Surveying
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Module - 05
Lecture - 04

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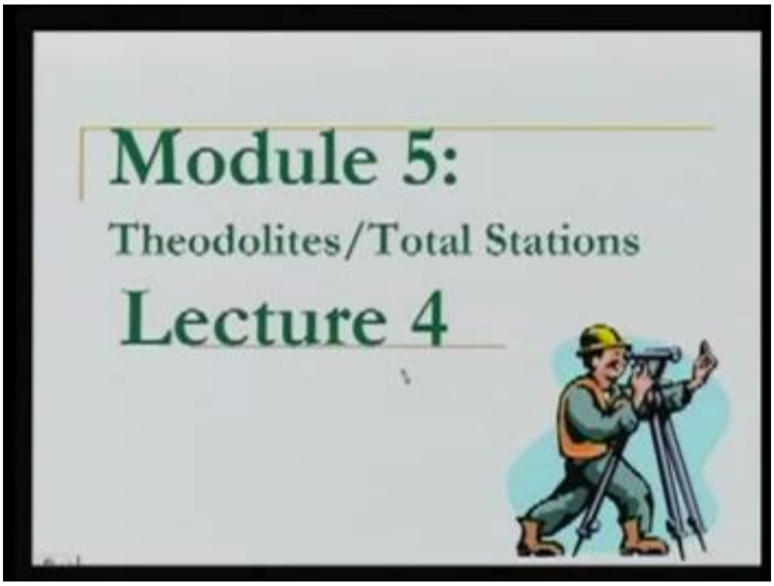

Welcome to another lecture on basic survey. Today, we are on module 5 and will be doing lecture number 4.

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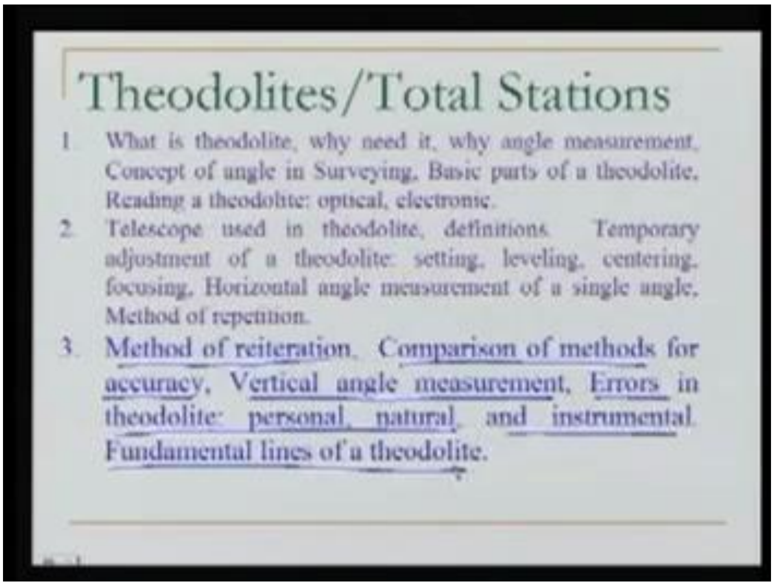

Now, before we go for this lecture number 4 of module 5 which is on theodolites and total stations, we would like to see, what we did in our last video lecture. In the last lecture about the theodolite, we talked about the angle measurement, and we measured the angles using the methods of reiteration. We saw what is the, you know, advantage of methods of reiteration. If we have to measure multiple number of angles from one station, we go for this method. Then we compared the method of reiteration and method of repetition for the accuracies.

We did a little analysis, how the errors propagate? The errors as we saw do occur, because of number one bisection, number two reading. So, in the case of the repetition there were only two readings, while in the case of reiteration there are several readings. So, how this, more numbers of readings in the reiteration affect the accuracy and this what we have seen, how all these little errors they propagate finally in our angle that we measure. Then we also saw the vertical angle measurement, how do we do it? What are the steps? How do we write it on a table?

And we were talking about the some errors of the theodolite, like the personal and natural errors. So, we saw from the causes a surveyor may introduce some error or there may be a error, because of the nature. Something goes wrong you know the reflective index of the medium, simmering of ranging rod this is what we talked about. We also saw towards the end of our lecture, the instrumental and the fundamental lines of a theodolite.

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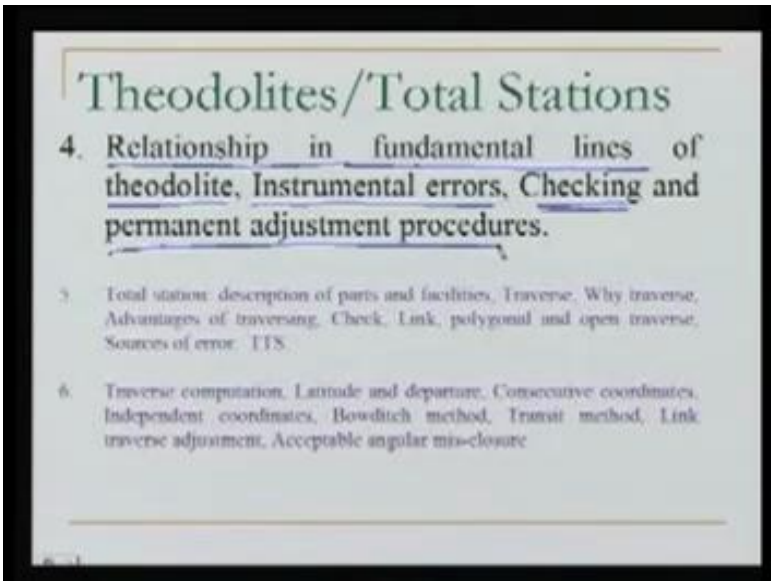

Now, we will go into the same error part of the theodolite today, and to begin our lecture, we will again talk about relationships in fundamental lines of theodolite. We have seen those lines, we will see them again today and would like to see very minutely, what are the relationships among those different lines? If those relationships are not so, as desired in the instrument, what happens? The instrument will have the errors, how we check these errors and how to eliminate these errors. You can eliminate the errors, by adopting some strategy in observation, also we can eliminate by permanently eliminating the error, while working in the theodolite.

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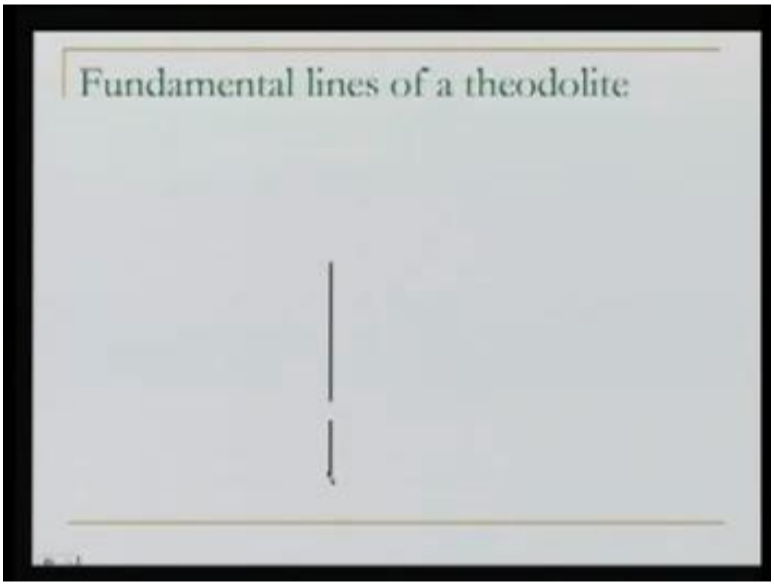

So, these are all that we are going to do today, to repeat what are the fundamental lines; the fundamental lines are this is a vertical axis.

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Vertical axis means, if I show you here in the theodolite I am rotating this theodolite, it rotates about a line here that is the vertical axis, then we have the horizontal circle. So, this circle is the horizontal circle, where we have the graduated circle, where we read the angle values.

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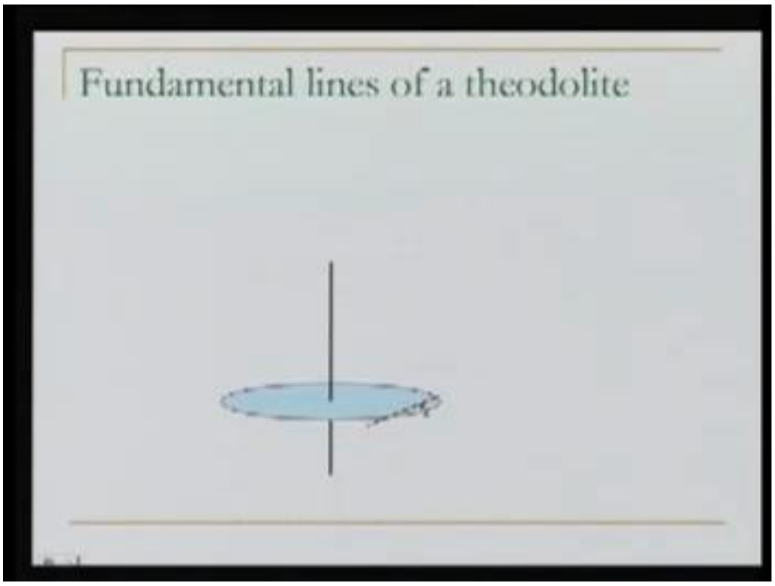

Then this redline here is the axis of the bubble tube. We have a bubble tube and for this bubble tube we can define the axis, which is tangent at this middle point this is the axis of the bubble tube. Then further, because we have not only the horizontal circle, but on top of that the vernier frame with these two index, because we are making use of these index a and index b or we can say vernier a and vernier b to take the readings.

So, we have this another frame our this entire theodolite, if I clamp it by the lower clamp. Now, still it is rotating, so the lower plate is not rotating now, only the upper one is rotating. So, this entire theodolite is rotating now, as well as the verniers.

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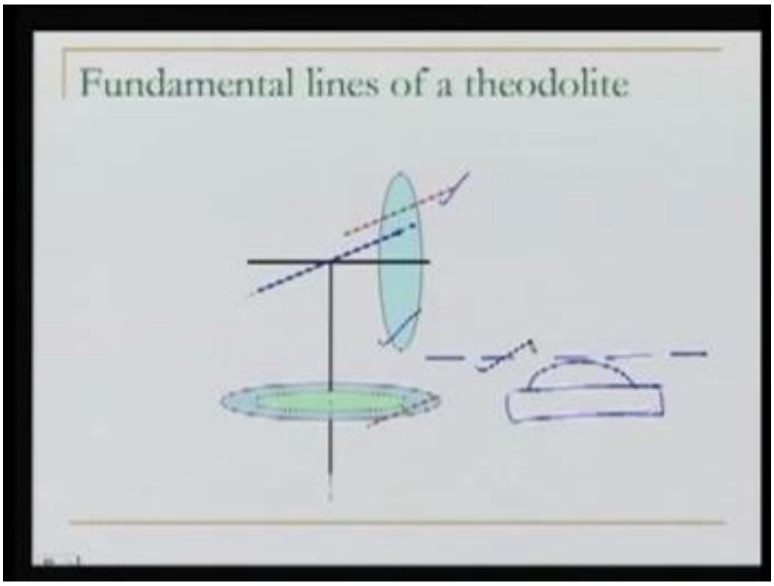

So, there is another axis which we can define, this is the axis of the vernier frame or we say inner axis. So, this dotted line here is the inner axis. If you go further or we have the horizontal axis, this is the horizontal axis about which we can rotate the telescope. Well, we go further this is the line of sight. Line of sight means, the line which is here in the telescope.

We have defined this line of sight, the line of sight is defined by intersection of the cross wire and the center of the objective lens. So, the line joining these two is the line of sight. Also we have line of collimation, again another line here which is joining the center of the eyepiece lens and the center of the objective. Then on this side we have the vertical circle, and as we can see here this is our vertical circle, which we make use to observe the vertical angles, and as well as this is the axis of altitude bubble.

If you see here in the theodolite that is where altitude bubble, and we can define an axis for the altitude bubble, at the because the bubble as we know bubble will look like this. And this is the line, which is tangential at the middle of the bubble. So, this is the axis of the bubble tube. Similarly, here the same line I can visualize it like this. So, this line is the axis of the altitude bubble.

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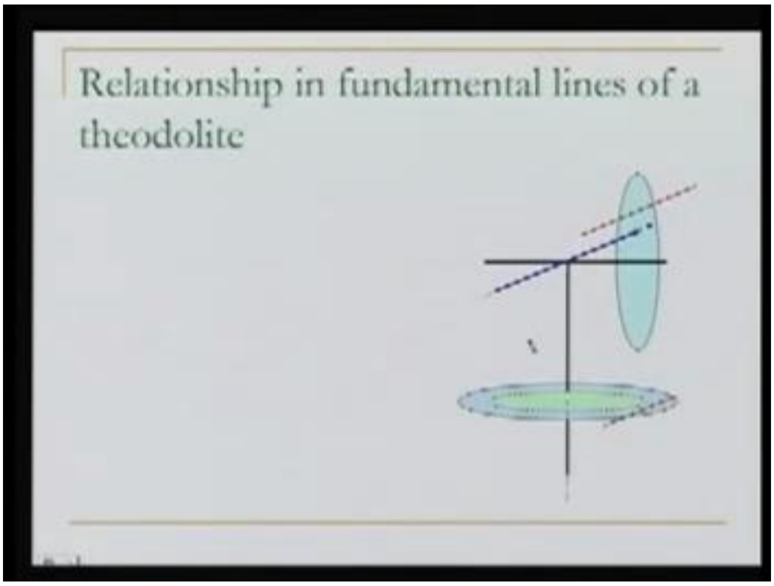

Once you have seen these lines, what is the fundamental relationship between these lines this is very important. And when we want to talk about the theodolite, when we want to take the observations from the theodolite, when you want to eliminate the errors of the theodolite, we should know these relationships.

Now, in order to understand these relationships, because we are talking about this instrument, I will try to show you some relationships here in the instrument. You will have to visualize these things. And when whenever you have an opportunity to handle an instrument like this, try to see those lines yourself where these lines are. Of course, all these are imaginary lines, which you are thinking that yes they are there.

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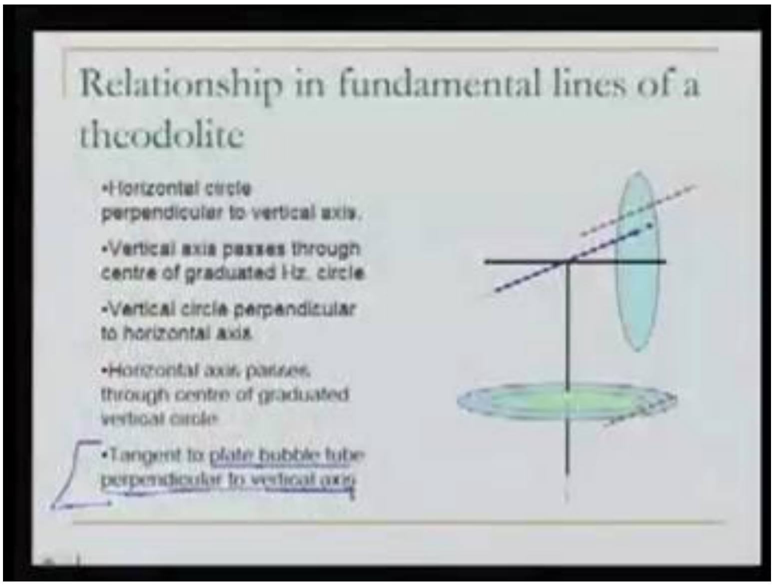

So, we will start one by one, the very first relationship is we are writing here, horizontal circle should be perpendicular to vertical axis, what is the meaning here? This is our vertical axis and that is our horizontal circle these two should be perpendicular, why they should be perpendicular, because it my vertical axis is vertical in the direction of the gravity. And this horizontal circle is perpendicular to the vertical axis. Then this horizontal circle will be actually horizontal, this will ensure that we are taking all our angles in horizontal plane which is desirable.

Then second thing, the vertical axis should pass through the centre of graduated horizontal circle. Now, why is it so, that is the centre of graduated horizontal circle here, and this is the vertical axis. Now why it is so, because all the observations for the horizontal angle that we are taking, we are taking for with respect to the point as we can see here, this particular point. And our circle is also graduated with reference to this point only this is the origin, all the angles are being measured with reference to this point.

So, this is why, the vertical axis should coincide with the centre of the horizontal circle or the graduated circle. Now, we go further, vertical circle should be perpendicular to the horizontal axis. Well, this is the horizontal axis and this horizontal axis is also called trunnion axis or transit axis and this is the vertical circle. So, these two should also be perpendicular as you can see here in the theodolite. This is our horizontal axis thus the vertical circle. So, this vertical circle should be perpendicular to the horizontal circle horizontal axis.

Again why, because by making this instrument leveled by making the vertical axis vertical, this horizontal axis will be horizontal. If it is horizontal, then our vertical circle will be vertical and we want it like that, because we are observing all the angles in vertical. So, in order to measure the vertical angles, our vertical circle should be vertical, this is why this relationship.

This one is same as this, that for this graduated vertical circle, it is centre should coincide with the horizontal axis, the why it is so the reason is same as we discussed here. Then finally, the tangent to plate bubble tube should be perpendicular to vertical axis. Now, why this relationship here is the plate bubble tube the tangent of the plate bubble tube goes like this, and our vertical axis is here. Now, these two should be perpendicular, why we make our vertical circle axis, vertical by making use of this plate bubble tube.

We bring this plate bubble tube to the centre, once it is in centre the axis of the plate bubble tube will be horizontal, and if this axis of the plate bubble tube is perpendicular to the vertical axis, our vertical axis will be vertical. So, in order to ensure that our vertical axis is truly vertical, we need to have our plate bubble tube axis perpendicular to the vertical axis. So, this is what this relationship is there.

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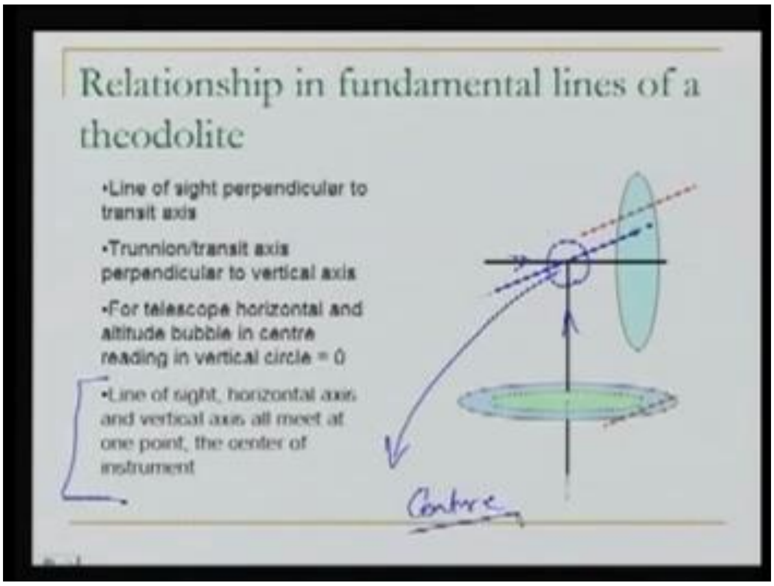

Well we go further, this is line of sight should be perpendicular to transit axis, now why it is so. If we see here, this is the transit axis or horizontal axis or trunnion axis, this one here about which I can rotate my telescope. Now, the line of sight is here, the angle formed as we can see here the angle formed form line of sight to the horizontal axis. So, this angle, this angle should be 90 degrees whereby take it this angle, wherever take it this angle. So, from the line of sight to the horizontal axis this angle should be 90 degrees, why it is so. It is so because, if my horizontal axis is truly horizontal.

Now, if I rotate my telescope by rotating this telescope or the line of sight I want to rotate it in vertical plane. So, if this angle is 90 degrees, then only it will rotate in a vertical plane. If it is not then it will form some other plane. So, in order to ensure that my line of sight when I rotate it, it forms a vertical plane this line of sight should be perpendicular to the transit axis.

The next relationship is the trunnion axis or transit axis or horizontal axis, it should be perpendicular to the vertical axis. Now, as you can see here this is what the relationship is, now why so, again our horizontal axis and the vertical axis. Let us see using the plate bubble tube here, we have made our vertical axis to be truly vertical, so vertical axis is truly vertical. Now, we want our horizontal axis to be truly horizontal. Now, it will be so only if, if the horizontal axis is perpendicular to the vertical axis.

Now, the next relationship it says for telescope horizontal and altitude bubble in centre, the reading in vertical circle should be 0. Now, what is the meaning of this? When we measure the vertical angle, we measure the vertical angle always from horizontal. So, now here somehow I make the line of sight horizontal, let us say that line of sight is horizontal now. This altitude bubble is in centre, in this case when the altitude bubbles in centre, line of sight is horizontal the reading over here should be 0 0 0, because I have made the line of sight horizontal and that is my reference.

So, the reading here should be 0 0 0, if it is not so. So, this is another error in the instrument will need to take care of that, will need to account for that. So, this is what we will see. Then finally, this important as you can see here this is vertical axis, the horizontal axis and the line of sight and all these three meet at one single point. Now, this single point is called centre of instrument.

Now, here if you see we will have to visualize it the vertical axis is coming like this, the horizontal axis is coming like this and the line of sight, I can rotate this one the line of sight has been rotating, it is here like this. So, all these three intersect like this, so we have a relationship vertical axis, horizontal axis and the line of sight. And all these three they meet at a single point that point is the center of instrument. So, all the angles whatever we do all the measurements, you know in vertical we are measuring the vertical the angles.

So, where is the reference? The reference is here it is not here, the reference is here. If I say the height of the instrument, so height of the instrument means I measure the height of that particular point from the ground. And that particular point to measure the height can be approximated using this screw here. So, the centre of this from the ground this distance is the height of the instrument.

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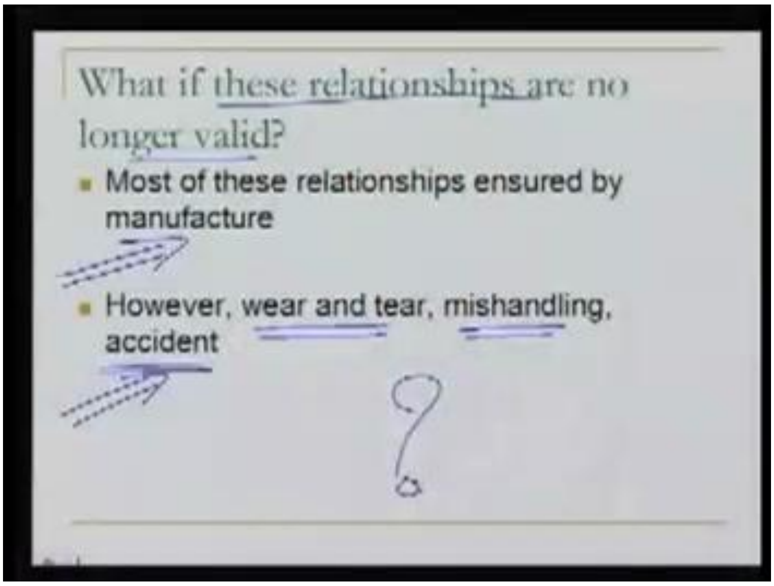

Now, we have seen all these different kinds of relationships. Now, if this relationship or these relationships are not there in the instrument. We want this instrument ideal instrument should be like that, but if it is not so, what to do. Let us be assured that in most of the instrument, particularly the modern instruments the total stations, most of these relationships are ensured by the manufacturer, and very really these will go out of adjustments.

But, still we are using this instrument in field there is continuous wear and tear, some mishandles it. For example, I apply some you know pressure some pull or something and some relationship goes wrong. So, mishandling of the instrument or sometime the accident also, this instrument false what might happen? Some of these relationships what we talked about they might deviate from the standard ones from the desired relationships.

Now, if it is so what will happen, just you know a single thing. If my axis of the plate bubble tube is no more perpendicular to the vertical axis, what will happen? I am making it to the center. So, my axis of the plate bubble tube is horizontal, my vertical axis is perpendicular to this or not let us say not perpendicular. So, what will happen? Then now, my vertical axis will not be vertical in order to have the vertical axis to be vertical, it should be perpendicular to this, but it is not so.

Now, if my vertical axis is not vertical, my horizontal circle will inclined then entire instrument will incline. So, there will be you know different kinds of errors which we introduced in our observations that we want to take. So, we need to ensure all these relationships, now how to do this?

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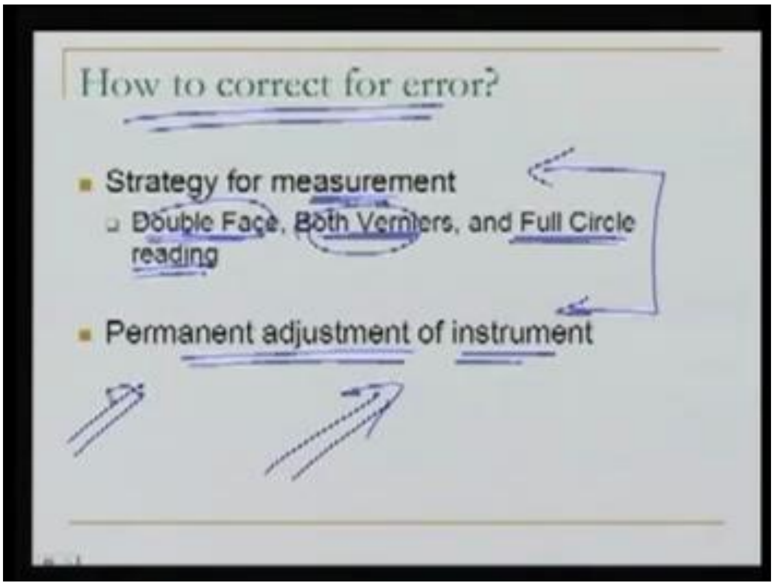

If at all they are errors like this, these relationships are not maintained in instrument, what to do? One strategy is which we say by measurement, if you follow some strategy while we are measuring the angles, then even if this instrument has got error those errors can be eliminated. Now, what is this strategy, mostly as we also saw in all our tables which I gave you? We take the observations on both face using both the verniers, if we take the mean of both the verniers a and b or c and d.

We take their mean, we take both these observations again their mean, and if possible we should also take full circle reading. We do not like to measure angle only in one part of the circle, rather in different parts of the circle. Now, this is one way it is the soft way, there is a hard measure also. This hard measure is we can permanently adjust some of these relationships. If we come to know, well in my instrument there is some problems, some of the relationships are not maintained, what we can do we can carry out some tests in the field, and some adjustment procedures which we say permanent adjustments.

And we can adjust our instrument, so that those relationships are maintained. So, what we will see now, we will see how to carry out these permanent adjustments? How to check if the instrument has got error? What should be the strategy for taking the observations in the field. If you want to eliminate these errors by soft measures. The very first error, we said well we have the lower plate for the horizontal angle and the upper plate, upper plate means these two verniers. And when we rotate it we can measure the angles, ideally speaking the axis about which this plate rotates, and the axis about with this plate rotates should be constant, if it is not so.

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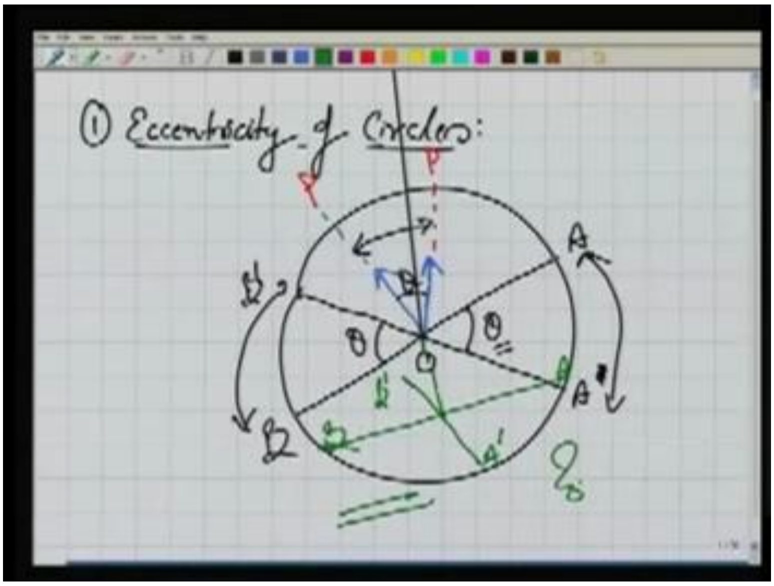

Well, we are going to talk about this error. So, in ideal case what will happen? That is my horizontal circle. Now, here this is the center of the horizontal circle and our vernier is also coincident with this. So, in order to measure any angle what we do, as you can see over here. These are our vernier A and B and that is the line of sight, so I can show the line of sight here like this. So, if there is a ranging rod here, I take a line of sight to this ranging rod, and I take the observations in A and B.

Then, I take another line of sight, let us say this way to another ranging rod and here what will happen our verniers will rotate by some angle. So, the angle between the objects theta is the same angle, which is being measured here. So, what we do, we take the readings at A dash and B dash. So, the vernier A reading from here to here, and vernier B reading from here to here. And these two readings they give us the angle value theta, which is same as the angle between these two ranging rods at O, where the observer is.

Now, we are going to the problem. The problem is the situation is slightly different, our center has changed. Now, our verniers are centered here and this is my vernier A and B and any rotation of the vernier will rotate it like this A dash and B dash. So, what will the problem, because of this we are going to see this particular problem, we are going to see how to eliminate it, not to do that.

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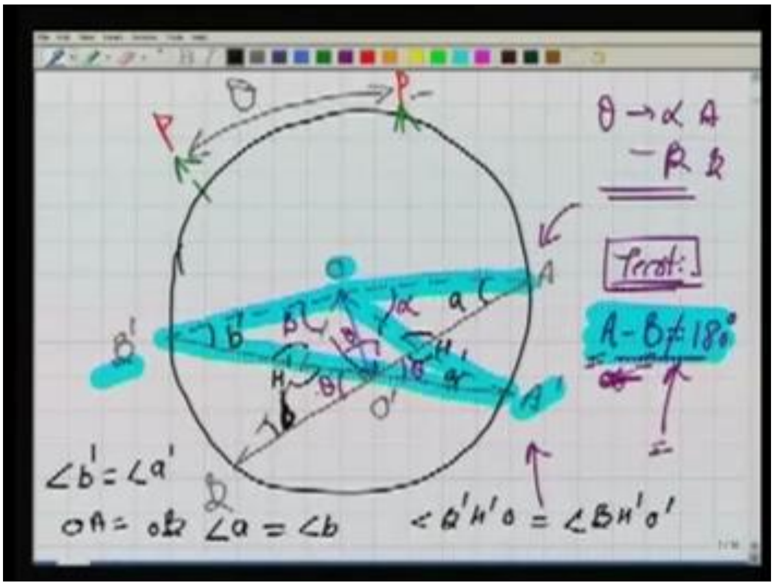

I will draw again this horizontal circle, Let us say this is our horizontal circle or the lower plate, and this is the actual center of it or the center of the lower graduated circle. Now, on this our verniers have shifted here, there is a eccentricity in the centers of these two circles. Now, any angle that I measure now, any angle that I measure, let us say the ranging rods are here and here as in the previous case.

So, in order to measure these angles what I do, I take a sight to this and I take a sight to this. So, these are the two sights, while I am taking these two sights, what is happening of the verniers, the verniers here in this case they are A and B. And here in this case, for the case of this ranging rod the verniers will be A dash and B dash. Well the important thing here now, what angles we are observing, just to clear this figure I will delete these lines, because we have seen already that these are the lines of sight.

Now, what is happening there? When we take the angles at A and at A dash, I am actually reading the angles about this center, I will explain what I mean. And similarly here, for B and B dash I am taking the observations about this circles. So, if this is point O and this is O dash, what happen actually, the angle between these two, if it is theta and as we saw over here also, this was angle theta. So, this was angle theta, and what is happening? Whatever is the amount of rotation this bisecting first ranging rod now?

Then I rotate it, it is bisecting the second ranging rod, so whatever is the amount of rotation of this telescope that is the angle value in the field. If we see in the diagram here, this theta is same as this theta here. So, this is angle theta and we can write this theta here like this theta, but what we are reading, are we really reading this theta, when we are reading in the horizontal circle. We are reading our value corresponding to A and corresponding to A dash.

And if you find the difference of these two readings will it give us theta, it will not give us theta, because we are not reading this theta, we are reading some other value here. Let us say if it is alpha, and this is beta here, because our graduated circle the lower plate has it is origin at O, not at O dash. Because of this, I am while taking this theta observation, I am reading alpha and beta by vernier A and by vernier B. So, this is an error in the instrument, because of the eccentricity.

Now, how to test it, if it is so what is the test of the error, the test of error is we can take the readings in vernier A and vernier B these two angles. The angle value in vernier A and vernier B let us say alpha minus or let us say the readings only, the reading in A and the reading in B, the difference will not be equal to 180. Now, you can see here the difference in A and the difference in B, that is our A, this our B is not half circle here, so this difference is not 180.

Similarly, A dash and B dash it is also not half circle, so this difference will not be 180. In case of the, if there was no eccentricity the A was here, B was here this is half circle, so the difference between A and B 180. Similarly, for A dash and B dash this is half circle, so the difference in A dash and B dash again 180, so this is not the case here. And this is how by doing this test, we can find the error in the instrument, yes there is an error in the instrument, because of eccentricity of the circles.

Now, one more thing this difference as you can see over here, this arc is different in length, than this arc from A dash to B dash and A to B. And because of this reason this difference will not remain, whatever is the difference at any time this will not be a constant difference, it will change, it will vary. So, this tells us, yes there is error in our instrument. Now, how to eliminate it, in order to eliminate it what we will do?

We will do a little analysis here, now this angle also we know it is theta, I am going to delete this one here just to have better clarity in the figure. If I write this angle over here as let us say a and this is a dash, and over here I write this as b, small b and this is b dash. Let us say these are the angle values here, just for our derivation purpose b here and the b dash.

Now, in triangle if you look at the triangle, in triangle O A and this particular point, let us nam, this point as H, and the point here is H dash. So, in triangle O A H and O dash H and A dash, the angle over here are same this angle is same as this angle, as it is very much clear here. So, if these two angles are same, then the sum of alpha and a should be same as theta and a dash.

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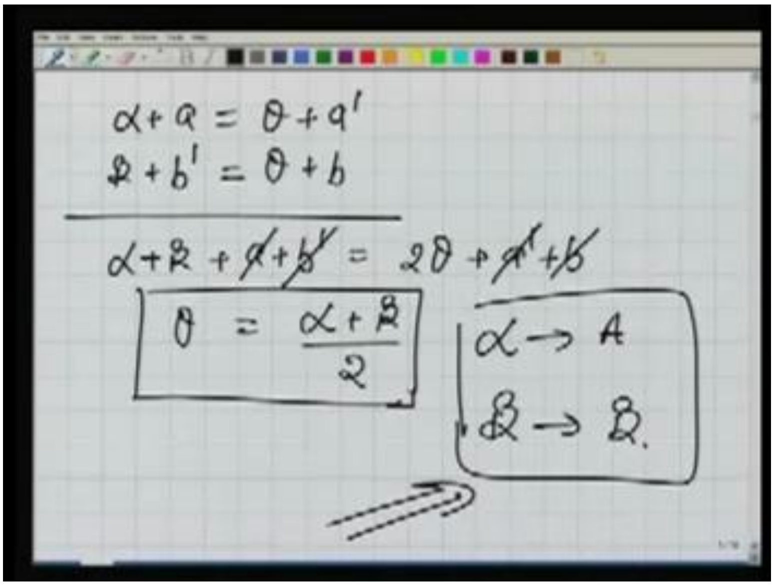

So, I am write I am going to write it, alpha plus a should be same as theta plus a dash. Now, that should be clear to you, similarly here in triangle O B dash H dash and in triangle O dash H dash and B, here also these two angles are same. The angle B dash H dash and O angle I can write it B dash H dash same as angle B H dash and O dash. Now, if it is so, I can write that this theta and b, the sum of these two angles should be same as sum of the angle beta and b dash. So, beta plus b dash should be same as if you see here, theta plus b theta plus b.

Now, I sum these two, so it gives me alpha plus beta plus a plus b dash this is 2 theta plus a dash plus b. Now, after this if you go back to the figure, now in the figure O is the center of the graduated circle. Now, let us look at the triangle O A dash and A dash here, and you join this, because this is a straight line. So, in the triangle B dash O and A dash. If you look at this triangle then our B dash O is same as O A dash, because they are simply the radius in our circle. Now, if it is so our angles b dash will be same as a dash.

Similarly, in the triangle O B and A, again OA is same as OB. So, we can write our a angle a is same as angle b. Now, if it is so we go back here our b dash is same as a dash, a is same as b. So, I can eliminate these and I can write now theta as alpha plus beta divided by 2. Now, what is the meaning of this, let us understand the meaning alpha is reading taken by vernier A, beta is reading taken by vernier B, what does it say?

It says even if our instrument has got an error, and if you take the observation with both the verniers, and we take the mean of these two observations. So, whatever is the reading given by vernier A, whatever is the reading given by vernier B. We take these two readings and find the mean of these two, the error because of the eccentricity of the centers will be eliminated this is what it says. So, this is important that we can eliminate this error. It is very difficult to eliminate this error by working with the instrument, but we can eliminate it easily by adopting this procedure of taking both the verniers and their mean, and we can eliminate the readings the errors.

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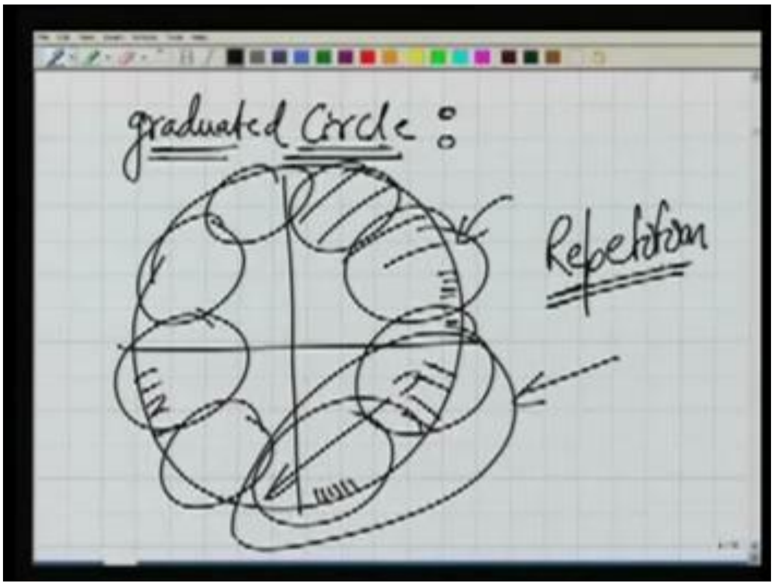

Now, the next error that we are going to is error due to graduated circle. Now, in the previous case I was giving you example of the horizontal plate, but the same is true for the vertical also. If there is eccentricity in vertical circle and the vernier, again we need to take the observations for vernier A and vernier B. In vertical we were saying vernier C and vernier D take their mean the error due to eccentricity will be eliminated.

Now, when I say graduated circle, I mean the graduated circle is non uniformly graduated, we have seen this before also. Non uniformly means, the graduations are far somewhere they are very nearby, they are very far somewhere and they are very nearby. If this is the case, it might be so because, this is a plate which has been manufactured there might be some manufacturing errors or may be because the temperature also. The part of the graduated circle is exposed to the sunlight. So, because of the temperature it is expanded, while the rest is not.

So, if this is the problem in the instrument, how to eliminate it? We have seen the answer of that, the answer of that was we should take observations in different parts of the graduated circle. So that, and the mean of these, this is so in the method of repetition. In the method of repetition we ensure this, we take the observation this way and any error which will be there, because of non uniform graduations will be eliminated.

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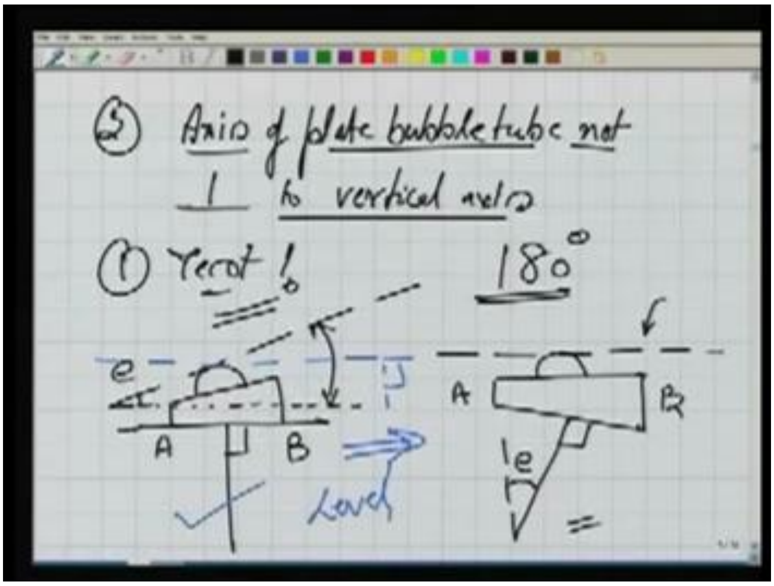

Then next error which may be there in the instrument is axis of plate bubble tube is not perpendicular to the vertical axis. Now, if it is so number one how to test it, whether this is so or not, so the test is very simple what we do in our instrument. First of all as we have seen, we level let us say that is my plate bubble tube here, these two and these three these are the foot screw. So, I level this plate bubble tube.

Now, let us say first like this it is leveled here, then I rotate I level again, then by trial and error I rotate it and level it and level it. So, after doing this trial and error for some time, you will find this plate bubble is in centre in this position also and in this position also. Now, to check whether the axis of the plate bubble tube is perpendicular to the vertical axis or not, what we do? Once it has been leveled and you find yes it is in center. We rotate this plate bubble tube by 180 degree, what is the meaning of this?

Right now, if you see this bolt is on that side, now I rotate it by 180 it is rotated. Now, it will be difficult for you to see, but the bolt is here now, so that bubble tube which was like this has been rotated this way. Now, in this case if this plate bubble tube or the bubble goes out of the center, there is an error. And if it does not go out of the center it stays there, there is no error. Now, what is the theoretical background for these, we will try to do it here by the diagram.

Well, thus my vertical axis and the horizontal plate, we have A end and B end of the plate bubble tube. And as we are saying the problem is our plate bubble tube axis of the plate bubble is making an angle here. Ideally this should be parallel to the horizontal circle or we can say it should be perpendicular to the vertical axis, but it is not so. Well, in this case if I level it as you are doing early in this instrument.

If I level it, the leveling will make this plate bubble tube horizontal that means this is the axis of the plate bubble tube now, which is horizontal A and B. And now the vertical axis is like this, so what it has done? If you look at the diagram this angle remains is 90, because this is how from the construction of the instrument. This is horizontal, but my vertical axis is no more vertical now, rather it has gone eccentric by an value of e, e is the same value by which my plate bubble tube axis is away from the perpendicularity with the vertical axis.

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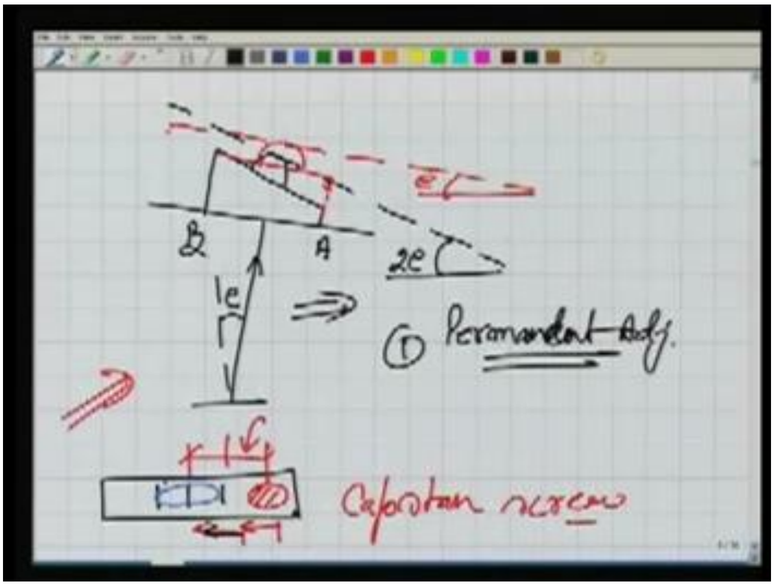

Now, this is the situation and in this situation we saw the test, the test was rotate your plate bubble tube by 180 degree. Now, if you rotate this, so by rotating this what will happen? This is how the situation is the B comes here and the A goes here A and B. If I go back the A is here now, A side of the plate bubble tube and this is the B side of the plate bubble tube, and this is how the situation is here.

If I rotate it by 180 this A will come here and B will go there, so the B goes here and A comes here and that is my plate bubble, this is a still at an angle of e. Now, because of this you can easily find at this stage the axis of the plate bubble tube will make an angle of 2 e from the horizontal. Now, how to eliminate this error, how to permanently adjust our instrument, permanent adjustment number one can we eliminate this error by observations, by taking some strategy of observation no it is not possible.

And what this error is going to do, this error is going to make my horizontal circle inclined. So, I am going to take the observations in an inclined plane not in an horizontal plane which is desirable, which is desired. So, to eliminate this permanently from the instrument, what we do. The permanent adjustment is first of all as we have seen here now, after rotating this by 180 the bolt is here and the other side is here. What I do next, I eliminate the bubble has gone out of centre. So, half of the bubble, whatever the bubble might have gone by you know whatever is the distance.

If I draw it here in the diagram this is the central line. Let us say, these are the lines for the bubble, and if the bubble is in center it might look like this, but now the bubble has shifted here. So, that is the total shift of the bubble, what we do half of the shift of the bubble, so we bring this bubble half here using 40 screws. And then further half, we bring it here using the capstan screw. So, we use this capstan screw, we can change it so what we can, what we have basically doing we can raise it or lower. The plate bubble tube if I draw it here, if I do the same thing here in the diagram.

Well in this case now by bringing this bubble, half by capstan screw, what we are doing actually we are raising it up. So, my bubble becomes like this and the line of sight, and the axis of the bubble tube is now this way. Now, this angle will be obviously e, so half of the error has been eliminated. Next, if I further now change or bring the bubble to centre using the foot screw, so when I using the foot screw basically what we are doing? We are changing the orientation of this vertical axis.

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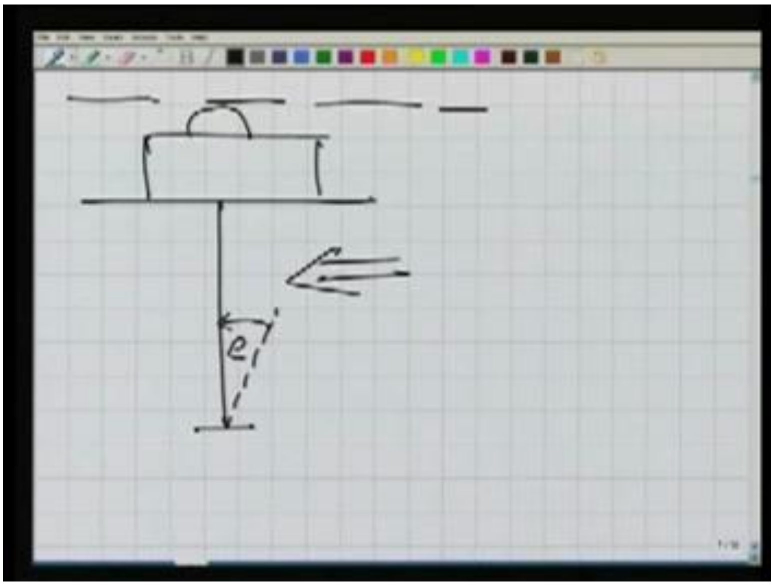

So, what we do in this case B and A. And this is how the bubble will become now, because we have by using the foot screw, we have changed this vertical axis from this position to this position, eliminated this error of e. So, our finally stage will look like this. So, we can eliminate this error from the instrument, we have seen the test of this, we have seen how to eliminate this. So, this is a kind of permanent adjustment of the instrument.

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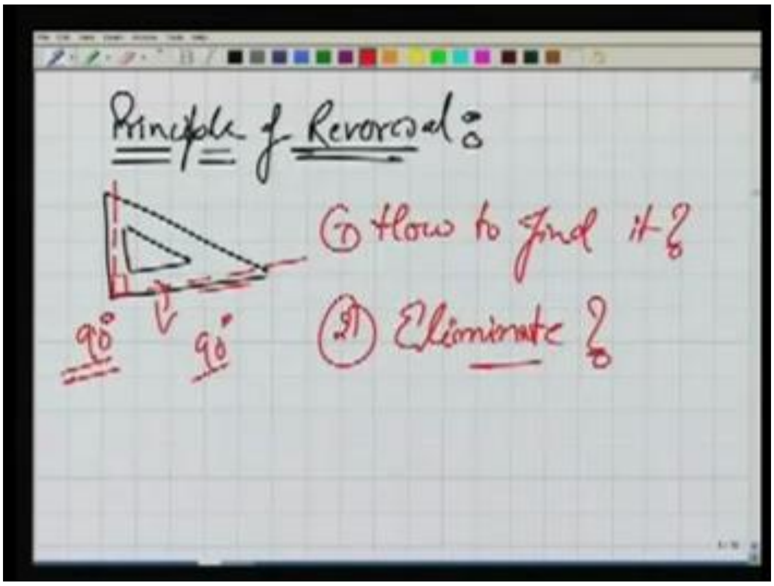

Next, we are going to talk about some more errors, but before that I will give you a principle of reversal. Because, we are going to use this principle of reversal, henceforth in our adjustments or also in our strategy that we are making to take readings, you know mean of face left and face right observation, why should we go for that kind of thing? So, what is the basic principle of that? It is very important, let us say we have a set square, all of you have worked with the set square, and this is the set square.

Ideally speaking the angle in the set square should be 90 degrees, we assume it to be 90 degrees, but is it really 90 degrees. It has been manufactured somewhere, the company or the vendor they try to make it 90, but it will never be 290 only we let us say by continuous use of this instrument. One edge of the instrument has got wear or may be both of them. We had been drawing the lines altogether about these edges. So, these edges have got now some kind of wear and tear.

So, this angle is no more 90 degrees, it may be more than 90 degrees less than 90 degrees, but it is not 90 degree. How to find it that is the question, how to find it number one. And number two question is, if you find it there is an error, how to eliminate it? Can we really eliminate it, we do not want to do anything with this set square, because we cannot manufacture ourselves now, but should be use the set square in a proper way. So, that we can eliminate this error, how can we do it?

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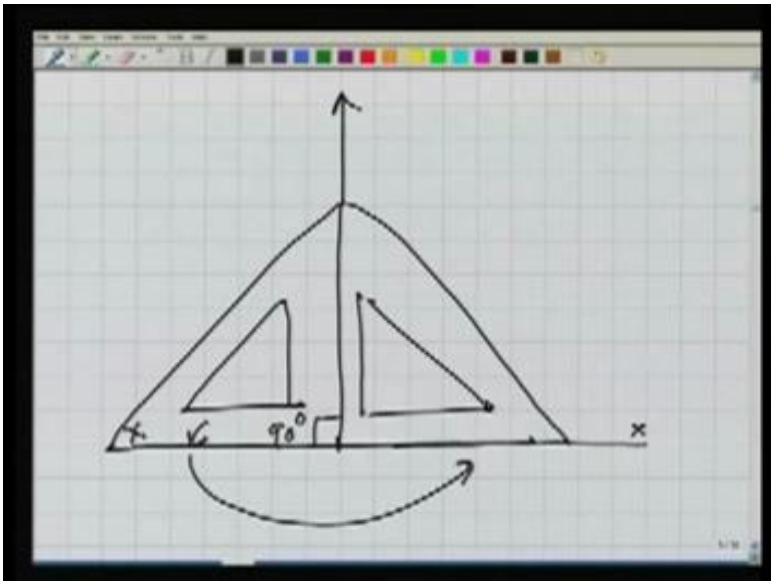

Well, the answer lies, let us say we have a straight line here, I keep my set square over here that is the set square. Now, if the set square angle is 90 degree, let us assume that this is 90 degree, and I now rotate my set square, rotate means I take this sight over here. So, my set square will look like this, what I have done? I have just rotated it or other way round, we can say I keep this as of the set square on this line and I draw a line. So, these two lines will be same, however if there is problem.

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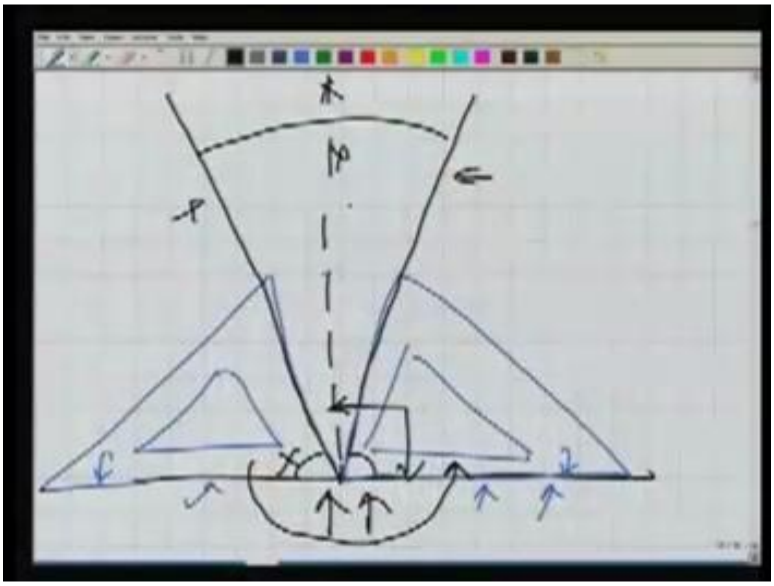

I keep my set square, let us say there is error in the set square, I am as creating this error, and thus the value of the error. So, if I draw a line using this set square the line will go like this. And in this case, what I had done, I had kept this as of the set square on this line, what I do now? I again keep this as of the set square on this line. So, I by rotating it, if I rotate it what the set square will look like. Well, by aligning the set square of this edge of the set square is aligned with this line. So, this is how the situation will be; now in this case if I draw a line, the line will go like this.

Now, none of these lines are at 90 degree from this line, but we can easily bifurcate this particular angle. And now the line which is bifurcating this angle will be at 90 degree from this line. So, what we saw here by changing the face of the set square from here to here, even if there is an error in our set square, we can eliminate it. We can still do our job with the set square which is wrong construction, because this line is at 90 degree angles.

Now, what we will do in all our adjustments, henceforth or while we are taking the observation with theodolite or many surveying instruments. We make use of this principle, we change the face, we reverse our way of taking the observation and many of the errors are eliminated. So, we should keep this principle of reversal in mind. Well, the next problem in the instrument may be the horizontal axis is not perpendicular to vertical axis. Now, let us see this problem in the instrument, here is the instrument this is the horizontal axis, this is the vertical axis and they are not perpendicular, what might happen? If it is not so.

Let us assume well, by making this plate bubble tube horizontal. We have made our vertical axis to be vertical, truly vertical. So, all these rotations of the instrument are in truly vertical with the reference to the truly vertical axis. Now, the horizontal axis is inclined. So, the situation is like this, this is the vertical axis, this is the horizontal axis. The horizontal axis is inclined, now what will happen because of this, just think of the line of sight, here is the line of the sight. If these two are perpendicular and the line of sight is going like this.

If these two are perpendicular line of sight is going like this, if I rotate my telescope. Now, the line of sight is forming a plane and that plane is a vertical plane ((Refer Time: 49:29)) wherever I rotate this, it is forming a plane and that is the vertical plane. Now, you can start visualizing this plane, it is here yes very much it is here, but if this horizontal axis is inclined. Now, what will happen because of that, for an inclined horizontal axis.

If I rotate my line of sight, if I rotate it what it will do, it will still form a plane, but the plane will not be vertical anymore, rather it will be inclined, because the horizontal axis has now become like this. So, all the rotations which are taking place of the line of sight are forming a plane like this. So, this is an inclined plane, now what is the effect of this? The effect of this is the horizontal angle measurement becomes wrong.

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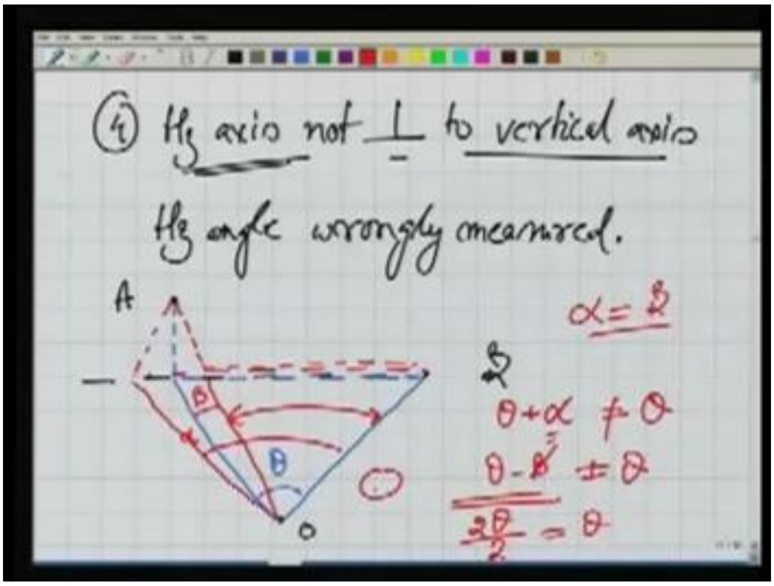

We will see how, why the horizontal angle is wrongly measured? Well, let us take one example here, there is some object A and another object is B, and we are somewhere at O. We want to measure the horizontal angle between A and B, how these A and B are. Let us say I am the observer A is here and B is here, in front of me and here is the theodolite, and the height of these two objects are different, this high and this is lower. So, what will be the procedure, the procedure will be first of all, I will set my readings in the instrument to be 0 0 0, I will bisect this A.

Well the A is bisected then what will I do, I will bring my telescope down, and then rotate it like this in order to bisect B, and whatever is the rotation over here in the theodolite that is the angle, which is a horizontal angle. Well, if you are doing the same thing, this is the line corresponding to the elevation of B. So, what I am doing, I am bisecting A then bringing it down, and then I am taking it to B and whatever is the rotation of the telescope, because this telescope first it is bisecting A. Let us say, it has bisected A the reading is 0 0 0, I bring it down then I rotate it in horizontal. So, after bringing it down the rotation in horizontal is the angle between A and B.

So, this angle theta can be observed in the theodolite. Now, this case which I have shown here is the case when there is no error. If there is error, what will happen now? Because, we are forming a plane like this our horizontal axis in incline, we are forming a plane like this and when I bring this telescope down, it goes not vertically down, but in inclined way. So, it goes somewhere here, and then what I do I take it to point B and I take the angle. So, angle which is measured in this case is actually, theta plus alpha. So, theta plus alpha is the angle which is measured, and this is not equal to theta our actual angle obviously. So, this alpha is an error which is being introduced here, so this particular problem of horizontal angle.

So, the horizontal axis not being perpendicular to the vertical axis will lead to the error in horizontal angle measurements. This will not give error, if two objects are at same height, but if they are at different heights it will produce the error, how to eliminate it? One thing I am going to do it, and you have to follow very carefully. The horizontal axis of this instrument is like this, I am going to change the face, right now the face is face left I am going to change the face, if I change the face just observe what happens?

The eye piece comes here still the horizontal axis is like this. Now, I rotate the instrument, if I rotate the instrument the horizontal axis is like this, I rotate further the instrument the horizontal axis is like this, and I rotate it further. Now, the horizontal axis like this, now eye piece is towards me face is right, and now horizontal axis like this, earlier it was like this. So, by changing the face my horizontal axis is now this way, if I make again I bisect A bring it down earlier it was going like this, now it will go this way.

So, by changing the face what will happen? I will bring it down here and then take it to B, and then I will observe the angle. So, the angle that I will observe will be this angle, which will be let us say this angle is beta here. So, the angle that we are observing is theta minus beta which again not equal to theta. Now, in our instrument this alpha will be equal to beta, so what we can do? If I take the sum of these two angles, so that will be 2 theta because this alpha is equal to beta and divided by 2 gives me theta.

So, basically what we are doing? I am taking the face left observation earlier it was face left observation, whatever is the angle value recorded by these two verniers. Then I change the face, now it is face right observation, whatever is the angle value. If I take mean of these two, face left and face right observations I get my actual angle, even if there is error in the instrument. So, by taking face left and face right by this principle of reversal, the error can be eliminated.

So, what we have seen today, we saw today some of the basic relationships in the fundamental lines of the theodolite. Then we saw if these relationships are not as desired, what will happen? It will lead to the error. Then we saw some of the errors, number one was eccentricity in the circles the upper plate and lower plate the eccentric, what will happen? What will the error? How to test it? How to adjust it in observations?

Then we saw you know, if our horizontal axis is not perpendicular to the vertical axis, what will the problem? How to eliminate it? So, far we have not done permanent adjustment of this error. So, in our next class we will do the permanent adjustment also of this error, plus we will also see some more different kinds of errors in the instrument.

Thank you.