Forest Biometry
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Lecture - 36
Density and Mass Measurements

[FL]. In this week, we shall look at some other computations of biometric beginning with density and mass measurements. So, we know how to calculate the volume of a log or the volume of a tree. Now, if we wanted to compute the amount of carbon that has been sequestered inside, the first step would be knowing the mass of that portion of the log or that question of a tree. Now, consider a huge size tree. Now, we cannot take the whole tree and then measure it somewhere else, so which is why we require a measure of its density.

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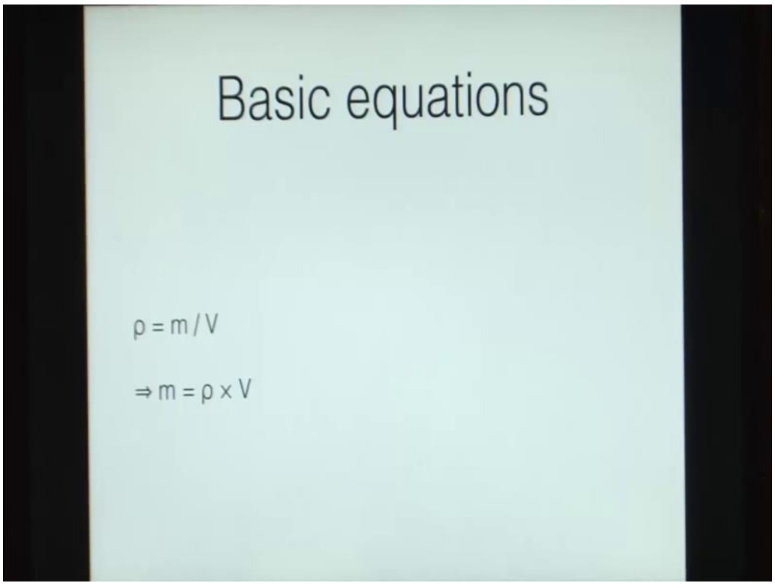

So, these are the basic equations as you can see on your screen. So, we have these two equations rho that measures the density is given by mass upon volume. Now, rho in most cases is fixed for the kind of material. So, for instance, the stem of a tree might be having one particular value of rho depending on its species and depending on say the kind of treatments it has received the amount of drying that it has undergone. But then rho will be a fixed quantity for the whole stem or it can be considered to be a nearly fixed quantity for the whole stem.

So, if we know rho, we can calculate the mass of that chunk because we know how to calculate its volume; if you multiplied that by the density will be getting the mass. Now, here the trick because we know how to calculate the volumes the trick is to know the density. So, how do we calculate the density of any given sample?

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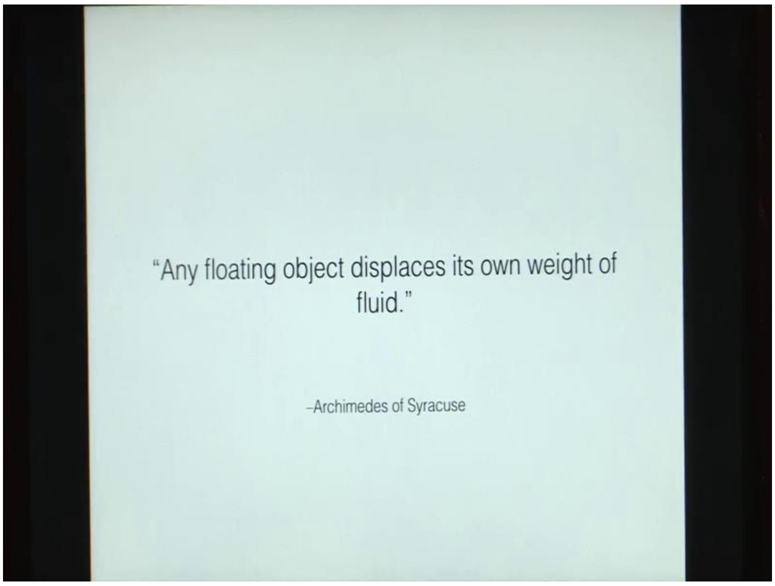

We might use the Archimedes principle, which states that any floating object displaces its own weight of fluid. So, what does that mean?

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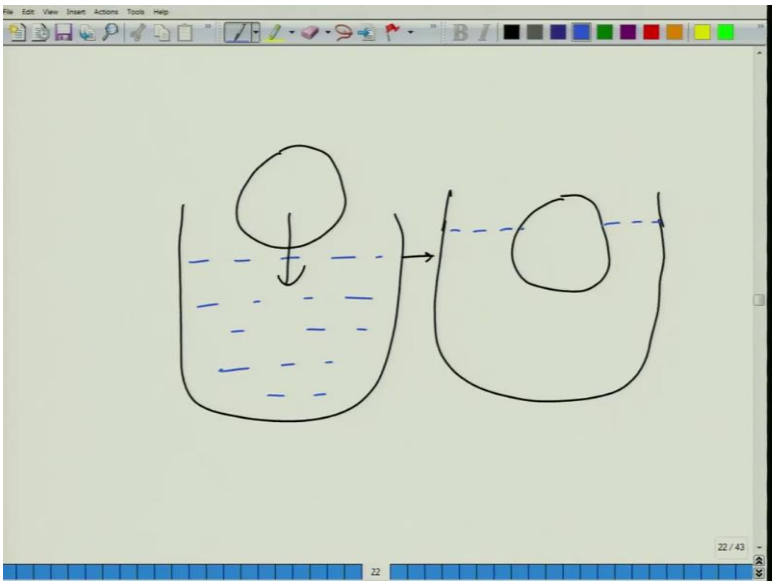

Suppose we take a container, we fill it with water and then we put a sample inside it, when the sample is floating. So, when your sample is floating, you have a situation like this. So, here you have your floating sample the water level because this sample has displaced some water. So, now the water level will increase. So, suppose this is the water level, the weight of the fluid that is displaced is equal to the weight of the object. So, we shall look into it in greater detail in this in this class.

So, how do we first of all we need to get a sample. So, how do we get a sample from a tree? So, we can use a borer.

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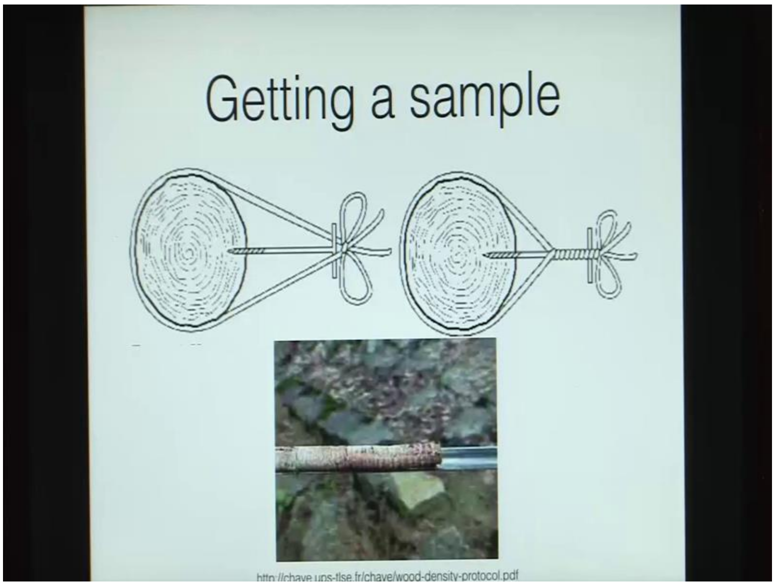

So, as you can see on your slides now, you can use a borer. So, a borer is used to get the ring counts that we have seen earlier. In the case of hardwood species, we generally put a rope around the tree. So, this is a rope here you have the borer. So, when you turn the borer then this string it gets turned around the borer like this, and when it does so then it exerts a pull towards the tree. So, when you do this your borer will go on penetrating the tree with each turn. And this is a sample a picture of a sample that has been received from the borer.

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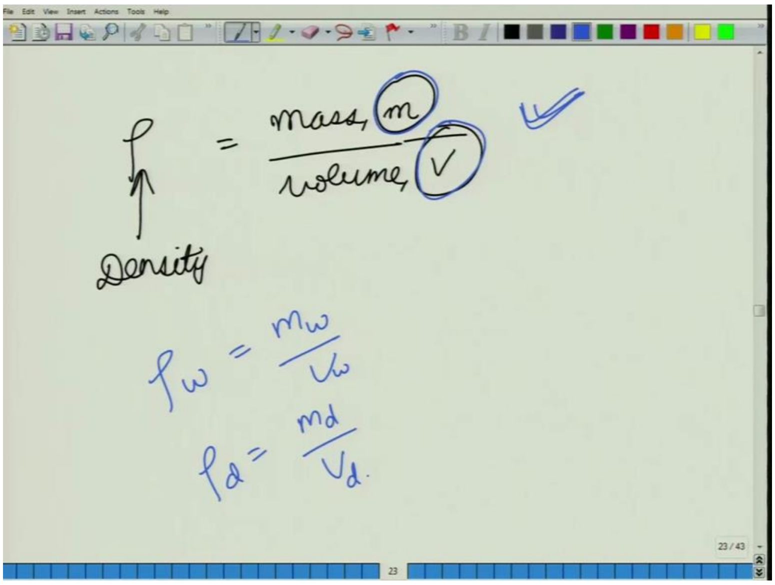

So, now, remember that we give density so which is given by rho. So, rho is your density is equal to mass m upon volume v. So, to calculate the density of the sample that we have received from the borer, we need to find out its mass and its volume. So, how do we measure the mass? We will make use any balance, but in the case of trees, because these are living entities with lots of water, the mass will reduce when you remove water from it.

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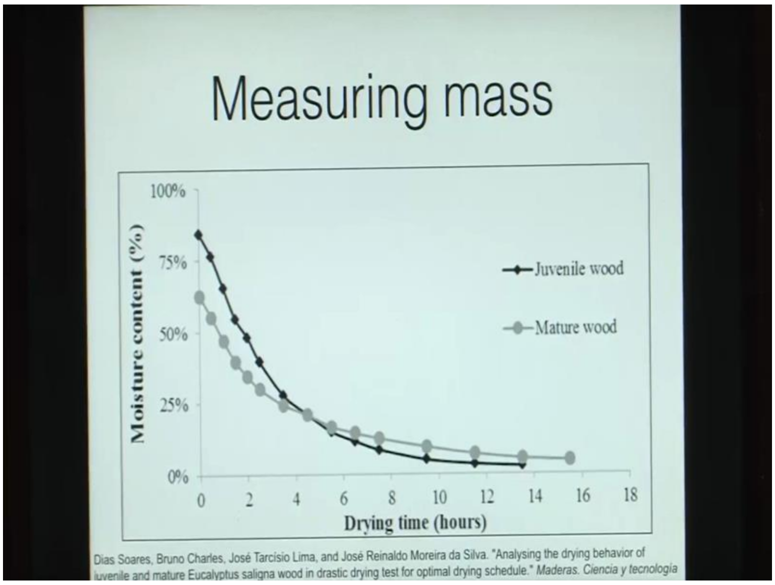

So, for instance, this curve is showing you two samples one from a juvenile wood that is a young wood; and one from a mature wood as against its drying time in hours. So, on the x-axis here, we have plotted the number of hours of drying time; and here we have put the moisture content. So, as we can see the moisture content goes on reducing with time and ultimately it reaches to a point where two readings are roughly similar. So, in at this point, we say that the wood has been completely dried.

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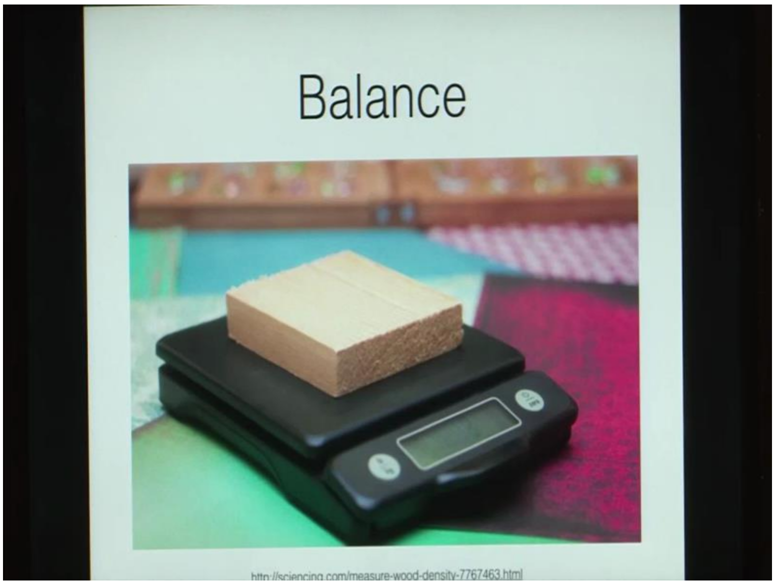

So, we can take the weight of the sample of wood or the mass of the sample of wood when it is in the fresh condition and also when it is in a dry condition.

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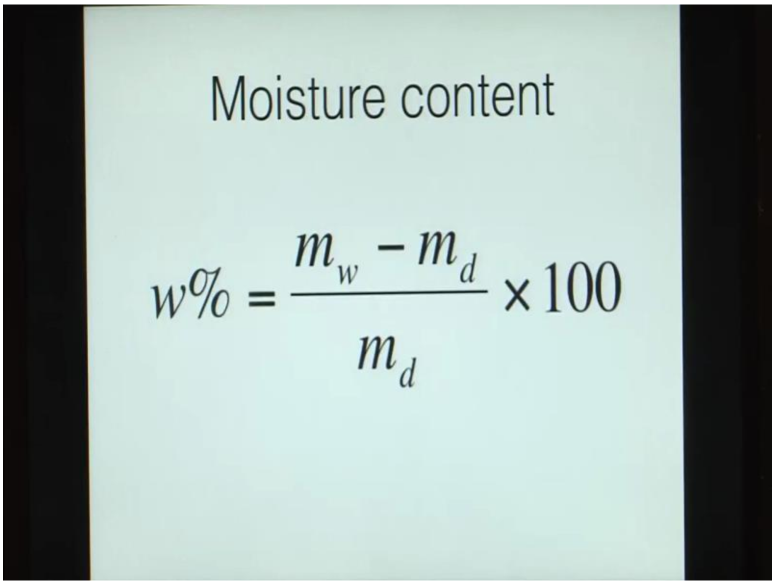

When we do that so we can calculate m and from these two readings, we can calculate the moisture content of the wood. So, the moisture content or the water content of the wood is given by its mass when it was a fresh wood containing moisture minus the dry weight. So, the dry weight is the weight that we have received once after drying the weight has stabilized. So, m w minus m d gives you the amount of water in grams or in kilograms that was there in that sample; you divided by the dry weight and multiply it by 100 percent, so that gives you the moisture content in percent in that piece of sample.

So, now, when we talk about density, so coming back to the equation here when we talk about the density we can calculate that the density when the wood was in a wet condition. So, when we consider it in a wet condition, we will have the wet mass divided by the volume. And when we consider the dry density, it will be the dry mass divided by the dry volume. So, we can use these values of density to calculate the mass of larger sized samples of wood. So, we can calculate this m with a weighing balance if our sample is small. The next thing is to calculate v. So, how do we calculate v?

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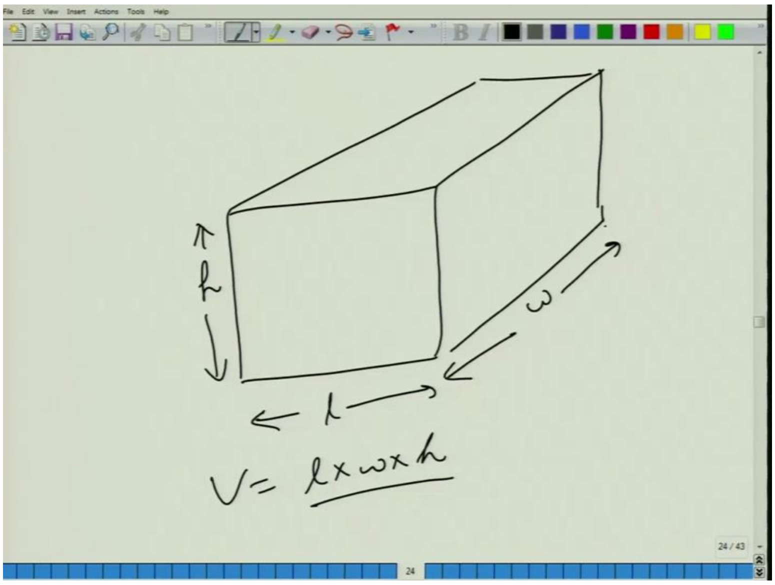

It is simple if we have a sample of a determined size. So, suppose this is our sample. So, our sample has a length of l, a width of w, and a height of h. And let us consider this sample to be a cuboids. So, in this case, we will have the volume is equal to length into width into height. So, while making the computations for density we can either take our samples in fixed sizes, so it could be a rectangular, this cuboidal shape, it could be a cylindrical shape and so on in which case we can measure the volume.

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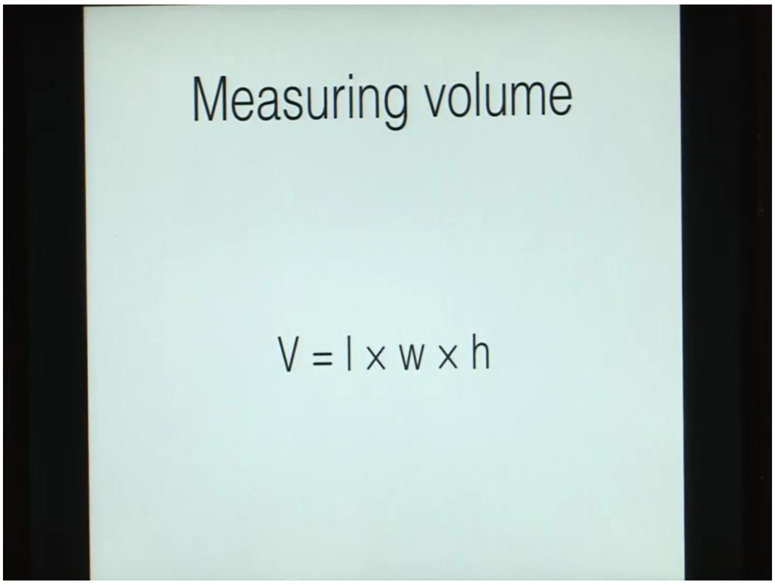

So, volume can either be measured or this volume can be had from say water displacement.

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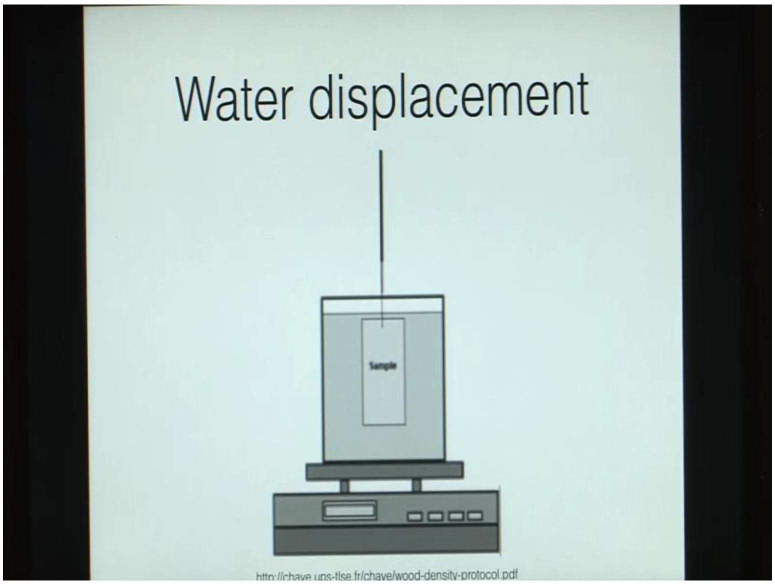

So, what this slide shows us is that here we have a balance; on the balance we have kept a container say a beaker. This beaker has some water inside that water is not filled to the brim, but allows for some more amount of water to be filled in; then we take the sample. Now, because the density of wood is less than the density of water, so this wood is going to float on water. But what we can do is without the sample just with the beaker and the water on, we can take this weight reading from the balance, then we can put our sample it will float on the water and then we will use a thin needle to press the sample inside the water.

So, once this sample is completely inside the water the level of water has risen. And from the point of view of the balance it just considers that this much amount of water has been added to the beaker. So, in this case, we can get the next value of mass.

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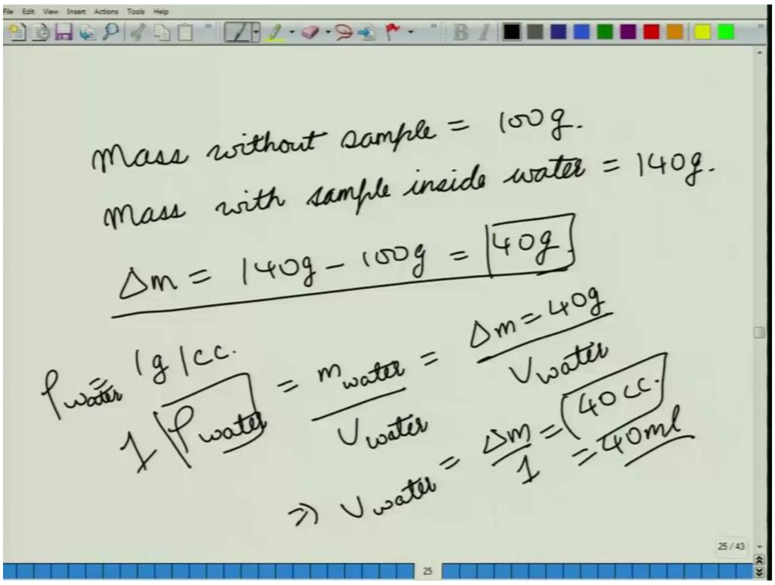

So, suppose our mass without the sample was say 100 grams and the mass with sample inside water. So, here we have pressed our sample or pushed our sample with a fine needle, and suppose it increases to 140 grams. So, this will be the equivalent of the mass that is added is 140 grams minus 100 grams is 40 grams. So, we know that the density of water at 4 degrees Celsius is 1 gram per cubic centimeter. So, this is the density of water. So, we can calculate the volume of water that has been put in by using the equation, the density is given by the mass upon volume.

So, here mass of water that the instrument sees that has been put inside is given by delta m is 40 grams divided by the volume of water that has been put in. Now, this value is one. So, we will get the volume of water is equal to delta m by 1 is 40 cc or 40 milliliters. Now, this volume will be equal to the volume of the sample that we had put in. So, the volume of the sample here in this in the key example is 40 cubic centimeters.

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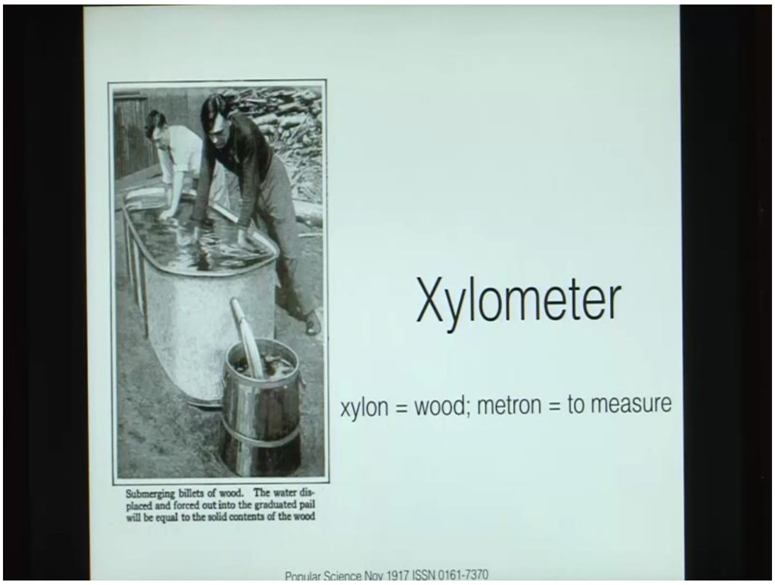

We can also calculate the volume by an instrument known as Xylometer.

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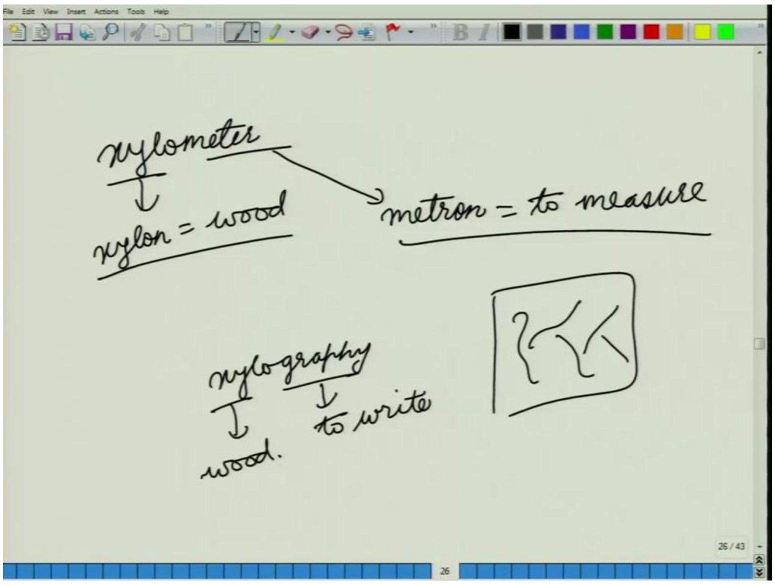

Now, xylometer, so if you looked at the word roots xylometer. Now, xylon means wood and metron is to measure. Now, metron is the same word that goes in biometry or say photogrammetry or say trigonometry. So, metron means to measure; xylon means wood. So, this term comes in say xylography. So, xylography now graphy means to write xylo means wood. So, it this is an art in which you take a piece of wood then you make some engravings here on the wood, and then those engravings are then applied with ink and then that engraving is used to create an inscription on a piece of paper or on a piece of cloth. So, xylography is a method of writing with wood.

Similarly, the xylometer is an instrument that uses and that is able to calculate the volume of wood. So, if we go back to the slides now, so here we can see that we have a big pan here which has this outlet and here we have a small pale or a bucket. What these two gentlemen are doing here is to put a large sized volume of wood inside and then they are pressing it, so that this whole volume of wood came inside the water. When it does so some amount of water will be displaced which will come into this pail or bucket and then this buckets water will then be measured to give you the volume of wood.

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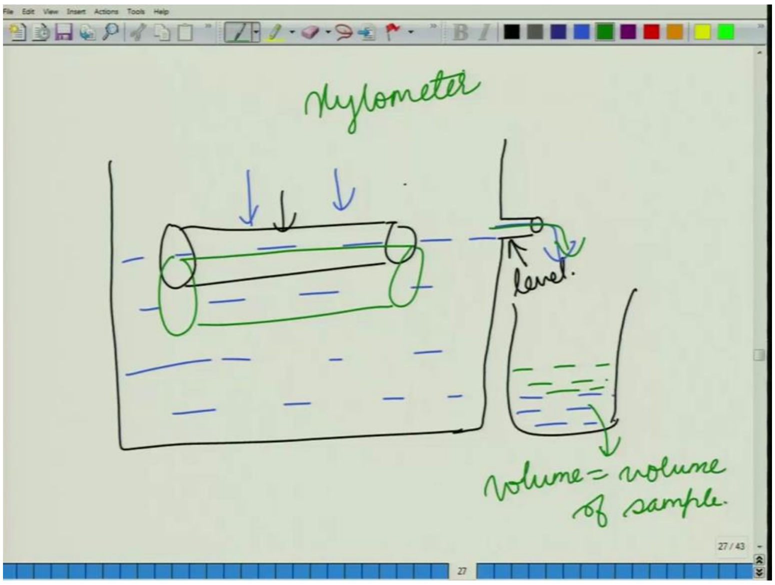

So, essentially what these people are doing is that you take a big vat and you fill it with water to a certain level. Now, at this level itself your pail, will your vat will have an outlet. So, here you have an outlet. So, now, you have put so much amount of water that it has reached to this level. Now, next what you do is you put a bucket here, and then you take a large sized piece of wood and then you put it inside. What will happen is in the first case this wood will float on water when it does so it will be displacing some amount of liquid that is equal to its own weight by the Archimedes principle. So, some amount of water will then flow out and collect here. So, this level can give us the weight of the piece of wood.

Then what you do is you apply even more force to this wood such that this wood now gets completely immersed in water when it does. So, it will displace even further amount of water and this volume the amount of water that has been displaced will be equal to the volume of the sample. So, in this way, you can compute the mass or the weight of the sample and the volume of the sample at the same time. So, this instrument is called as a xylometer.

Now, coming back to the slides, if you looked at the reference here it says popular science November 1917. So, this is a picture from the World War 1 era; and so this is a very old method of calculating the measurements of wood both its weight and its volume both can be computed using the xylometer.

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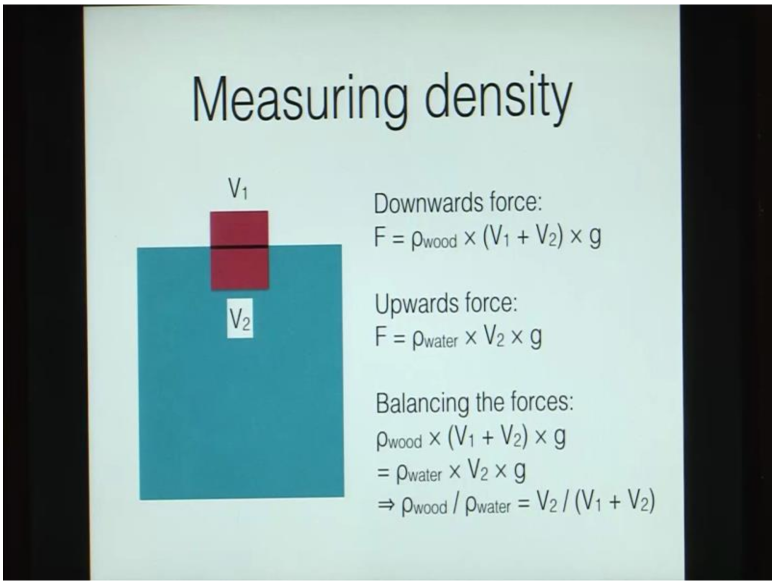

There is one other way of measuring density in which we can take this density directly from a sample that is floated into a liquid. So, how do we do that?

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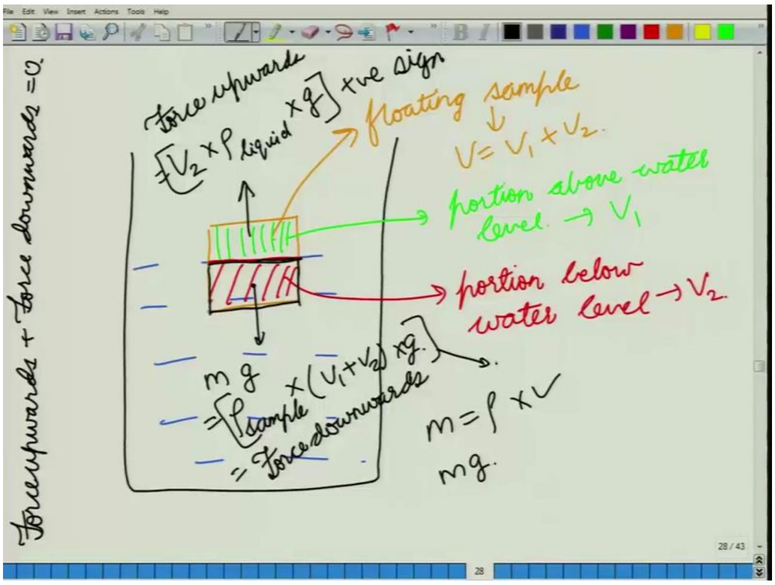

So, let us again consider a beaker in which you have some amount of water and you also have a sample of your wood that is floating here. So, consider this to be a floating sample. Now, when this sample is floating then some part of it will be beneath the water level. So, now the water level has risen, but in the equilibrium position, you will have some portion that is below the surface. So, this is the portion below water level and we have some portion. So, this portion is the portion above water level.

So, now, let us consider that this portion has a volume of v 1 and the portion that is below has a volume of v 2. So, what is the volume of the floating sample, the total volume v is equal to v 1 plus v 2. Now, let us draw a free body diagram for this piece of sample. So, what are the forces that are acting downwards. So, the downward acting force is mass into g. So, m is the mass of your sample. So, it is m into g. Now, m into g is given by the density of the sample, so rho of sample into its volume the volume is given by v 1 plus v 2 into g. Now, this is the force that is that is acting downwards.

What is the force that is acting upwards? So, the force that is acting upwards is equal to the weight of the liquid that has been displaced by our solid using the Archimedes principle. So, the upward acting force also known as the buoyant force will be given by the weight of the liquid that has been displaced now the weight of the liquid that has been displaced is equal to or the volume of the liquid that has been displaced is equal to this volume. So, it is v 2 into the density of the liquid multiplied by so this gives us the mass is equal to rho into volume; the weight is given by m into g. So, multiplying this by g will give us the upward acting forces. So, this is the force upwards, and this is the force downwards.

Now, we have considered our sample to be in an equilibrium. So, this sample is floating and is in equilibrium. So, when it is in equilibrium it is neither going up nor it is going down. Now if you remember Newton's laws of motion, they state that a body at rest will continue to be in rest and a body in motion will continue to be in motion till any forces applied to it. So, now because this at the equilibrium condition this body is at rest and it is continuing to be at rest. So, it means that all the forces that have been applied to this object have canceled each other which would mean that the upward acting force and the downward acting forces both have equalized and the net amount of force that is there on the object is 0.

What does that mean, it means that the force upwards plus the force downwards is equal to 0. Now, remember that force is a vector quantity. So, when we say a vector quantity, it has a unit and it has a direction. So, let us take the upward direction to be the positive direction. So, in that case any force that is acting upwards will be given a positive sign and any force that is acting downwards will be given a negative sign. So, the force upwards will be given by this value with a positive sign; and the force downwards will be given by this value with a negative sign.

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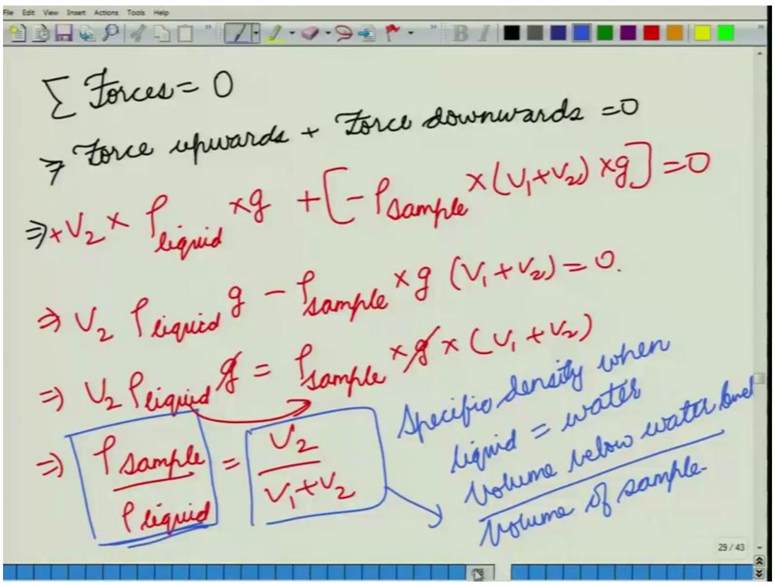

So, once we have that let us write the equation again the sum total of forces because this body is continuing to be at the same position its neither going up nor down. So, all the forces in these directions have canceled each other. So, the sum of forces is equal to 0, which gives us that the force upwards plus the force downwards is equal to 0. What does that mean how much is the force upwards. Now, force upwards is given by this equation with a positive sign.

So, let us take this portion. So, it is v 2 into rho of liquid into g; so v 2 into rho of liquid into g with a positive sign. So, this has a positive sign and this portion has a negative sign. So, the force downwards, so it has a negative sign. So, plus a negative sign of rho of sample into here we have v 1 plus v 2 multiplied by g is equal to 0. So, what does that give us? So, this implies v 2 into rho of liquid into g minus rho of sample or the density of sample into g times v 1 plus v 2 is equal to 0. Which will give us v 2 into a rho of liquid into g is equal to rho of sample into g into v 1 plus v 2, now g and g get cancelled. So, we have a rho of sample upon rho of liquid. So, putting this portion downwards is equal to v 2 upon v 1 plus v 2.

Now, this portion the density of a sample divided by the density of the liquid. When we consider the liquid to be water, then this portion is also known as the specific density when liquid is equal to water. So, we have the specific density when we are using liquid as water is equal to v 2. Now, what is v 2? V 2 is the portion that is below water level. So, we have this is equal to the volume below water or below water level divided by the volume of sample. Now, in most of the cases, we use this sample to be of a uniform cross sectional area.

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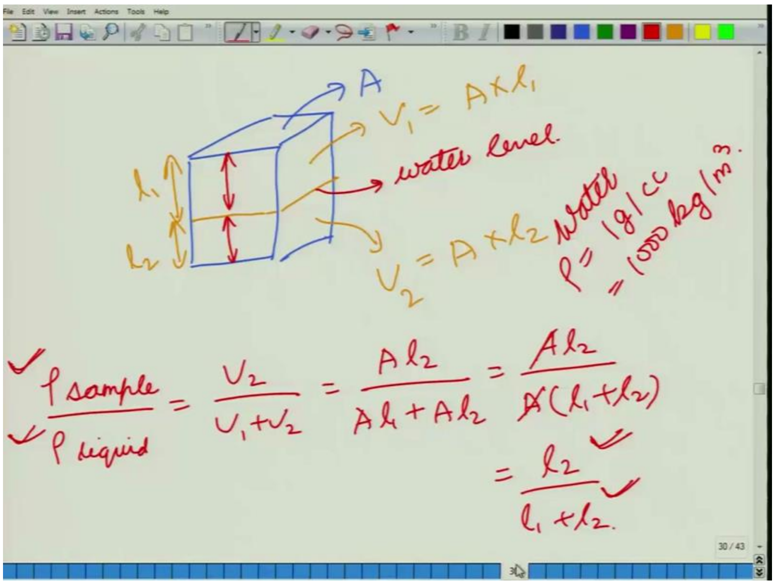

So, when we have a uniform cross sectional area so suppose this is our sample let us consider it to be cuboidal sample of the top area to be equal to A. So, now, when we have divided it into two parts, the lower portion has a volume of v 2 and the upper portion has a volume of v 1. Now, v 1 is given by A into l 1, where l 1 is this length and this v 2 is given by A into l 2, where l 2 is this length. So, essentially when you have put your sample inside water, you can mark the water level. So, this is your water level. When you have marked your water level, you only need to measure these two lengths the length below water and the length above water.

And you can modify your equation now. So, this equation becomes the rho of sample upon the rho of liquid is equal to v 2 upon v 1 plus v 2 on v 1 plus v 2. So, now, v two is equal to a into l 2 divided by v 1 which is A into l 1 plus v 2 which is A into l 2 is into l 2 upon A l 1 plus l 2, A and A get cancelled is equal to l 2 upon l 1 plus l 2. So, what we get from here is that the density of the sample divided by the density of the liquid in which it is floating is given by the length of the portion that is below the liquid level or in this case the water level divided by the total length of the sample.

So, just by taking these two measures of the length of the sample and the length that is below water or above water we can get to this ratio of rho of sample upon rho of liquid. Now, when we are using the liquid to be water; so when we have water the rho is given by 1 gram per cubic centimeter which is also equal to a 1000 kg upon meter cube. So, when we do that we can get the specific density of our sample or we can get the density of the sample by multiplying it by the density of water. And we can get it just by taking these two readings of the length of the sample above the water level, and the length of the sample below the water level, because this l one plus l two is equal to the total length of the sample. So, if you know the length of the sample and you if you take just one measure of either the portion that is above water or the portion below water, you can get the density of the sample.

Now once we know the density of the sample we can calculate the mass of any large sized portion that is made up of the same material as that in the sample just by taking its volume and multiplying it with the density of the sample. Now, one thing to keep in mind when we are doing such experiments is that your lengths l 1 and l 2 should be measured nearly as soon as possible, when your block is put inside water. Why is that so that is because your wood is a material that absorbs water it absorbs moisture. So, as we saw in a previous curve.

Students: (Refer Time: 28:06) sir change that length.

So, when we plot the mass of your sample versus time t when you are putting it for drying the mass reduces with time, but when you put your sample inside water, and you are plotting mass versus time your sample is going to absorb water till it becomes fully saturated with water. So, essentially when you are putting your sample inside water, you should take your measurements as soon as possible or otherwise your sample itself is changing with time.

To overcome this problem you can cover your sample with any hygroscopic material. So, for instance, you can put a layer of wax on top of your material or say a layer of plastic over your material and repeat this same experiment. And if the amount of wax or the amount of plastic that has been grabbed on the material is negligible as compared to the sample itself, then your readings will be very close to the readings of the sample itself.

So, in this lecture we looked at how to calculate the density of a sample by two methods either by taking its measurements of mass and volume or by taking its measurements when it is floating on a liquid. We also saw how to calculate its volume. So, we can calculate it either by taking its measurements or we can put it into a xylometer. Or we can use fluid displacement method in which you take weighing balance put a container of water inside on top of it and then you put your sample and push it with a needle and find out the mass difference which will give you the volume of the sample.

And the mass of the substance can be you can be calculated using a balance, but we also need to keep in mind that our wood is a biological substance and the amount of water that is inside the wood might change with time.

Thank you for your attention, [FL].