by 10 degrees. The new position is from here to here, but the steps which are involved as I had explain here is to go from here to here and move this from here to here then effect the rotation around this by make 10 degrees and then moved this point back to 5 and then this will reach here.

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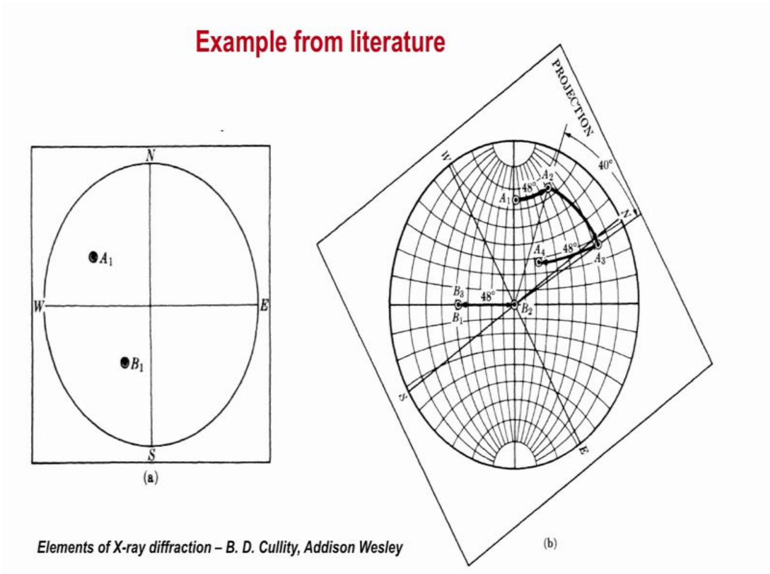

These is another example which have taken from the literature, where are what happens is that the pole a is being rotate around pole b, but b is not lying on the equatorial plane or on the north with axis. In this case what as to be done is first we have to rotate this tracing sheet so that the b is going to lie on the east west axis with respect to stereogram that is what is it is being done. Then measure this angle then this is being rotated from here to this position, and then what happens a moves from here by the same angle it is rotated here and then from here the clockwise 40 degree here rotation which is being given to the new point. And then move b from here to the original position and then this will be moved from here to this particular position.

Essentially now we can make out the; and now we rotate it back to a position then you know that from here to here this is the position, the new position which is going to occupied. This is how quite often when we do analysis of the affection patterns and wondered to find out habit pain and orientation relationship. These sorts of operations have to perform. What essentially I am trying to show in this lecture are some of the example which have taken is what all the basic operations which has to be done on a stereographic projection and one should be quite familiar with this sort of operations; that is the most important thing.

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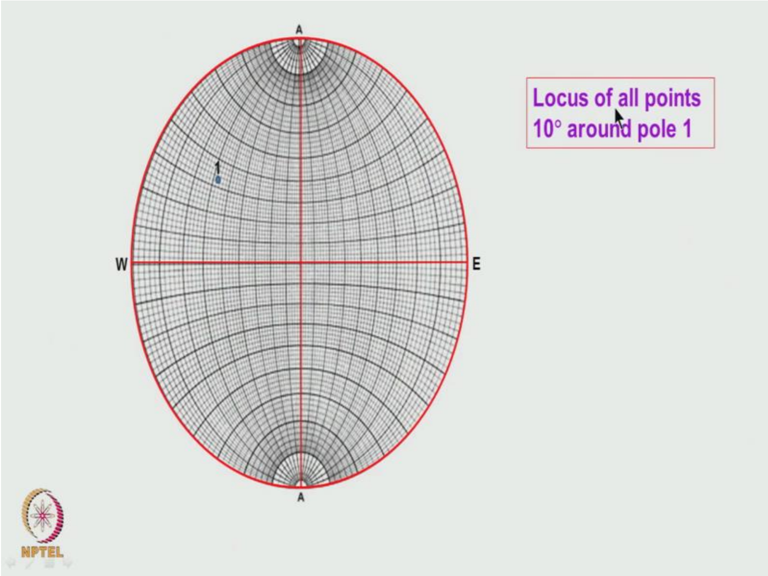

And another example which I am taking is locus of all points which are 10 degrees around this particular pole which we have to find out; one how do we go about it. For all these points first thing which had be we have to rotate the tracing sheets so that this is going to lie on the east west axis.

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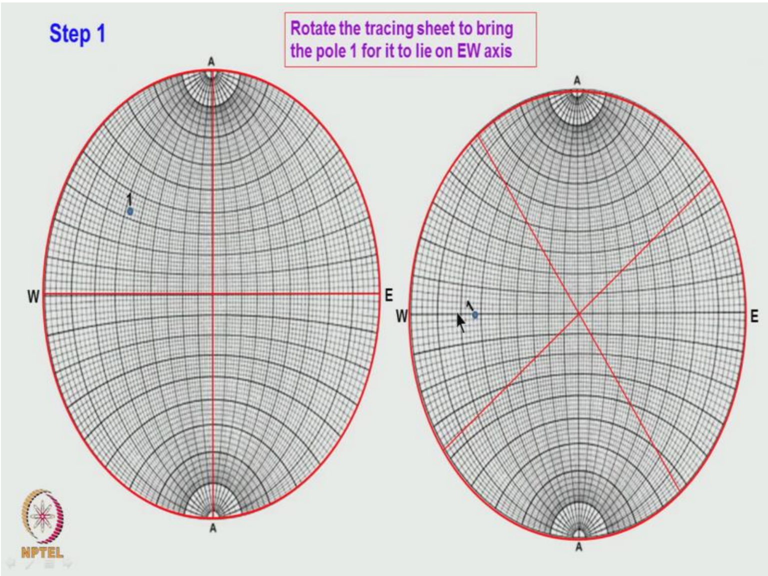

That rotation when is being done perform these is a step one so that is being done now we can see it is lying on that east west axis. Now what we have to do 10 degree we have to find. So, want to the left as well as the right measure 10 degrees mark two points. After marking those two points find out the actual distance and find out the midpoint of it using that this as the diameter. Draw circle around that center point which we have defined.

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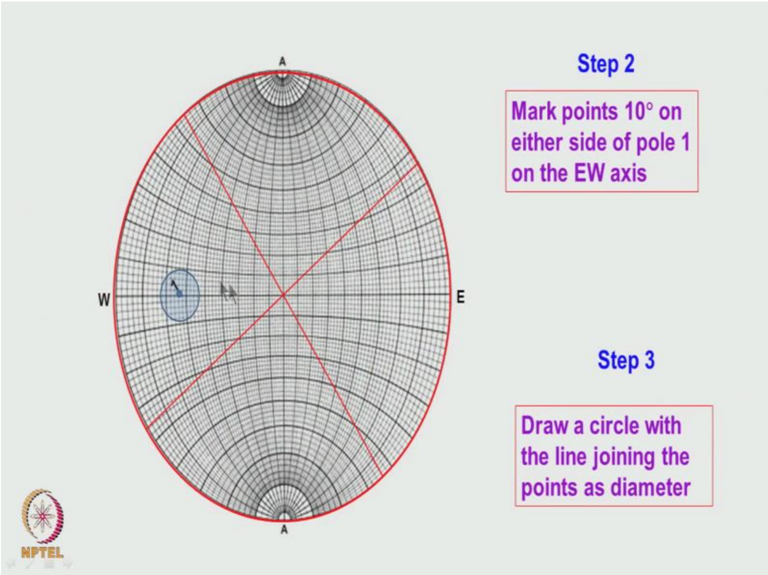

And this is what essentially the locus of all the points which are going to be there. Now what we do it is that this we have done it the original position of this tracing sheet was essentially trust be now we can rotate it back.

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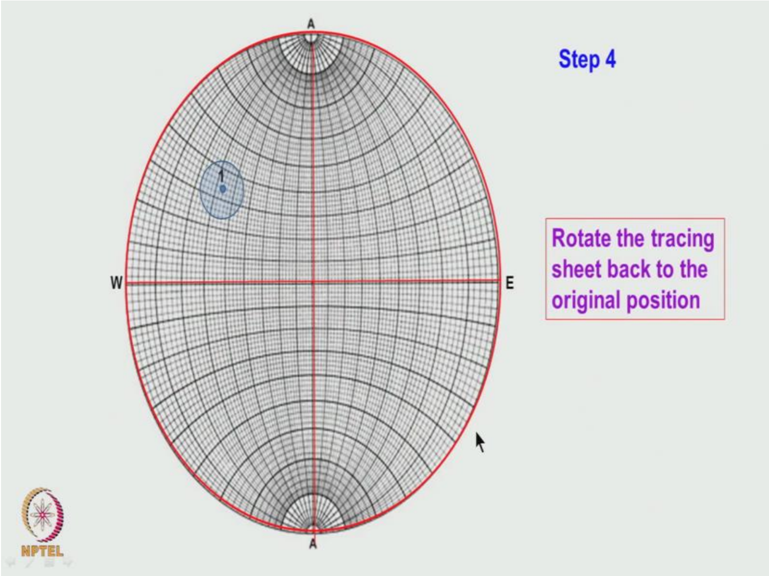

When we do this now we can see this the circumfluence shows the locus of all point which are 10 degrees. What essentially it means that if you look here on this projection it may not appears so, but actually this what it means is that on the surface of this sphere from this particular point all points which make an angle of 10 degrees that projection is what is being shown here.

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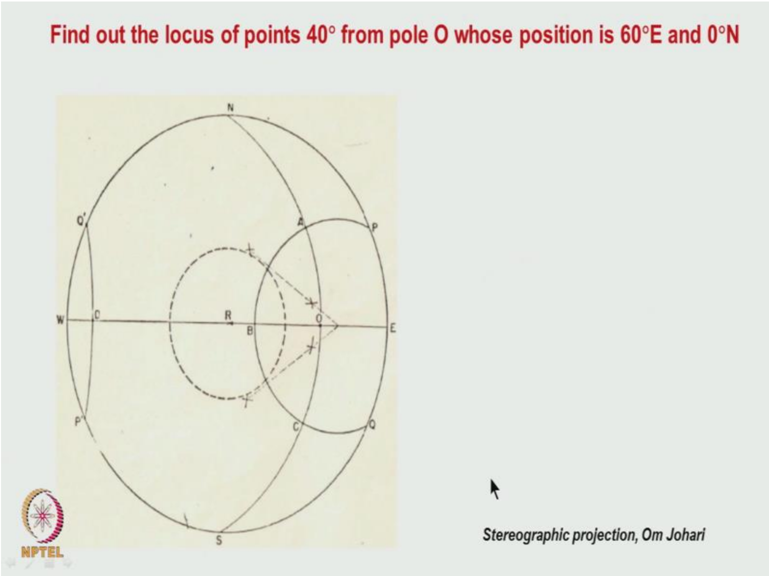

This is another case where we have considered it is that, in the case which we have considered that earlier. The locus is all lying within the primitive itself. A case which can happens is that part of the locus is not lying within that circle. How it will come? That projection as we have discus earlier. That will essentially be coming on the opposite side. For this particular point what our is going on the opposite side that as to come here, this particular point which has because has I had shown when on a latitude we move we are reaching a point and a beyond that a rotation as to take place then it will be coming on the opposite side. That is precisely what is shown here.

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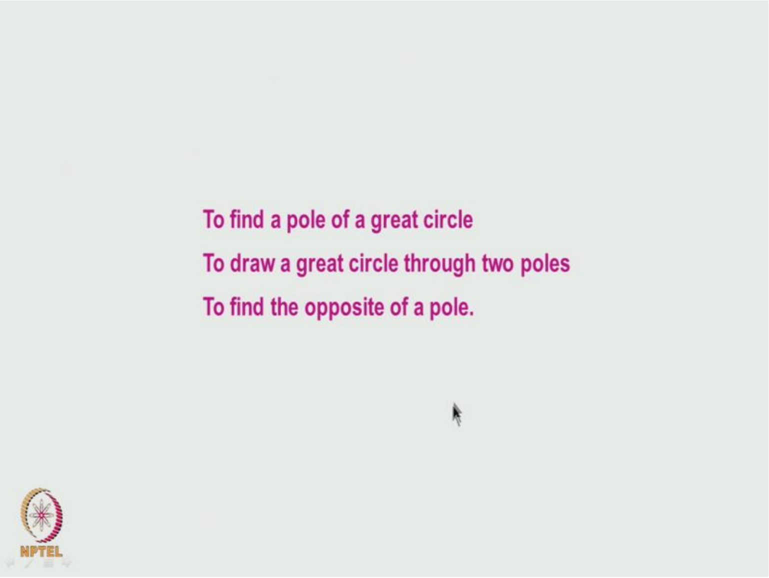

Another is to find the pole of a great circle. To draw a great circle through two poles, to find the opposite of a pole.

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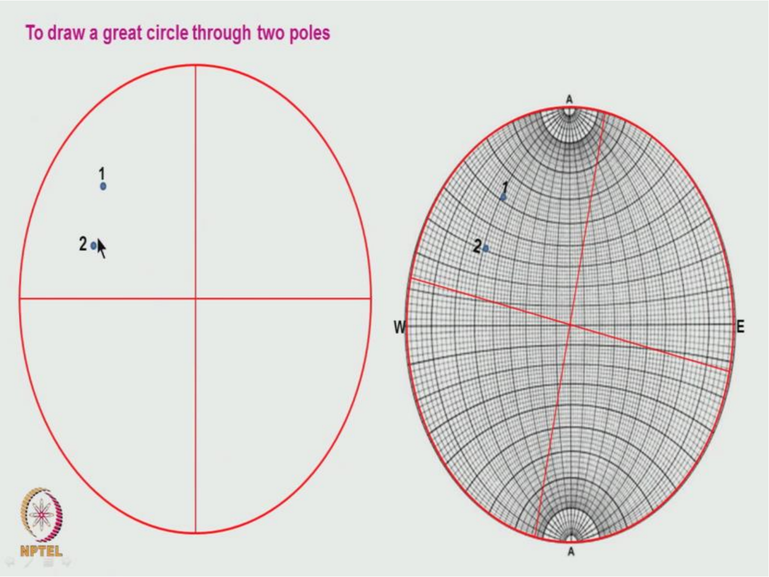

These are two points which are there on the stereogram, and we wanted to find out great circle which is passing through this points. For which what we have to do it is keep the Wulff net; keep the stereogram on top of the Wulff net. These points are not lying on a latitude or longitude. Then what we do it is we rotate that tracing sheets. So, that these two points are lying on a longitude and then if we draw the this is the great circle which is passing through this if we draw this line this is what essentially is the great circle which is passing through these two points, this is how it can be draw.

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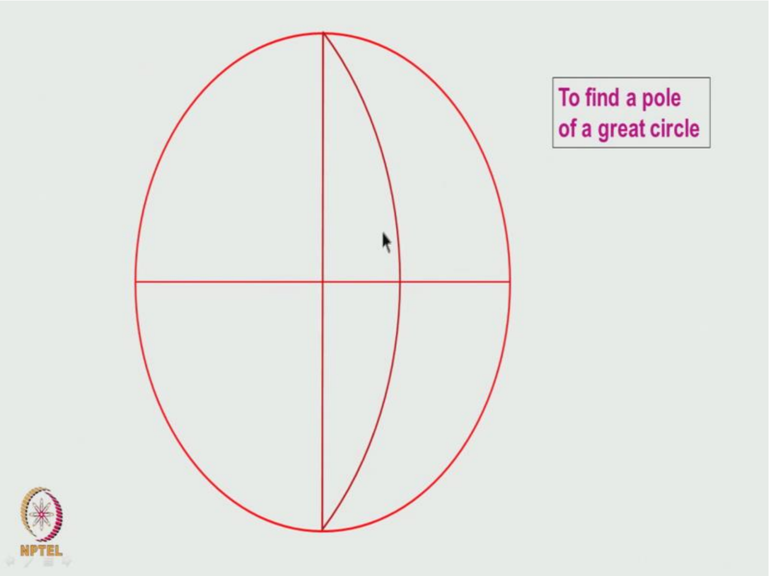

This is a great circle which is being given we have find out we a pole corresponding to the great circle.

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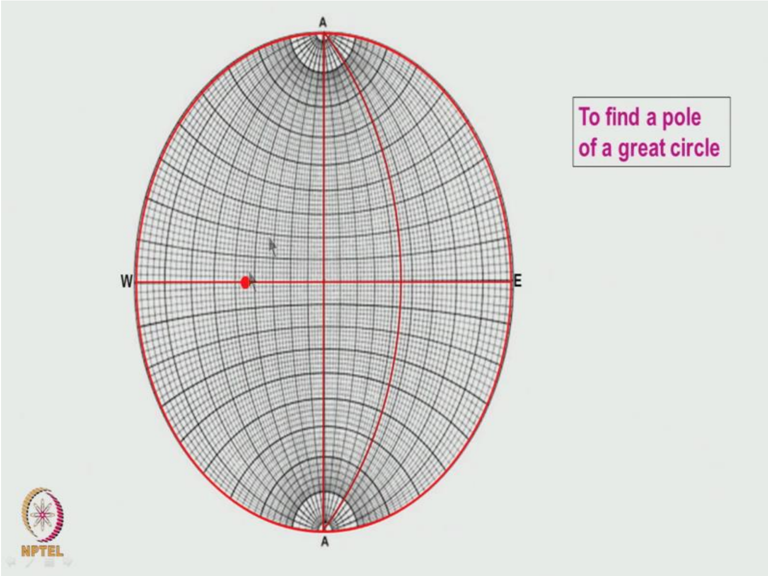

What doing it here essentially is that keeping a Wulff net at the keeping the tracing sheets on top of a Wulff net and the then measure and angle which is 90 degree on the equatorial plane and mark that point. So, this point is essentially 90 degree away from all the points on this longitude or this great circle.

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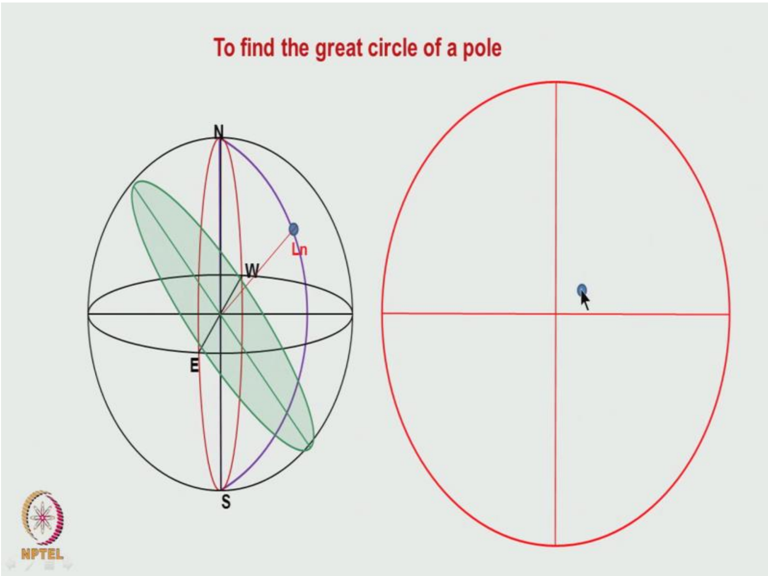

Similar way, if we have to draw a latitude; if we have to draw a longitude corresponding to a particular pole this is a three dimensional figure which I had in showing it here. If this is the pole, the great circle is the one which is passing through the center of that sphere and lying on the surface of this sphere. And the projection of it if try to see it this is how the projection of this points looks like for this. Particular point which is lying on the stereographic projection, we wanted to draw a great circle corresponding to it. How exactly it is being done that one know we keep it on top of the Wulff net.

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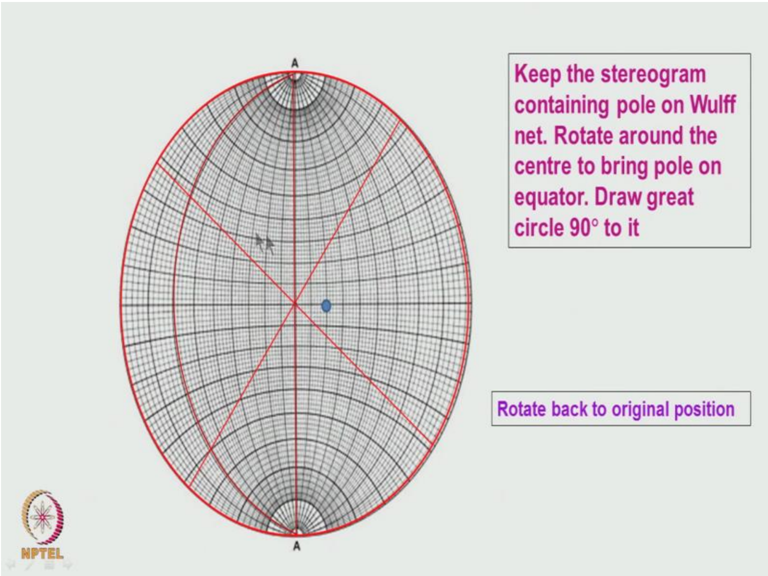

Then the tracing sheet we rotate it so that this pole is lying on the equatorial plane. Then when lying on the equatorial plane from here measure and angle which is 90 degree. Then draw the great circle which passes through this is what is shown with is red line, this is the great circle which is 90 degree away from this pole.

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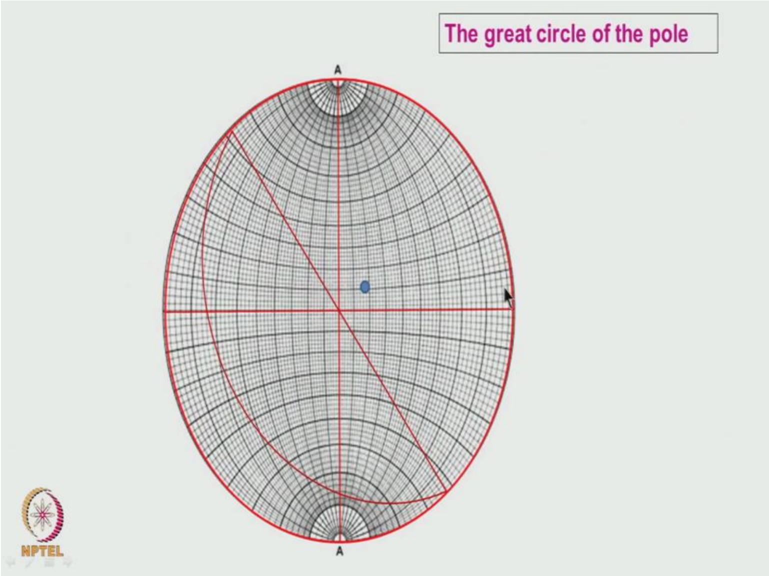

And then rotate it back to the original position. So, with respect to original position the stereographic projection where the axis are remark. This is what the great circle corresponding to a pole.

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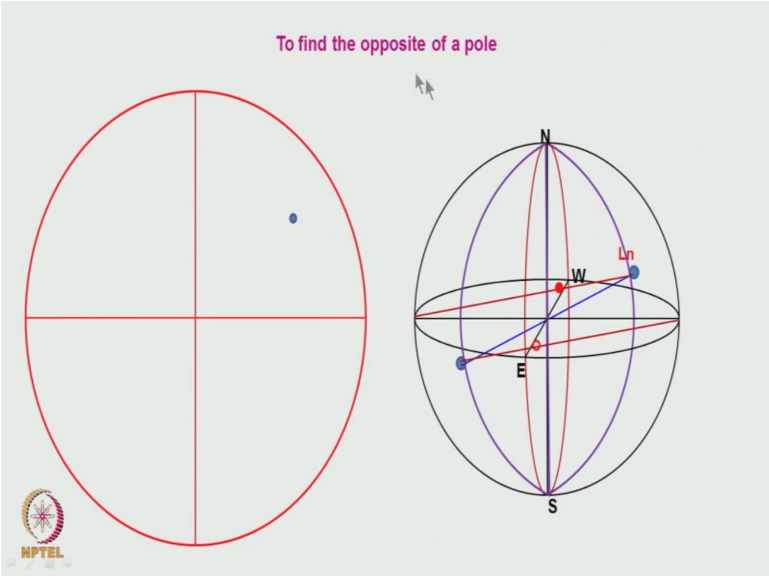

Another fact also which we are consider is to find the opposite of a pole. Suppose there is a pole which is there 180 degree rotation if it see if it going to be there this comes and the under opposite there will be a pole which will be there, which is essentially a line passing through the center, where it cuts this that is what the opposite of that pole. And this projection if we see it on this hemisphere the pole which is lying on the right hemisphere it is going to be here, that is what essentially is being marked.

To find out the pole which is going to be there on the opposite side as a mentioned earlier what we have to do is that the view direction you change from the right left side to the right side then the projection of this pole is going to come here on the equatorial plane that is what a essentially is being done.

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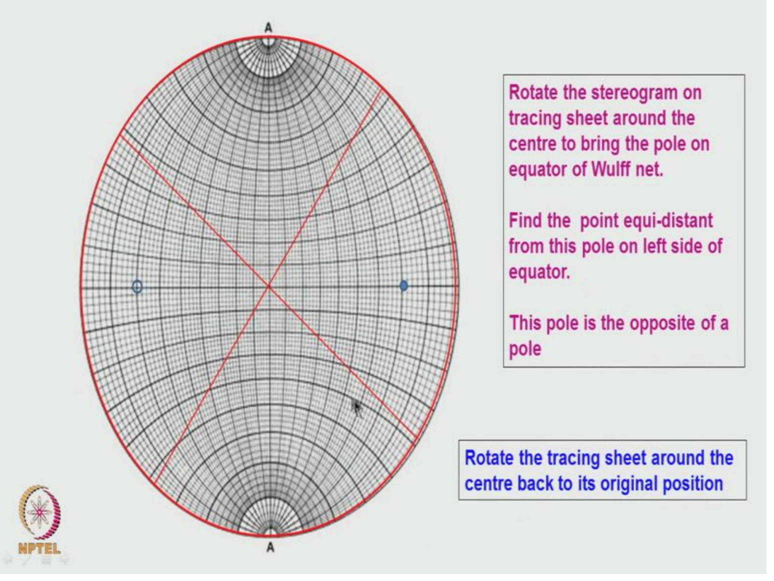

To do that what we do it is you keep the stereographic projection on top of the Wulff net and then rotate this and bring it here. Measure what is the angle which is here from the center and the same angle you measure it and the marked that point. Since this is on the opposite side of it if this is use with a close circle to represent point which are all from the right hemisphere which is projector for the left hemisphere we use and open circle. So, this way this shows the projection of the pole which is going to be under the opposite side. Now if we rotate in back we will be getting this pole

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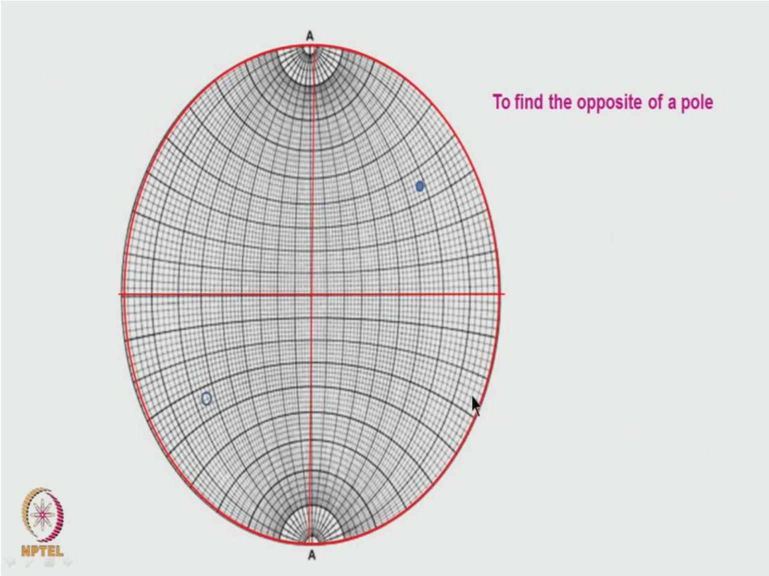

Now we have rotated it, now we is know this is the pole which is corresponding it, this is the pole on the stereographic projection for a pole on the northern hemisphere on the right hemisphere, and on the opposite pole this is exactly how it will be represented.

Now I will stop here, we will take the case of construction of a stereo gram for different crystals and the point view representation in the next class. We will stop here.