GPS Surveying
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Lecture – 06
GPS Position

Friends! Welcome you to sixth class on GPS surveying. Today, I am going to discuss on GPS position. Actually, GPS provides us position in certain particular reference frame. So, we need to know in detail about how this position really looks for, in our GPS surveying.

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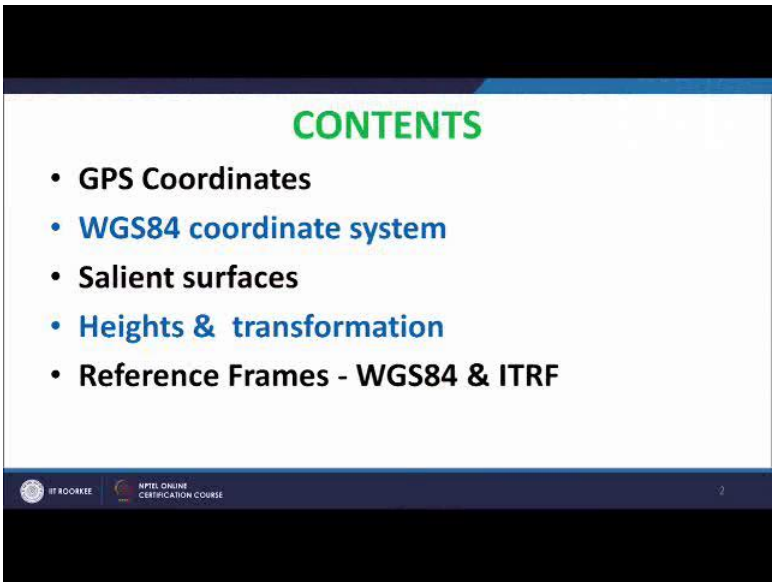

Now, this class will be dealt under following head: like GPS coordinates, then your coordinate system in which the GPS provides us the coordinate. Then, we need to know the salient surfaces, which is fit to, which we measure the height. We consider the height of any point on the surface of the earth, then different types of heights and their transformations to each other. And then, finally we need to talk on reference frame. This is required for precise measurement of position.

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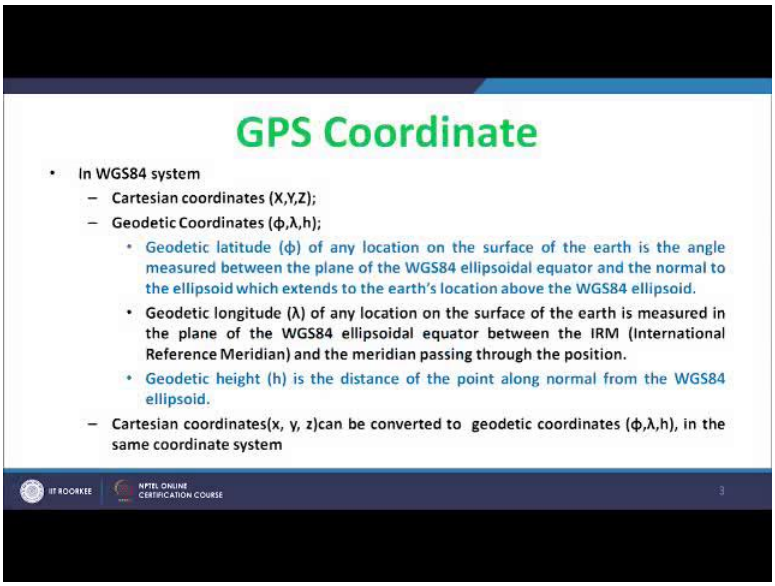

Now, GPS coordinate; actually, whenever we go for measurement of any position using the GPS system, it provides us the position in three dimensional coordinate. And, the coordinate may be of two types. One is that Cartesian coordinates; another is Geodetic coordinates.

Now, as we know whenever we talk about coordinates or position, it must be with respect to some reference. So, we need to know the references with which these coordinates are being defined. Now, whenever we look for a coordinate system, the first thing we need to know is origin. Actually, GPS provides us coordinates in WGS84 coordinate system.

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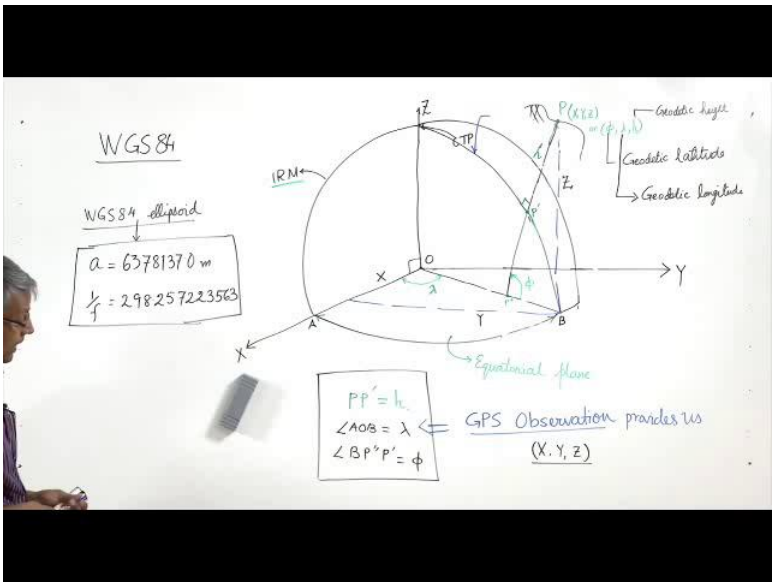

Now, this coordinate system has the origin at the center of mass of the earth. Now, when we will consider the center of mass of the earth, it is the mass of the solid earth along with the mass of the liquid; that means water in the ocean as well as the atmosphere. Considering all this together, the center of that is the center of mass of the earth. And, this is considered as the origin of the reference coordinate system, that is, the WGS84 system. And, scientists are has defined a position on the surface of the earth, which is known as conventional Terrestrial Pole.

Now, the line joining the center of mass of the earth and the Conventional Terrestrial Pole and beyond, that is considered as the Z-axis. So, it is the mean line along which the earth rotates about its own axis. So, it is the mean axis of rotation of the earth. Now, this is the Z-axis.

Now, if we imagine a infinite plane perpendicular to this Z-axis passing through the center of mass of the earth and a plane passing through International Reference Meridian, then the intersection of these two will give us a line; that is considered as X-axis.

So, this is in the equatorial plane and this is the International Reference Meridian, this is your CTP, this is right angle. And, this WGS84 coordinate system is a right handed coordinate system. So that means, we take a line perpendicular to the X-axis in the

equatorial plane, and that is considered as the Y-axis. So, these three axes X, Y, Z with O as the origin defines the WGS84 coordinate system axis.

Now, if we say this is the earth and P is the position on the earth, now this P is the position of this point, then it can be defined by X, Y, Z or it can be defined by phi, lambda, and h. Now, I am to explain this with respect to our WGS84 system. Now, apart from these three axes and origin, another, another thing is important which is the vertical datum surface. And for this system, it is the WGS84 ellipsoid.

Now, ellipsoid means it is an ellipse having semi major axis a, which is having, for this we will have the value 63781370 meter and flattening 29, one by f two, ninety eight point two five seven two two three five six three. So, these are the two parameters which define the WGS84 ellipsoid. And, if we take the minor axis along this Z and if we revolve this ellipse about this Z axis, then the ellipsoid, whatever I will get that is called WGS84 ellipsoid. And that is the considered as the reference surface.

So, if we drop a perpendicular, then, so here you can see this point P, we can reach from origin O by taking the route. This is the X and this is the Y and this is the Z, in this way how we define the Cartesian coordinate of the point P.

Now, for the Geodetic coordinate; phi, lambda, h. Phi means, it is the latitude. This is your geodetic latitude; this is your geodetic longitude. And, this one is geodetic height. Also, it is known as ellipsoidal height. So, these three parameter; geodetic latitude, geodetic longitude and the geodetic height, how we do define? It is like that we should do take a, this is the ellipsoid on which we will take a normal. So, this is a normal. Now, this is a point P, whose position we want to know or we have determined, which is phi, lambda, and h. And, if we draw a normal; that means, perpendicular, this is the ellipsoidal surface on which it is perpendicular. So, we have drawn a normal on it. It will be intersecting with the ellipsoidal surface at this point P dashed. Now, and it will be intersecting with the equatorial; this is the equatorial plane. So, it will be intersecting at equatorial plane at P dashed.

Now this angle, that means, the vertical angle between the equatorial surface and the line normal to the ellipsoidal surface passing through the point P, this angle is known as geodetic latitude. This is the International Reference Meridian, this is the point of which position we have to determine, and this equivalent point on the surface of the ellipsoid is

this one. And, this is the pole, this meridian of the place of observation or point of observation.

Now, the angle between the Reference Meridian I R M and the meridian passing through the point, angle, and this one is nothing but this one; that is called geodetic longitude. And, the height of the point above the ellipsoidal surface; this one is called geodetic height. So, P P dashed; P P dashed is equal to small h.

Now, if I say like A, this is B, then angle AOB is equal; is the geodetic longitude and angle B P double dashed P dashed is latitude. So, this is the geodetic location of the point P. So, in this way how we define the GPS provides us this angle, this angle and this height. So, from GPS observation provides us this as well as GPS observation provides us the X, Y, Z. And for this, the references are like this; that for these are the X, Y, Z axis and the reference ellipsoid is WGS84 ellipsoid, with respect to we get the height.

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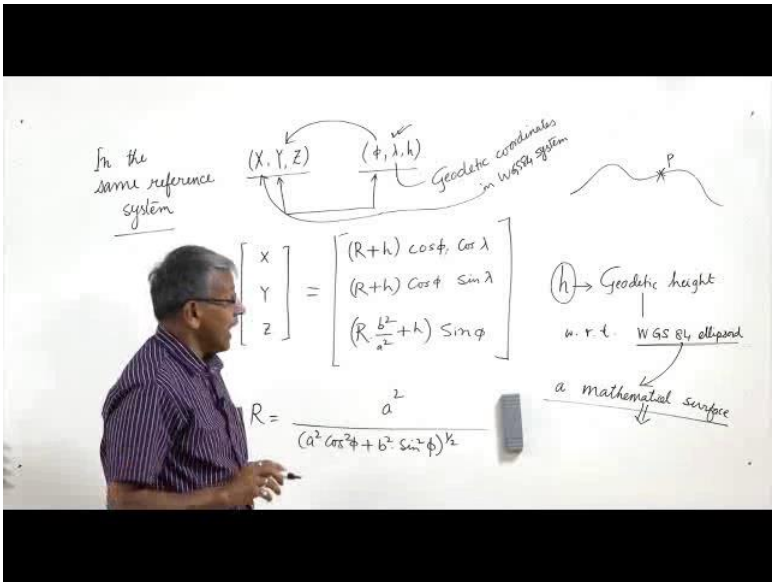

Now, we have seen that the position of any point can be defined; either GPS provides us the position in Cartesian coordinate or in Geodetic coordinate. Now, in some cases either of them may be available. In that also, it is very easy. We can convert between these two by transformation matrix. So, the conversion is like this; X Y, Z can be obtained. Cartesian coordinate can be obtained from Geodetic coordinate by using this relation. So, by using this relation we can convert the Geodetic coordinate to Cartesian coordinate.

And, if we have the Cartesian coordinate by transforming it, we can do it; in this case, the value of R is finding out by using the relation.

Now, one thing we have to remember. This conversion has to be done in the same reference system; that means, if we have the geodetic coordinate in WGS84 system, and then we will obtain the Cartesian coordinate also in WGS84 coordinate system. So, in this way we can get; we do get the GPS coordinates. Now, one thing here to be noted is that height. So, this height is the geodetic height, which we get with respect to WGS84 ellipsoid.

Now, this WGS84 is a mathematical surface. So in practical utility, here we do not have that much practical utility of it; means, when we are considering the height of any point on the surface of the earth, then we need to have the height on some physical surface of the earth, not from the mathematical surface. So, we need to convert this height to some useful height.

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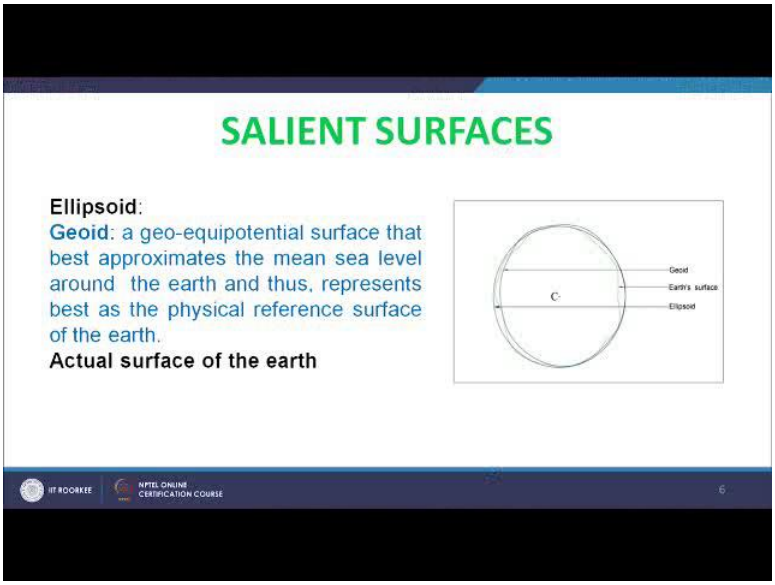

Now, I am going to speak on it. Before that, we need to know the different salient surfaces, which we consider during measurement of position on the surface of the earth. Now, in surveying, in GPS surveying, specifically there are three kinds of surfaces which are of our interest.

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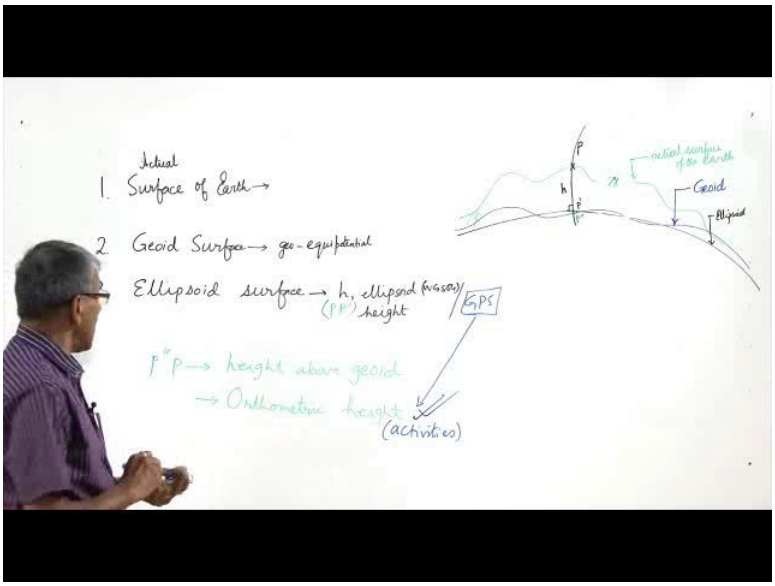

The first one is that the surface; the actual surface of the earth; surface of the earth because all our activities will be carried out on this surface of the earth. And, we are interested to know the position of any point on this surface of the earth. So, actual surface of the earth which is very important for us, which is most important for us, but it is, but this surface is actually very much undulating in nature.

Next, another surface which is of our importance is called geoid surface. Now, what is geoid surface? It is a geo-equipotential surface, which best approximates the mean sea level of the earth. Now, this surface is again quite turbulent, but it is having equipotential. So, physically we may have this thing. And that is the reason this geoid surface is considered as the physical surface of the earth. And, this earth surface is the actual surface of the earth. And finally, another; but, this is also very turbulent in nature. So, it is very difficult to develop a model or measurement on it. So, geodesists had defined another surface that is called ellipsoidal surface, which is quite regular in nature.

Now, if we see this thing in terms of whole earth, it may be shown like this figure. Here, we can see the green line is our actual surface of the earth, which is very much varying. And then, the geoid surface which is blue in color, which is comparatively regular than the actual surface of the earth, but still there are lots of irregularity. And the third one, the black in colors, that is, the ellipsoid which is quite regular in shape. But, here you can

see that the surfaces, sometimes the earth surface going down and geoid surface is going up; that means, all this area we have the sea surface.

Now, if the surface of the earth is something like this, wherever we find the surface of the earth is like this and the geoid surface is like this; that means, this area is having ocean, water bodies.

Anyway, so the third surface is the ellipsoid surface. If we consider a position point P, now the height of this point with respect to ellipsoid, so if we draw a normal through a equivalent, suppose this is the point, equivalent point of P on the ellipsoid, if we draw a normal, then it will pass through the point P and from P to P dashed, that is, our geodetic height h, also called as ellipsoidal height; that means, height over ellipsoid. And in case of GPS, it is the WGS84 ellipsoid.

Now, since our activities are based on potential energy, so the height above equipotential energy or the equipotential surface. Now, in this case geoid is more important for us. So, the height from this point, suppose P double dashed from P double dashed to P; height above geoid. And, this height is known as orthometric height. Actually for surveying, we are in need to find out the orthometric height, but GPS provides us the ellipsoidal height. This is the GPS provides; the ellipsoidal height, but for all our activities requires orthometric height.

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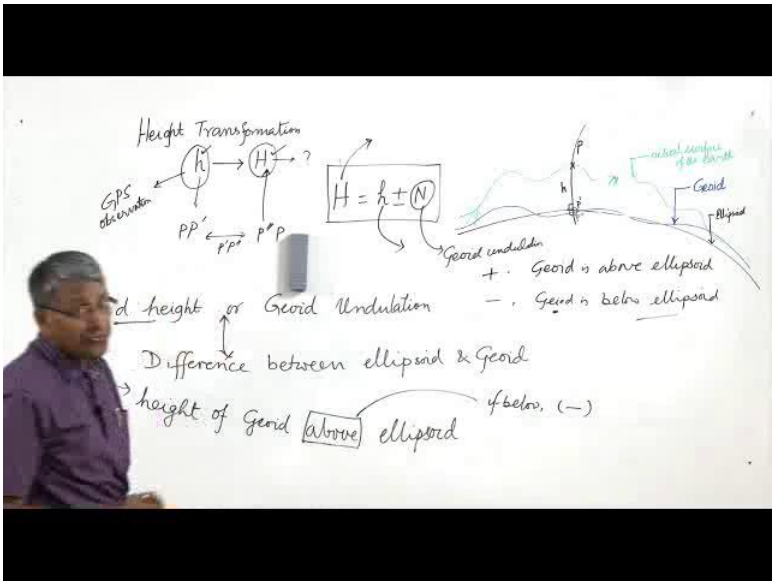

So, we are in need to know how to convert GPS height to orthometric height. That is called height transformation. Now, in order to transform the height; so orthometric height is denoted by capital H, ellipsoidal height is denoted by small h. So, and this ellipsoidal height we get from GPS observation. And, this orthometric height we want to find out.

Now, if we see into diagram, now h is nothing but our P P dashed and capital H is P double dashed P. So, the difference is that; the difference is P dashed P double dashed. Now, we need to know; if we want to find out capital H, from small h we need to know P dashed P double dashed.

There is another type of height; that is called geoid height or geoid undulation. This is another term we need to know. What is this? The height of or the difference between ellipsoid and geoid is known as geoid height. Geoid height is the height of geoid above ellipsoid. Now in this, that means, height above I have written. So, if it is below, then it will be denoted by; if below, then it will be negative. So, positive means geoid is above ellipsoid and negative means geoid is below ellipsoid, anyway. So, what we can see? Why we can (Refer Time: 32:09) now that small or you can say that capital H is small h plus minus N. So, if the geoid is below ellipsoid, then we have to add N. And, if it is above, then we have to subtract N from ellipsoid height. So, this is the relation which we get between the ellipsoidal height, which we get from GPS and do the orthometric height, which we are into need. And, N is the geoid undulation. Now, next question is how to get the geoid undulation. Geoid undulation is the difference between the ellipsoid and the geoid. How we can determine this thing?

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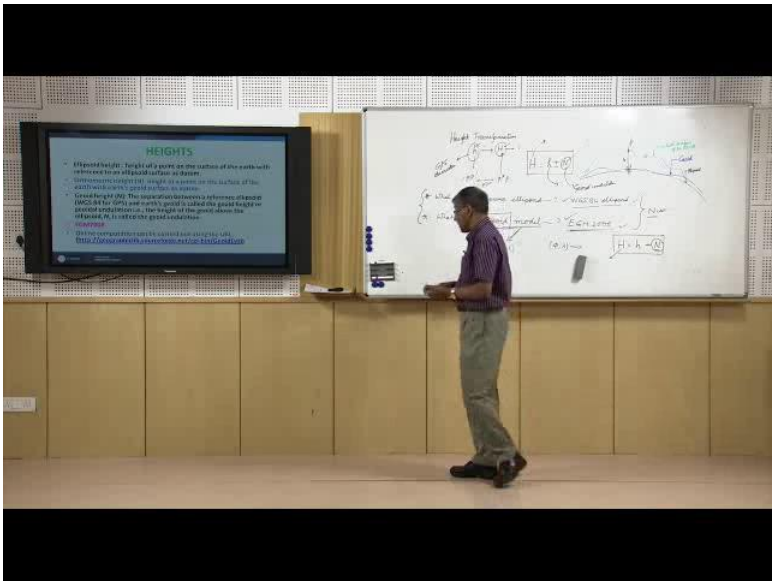

Now, to determine geoid undulation we need to know two things. One is that what is the reference ellipsoid we want to consider. Now, in case of GPS it is the WGS84 ellipsoid.

And, next thing you need to know what is the geoid model; that means, because you already have defined geoid is the equi, geo-equipotential surface, which best approximate the mean sea level of the earth. So, and that is represented by mathematical model. A mathematical function as a function of latitude and longitude that is the way how we do define a geoids model, so before we want to find out the N, we need to know these two.

Now, in case of GPS it is the EGM 2008 earth's gravitational model, 2008. This is the latest model that we have for the geoid surface. So, these two are to be considered to find out the value of N. Now, at present online facilities are available which provides you directly the value of N. If you provide the latitude, longitude of the place for which you want to find out the N. And, in that software you have to select the ellipsoid. So, in case of GPS observation it is the WGS84 ellipsoid. And, you have to select the geoid model. And, generally we will (Refer Time: 36:05) now EGM 2008. So, these two we will select. And, only this thing you need to know about the position for which you want to find out the geoid undulation. Then, you will get directly from the online software. So, once you know the capital N, which is your undulation, you will be able to find out the orthometric height of that point or the position on the surface of the earth, if you take the GPS observation which will provide you the ellipsoidal height. And, this is the relation.

In fact, we need to; we need not write this thing because whether it is positive or negative, automatically it will be coming from the software. So, if you make you, automatically it will be positive or negative. So, automatically you need not know. You need not give plus or minus. So, finally we can end up with this, if we find out the value of N from online software. In this way, we can find out the orthometric height quite easily using the GPS surveying, which is the boon of GPS surveying. Actually, in conventional method of surveying, finding out the orthometric height is a very real challenging, real problem of challenge, challenging problem and which can be done quite easily in GPS.

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So, that is all about today's class. Let me summarize the contents of today's class. Today, I first discussed about position that we get from GPS measurements. GPS provides us the position of any point in a three-dimension coordinate. That coordinate may be Cartesian coordinate X, Y, Z or it may be geodetic coordinate, which is phi, lambda, h; latitude, longitude and ellipsoidal height. However, we as a surveyor or to carry out to make use of surveying measurements, it is the orthometric height which we really need to know. And, the orthometric height is the height above geoid which is an equipotential surface.

And, to find out the orthometric height from the ellipsoidal height we need to know another parameter, which is called geoid undulation. Geoid undulation is nothing but the

separation between ellipsoid and geoid. And by nowadays, online facilities are available to compute the value of geoid undulation. If we feed on the latitude and longitude of that place, along with if you select the ellipsoid and the geoid model, and from there by making use of capital H equal to small h plus minus n, we can get the orthometric height. That is all about today's class. Next class will be on procedure for GPS surveying. See you again.

Thank you.