Surveying
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Module - 7
Lecture - 2
Levelling and Contouring

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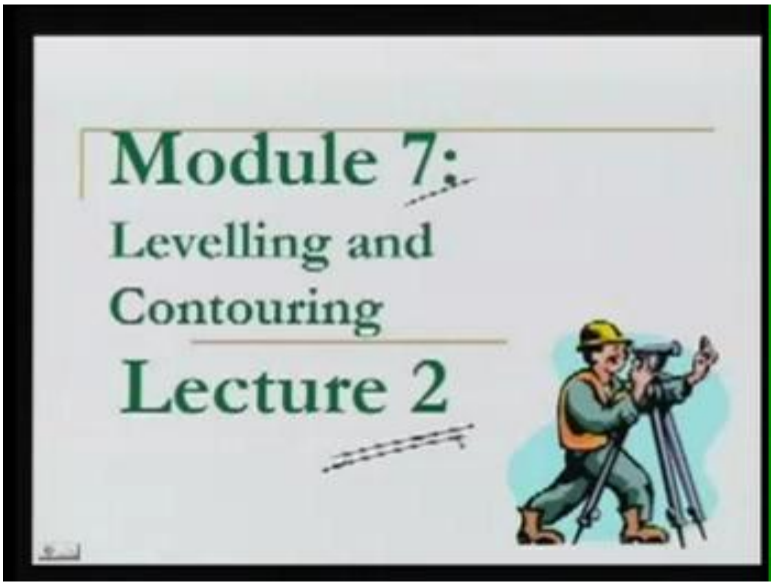

Welcome to this lecture series on basic surveying. And today, we are in module 7 and we will talk about lecture number 2, and this is about Levelling and Contouring.

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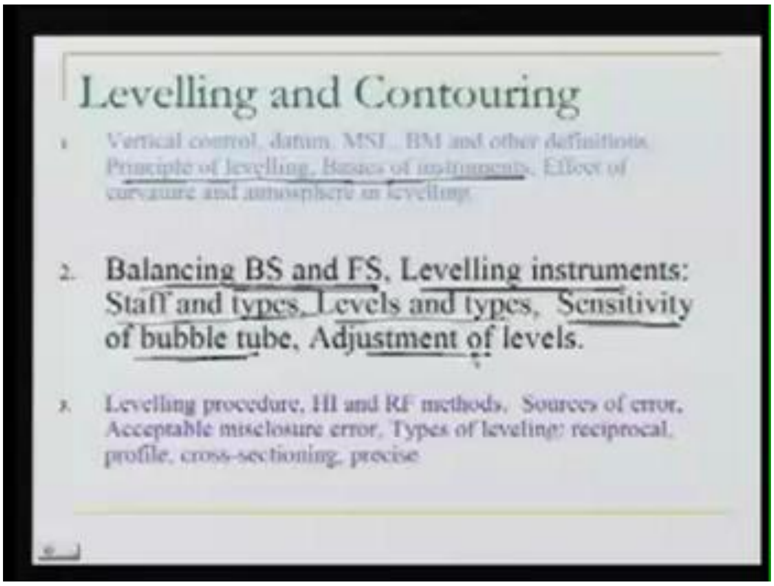

What have we done so far in levelling and contouring? We talked about the datum. What is the datum? The mean sea level. We also gave the definition of the benchmarks and what are the uses of the benchmarks. Then we were talking about the principle of levelling. Then, you know basics of the instruments; what is the basic philosophy behind the instruments, which we use in the levelling?

Then, we talked about one more interesting thing there, that was - because there, in the earth's surface, we have the curvature, and as well as because of the atmosphere, the line of sight is not horizontal, neither the line of sight is going along the level line as we desire. So, in that case, when we take the observations on the staff using the level, our line of sight is not, you know, along the level line; it will have some error. So, we saw the effect of that error also, and also we found the correction for that error - how we can eliminate that.

What we will do today, we will be talking about balancing back sight and foresight. Then, we will see in detail some levelling instruments: the staff and their types, levels and their types; and we will try to define the sensitivity of a bubble tube; and finally, we will try to see, if the time permits in this video lecture, the adjustment of levels - how we adjust them. So, we will start with this balancing back sight and foresight.

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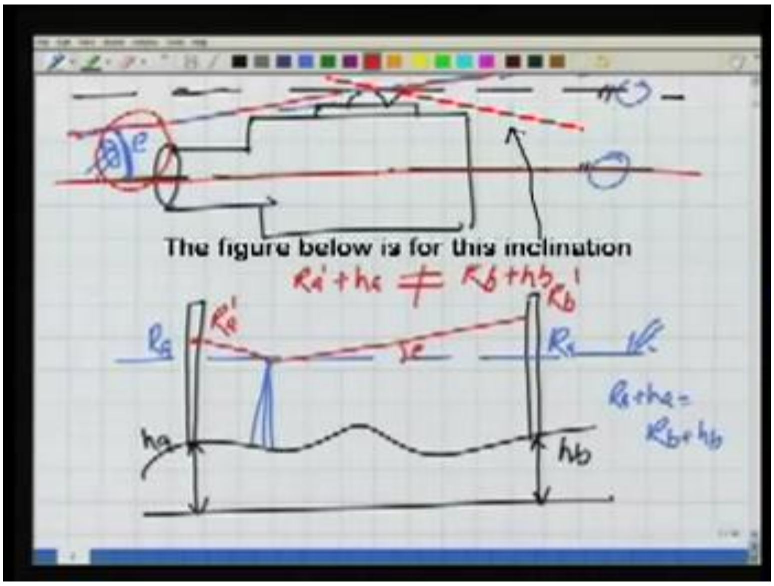

I am going to draw another level here, and this is the line of sight, and over here our bubble tube. And in ideal case, the axis of the bubble tube is parallel to the line of sight, if it is not so - let us say, because of some reason - the axis of the bubble tube is like this, and it makes an angle theta or let us say because this is an error angle e; so I write e.

Now, if these are not parallel to each other, then what will be the problem? Let us do the datum; this is the terrain; and over here, I know let us say ha, and my desire is to determine hb. I am keeping my staff at this point and at this point. My level, which is kept somewhere here, if the level is, the case is the axis of the bubble tube, is parallel to line of collimation, then once I bring my axis of the bubble tube, or once I bring my bubble in center, my axis of the bubble tube will be horizontal and because it is parallel to the line of collimation or the line of sight, my line of sight will be also horizontal; I am looking along the line on a horizontal line of sight.

So, in that case, this line is the horizontal line of sight. And for this line, the observations R a R b will satisfy our equation. The equation was R a plus ha is R b plus hb. Now, in the case of the problem we discussed, what will happen with that problem? If it makes an angle e here, as you can see, I highlight this; now these two are not parallel; this is the axis of the bubble tube; this is the line of sight. If that is the case, my instrument, once it reads the staff kept here, the line of sight will bisect somewhere here, and then it will be looking somewhere here. So, in this case, my R a will be R a dash and R b will be R b dash.

Now obviously, you can see it very well from here, if this is the case, because of this angle e - error - now in this case, R a dash plus ha will not be equal to R b dash plus hb. If they are not equal, then we cannot determine hb or if we determine the hb, the hb will be determined by some error. So, there is some error in determination of this hb. So, we are seeing - we are looking into - a problem. Now, how can we eliminate this problem? Is there a way, so that we can eliminate this problem?

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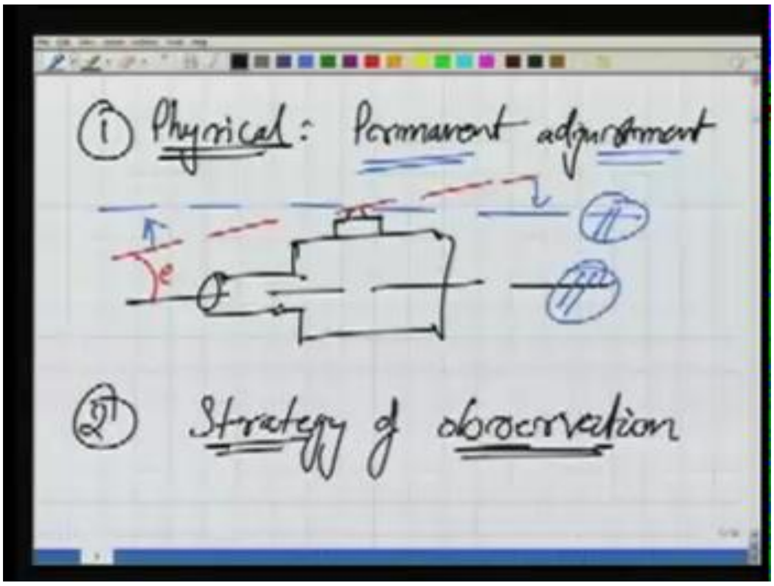

Well, one method could be, we can say a physical method; you know we are eliminating it physically; this is also called permanent adjustment. Now, somehow in my instrument - I am just making very rough figures here fast - what do we try to do? The line of sight - that is the bubble tube - and the line of the sight was not parallel to axis of the bubble tube; they make an angle e. I somehow try to take this axis of the bubble tube, we correct it; we change it; we make it physically parallel to line of sight again. So, we can do it physically, by playing with the instrument. There in the instrument, there are some provisions; capstone screw, we say - we will talk about that later – and by using, by playing with those, we can again bring them parallel to each other.

So, we should have a method for doing that, because you know - how to check whether they are parallel or not? How to check it? Right now, I am saying I have made them parallel, but there should be a way to check it - that they are parallel; how to do that? So, this is something, which we will do, when we talk about the permanent adjustment. So, permanent adjustment is one method by which we can eliminate or minimize the effect of non parallelism of line of sight and the axis of the bubble tube.

What is the second method? The second method is - we do not do anything with the instrument, because not always we can change those things in the instrument, rather we adopt a strategy of observation; as you will recall, in case of theodolite also, we were observing the angles in a particular fashion; you know, face right, face left, taking the average; similarly, we will do - try to do - something here. In case of theodolite, we could eliminate the errors by principle of reversal; something like that we will try to do here also.

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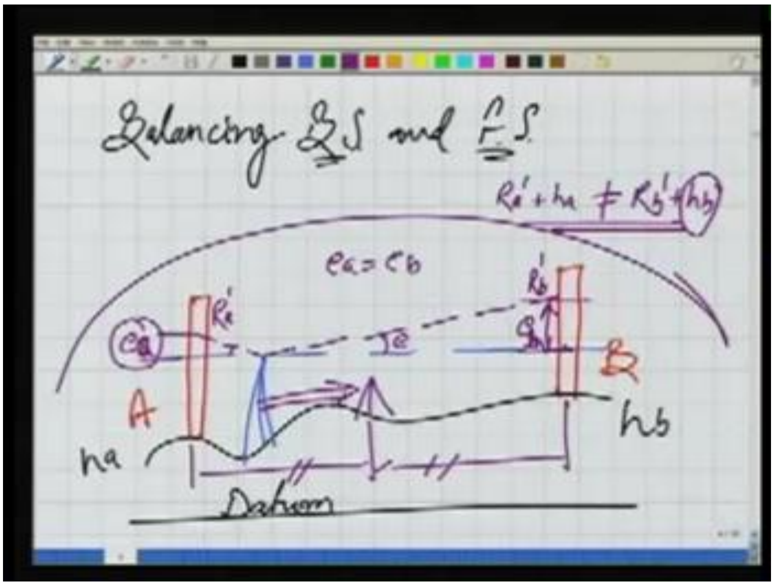

Well what can we do? This is what we do. We say as balancing back sight and foresight. Now, let me also explain this back sight and foresight - what these are. Now, here is again we have a ground, that is our datum, and somewhere we have kept our staff, and the another staff; and that is point A, point B; I know the RL of A; so, ha I want to determine RL of B hb.

Now, we have seen the problem of non parallelism. This is the ideal case - the blue line is in the ideal case, while this is the case of the error. If my instrument has got this error of non parallelism, I will be taking the observation at R a dash and R b dash; we have seen this. Now, how to eliminate this? What to do in the observation? If you observe over here very carefully, if you observe within this very carefully - this error - because right now my equation R a dash plus ha is not equal to R b dash plus hb. In order to make them equal, what should I do? If you see here, because of the error in the instrument we have some error here - ea. Similarly, here also we have some error - eb. Is it not? Somehow we have to make these two error same; how to do that? We will bring this instrument somewhere in the middle. So, if I keep the instrument - instrument means the level - somewhere in the middle of these two staffs. So, these two distances are the same. If that is the case, eb is here and ea is here. So, in that case, ea will be equal to eb and in that case, this will be satisfied obviously. And if this can be satisfied, I can now determine hb. So, even if the instrument has got error I can still determine hb. So, what we are doing in this case, we are trying to make my sight to the known point.

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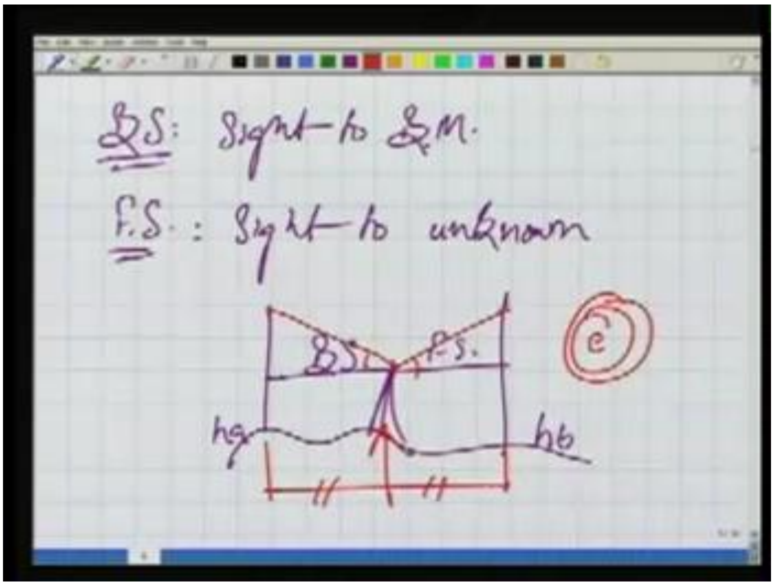

Let me also define this - the back sight is a sight to, I can say benchmark - benchmark means something for which we know the elevation - it could be known point. And foresight is sight to unknown; we do not know the elevation. So, in this case, if I know ha, so this is my back sight, and we want to determine hb, this my foresight.

So, what we saw here? We can eliminate the effect of non parallelism error by keeping my level somewhere in between, so that these two distances are equal; so, the effect of this error will be gone. And this is what we say balancing back sight and foresight; it is a very important thing. Now, wherever possible you should know - we do not know about our instrument - that how much error is there in the instrument e; we do not know about it; we are not going to check it at every point; of course, frequently we should do that checking up, and if possible, we should also permanently adjust the instrument, but you do not know at what point the error has occurred in the instrument. So, it is advisable that always whenever we are doing the surveying, we should try to maintain this balance of back sight and foresight; this is important.

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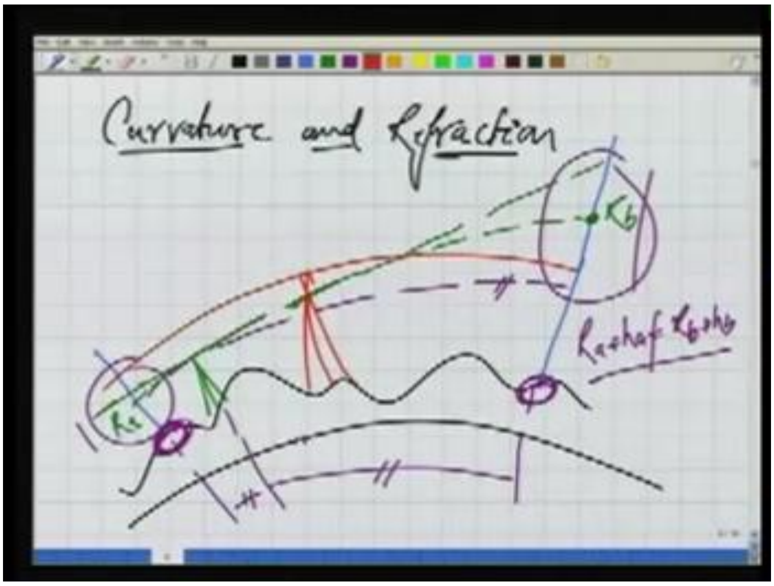

This is important for one more reason; that reason is, we have seen the effect of curvature and refraction. What was that? If my datum is - that is the datum, the geoid, the mean sea level - and somewhere here is my terrain, and over here I am keeping my staff, and another staff is kept here vertical, and somewhere here is my, you know, instrument; that is the instrument. And we know, when we take the observation with the instrument, the instrument tries to establish a horizontal line of sight. So, a horizontal line of sight here will be like this, which will not follow the level line; also we know with the effect of the refraction, we actually do not observe along the horizontal line of sight, rather we observe along a curvature, and we take the readings somewhere here. Now R b and somewhere here R a.

In ideal case, I should have observed along a surface - which is the level surface you know parallel to this surface - so that would have been, you know, parallel to that; something like this, but we cannot establish this; we know it already; we have seen the effect of curvature and refraction. So, here in this case, as you observe, if my instrument is at the location which is not in between these two, these two are not equal; my instrument is not in between two staff positions, then the effect of curvature and refraction is also not uniform in these two staff positions. We can see this; effect is very large here; it is very small here. And because of this reason, because the effect is non-uniform, we cannot write our base equation that R a plus ha is R b plus hb; they will not be equal.

So, again, we can eliminate the effect of curvature and refraction, when we are transferring the RL of a point here to a point here by keeping our staff somewhere in between. Now by keeping the staff still I am observing along a wrong surface; I am not observing still along the level surface, but the effect of the error is eliminated. So, this is the utility of balancing back sight and foresight.

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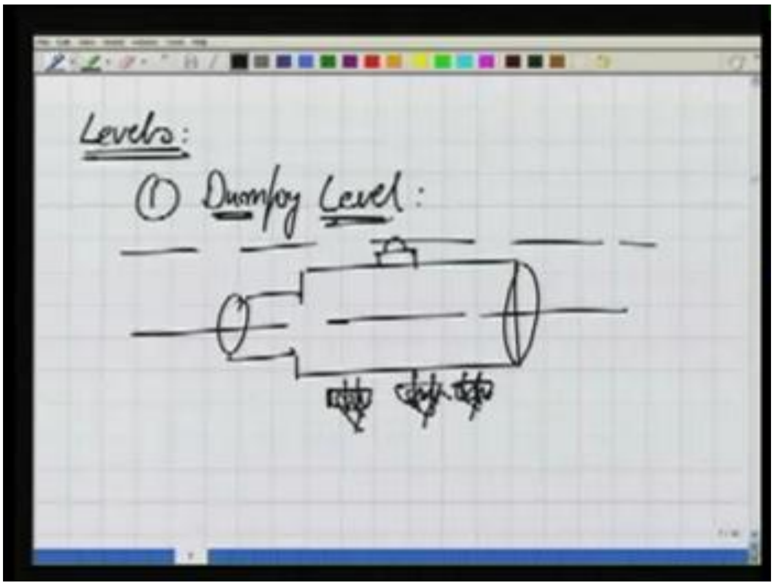

Now we are going to talk about the instruments - the levelling instruments. First we will you start with the Dumpy Level. now in the case of the Dumpy Level, we have the eyepiece and the telescope here; that is the objective; again the line of sight will be there and a bubble tube; and the bubble tube is parallel to this; along with all these we have the levelling screws here. These are the simple construction of Dumpy Level. What we do with the Dumpy Level? We first level it and then we start taking several sights. We will see a demonstration of dumpy level now.

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Here is Dumpy Level. In this Dumpy Level as you can see the various parts. Over here is the bubble tube; and this is the telescope, this line; and the line of sight is here; axis of the bubble tube is here; and they have been made in such a way, that axis of the bubble tube and line of sight they are parallel to each other.

Well what we do? Making use of the three screws here, as we did in the theodolite, then similarly, what we will do, I will keep it parallel to two screws; for example, these two screws, and I will level my bubble tube. Next, I will keep it perpendicular to that and using the third one, I will again level it. So, by repeating this procedure it will be leveled.

The meaning is, now wherever I take it the line of sight it will remain always horizontal. Having done that, what we do we, have the eyepiece here. So, looking through this eyepiece, because there in the eyepiece, we have the cross-wire, we can sight the staff, and we can take the reading.

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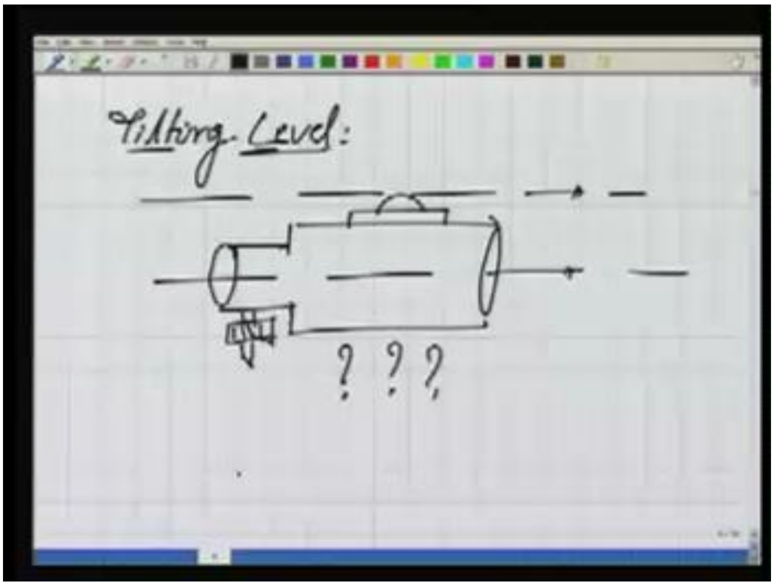

Now, the second level in the series is Tilting Level. Now, what is the special about the Tilting Level? If I draw the line diagram here, this is the eyepiece, telescope, the objective, line of sight; again, we have a bubble tube here with the axis of the bubble tube. And by construction, these two are parallel. Now in Tilting Level, the advantage is, it is very fast. Why? Because instead of having these three levelling screws or three levelling head we have only one levelling screw here, and using this, we can do the quick levelling. We will see a demonstration on the Tilting Level now.

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Well this is the Tilting Level. In case of the tilting level as we saw that the telescope has got a screw and just by using the screw, I can tilt the tape telescope. So, we use this for levelling.

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When it is here, if I rotate it, this is the telescope and the line of sight, and over here, I can see, in this case, from here the bubble tube; there are different kinds of bubble tube; one which we have seen in the Dumpy Level, which we see externally.

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Here we see the bubble tube, which is internal, and this internal bubble tube makes a U, you know, there will be two U (s), and they will move about, and once it has done one full U, then this is leveled. Well, how do we do that? This is the tilting screw; using this tilting screw, right now what will happen? If I rotate it up, and you know, whatever the way - right now this telescope is tilting this way or that way. So, if I have to sight, I have to take a back sight somewhere there, what will I do? My staff is kept there, I will just turn it there, make use of the target sight - this is the help - and using this target sight, I will bisect the staff; after having bisected that, I will focus it - that is the focusing objective; once I have focused it, I want to level it. So, to level it, I will use the tilting screw. So, using the tilting screw, my line of sight is horizontal, and I will take the observation.

The problem in this case is, the moment I change it, the levelling will change, because we have leveled it only in one direction. So, we use this for the kind of things, which we said - fly levelling - where we can do it fast; while in the case of Dumpy Level - this instrument here - once it has been leveled, you can use it anywhere; everywhere the line of sight will be horizontal. So, the thing is wherever the staff is kept I can take the observations there.

As we have seen, the Tilting Level and Dumpy Level, let us see that how we work with them or rather the utilities - where we use them. In case of the Dumpy Level, you saw that once we have leveled it, using these three levelling screws, we can rotate the telescope in the entire horizontal plane, and the line of sight will be always horizontal, wherever you rotate it. So, in view of this, what we can do, if I draw now everything in plane, we are looking from top.

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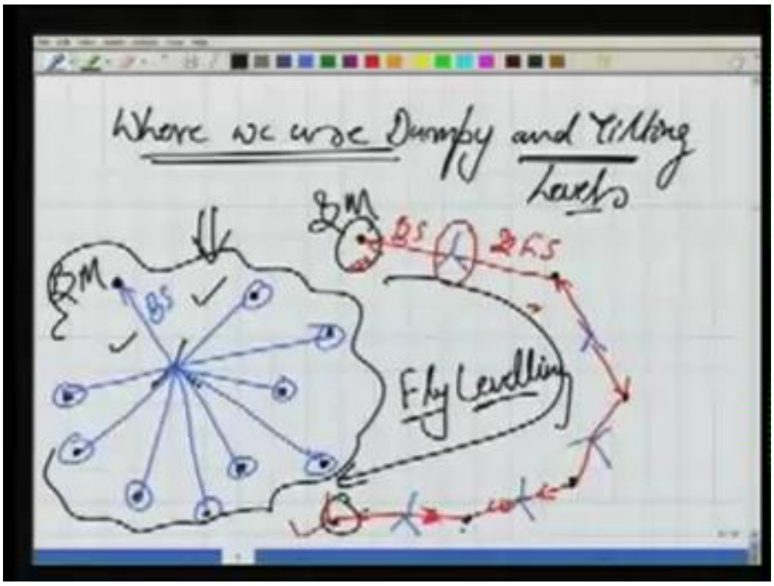

Well we have a point, which is our benchmark, and this is where my Dumpy Level is. What do I do? I take or rather there are many more points for which I need to determine the RL; I know the RL of benchmark. So, the procedure is once I have levelled my Dumpy Level, now after taking this back sight, I can take several of these sights to each of these points. So, what am I doing? I did levelling only once, and after doing that, I am just rotating in the horizontal plane and taking observations by keeping the staff at all these points, so that I know the RLs of these points.

In case of Tilting Level, how is the Tilting Level different? In case of the Tilting Level, well the problem is, I have a benchmark somewhere here, and I want to determine the RLs of some points, which are along a road. It is a linear thing along a road. So, what I do? I keep my instrument somewhere in between like this; these three lines, they indicate the tripod; and then, first of all, I bisect my staff which is kept at benchmark, and then, quickly I level it, because we have seen the procedure how we level the Tilting Level; it is a very quick procedure. So, while I am taking the back sight on this staff I level it, then I rotate it in the horizontal plane and again I take a sight, which is foresight. Then I change the position of the instrument; again, I take the back sight and a foresight; again, a back sight and a foresight; again, a back sight and a foresight and so on. So, finally, this way you can determine the RL of this point.

So, what we saw in case of Tilting Level, we use it if at any instrument position, we have to only take one back sight and one foresight, because the levelling is very quick; just two times levelling, and levelling is very fast; I can very quickly take the observations here, and observations here; I am not wasting my time in levelling my Tilting Level as in the case of the Dumpy Level, for the, you know, 360 degree. Dumpy Level is levelled for entire 360 degree; wherever you rotate it, it will remain levelled. But that is not the case with the Tilting Level, we level it only twice - for back sight and for foresight. So, Tilting Level is generally used for a levelling like this.

What did we do? Starting from a known benchmark, we determine the benchmark - you know a temporary benchmark here - or the RLs of several points; this kind of levelling we say fly levelling. You know, we are just moving and doing the levelling; it is not like the levelling, which we did here. With this kind of levelling which we are doing with the Dumpy Level is more suitable or more appropriate, may be, in a building construction moment where we need to establish RLs of several points.

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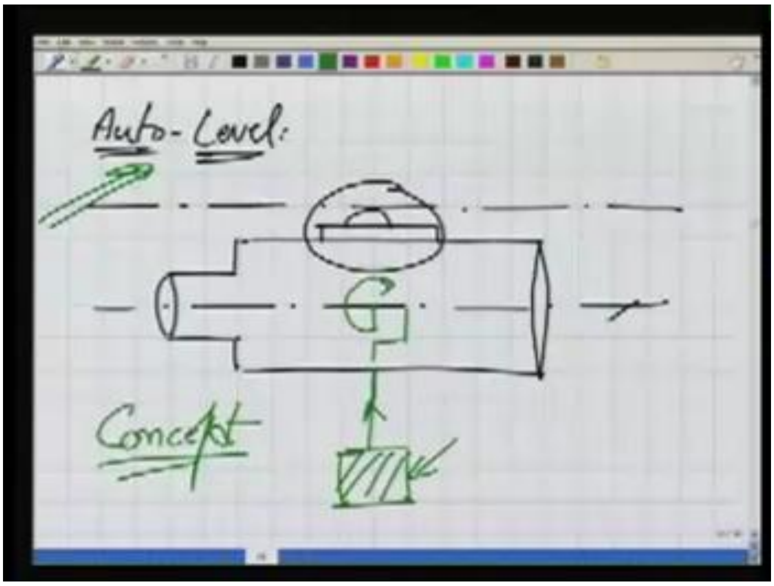

Let us now look at another level, which is Auto Level. Now in the usual level what we saw that we have a level tube, and it is helping us to make the line of sight horizontal. Well, we are thinking of some, you know, innovative way of making the line of sight horizontal. What could that be? Let us say if I suspend a very heavy load at this point; it is a very, very heavy load, and over here, at this point we have a hinge. So, my level or this telescope is free to rotate. Now, this load is attached to the body of the telescope. Now this load - if I swing my telescope in this case, what this load will try to do - it will always try to come in the center, and this line will always try to become vertical, if it is so, and we ensure that this line is perpendicular to the line of sight, my line of sight will always be horizontal. So, this is a very good concept, you know, to make the line of sight horizontal, because this load will always align or will always be in the vertical direction; in the direction of gravity. Now this concept how to realize that actually in a level? Now in a level in which it has been realized we say that as Auto Level. So, in the case of the Auto Level you have to do the levelling only a little bit, but the level automatically will make the line of sight horizontal. How is it done?

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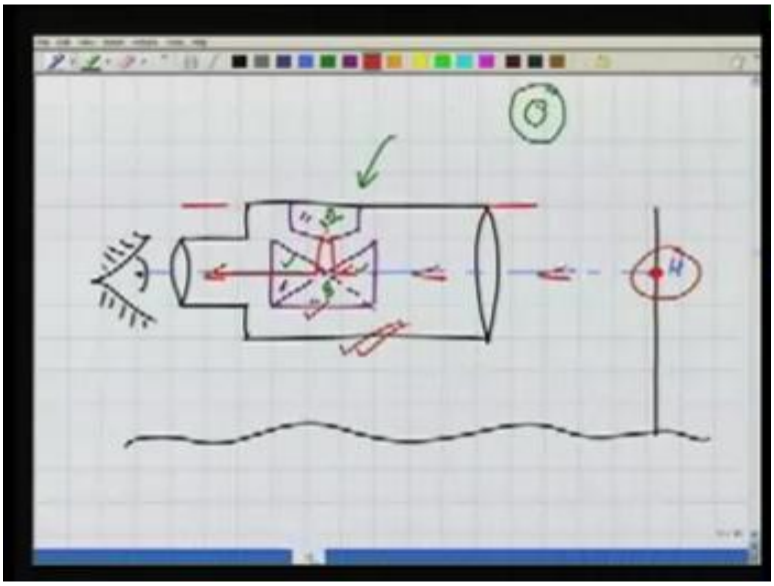

If you look at the diagram here; now in this diagram, along with, there is no as such you can see here, the long bubble tube; of course, we still have a circular bubble tube there, in order to help us - we will see why in a moment, but in addition to the rest of the level - the level is same as the Dumpy Level case - the telescope is nearly same; the difference is we have some extra optics here, as you can see here.

Now this particular part - A part - is attached to the body of the telescope, while the part B is freely suspended; this part is freely suspended, so this part always maintains its position. So, even if I change the orientation of the level, the part B will remain as it was. Now how will it helps us? It will help, because right now if I am bisecting H, whatever is there H, the reading, those rays of light they are coming like this, and if in this assembly A and B would not have been there, it would have been like the blue line here. So, directly this blue line would have gone into my eye, and I would have read what is the value here or the reading there, but by addition of this extra assembly A and B, what happens? Again from B it gets reflected and through this optical terrain again it comes back and it follows the path same as the blue line in this case, while my this level is horizontal.

This is the case when the level was horizontal. So, in the case of the horizontal this will not make any difference it will just, of course, change the root of line of sight or the range which will come like this, go to A, and then go to eyes.

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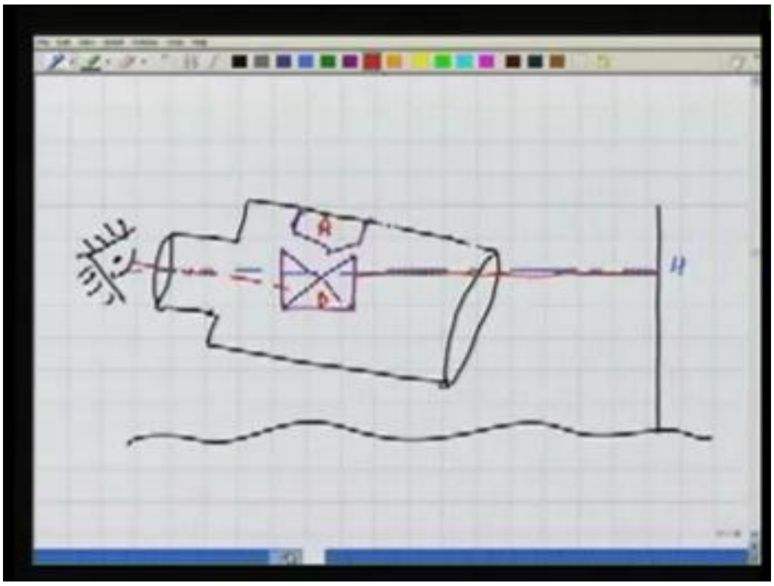

But what happens if I tilt my level now? If I tilt my level - as in this case - this part A will tilt with the body of the telescope, while the B will remain where it was.

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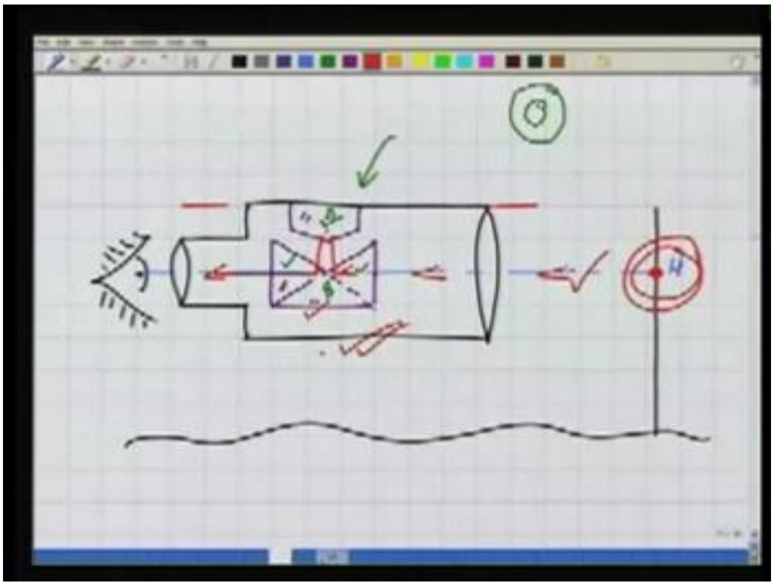

Again from the same point as, because this is the line, which is horizontal line as in the previous case, this is the line, which is the horizontal line; if my instrument is kept there, I should read point H for the horizontal line.

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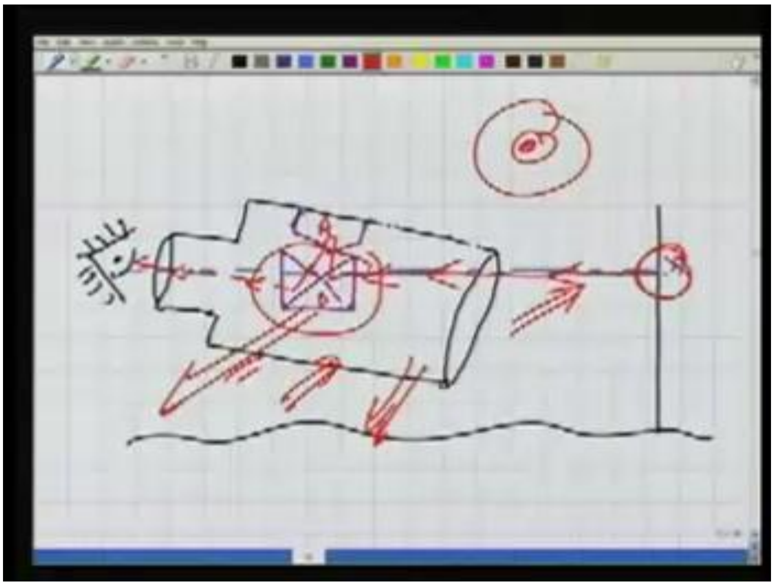

So, the point H which is being intersected by the horizontal line of sight here - this point; the range they travel over here, and again by the optical assembly B and A they get reflected in such a way that what my eyes see now, it is still point H. So, even if my telescope is slightly tilted, I am still looking at the same point H. So, what is the meaning of that? The meaning is - well what we can do, even if my telescope is slightly tilted it does not matter, because the assembly - optical assembly - there inside is ensuring that the line of sight is horizontal, thus ensuring that what I am looking at the reading that I am reading, is corresponding to the horizontal line of sight.

Now, can I keep tilting my telescope to any angle? No, because this particular assembly B will start, you know, striking with the body of the telescope. So, for this also there is a limit. So, what we do while we work with this auto level, we make use of circular bubble; now we know the use of the circular bubble; circular bubbles are lethargic; they do levelling, but not very accurate; so, we do inaccurate levelling with that. So, first levelling we do with the circular bubble. So, my telescope is near the level, the line of sight is not horizontal yet, nearly levelled. Now the rest of the job is being done by the assembly B and A; they will ensure, even if my telescope is nearly levelled, or not, you know, perfectly horizontal, the line of sight for me is now horizontal.

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We will see a demo on this Auto Level now. Now, this is Auto Level. Now in the case of the Auto Level, as we discussed before, it is same as Dumpy Level; there is not much difference; the only difference is inside this telescope, because the telescope is here, this is eyepiece, this is objective lens, and this is our telescope here. Now, there inside we have an optical assembly, which is suspended. Even if I tilt it, what will happen that optical assembly will maintain its position; it will keep hanging in this original position; by using that kind of assembly - that optical train - it is possible as we have seen just now, that we can always see along the horizontal line of sight.

Now, how do we work with this? Well first of all, we bring this instrument and let us say I want to keep this instrument here. So, I set it up here; set it up means I will make use of tripod legs; and I will try to make the tripod head - that is the tripod head - nearly horizontal; we know it - how to do it. One more thing, as you will know, it is obvious there is no need of centering of any of these level; we do not need to center it, because we can keep it anywhere; we are not interested in the height of this point, well we are rather we are interested in the heights of the point where I am taking the back sight; I know the elevation of that point, where I am taking the foresight, I am interested in the height of that point. So, we can set it up anywhere. Well this is partly levelled.

Then next, we make use of these three screws and we try to bring the circular bubble - the circular bubble is kept here - and I can see this circular bubble even from the sight if my eye is here, I can see the circular bubble without going on the top; that is why a mirror is provided here, so the reflection of the circular bubble can be seen on the mirror. Well once this circular bubble is in nearly center; that means, rest of the job will be done by the compensator. Now the compensator makes the line of sight horizontal, and we are ready to take the observations.

Now, here in this case, in many of the levels, you will find that we have also - as in this case some - graduations. Now these graduations here are zero to 360. So, you know, it gives you an idea of measuring the angles also; sometimes you will use to measure the angles. Well, in this instrument, to focus the objective and this is to give very small - I can rotate it by hand of course; I can rotate it by hand - but to give very small tangential or very small rotations we use these tangent screws. Similarly, as in all the instruments we have the line of sight or the Raffle sight here. So, the initial sight that we take on our staff, we make use of Raffle sight.

So, this is our Auto Level. How to check it - whether it is working or not? That compensator inside - it is really working or not? Is there is any way that we can check it? Well what I will do, let us say, right now, using this I bisect a staff. So, I am bisecting a staff, I focus it and now I can see a reading there; I am seeing some reading there. Now what I will do, I will change using one of the footer screws a little bit here, I just rotate it a little bit, what will it do? It will rotate my telescope - whether it will bring it down or up. So, it will tilt it; if the telescope is tilted and if the compensator is working, the reading there on the staff should not change. So, now again, I see that reading; if the reading has not changed from the previous one; that means, the instrument or the compensator inside or the Auto Level, the way it works - is working.

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Now, this is one staff; now staff as we are seeing that it is, you know, a vertical scale. Using our level, we sight the staff, and we read the reading.

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Now as you can see here, this is the big staff here, and we can fold it or unfold it, and we can unfold it and the total length of it can be increased up to 4 meter. There different kinds of staff: this one which is folding or a telescopic one, because it is a telescopic one, one staff will get into the other one. We have also then folding; the staff this is made of wood; now, in this case, if you observe closely, you can see the graduations here; now look at the graduations, you can see very well what is the least count of this; the least count in this case is half of the centimeter. Now it is important when you read it, sometimes you may see this staff inverted; inverted because your telescope is producing an inverted image. So, you have to be careful how to read this staff from top to down. If the staff is seen erected, you read it from down to top. Right now also if you are reading somewhere here, because how do you read it? You will have a cross-wire and the cross-wire will be sitting somewhere here like this. So, corresponding to the horizontal wire of the cross-wire, you read your staff. Now, this is another staff; this is made of aluminum.

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And again, you can see the graduations here. In this in this case the least count is, as you can see, 1 centimeter. One thing you will observe, along here in staff the graduations are written either in red-white combination or as we can see down here in black and white combination. This is in order to see this staff against any kind of background. Now how to work with this? When we are holding this staff, this staff should be vertical, obviously; in order to make it vertical, generally what we do, we hold this staff in this position; we generally we stand vertical. So, right now this staff is vertical. In order to ensure that the staff is really vertical, we can make use of a bubble tube.

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Now over here, you can see we have a bubble tube. Now this bubble tube…bubble tube means it is a circular bubble. So, I try to make this circular bubble in center. So, once this circular bubble is in center, our staff will be vertical. So, this is important, that how we hold it and we should hold it vertically.

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Now, here we have Digital Level. Now the Digital Level - many of the things are being done electronically now. Now, how it functions? Well here also we have a telescope.

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And the telescope as you can see is this; this the objective lens, and here is the eyepiece, and the line of sight is here; that is the line of sight. Well we have again three screws and using these, we can level it. It has also an inside an Auto Level. So, using this Auto Level, I will level it only up to a little, you know, levelling, so that the circular bubble is in center. The rest of the job is being done by the Auto Level. Well once, it is levelled what we will do with this?

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Over here, if you see carefully, we have an alphanumeric keyboard. We also have an LCD panel, and whatever we are doing, we do all those commands through this keyboard here. Well when we have to sight the staff, the staff in this case is like this, as you can see, this is the staff and the staff is made of bar code.

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So, the entire staff is made of the bar code. We do not have any graduations written here. Now what this instrument does it will bisect the staff.

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After bisecting it, it will capture an image of the part, which is bisected. So, the image of the bar code is captured. Now this image is fed into the level, and we have some reference images of the bar code. Now, the image which is captured is correlated with the reference images which are kept in the digital level, and by this correlation, you know, something which we are capturing and the entire image is there, we slide it like this and we find the best correlation. So, what are we trying to do? We are trying to ensure where my line of sight is actually bisecting it. So, using this bar code, using this correlation of the images, it is possible that we can know or we can compute, what is the value of reading here. So, the human being or the observer here, does not do any observation. What does he do? He only bisects it and he presses a button here, and the observations are automatically captured. Well, in addition, to the elevation of the point or the reading over here, the distance from digital level to the staff can also be measured by the same philosophy.

Now, in this instrument, the advantage is if all these observation which we are taking - you are not recording them manually, the instrument is recording them; as well as you need not to write them in a field book, rather these observations are being recorded inside the memory of this. So, you take the instrument back to the laboratory, you plug it with the computer, and you can take all these observations, download all the observations. So, the errors, which may occur in otherwise case due to manual recording is also eliminated in this case. So, this is used for very precise kind of levelling operations. Now, we look into an aspect, which we say the sensitivity of the bubble tube, because we have been using the bubble tubes in all our instruments the theodolite level. So, what is the sensitivity of the bubble tube? We will try to define that.

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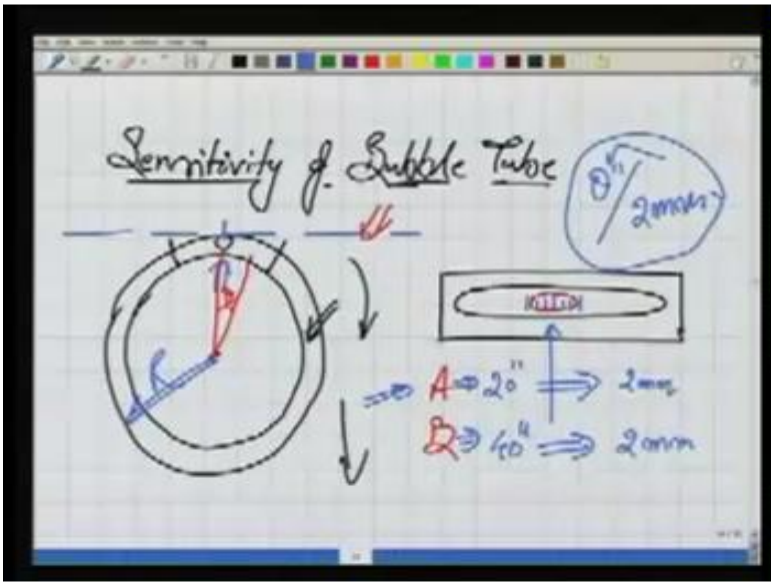

We know what the bubble tube is. A bubble tube is made from a very large circular tube; and then we can assume it to be like that; a very large circular tube, and in that circular tube, you fill some liquid which has low viscosity because, so that it flows very easily. Now what we do, if you fill that liquid and you leave a little gap there, so that gap will become a bubble. So, right now if this is the direction of gravity, the bubble will be there on the top. If I rotate this circular tube, you rotate it, still the bubble will maintain its position; the bubble will remain always on the top.

Now, our actual bubble tubes, which we use in the level instruments, are only a part of this. So, what do we do? We cut a little part of that big tube, and we use this little part. If I see this part in plan, it will look like this; that is the casing within which my bubble tube is, and somewhere here is the ,let us say that is the bubble tube which is being seen to us, and that is the middle of it, and these are the graduations in that.

Now, we have defined this particular center part of it over here, let us say here, and a line at this point, tangential to it is the axis of the bubble tube. So, at a point here tangential to it is the axis of the bubble tube. Now, when we say the bubble is in center, as the bubble is in center here, what is the meaning of that? When the bubble is in center that bubble will appear as if it is like this. So, we try to achieve this; we try to tilt our bubble, so that it comes to the center. Once the bubble is in center, my this line - axis bubble tube - will be horizontal; that is the basic thing.

Now, the sensitivity of a bubble tube is I give you two cases. Let us say there are two bubble tubes A and B. In case of A, and over here, if I rotate this bubble tube, this big tubular circle I rotate it by a small amount - let us say this is theta angle - I rotate it by theta angle, what will happen? The bubble will move slightly or I should say bubble will not move, but the tube is moving of course, that is the relative thing. So it will appear as if bubble has moved slightly. So, if I make some graduations here, in our bubble tubes generally the graduations are of 2 mm.

If for tube A, I need to rotate it by 20-second angle, in order to move the bubble by 2 millimeter, and in the second case I need to rotate it by 40-second again to move it by same 2 millimeter. Now, which of these two bubble tubes is more sensitive? More sensitive means more active. Now, we know it, now that for this bubble tubes, only little angle movement, only slight movement move the bubble by 2 mm. So, this A is more sensitive.

So, we define this sensitivity like this only; you know - what is the angle theta by which we need to tilt the bubble tube in order to move the bubble by 2 mm? So, this is how we define the sensitivity. This is theta second 2 millimeter; that is the sensitivity of a bubble tube.

Now, what are the factors, which will control the sensitivity of the bubble tube? Well you can think about those you can imagine, you know, you start thinking, viscosity of the liquid - yes; the radius of the circle here, this radius - the larger this radius better will be the bubble, more, you know, fast, more active; that is the sensitivity. The internal friction because there is a tube, and there are the walls, and when this liquid is moving, it will have the friction. So, if the walls are very smooth here inside, it is definitely better. So, these are the parameters, these are the factors on which the sensitivity of a bubble tube will depend upon.

Now we will talk about permanent adjustment of a level. We have seen the problem with the level. You know, it may happen that the axis of the bubble tube is not parallel to the line of sight. And we have seen what kind of problems it will lead to. We know how to eliminate this problem by taking a method of observation, you know, a strategy of observation, by balancing back sight and foresight. But not always it is possible to balance back sight and foresight; you know, the field is very different. So, in that case, it will be desirable, that we eliminate this problem from the instrument itself, and this is called permanent adjustment.

So, what we will do, we will try to see you know, how we can adjust some instrument and before that to test if these two are parallel or not. So, in order to do that, what we will do, we will carry out a test which is called Two Peg test.

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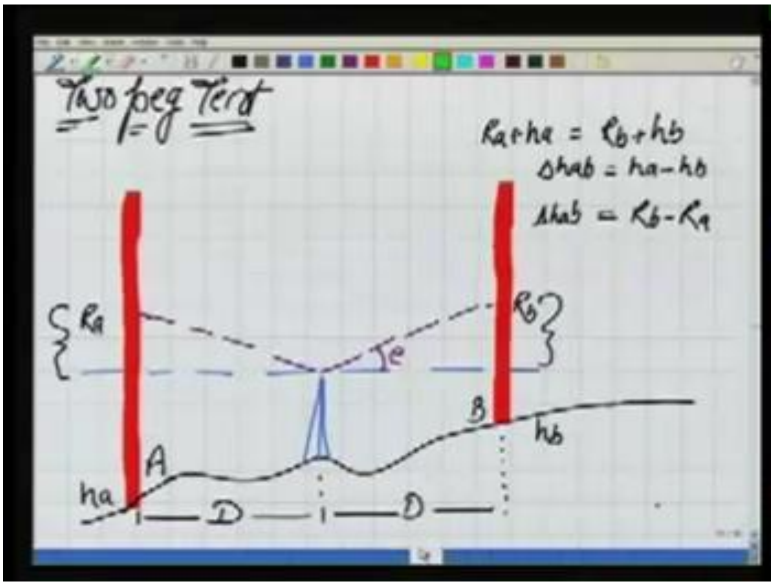

Now how this Two Peg test is done? We will see it now. Over here we have the terrain; again the point A and point B are there; point A the RL of that is ha and this is hb which we want to determine. Well this is our level, and as you can see, the level ideally should look in the horizontal sight or in the horizontal direction, which is not the case. I have kept the level here and the level is looking in an angle - at an angle - the angle value is e which is the error.

So, this e is nothing but the line of sight and the axis of the bubble tube they are at error; they are not parallel; rather they make some angle here; that is the e; and we want to check it - whether this is so in our instrument or not.

So, in this what we have done, we have kept our level somewhere in between. I will say let us say exactly in between point A and point B; if it is exactly in between point A and point B, the amount of the error - where is the error ? The amount of the error over here, over here - these errors will be same.

And if the error is same, what I can do? I can still write as R a plus ha is equal to R b plus hb, because whatever I am reading R b or R a though they have got error, but the amount of the error is same. If the amount of the error is same, I can still determine the difference in elevation between these two points as R b minus Ra. So, this we can write very easily from here. This is something, which we do in the field, because this Two Peg test we do in the field. In field this distance D, could be you know, 20 meter, 10 meter that kind of thing.

So, I keep my instrument here and 20 meter away from the instrument I keep the staff at A, and 20 meter on the other side I keep the staff which is at B. So, this is what we are doing here. Well having done this, I have determined the difference in elevation between A and B, which I am writing here is delta hab.

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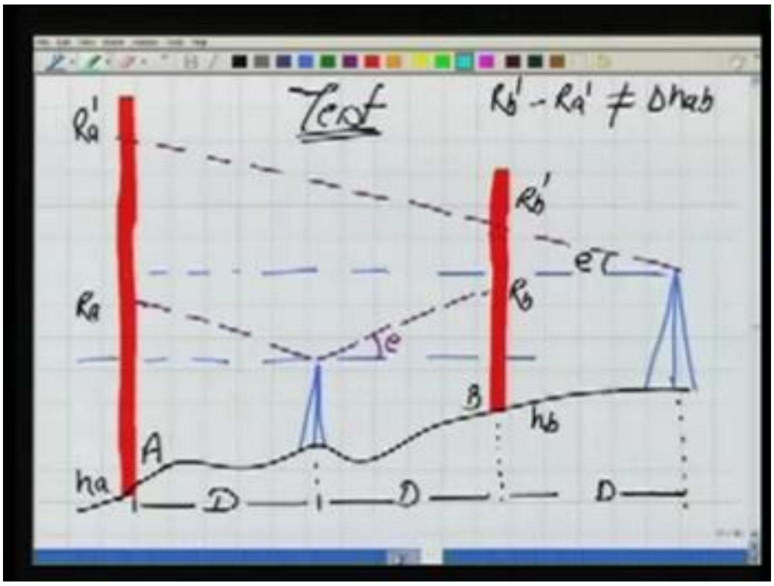

What is the next step? In the next step, we take our instrument - instrument means the level - again a distance D away from B . So, this is a distance D, and in the same direction, the direction A B and this is the point C, they all are in one line. Now from here I take the observation, and if I take the observation, you know, eye sight again I will have the error e. In ideal case, I should have looked in the direction of horizontal here; you know the horizontal direction; in ideal case this is the direction, but because of the error, I am looking in this direction, and I am bisecting, and I am observing the values R b dash and R a dash; this is what I am observing.

Well having done this, if at this stage I find R b dash minus R a dash, as we did before, we found that the difference in elevation was R b minus Ra. Here also if I do the same thing R b dash minus R a, I will find that this is not equal to delta hab, which is obvious from the geometry here; we have seen this before. So, if this is not equal to, this is a test; a test means I have determined now that because this is not equal to delta hab, I have determined that my instrument has some error of non parallelism e. So, this is the test to know it - whether the error is there or not. If there is no error, in that case still this should have been satisfied - R b dash minus R a should have been the same value as we got over here. Well, if your instrument has got the error, so what we would like to do? We would like to eliminate it.

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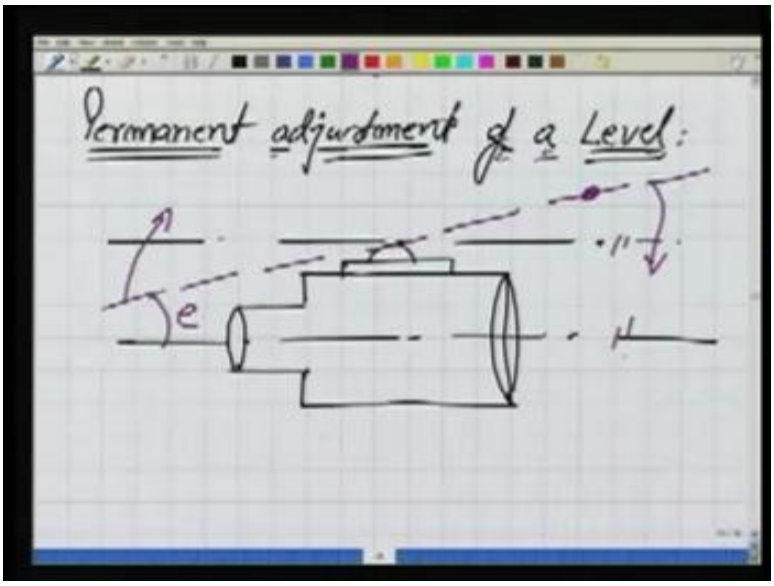

And elimination of this error means what I am trying to do? The meaning of error is my line of sight is not parallel to the axis of the bubble tube, and this is the angle e which we are talking about. So, what we will try to do in the adjustment? W e will try to bring this bubble tube in such a way - we will rotate the bubble tube in such a way - that this line axis of the bubble tube it becomes parallel to the line of sight again by the rotation, you know that. Now how to do it? What is the procedure?

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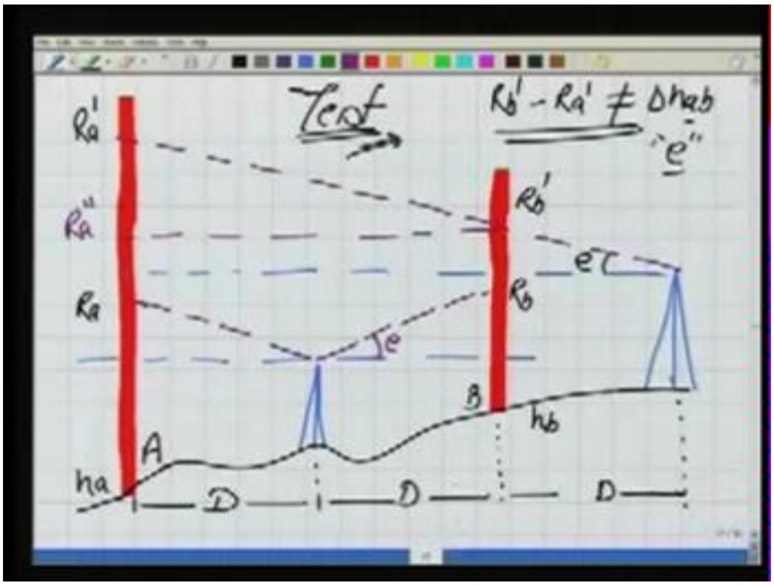

Well the procedure for that is, if we look carefully here, had there been no error corresponding to this R b dash, corresponding to this R b dash the corresponding reading here R a double dash we can determine simply by, you know, the reading at A corresponding to R b dash which we are writing R a double dash as this.

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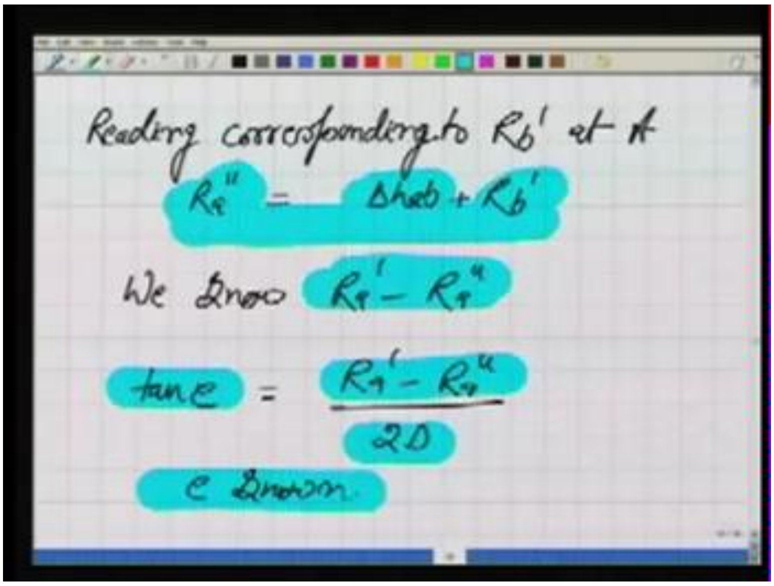

What is the meaning of that? The meaning is had there been no error, had there been no error, and if my instrument is bisecting the staff at B at R b dash, where it should have bisected staff? At A; it should have bisected a staff at A At point R a dash, because the line of sight should have been horizontal. And if it is so, I can find the value of Ra dash. I can find this value. So, what is this value? This is the value a reading on this staff. I should have read at this point. If I should have read at this point, I know now because this can be computed, I know delta hab, I know R a b dash; I know both of them; so, I can compute this value. If I can compute this, I can also compute R a dash minus R a double dash.

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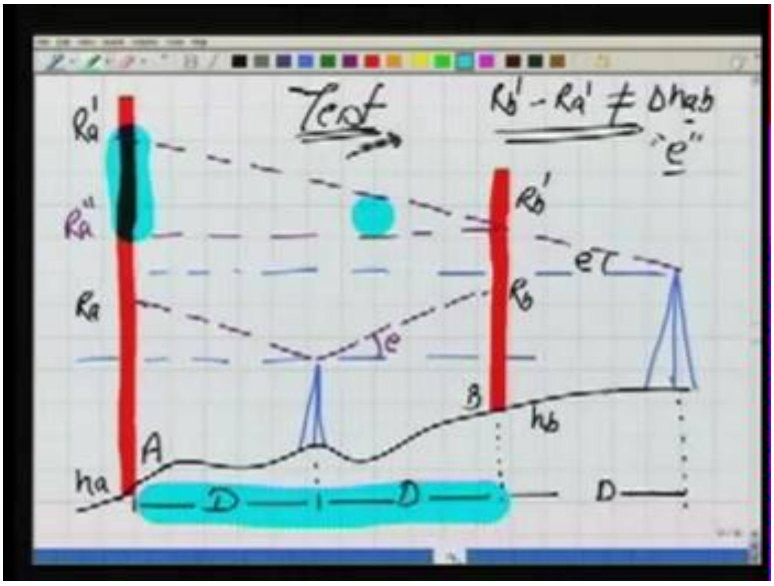

What is Ra dash minus R a double dash? It is this distance. I can compute it; if I can compute this, I know what is the distance D or rather 2 D. I can compute the angle e here. So I can write it in order to compute the value of angle e. So, angle e is known now, or the amount of error in my instrument is known now. What I can do? I can make use of this value of e also to apply corrections. Or otherwise, if I am going for permanent adjustments what I would like do?

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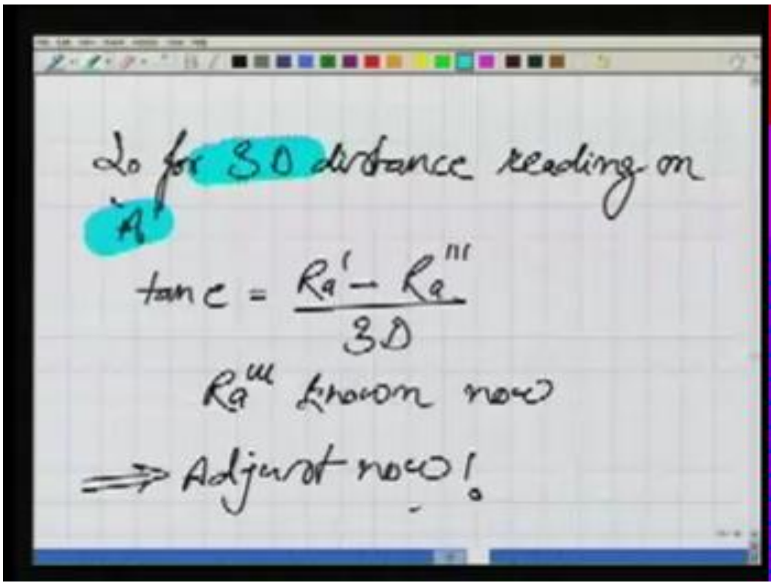

I would like to further know the reading at A corresponding to this entire distance of 3 D. What is the meaning of that? The meaning is - because right now my instrument is here, and my instrument is looking in this direction; had my instrument looked in horizontal direction where should have I bisected? I should have bisected at this point. If I write this point as this R a triple dash; I write this point as this. So, what should be the value? What should be the observation at R a triple dash this we can easily find, because we know now the value of e. So, R a dash minus R a triple dash divided by 3 D.

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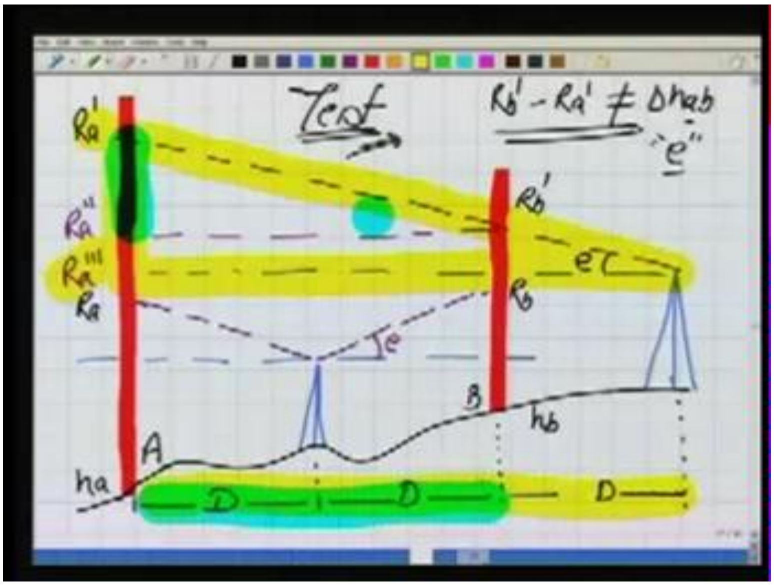

So, basically we are working, in this last triangle. Now we are working in the triangle, which I am highlighting by yellow; we highlight this triangle here. Now we are working in this triangle, and we are trying to determine the value of R a triple dash. We know R a dash. So, this R a dash minus R a triple dash - this length - can be determined because we know the value of angle e, we also know this distance 3 D.

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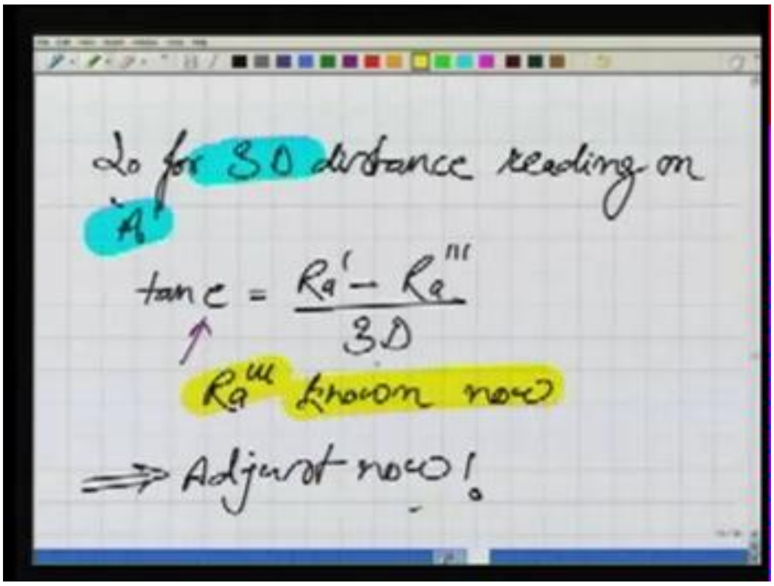

So, it can be computed. So, R a triple dash is known now. Now what is the meaning of this?

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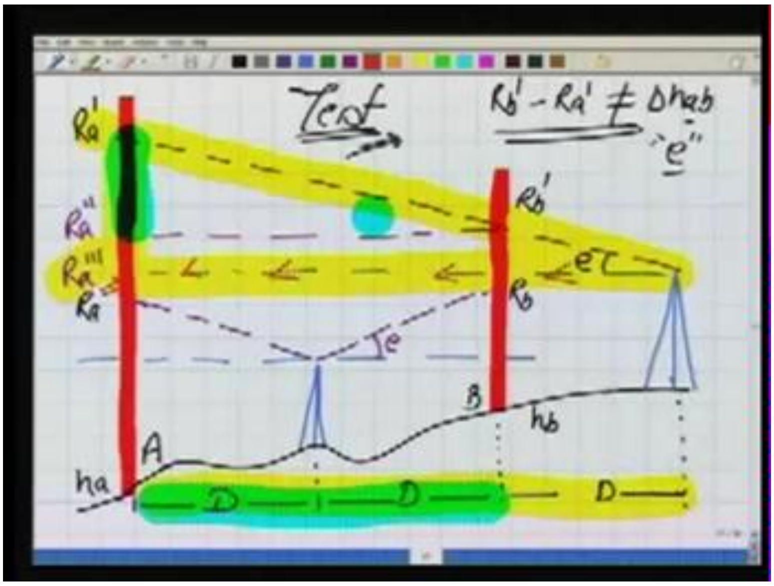

The meaning is, if my instrument is looking in horizontal direction, now I am drawing it here again by a red colour. If my instrument is looking in horizontal direction corresponding to a reading here, it should read R a triple dash - that I know now. If my instrument should look in the horizontal direction, it should bisect R a triple dash, but now - at the moment - I am bisecting R a dash. So, what should I do? I should change the … you know tilt my level, tilt my telescope in such a way that it starts bisecting R a triple dash. How will we do it? We will do it using the levelling screw. You will just use the levelling screws, and tilt your level in such a way, while you are looking through the eyepiece, that it is bisecting now R a triple dash on that staff. If you do it, what will happen to the bubble tube?

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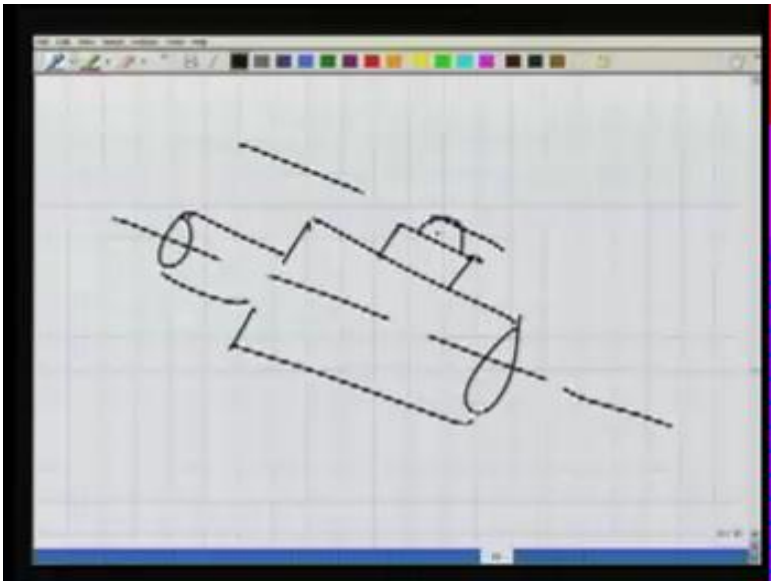

The bubble tube will go out of the center, because your level is now like this, because you are bisecting a different point. You know you have lowered it, you have tilted it, and because of that your level will go. You know earlier it was horizontal; earlier it was horizontal; now it will not be in horizontal or rather the level will go not in center, it will go out of the center.

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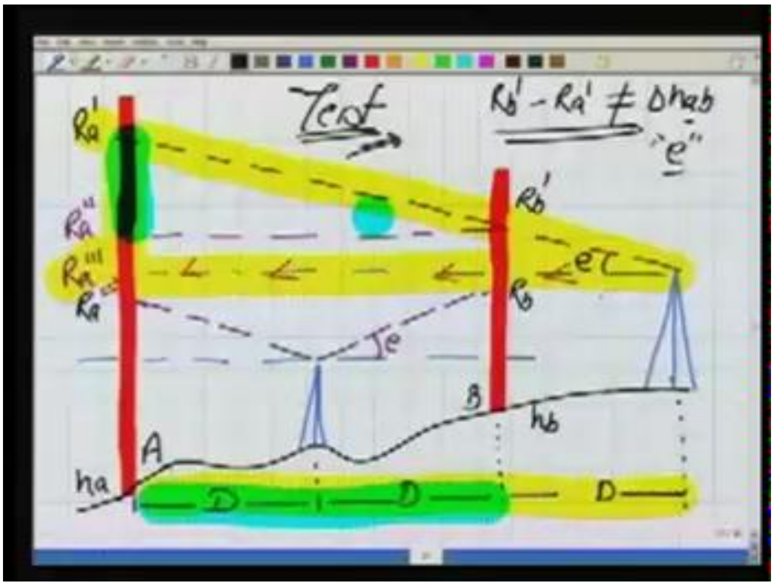

So, if that is the case, if the level has gone out of the center, this line of sight - at the moment the line of sight is horizontal - you know the way we did it, we have established a horizontal line of sight. Now what we want to do? Our telescope right now is horizontal - we know it by bisecting R a triple dash; but now my level is not horizontal. So, what we will do? We will change the bubble tube; we will use some screws there in the bubble tube - the capstone screws - and using those, we will either raise it or lower it, so that my bubble tube also comes in the center.

So, what we are trying to do? We are making a horizontal line of sight, my telescope is horizontal, by changing the level, I have brought it to the center. So, the axis of the bubble tube and the line of sight both are horizontal now. So, that can be established. So, this is the permanent adjustment in the instrument. So, we have seen the various kinds of levelling instruments today; the utility of balancing back sight and foresight; and we also saw that how permanent adjustment can be carried out in a level.

Thank you.