Experimental Physics I
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Lecture - 30
How to calculate the value of surface tension of water from the recorded data

So, in last class we have demonstrated the measurement of surface tension of a liquid by capillary rise method in our laboratory.

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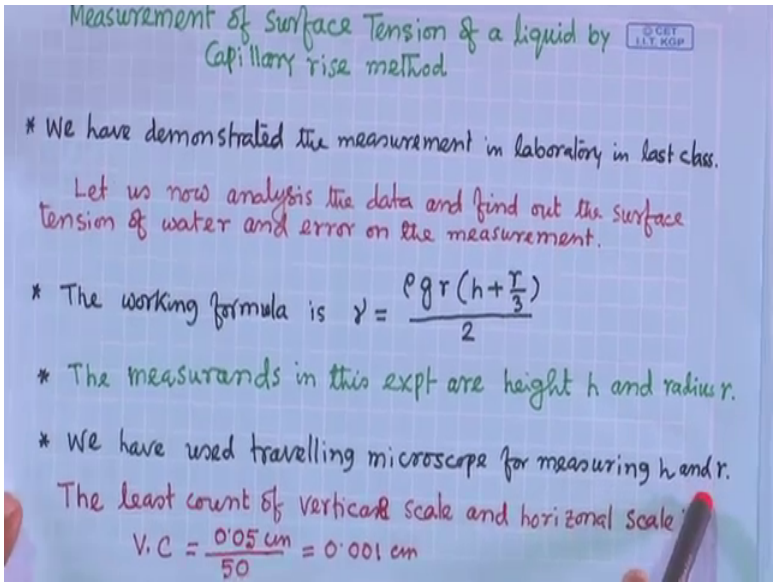

So, now let us analyse the data and find out the surface tension of water. So, we used water as a liquid during our measurement and we will calculate the error on the measurement. So, the working formula was surface tension gamma equal to rho g r h plus r by 3 divided by 2. So, rho is the density of water, g is the gravitational acceleration, r is the radius of the capillary tube and h is the height of the water column from the surface of the water of the container.

So, in this experiment we have seen that measurements what are the parameters we have to measure. So, that is just simply height h and radius r height h and radius r ok. So, radius of the capillary tube and height of the water column from the surface; from the surface water surface of the container ok. So, this capillary tubes are inserted into the water taken in a beaker is container and then this water will rise in the capillary tube. So,

from the surface of the container water what is the height of the water column in the capillary tube, so that is the basically h.

So, in laboratory you have seen that we have used travelling microscope for measuring h and r. So, least count of the it has 2 scale vertical scale and horizontal scale, so during the measurement of height we have used the vertical scale and during the measurement of r we have used the horizontal scale of the microscope. So but for both scale the vernier constant is a minimum smallest division in main scale that is 0.5 millimetre means 0.05 centimetre and it vernier scale have a total 50 divisions so it is basically vernier constant 0.001 centimetre. So, then we have seen in laboratory the setup and how you are taking the reading in the laboratory that we have seen.

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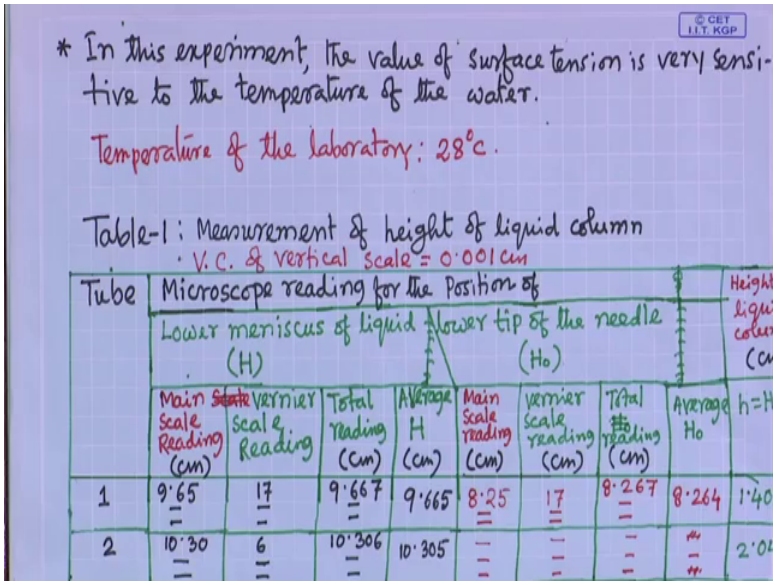

So, in this experiment the value of surface tension is very sensitive to the temperature of water ok. So, that is why it is very important to note down the temperature of the water or temperature of the laboratory basically, the water temperature will be same as the temperature of the laboratory generally in general if you do not cool or heat.

So, it will take the in equilibrium thermal equilibrium it will take the same temperature as the temperature of the room. So, temperature of the laboratory was 28 degree centigrade, so that we should note down. Now table 1 here this measurement of height of liquid column as I told that h we have to measure. So, we will use vertical scale of the

microscope that you have seen that we have used the vertical scale of the microscope and vernier constant here you should note down.

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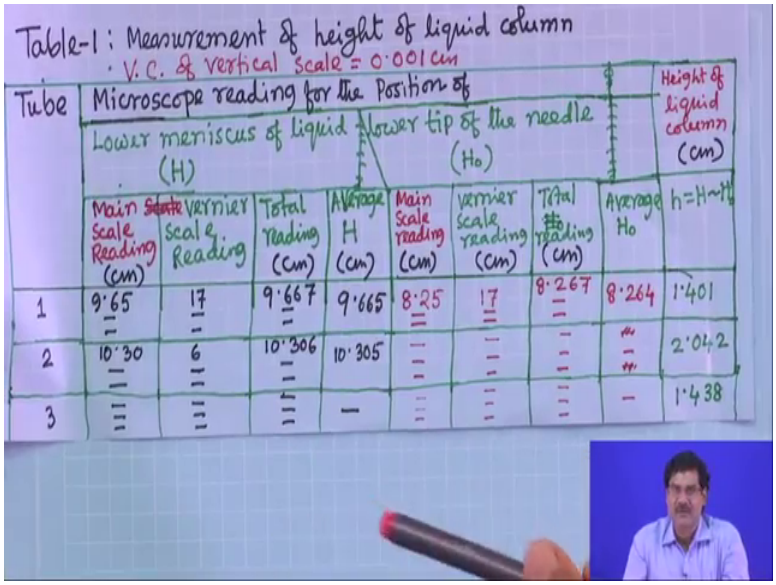

So, in during experiment you have seen that we have we took 3 we took 3 tubes of different radius tube 1 tube 2 tube 3 and so reading, we have to take basically microscope reading for the position of lower meniscus of liquid that is H say H and lower tip of the needle ok. So, that is needle tip is basically just touching the surface of the water of the beaker where we have we inserted the this capillary tubes and this. So, if this is H0, so your height of the liquid column or water column it will be height of the liquid column it will be basically h equal to difference between H and H0. So, here you note you see that we have I have written this unit it is very essential and very important.

So, all the time you should mention the unit in which unit you are you are basically noting down the reading. So, I was doing so there is there is a shortage of space, so just I have so extended it this row so but it is not. So, I think one should do more carefully this table so that this type of things it is not good to happen.

So, basically microscope we focused at the bottom of the; at the bottom of the meniscus that is we are telling lower meniscus and then take reading main scale reading in centimetre, then vernier scale reading then total reading. And here basically one should to take for each observation for each tube, so here basically you should take reading three times and then take average of it; then take average of it.

Similarly this for lower tip of the needle basically this top surface of the container, so there now we focused this microscope at this lower tip of the needles and then take reading main scale reading vernier scale reading total. Again you should take three readings for it and then take average take average of it so this to the average of it. So, difference of this two this; two is the height of the water h so it is a 1.401 ok.

So, here you just key we see here after decimal this 2 digits and here after decimal 3 digit because here main scale reading. So, here accuracy is 0.05 right main scale reading accuracy is 0.05 and up to second decimal. But this since is the three after decimal this 3 digits are there so ultimately accuracy we can get within the vernier scale accuracy you can get up to 3 digit after decimal so here and here so this the difference. So, that way you should not put say here 0 then here 10.30, so one can write 10.3 and most of the time we write but it is not the correct way to write.

So, here if we have to write we have to maintain up to 2 digit you know. So, this is the important here up to 3 digit you should maintain and result is of course up to 2 digit or a 3 digit you can you have to maintain. So, this a for tube 2 tube 3 same way one should take data we tube data but here I have not noted down. So, here it is a h for this tube one this for tube 2 this average height and this for 3 tube 3 this is the height of a liquid column, so this is the basically height measurement of liquid column.

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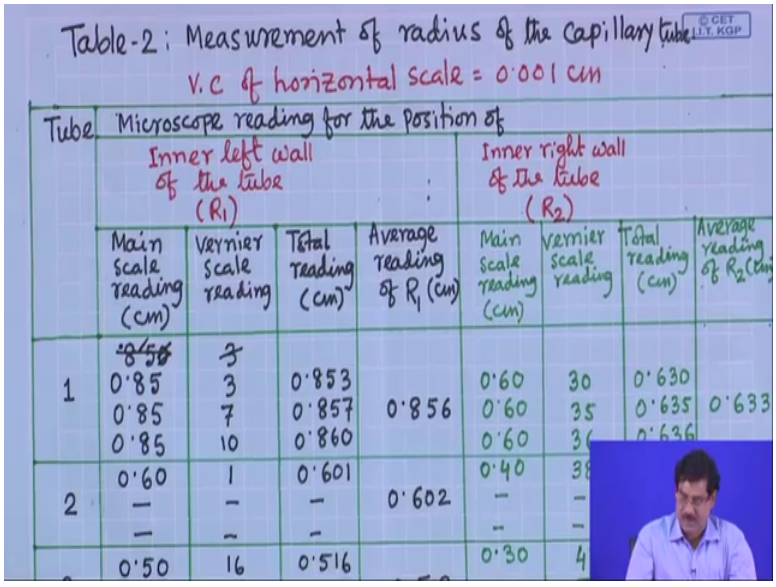

Then second table 2; table 2 is basically next measurement of next parameter measurement of radius of the Capillary tube right. So, vernier constant of horizontal scale it is a 0.001 centimetre horizontal scale of microscope that I have shown you in laboratory ok. So, now we are measuring the radius of the capillary tube, so there are 3 tubes. So, let us focus tube 1; tube 1 this wall of the tube 1 inner wall of the tube 1, so now that cursor you set at the inner left wall of the tube inner left wall of the tube that is R1 and take reading main scale reading vernier scale reading total reading and average as same way for height we have taken reading. Similarly inners then you focus just shift it is already focussed, so now just shift this cursor to the inner right wall of the tube that I showed you in during the measurement in laboratory. But the process I told you but I think when you are taking video of we could not show this exactly the focussed this focussed capillary holes. But I just mentioned and told you the procedure.

So, this the inner cursor inside just shifted to the inner right wall of the tube so, that reading say R2. So, for tube one again you take 3 reading and from there you take average ok, so that is the reading R1 similarly this is the reading R2. Now, radius is basically this is that R1 minus R2 or R2 minus R1 that is the basically diameter divided by 2 that is the radius R ok. So, we found the radius R is this 0.111 similarly for tube 2 0.0 I think 0.086 for tube 4 tube 3 so this is 0.086.

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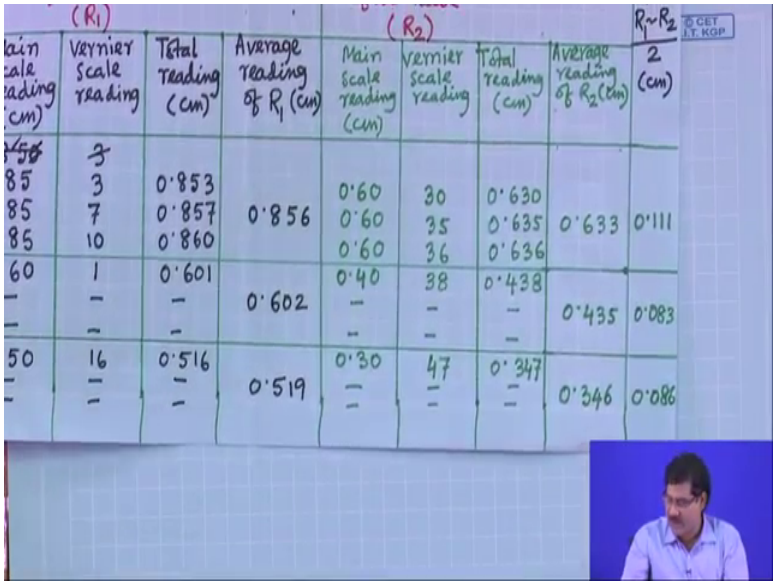

Now, this two radius are more or less very close so either I do not know we should not take this is very close this two radius, either some error in measurement of one of them or we should take radius we should take capillary tube having quite different here difference is 0.3 0.03. So, here also similarly it would be 0.05 also or 0.06 range. So, let us see so now we have measured the we have data for radius R and we have data for radius for water height liquid column water column height that is h ok. So, now we will be able to calculate the surface tension.

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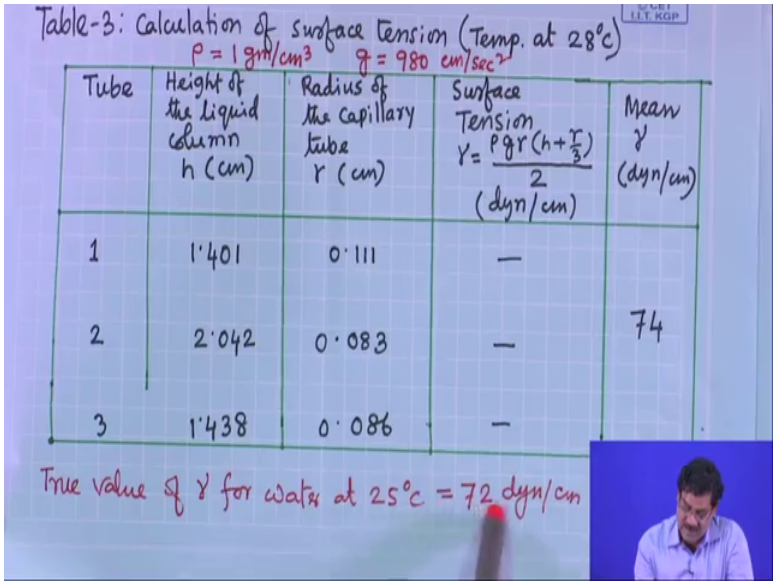

So let us make table 3 so calculation of surface tension here important is at which temperature ok. So, that we should mention because as I mentioned the surface tension is very sensitive to the temperature it is should varies. So, we should tell that this we are measuring surface tension whatever value we will get that is at temperature 28 degree centigrade. So, again for tube 1 2 3 then height of water column this for tube 1 is this tube 2 is this tube 3 is 1.438 and corresponding radius of the capillary tube is this this and this.

Here I can see this is the smallest radius, so if smallest radius water column this height will be higher so it is the highest that is fine and this is the highest radius. So, liquid column should be lowest one and that is what it is 1.401 and this is the you see now this. So, this is in between this is in between radius is although it is close to it but so although

it is close to it. So, what are liquid height it is supposed to be close to this value you know it is close to these value but it is supposed to be close to these values.

But it seems it is close looks to us that it is close to this value ok. So, something wrong in the measurement from here I can tell you because I have saw my student has taken my t a has taken this data and calculate. So, from analysing this seeing this data I can tell you that there is a something wrong in the measurement, either in height measurement or in column measurement. So, so this, this is close to this one, so this reading it should be close to this one, but it is not the case it is we can close to this so there is a some.

So, this the way anyway but there maybe mistake that is why we are taking for three that is why we are taking for three r ok, so that we can average out average out ok. So, that is the reason because there may be some mistake if we just measure one if it is mistake here so we cannot find out. So, if you measure this for 3 radius and seeing this one I can tell I can see that something somewhere something wrong. But it may happen and really it happens, so that is why we take more sets of data and we take average so, that we can minimise this error.

So, so this is average of this surface tension basically it is a right say 74 dyn per centimetre square ok, so after calculation we got this one. So, but if we see the table supply it I think this from data sheet if you see that is a true value of this surface tension for water at 25 degree centigrade it is 72 dyn per centimetre. So, in our case it is 74 is very it is close to this true value, so I think this measurement is quite and another difference is it is at 25 degree centigrade and in our case here we are measured at 28 degree centigrade ok.

So, generally so why it is higher value I whether I should justify in terms of temperature, no I cannot justify because when with temperature increment if temperature increases this the surface tension decreases ok. In case of water surface tension decreases so it is so at 20 degree 28 degree centigrade the true value 28 degree centigrade true value it will not be 72 it will be less than 72.

So, but it is a it is I think is between 72 to 71 so this at 28 degree centigrade so it will be slightly lower than 72 ok. So I cannot tell why it is higher, so that is because this temperature the difference that I cannot say because, it should be at high temperature it should be lower value. So, this way we can compare with the standard value true value

we should compare ok, so that is what we have done. Now we will do this error calculation for this measurement.

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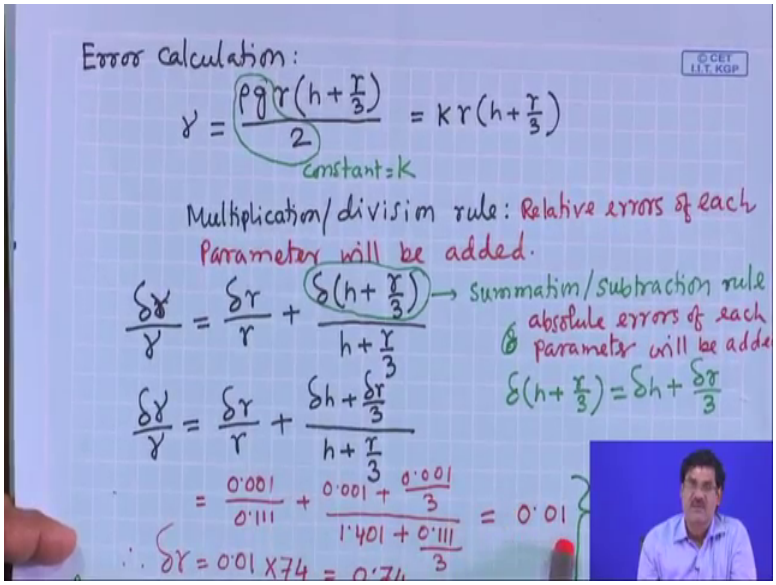

This gamma equal to this is the working formula , so rho g to this part is constant so I have written k so k r h plus r by 3 ok. So, gamma equal to this so this is the multiplication of 3 1 2 and this term. So, multiplication division rule tells the relative errors of each parameter will be added each term will be added.

So, dell gamma by gamma equal to d l r by because this is the constant it dell k is 0, so r dell r by r plus dell h plus r by 3 by h plus r by 3. So, this we are taking as a whole one term one parameter so relative errors of each term are added so that is what we have done. Now this part is basically from the that rule the summation and subtraction rule what is that?

So, if for summation or subtraction this absolute error of each parameters will be added, so that means this will be equal to dell h plus dell r by 3 is there it is a constant. So, it will be there. So you put it back; you put it back here so, you get this one then put this value dell r and dell h you know this 0.001 now. So, just calculate it is it will come around not exactly 0.01, but I think it is a 0.098 something so I have put this to ok.

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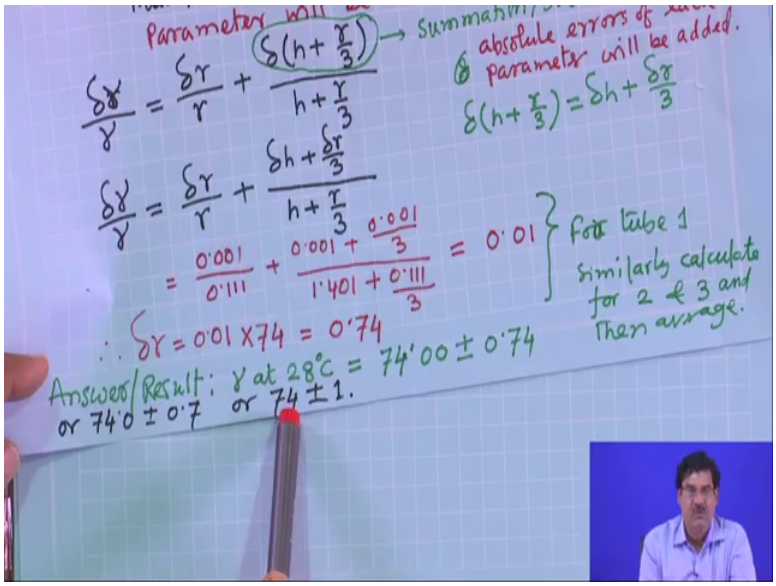

So, this error so then this delta gamma by gamma is this, so delta gamma equal to this into 74 so this 0.74. So, this for tube 1 similarly you can calculate for tube 2 and tube 3 and then take average ok. So, I have just more or less if this is the average value. So, then I have to write result so this gamma at 28 degree centigrade equal to 70, if this is the error then you should write 74.00 plus minus 0.74 or you can write 74.0 then plus minus you have to write 0.7 or you can write 74 plus minus 1 ok.

So, if it is one decimal point, so here also it should be one decimal 0.2 decimal point, so it should be same and no decimal point it should be this side. So, I would prefer to write this one I would prefer to write this one because this with temperature this variation is for I think for 5 to 10 degree centigrade it is varies it is decrease by 1. So, if it is to a at 25 degree centigrade if it is 72 it is seen at 35 degree centigrade it will be 71 45 it will be around say.

So, this variation itself with temperature, so it is the it is not in decimal point it is just in last significant number change in last significant digit. So, that is why I would prefer to write 74 plus minus 1 the result should be this. So, this the analysis of data and error calculation and the result of surface tension of liquid we have measured by capillary rising method. So, I think I will I will stop here.

Thank you for your kind attention.