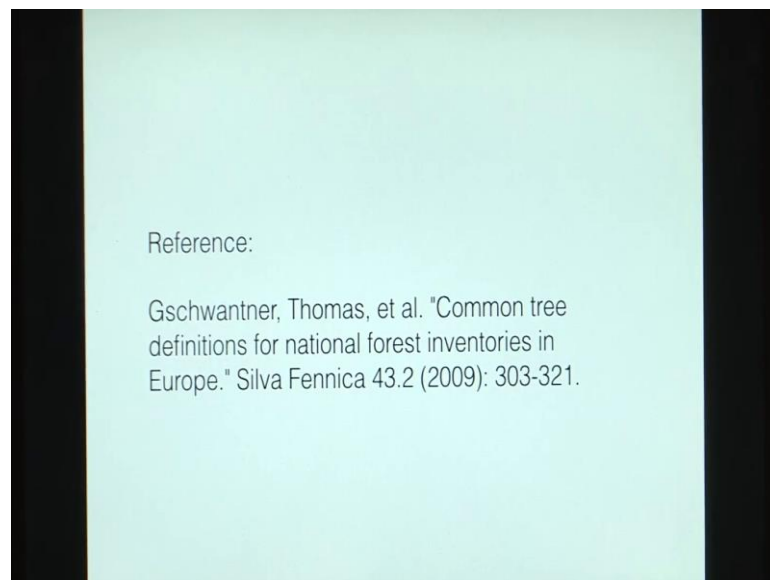


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**Lecture -16**  
**Tree height: Direct and indirect measurements**

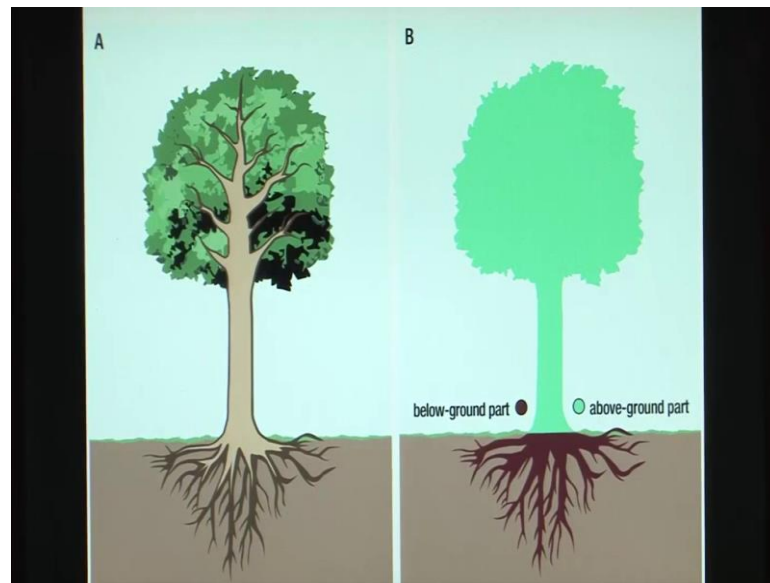
[FL] this week we shall be looking at the measurement of tree heights.

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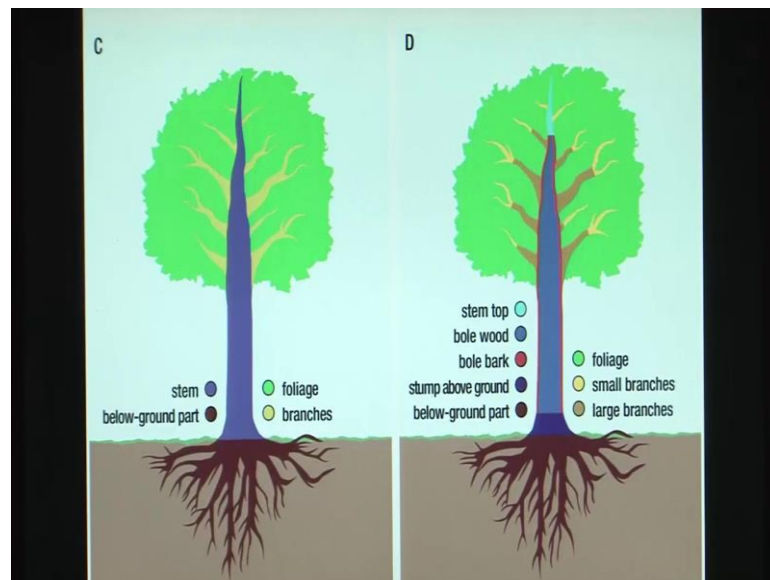
So, as you can see on your screen, this is a required reading reference that we shall be reference to for this lecture.

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So, when we talk about it a tree, how can we divided into various parts, well a tree has some part of it above the ground, and some part of it below the ground the part above the ground is called the shoot system whereas, the part below the ground is called the root system.

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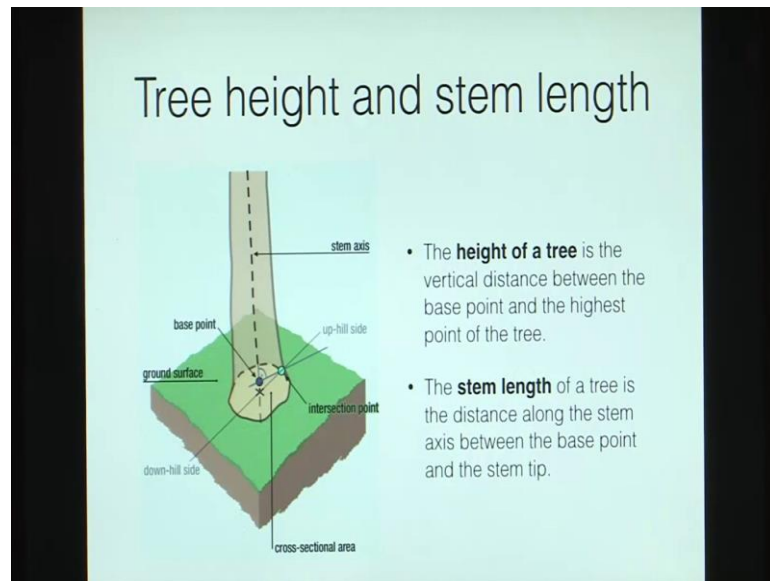


Now, these portions are a further divided into stem, foliage, branches and the below ground part as we can see in figure c, and in figure D we have further divided, it into the

stem top bole wood, bole bark, stump above ground, below ground part, foliage, small branches, large branches and so on.

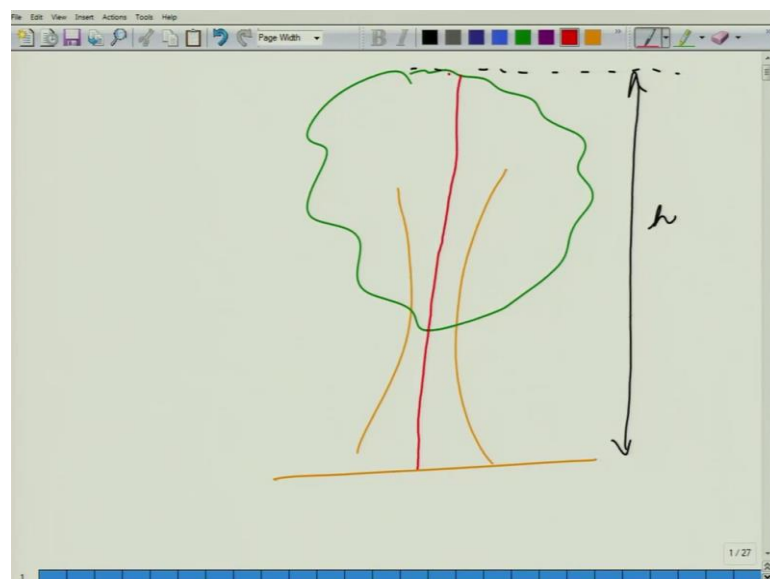
So, once we have done this, when we talk about a tree height, what do we mean by a tree height? So, if you look at the definitions.

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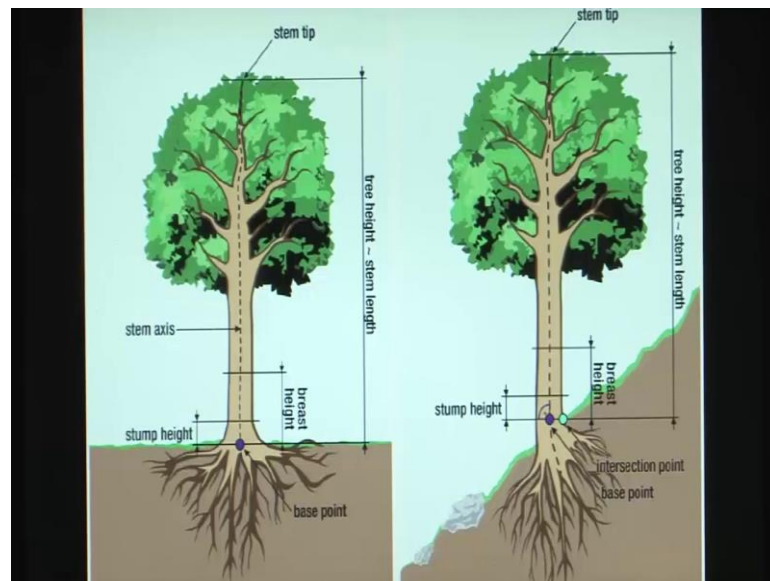
The height of a tree is the vertical distance between the base point and the highest point of the tree whereas; the stem length of a tree is the distance along the stem axis between the base point and the stem tip. So, what do we mean by that?

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So, let us consider a tree so if we draw a tree then its height would be the top portion height measured vertically above the ground. So, this is the height of the tree or the tree height, on the other hand we also define something known as the stem length, the length of the stem is this length as when it is measured along the tree axis. So, it would go like this to further elaborated.

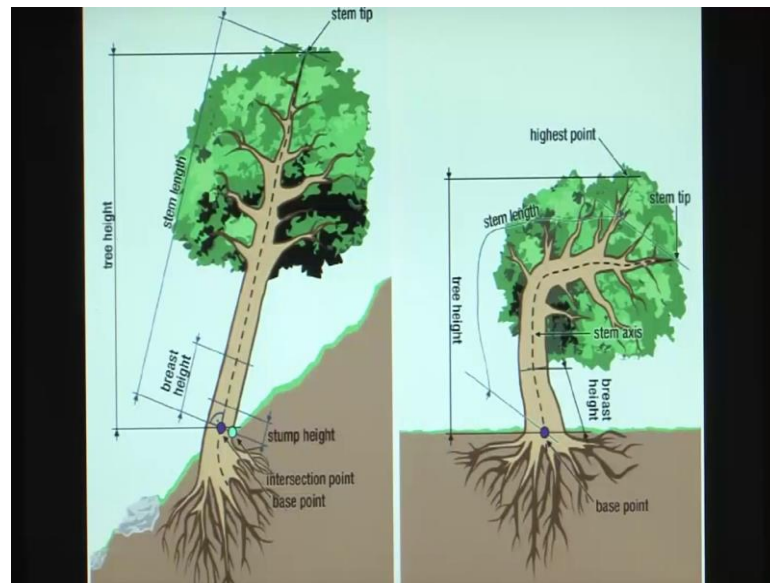
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As you can see on the slide, we are showing the stem tip and the tree height is the vertical height, it is also known as the stem length in this case because our tree is vertical and this stem axis is also vertical.

So, the tree height is the same as the stem length, we can also see the breast height and the stump height, the stump height is the height at which this tree would be cut it is generally one foot even on a sloping ground will have this stump height the stump length equal to the tree height, because here also the axis is vertical.

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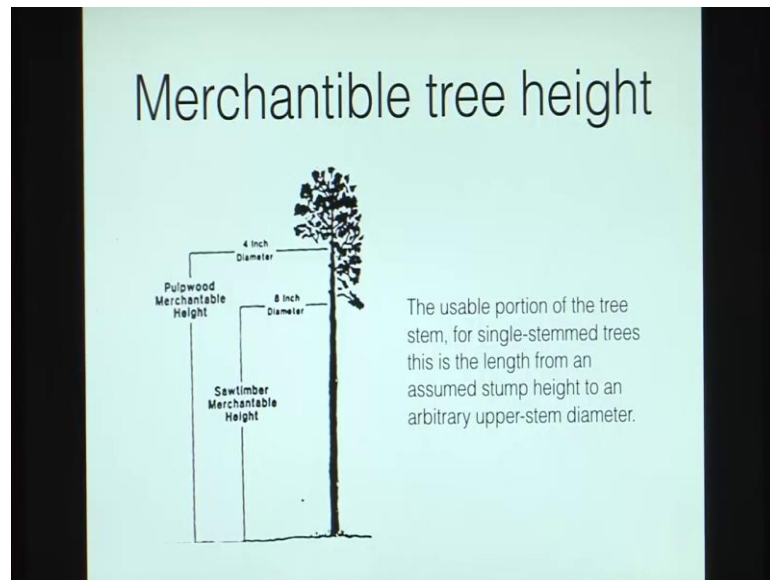


However, what will happen if the tree itself is leaning or if the tree is bent. So, we can see in these figures the tree height would again be the vertical distance from the tip or the top of the tree to the ground and here the ground would be measured at the point from which the tree is emerging from the earth surface, on the other hand the stem length would be measured along the tree axis.

So, in the figure on the right, we can see that the tree height is very much less as compared to the stem length, because here this tree is bent and the length of the stem would be measured along the stem axis. So, it becomes a very comparatively large figure as compare to the tree height.

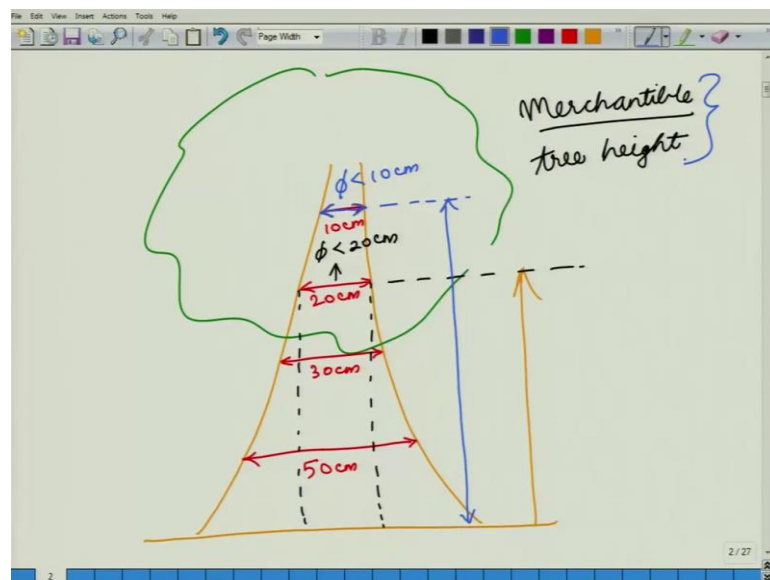
Now, in forest tree we used trees for the extraction of timber for commercially uses. So, for commercial uses we also define some other terms.

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So, one such term is the merchantable tree height, it is the usable portion of the tree stem for single stem trees that is the length from an assumed stump height to an arbitrary upper stem diameter. So, what does that mean?

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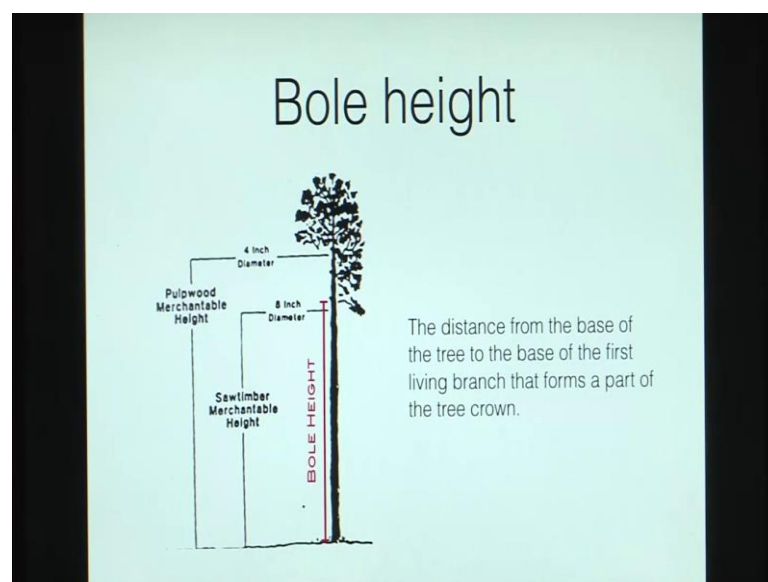
As we have seen previously, the tree is tapering from the ground as we go up. So, if this is our tree the diameter at this point suppose, it is say 50 centimetres the diameter at this point, might be say 30 centimetres then it would further reduced down to around 20 centimetres, then 10 centimetres and so on.

Now, when we are talking about, the merchantable tree height, so, merchantable means something that can be used by merchants or something that can be used commercially, now for some applications we might need a bole that is 20 centimetres or higher in diameter. So, in this case this portion would be the merchantable portion of the tree, because as soon as we go above this point the diameter is less than 20 centimetres.

So, we cannot use that now that could be for some applications suggest timber whereas, for some other applications say in the case of pulpwood we might have some equipments that can process our timber up till say 10 centimetres. So, in that case this would be our merchantable tree height, because any portion above this would have a diameter of less than 10 centimetres. So, merchantable tree height depends on the application.

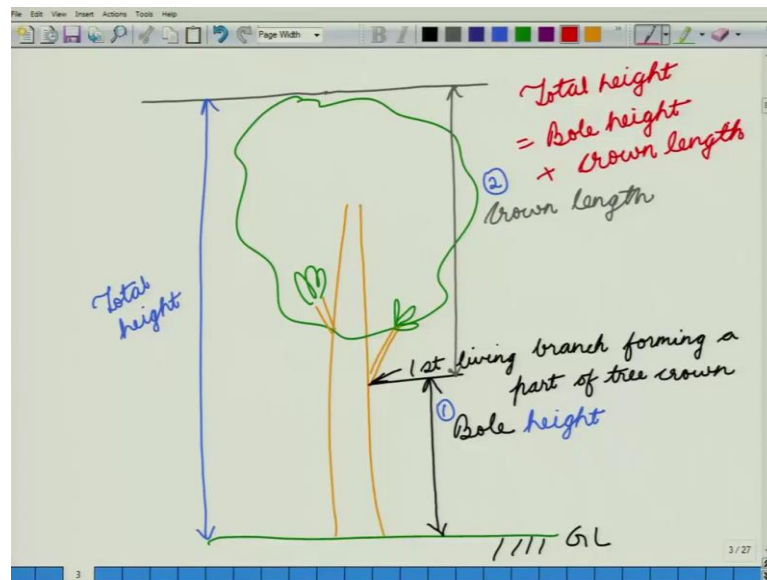
So, now if we go back to our slide, here you can see that we have defined 2 diameters, in 8 inch diameter for saw timber merchantable height and a 4 inch diameter for a pulpwood merchantable height. So, because 4 centimetre diameter, because of the table of the tree would be, above that of the 8 inch diameter; so, the pulpwood merchantable height would be greater than the saw timber merchantable height.

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We also defined another term called the bole height, now the bole height is the distance from the base of the tree, to the base of the first living branch that forms part of the tree crown. So, what do we mean by that? So, let us again draw a tree.

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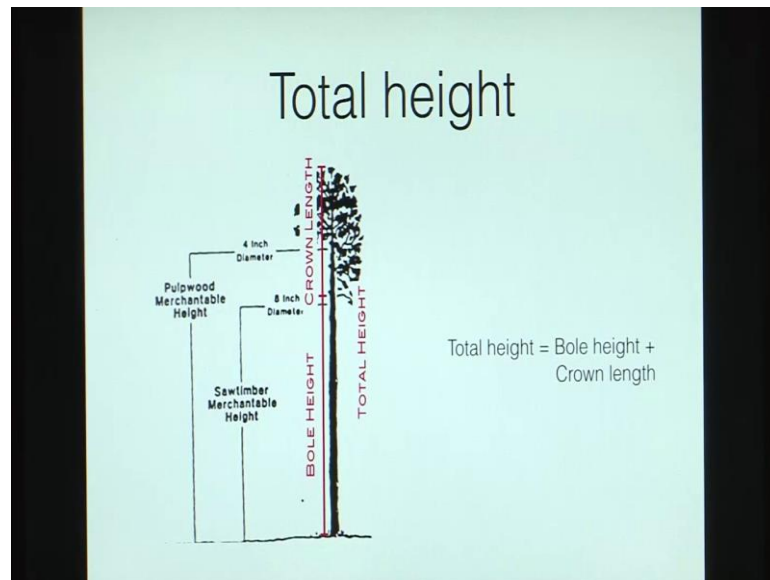
So, suppose this is our tree this is its crown and we have one branch that goes like this into the in forms part of the tree crown. So, in this case if this is the ground, this portion would be called the bole and the bole height is the height of the bole. So, it is the distance from the base of the tree that is the distance from the ground level to the base of the first living branch that forms part of the tree ground. So, this is the base of the first living branch forming a part of tree crown.

So, we could also be having some other branches, like a branch here that is also a part of the tree crown, but we will take a bole, till the base of the first living branch. So, what is the portion that is above our bole? So, this is what is known as the crown. So, this would be called the crown length.

Now, as we have seen previously this is the total height of the tree. So, this total height is divided into two portions one is the bole height. So, the bole height and the second portion is the crown length. So, we can also say that total height is equal to bole height plus crown length. So, we can see then this figure as well as you sees on your slide.

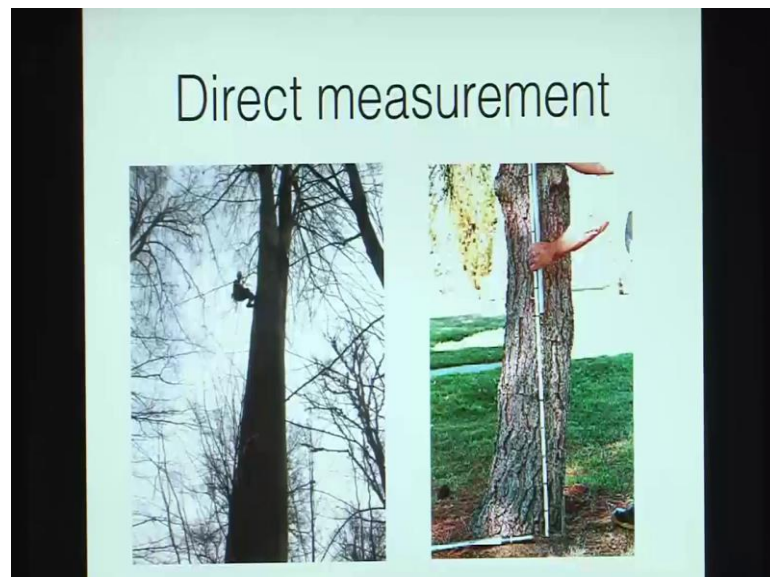


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We have divided the total height into bole height and the crown length, now how do we measure these heights we can do it by two wheels one is called a direct measurement. So, in the case of a direct measurement, if this is your tree you take the measurement directly across the length of the tree.

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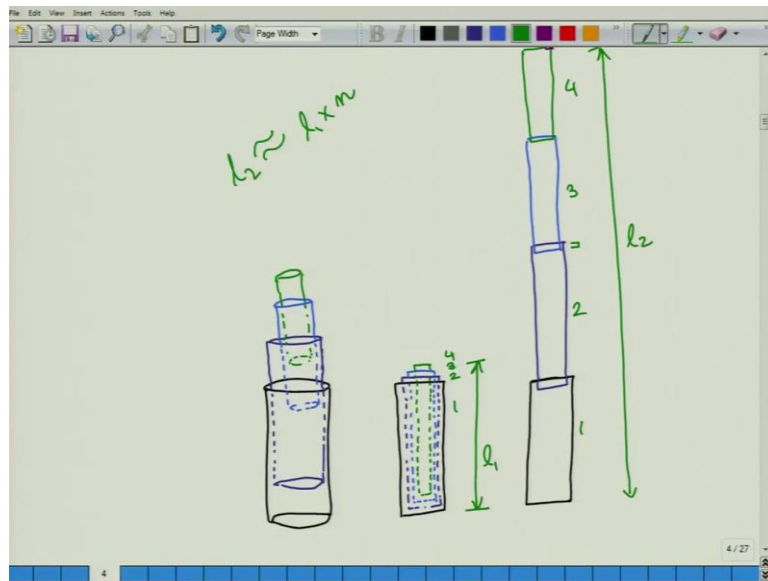


So, this can be done in two ways, one you could climb to the top of the tree and when you have climb to the top of the tree you said there and then you can throw a string with say a stone attached to it and when that string comes down and when that string stop then

the length of that string would be equal to the height of the tree. So, that would be called a direct measurement.

Another way of direct measurement could be through the use of equipments. So, for instants we have a telescopic end that you can attached to the bottom of your tree and then you can extend it upwards till it reaches the height. So, what do you mean by a telescopic end is this.

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So, you can have a tube that has another tube this portion is visible, then you have another end that is also going inside followed by and so on.

So, what happens in these cases, you can keep all these tubes together. So, when they are together you will have this end followed by a small protrusion here because most of the part of the second tube is inside, then have the third portion that is also having a very small protrusion followed by the forth potion.

So, when you have kept all these four portions say 1, 2, 3 and 4 together then they occupy a very small length, let us call it a length  $l_1$ , but when you extend all these tubes you will get something like this. So, this is the first portion followed by the second portion followed by the third portion you have 1, 2, 3 and 4.

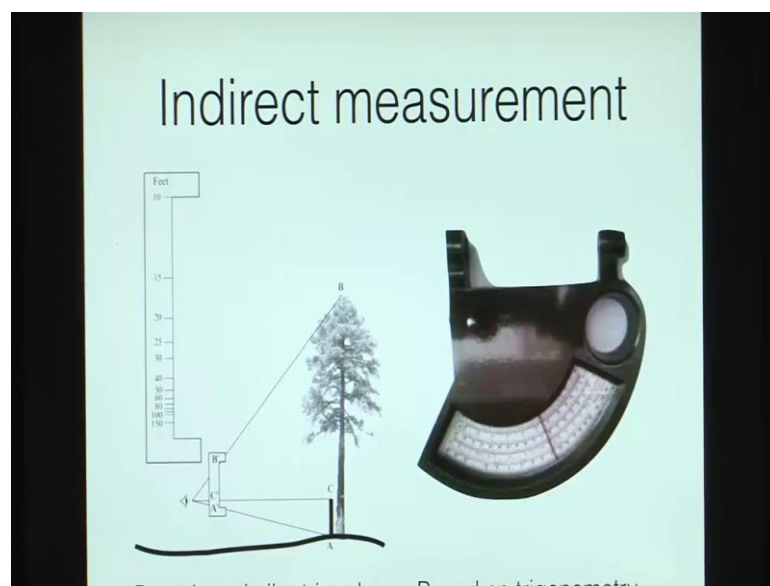
So, when you are expanding this, this length let us call it  $l_2$ . So, we will have  $l_2$  is approximately equal to  $l_1$  times the number of tubes that are there, why is it approximate

because a very small portion remains inside of the second tube, when we have completely expanded it.

So, when we use such a tube, so as we can see on a slide now in the second figure. So, you can put rulers on top of each other and then you can tie them or you could use this telescopic tube. So, you keep it at the bottom of the tree then you keep on extended get till it reaches the this top height of that of the tree. So, when it has reached the tip of the tree when the length of the telescopic tube will be equal to the height of tree. So, these are two methods of direct measurement.

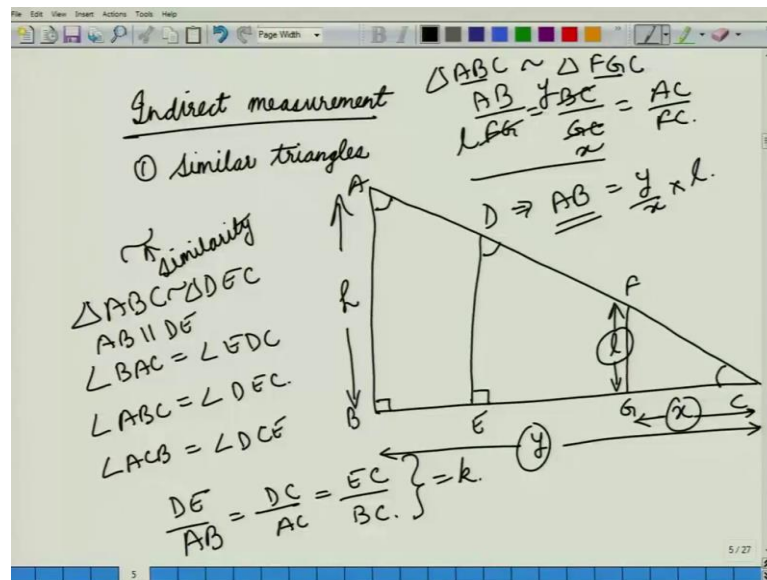
Another way in which you could directly measure a tree is by chopping a tree. So, when you have harvested one tree and that tree falls down on the ground then you can take this length, which will be equal to the height of the tree when it was standing another way of measurement.

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Is called indirect measurement, so indirect measurement so measurement that is not done directly across the length of the tree, but is done by using some mathematical formulae. So, we have two major types of indirect measurements.

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One is based on the principles of similar triangles. So, what do we mean by this indirect measurement, suppose we have a triangle and suppose we draw another line parallel to this axis. So, we have A B C D and E, now in triangles A B C and in triangles D E C we have that the angle B A C is equal to angle E D C these two angles are the same, because A B is parallel to D E, similarly both these angles are equal angle A B C is equal to angle D E C, both of these are right angles at the same time this angle is the common angle. So, angle A B C is equal to angle D C E.

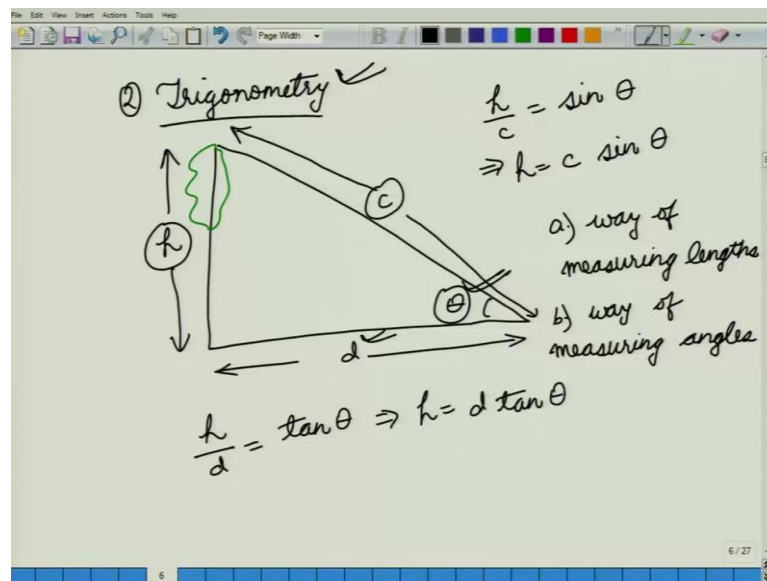
So, when we have such a situation when all these three angles are equal, we can have the relationship D E upon A B is equal to D C upon a C is equal to E C upon B C that is when all three angles of two triangles are equal then their sides are in a constant ratio. So, this ratio can be called as k. So, in that case suppose we drew a line and then we drew another triangle here say F G and if we were able to measure this length l, and if we were able to measure this distance x and this distance y, then we would be having A B because again triangle A B C is similar to F G C, now this symbol, is the symbol of similarity. So, here also the proportionate sides would be having a constant ratio. So, we have A B upon F G is equal to B C upon G C is equal to A C upon F C.

So, when we use this relation here we have F G, F G is equal to l G C G C is equal to x B C is equal to y. So, we can have A B, and now here A B is the height of the tree, A B is equal to by using this relation y upon x into l, now because we know y we know x and

we know  $l$ . So,  $y$  and  $l$  are known. So, we can get  $AB$  or the height of the tree. So, this method is known as the method of similar triangles and in another lecture we shall look at this method in more details and also look at the instruments that we use if we want to measure the height of a tree using similar triangles.

Now, another way in which you can do an indirect measurement is by using trigonometry.

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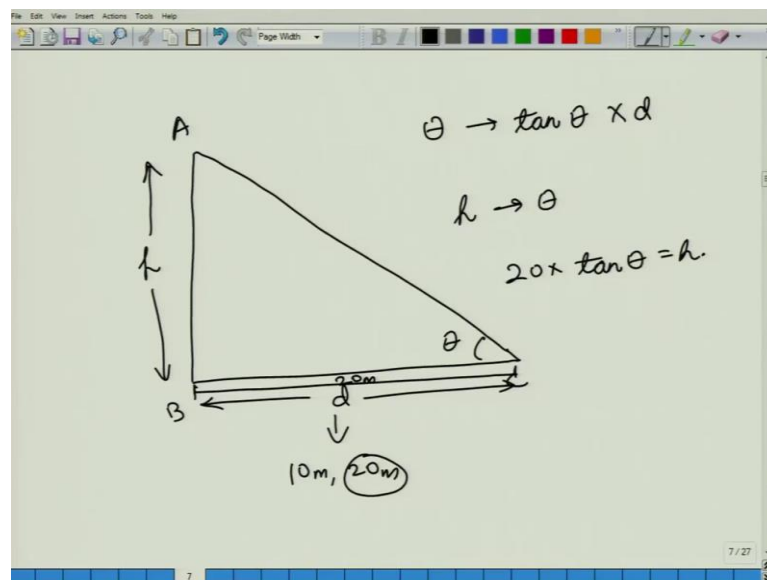
Now trigonometry was dealt with in an earlier class. So, what we do in the case of trigonometry is suppose this is our tree, and we can measure the distance  $D$  from the tree to a point of observation and if you can measure this angle  $\theta$  and we want this height of the tree.

So, we can use the relation  $h$  upon  $d$  is equal to  $\tan \theta$  which will give us  $h$  is equal to  $d \tan \theta$ . So, trigonometry as we have seen before trigon means triangle and matron means measurement. So, it is the measurement of a triangle, so if we knew this angle and if we knew this distance we would be able to find out  $h$  otherwise suppose we knew this distance, the hypotenuse then also we can use another relation  $h$  upon  $c$  is equal to  $\sin \theta$  which will give us  $h$  is equal to  $c \sin \theta$ .

Now, to use this method of trigonometry you need two things a you need a way of measuring lengths, and b you need a way of measuring angles, because you need to measure some length and some angle.

So, we have different instruments for the measurement of lengths and for the measurement of angles and we shall look into those in more details in later lecture. So, if we went back to the slide on the right we have we see a an instrument now this instrument known as an altimeter we shall look in to it in more detail in a later lecture as well it directly gives us the readings of the height. So, what we do in this case is that in this triangle.

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A B C this angle is theta; we take this distance d to be a constant. So, by using the instrument we can take this d to be equal to say 10 meters or say 20 meters depending on this scales as i given in that instrument.

Now, for every angle theta we could have a measurement of theta and then derive tan theta and then multiply that with d to get r height h, or else this instrument can give us directly the readings of h for different thetas, because we have taken a scale of say 20 meters. So, you need to stand at a distance of 20 meters from the base of the tree. So, this would be 20 meters and when you have this 20 metres in place of measuring a theta and then calculating tan theta and then multiplying, it by 20 you can directly have this instrument give you 20 multiplied by tan theta.

So, it will directly give you the height. So, which makes the measurements easier on the ground, we shall look at these base of direct and indirect measurements in greater detail in the lectures of this week.

Thank you for your attention [FL]