Experimental Physics I
Prof. Amal Kumar Das
Department of Physics
Indian Institute of Technology, Kharagpur

Lecture - 33
Data analysis of recorded data on viscosity

So, today we will discuss about the determination of coefficient of viscosity of liquid. See in last class we have demonstrated the experiment in laboratory. So, today we will analyse the data and find out the result.

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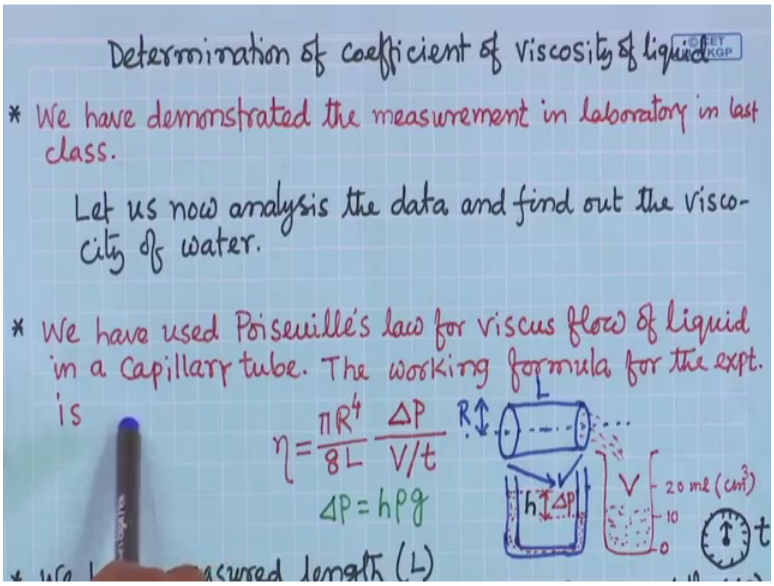

So, basically determination of coefficient of viscosity of liquid; so, we have used Poiseuille's law for viscous flow of liquid in a capillary tube. The working formula for this experiment was is basically eta equal to pi R to the power 4, 8 L, del P by V by t. So, this is the rate of change of volume ok. Rate of change of volume for a particular pressure difference between the two end of the capillary tube. R is the radius of this capillary tube, and L is the length of this capillary tube right. And this del P pressure difference, it is measured by manometer. So, basically means in two arms, what is the difference of height difference of liquid column and it is a water. So, on this if this height difference is h, so this del P will be h rho g ok.

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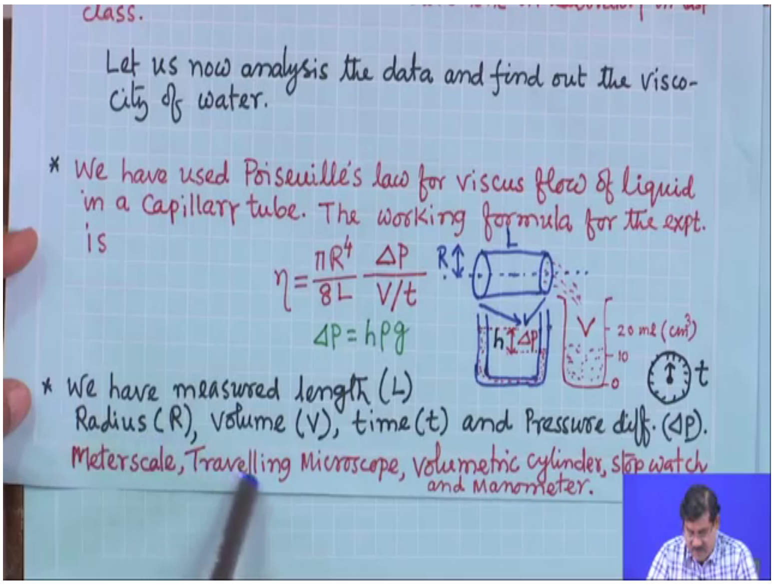

So, from this working formula, so we can see that one has to measure R, then length L, and then at different pressure difference, what is the change of volume, volume with time, so volume for a particular time ok. So in experiment in laboratory you have seen that we have measured length using meter scale or I have not shown but just I mentioned probably and radius we have measured using travelling microscope. So, as we have measured in case of surface tension, so the same way one has to measure because there also we use capillary tube.

So, here the same capillary tube of may be different radius we have used. So, the same way we have to measure see using travelling microscope or there is another method using mercury one can also measure the find out the radius of the tube. And then volume V means we will collect water we will collect water for a particular time t. The t will measured using the stopwatch. And for a particular time t, we will collect water. And then it is a volumetric cylinder volumetric cylinder. So, directly you can get the measurement, reading of this volume of the water. And that for a particular height, we will we have to collect water. And so this will be one set of data, then you can change the del P just changing the height and how to change height that I mentioned I have shown you.

So, this is the instrument we have used in the laboratory for measuring these the parameter. So, if you measure these parameters, all these parameters, then one can get this eta value. So, this is basically the coefficient of viscosity of water. So, in your case in our laboratory we have used water.

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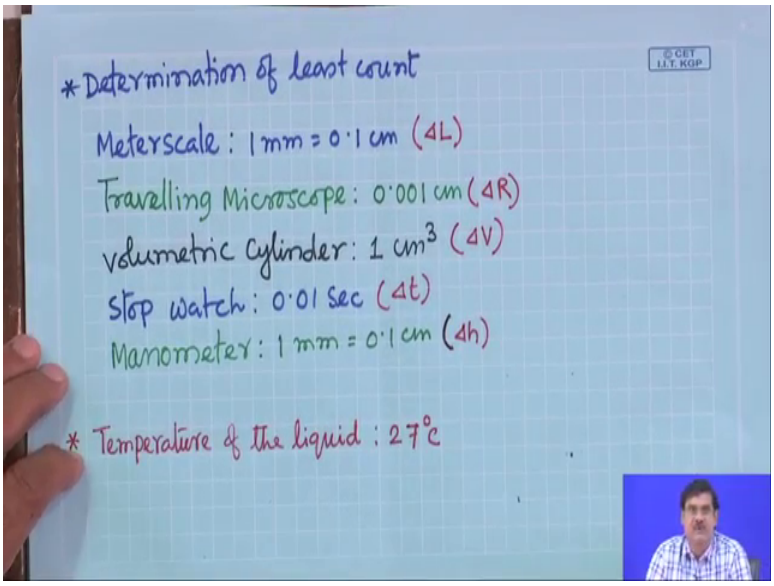

So, now, so those instrument or tools we have used. So, we have to note it down the least count of those tools. So, meter scale this is the least count was 1 mm or 0.1 cm so that is the in error calculation that is the del L. Then for travelling microscope is the 0.001 cm that is del R. Volumetric cylinder that is scaling that is the yeah, so the smallest division in that scale was 1 cm cube, 1 millilitre basically that is centimetre cube, so that is the basically error that is del V in measurement of volume V. Stop watch 0.01 second. And manometer so this height measurement basically h, so this is the 1 mm that scaled smallest division is 1 mm that is 0.1 centimetre, so that is the del h. And one has to note it down the temperature of the liquid, so it is in our laboratory, it is or this temperature of the water that is 27 degree centigrade that is the basically room temperature.

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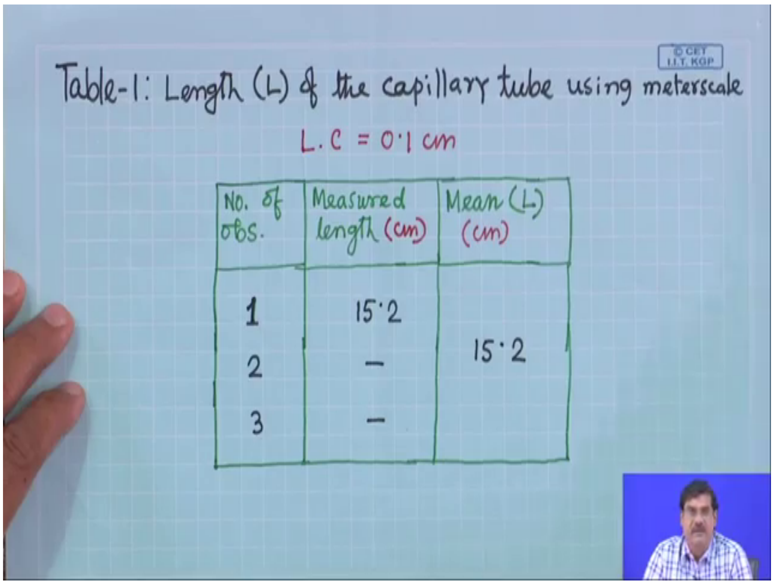

So, after noting down all these least count of the instrument, we have used in the measurement. So, then first we have measured the length of the tube of the capillary tube. So, basically one tube was used in the measurement. So, always it is difficult to detach it measure the length or radius of the tube, so that is why this exactly same tube is kept separately, so that tube one has we have used for measuring length and radius.

So, this table 1 is basically measurement of length of the capillary tube using meter scales. So, as I mentioned for other experiment that one has to write the least count on top of the table, so that is 0.1 cm. Now, it is very simple table. So, we have taken these three observations. So, write them, and take average mean value of this, length is basically say 15.2 cm. So, just important thing as I mentioned, it is one has to write the unit whether it is in millimetre or centimetre.

So, if one looks at this table, you should understand, there should not be missing of this unit, then it is you see this meaningless. It will be you know whether it is millimetre or centimetre or a meter. So, if it is missing, if this unit is missing say then that reading is basically meaningless. So, these are very important part of the recording data, recording of data.

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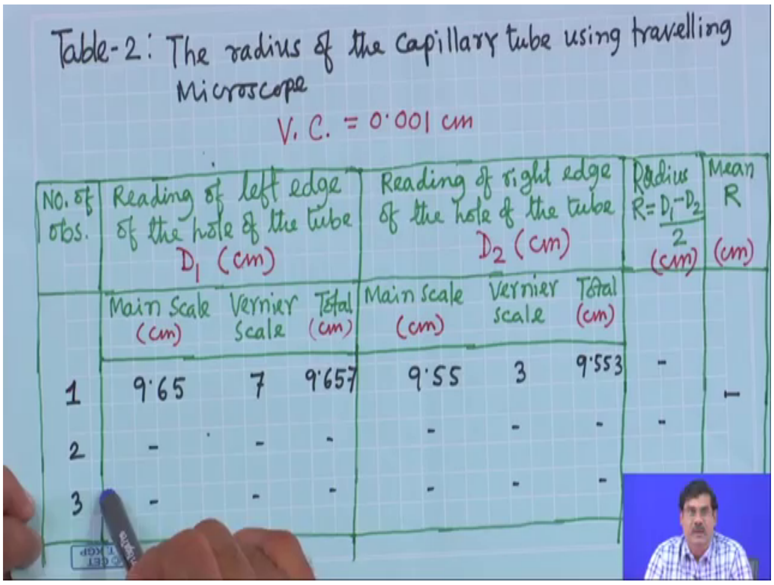

So, next we have measured radius of the capillary tube. So, there is a table 2, the radius of the capillary tube using travelling microscope. So, for travelling microscope earlier in case of surface tension, how looks the table that we have seen. So, same table we are using here. So, again this number of observation, then reading of left edge of the hole of the tube that is say D 1 in cm, reading of the right edge of the hole of the tube that is D 2 centimetre in cm. Then radius, so basically difference of these two reading D 1 and D 2 that is the diameter divide by 2 that is the radius in centimetre, and then mean value of R in centimetre right.

So, we have taken three observations. So, one has to note down. Say we have discussed in earlier experiments our experiments. So, same way one has to note it down. So, table should be neat and clean. There should be unit, there should be unit, and yeah number of observation is so, is 3 we have taken. So, finally, we have to note down the mean value ok. So, length and radius the two parameter is measured.

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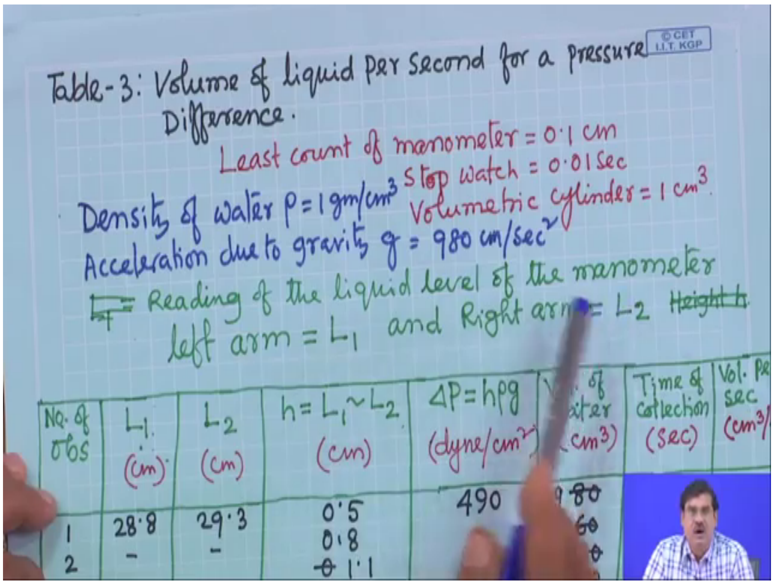

Now, important parameters for this experiment for important table for this experiment is basically table 3, this volume of liquid per second for a for a pressure difference. So, in this case, we will use manometer for measuring the pressure difference. So, this we have to note down the least count of them on the top of the table, so that is I have I have done ok. So, density of water also in this table we need density of water. Rho equal to 1 gm per centimetre cube also we need g that is 980 cm per sec square ok. Now here, I have defined two parameters L 1 and L 2. What is L 1 and L 2 reading of the liquid level of the manometer, manometer has one we have seen ok.

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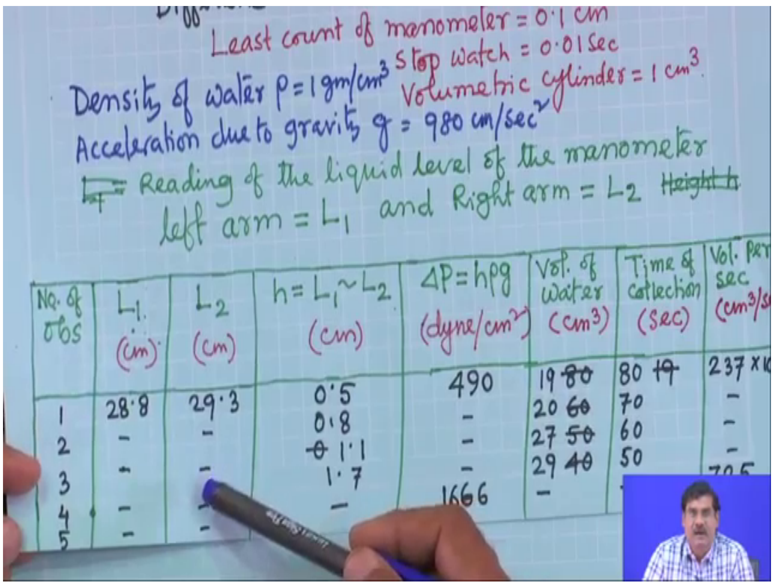

So, reading of the reading of the left arm that is if it is L 1 right one, right arm, if reading is L 2. So, then L 1 minus L 2 or L 2 minus L 1, so that will be the height of the liquid column or the water column in the manometer. So, that is the so that if we define L 1 and L 2, then it is easy to make the table. Otherwise here, we have to write, it will take longer space ok. And then it will be difficult to accumulate all these columns in the table, so that is why to reduce this size of the column, it is we have defined L (Refer time : 13:27). So, this is the tricks we have to use ok.

So, you see this, we I am showing the table in different way. So, for a particular experiment you can decide, you can decide which way you can write. So, even you can you can you can make better way than whatever I am showing. So, in different way I am trying to tell you. So, you may also think better way. So, it is not this is table not is not unique ok. It is not only the only the table you have to use. So, you can make you can even make it better.

So, again this first column number of observation, then L 1, L 2, then h will be L 1 minus L 2 or difference between L 1, L 2. Then corresponding pressure difference h rho g, so that is why this rho g I need and that is already this constant is retained out of the table. So, all data is available. So, then for a particular this pressure difference, so I will collect water volume of water in millilitre, so cm cube.

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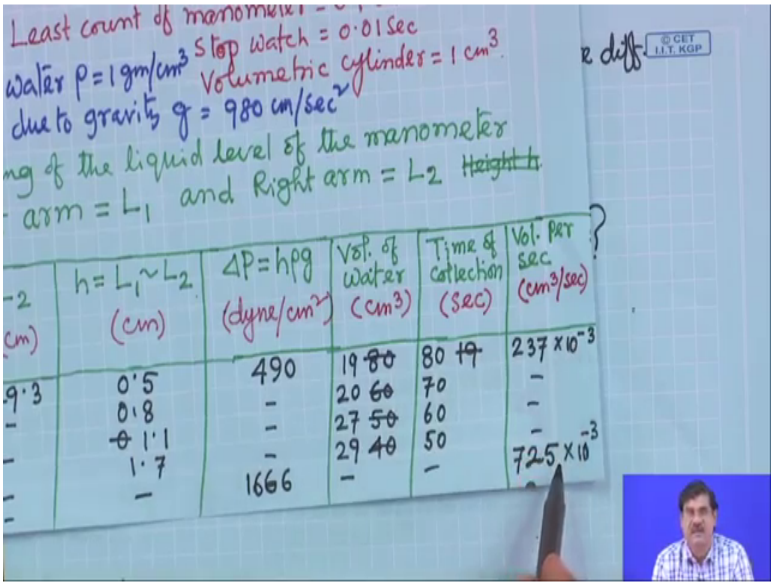

And then how long I will collect this water, so there is the time of collection in second ok so, then I will I can calculate this volume per second ok. So, rate of change of volume. So, this is the last column of this table. So, now just you set a particular you have to set basically this L 1, L 2 just for a particular pressure difference. So, you will get L 1 say in our laboratory. We have taken readings. So, there is a reading was 28.8, and then L 2 29.3, so difference will be 0.5 ok. Corresponding pressure difference if you calculate, it is the 490. Now, for this 490 pressure difference, now we collect water for 80 second, 80 second, and the volume is was 19 millilitre or cm cube ok. So, then you can calculate this volume per second. So, this is the 237 into 10 to the power minus 3 ok.

Similarly, for others other observation for basically next del P. So, we have taken here five reading. So, first and last one I have written here so, why I have written, so that you will understand. And here also I have written this two all data in this column, because here just to tell you that this so reasonable amount of water you have to collect, for that you have to select time ok. So, 80 second for this first observation for this pressure difference, we have collect water for 80 second.

Now, there is student will take for take 80 second for other cases also. So, they keep this on fixed, then for this for 80 second next one, next again 80 second for next one ok. So, then you see then volume of water will be higher and higher it is better, but since here this 19 20 millilitre is the good amount of water ok.

So, so, whether you will take 20 millilitre or 50 millilitre, if you collect more and more, but you have to be optimized, you have to be optimized. Looking at the I think looking at the precision of the measuring tools, one can decide this value. So, here this volumetric cylinder, this error is actually this least count is 1 cm cube. So, if you collect 20, so 1 by 20 ok. 1 by 20 means it will be I think 0.5, 0.5. So, error will be 5 percent. Error will be 5 percent.

So, to reduce error even I think it is better to water slightly more. So, it can be I think around 40 millilitre to 50 millilitre that would be better anyway. So, here we have collected for 80 seconds. So, it is better to collect for I think 2-3 minutes initially for this one ok. Then next one your time will be reduced, because pressure is becoming higher. So, the speed of the water will be higher ok. So, you will get higher amount of water for this same time.

So, to keep this amount of water in the same range, so you can reduce the time ok. So, here what about this actually my, what lab technician they have taken data. So, just I have I am showing those data, but I would suggest you that 5 percent error is you can see this. From these measurement, 5 percent on this on this volume measurement error will be 5 percent. So, I think you should reduced it, so at least come down to at least half of it 2.5 percent or 2 percent ok.

So, you should collect water more time for more time ok. Because, I cannot increase this pressure too much, because then this flow of water, it will not be then this it should be streamline motion. Otherwise it will be turbulent. So, then this formula will not working, formula will not be valid. So, I cannot use this very high pressure difference ok. So, there is there is a limit.

So, anyway so if pressure (Refer time: 21:30) if it is a lower, so you have to spend more time to collect water. So, here I would prefer to collect at least 40 to 50 millilitre for each cases around 40 to 50 millilitre. So, then basically here this volume per second is the 237 into 10 to the power minus 3, and this last one this pressure difference is 1666, and corresponding volume of water per second so that is 725.

So, now, you have data 5 data. You have 5 data for 5 difference of what difference of 5, 5 difference of pressure. And then this is the 5 volume per second this rate of water. Volume, volume the rate of change of water in volume basically, so that is the 5 data we have. So, why I have taken 5, why not 3, because this from working formula as I told earlier also that this eta equal to this one ok.

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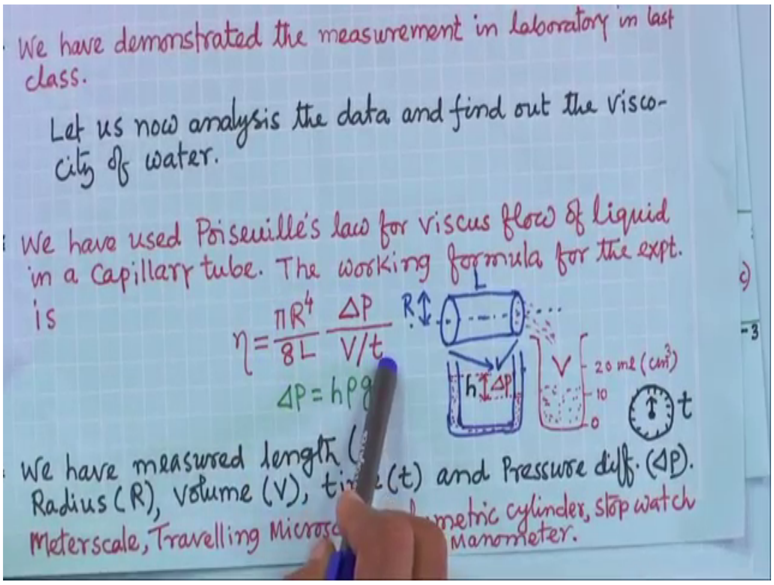

So, basically as I told this table 3 is important one. So, here for different pressure difference, if we measure this difference V by t. So, then we will plot graph of this del P versus actually this should be x because we are changing and we are collecting this also this should be y ok. So, rate of change of volume versus this pressure difference. If you plot this graph, then from that graph, we will get slope, from that graph we will get slope ok. So, the slope is basically then we can use this slope in this calculation. So, the slope will be will replace this by the slope ok. So, this value will get that is the basically slope of the graph or inverse of the slope of the graph ok, so that slope we will use here and R, R, R and L are already we have this data a minus R, a minus L. So, we can calculate eta. So, that is the purpose we have taken 5 data.

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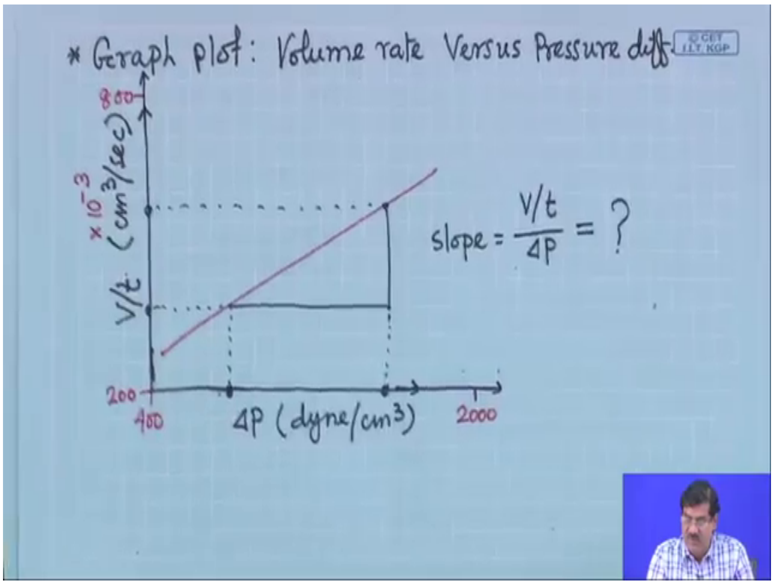

Now, we have to plot. We have to plot graph. We have to plot graph. So, yeah, so just graph plot volume rate versus pressure difference. So, this x-axis I have taken pressure difference and y-axis we have taken V by t ok. So, look at the data, look at the data. Say x-axis is the pressure difference is the 490 to 1666, so this is the lowest value and this is the highest value ok.

So, depending on that one should choose the scale of this axis, so that is why here you see instead of 0 I have taken 400 ok; and this upper one I have taken 2000. So, in between in between I have to I have to scale 400, 500 say what is the what is the it each box will be what is the value, so that one has to define here. One smallest box is what is the value so that you should you should mention for x-axis and for y-axis ok.

And of course, you have to write this level. You have level this one like this with unit with unit. Similarly y-axis ok, y-axis what was this, it was it was 237 to 725. So, I have taken from 200 scale, I have taken 200 to 725. Of course, it will be it has to be I think 10 to the power minus 3, 10 to the power minus 3 ok. So, now this all data have this 10 to the power minus 3. So, y-axis you see V by t in cm cube per second ok.

So, here so, this factor we can write into 10 to the power minus 3. So, here this I should write, so I just later on I have written this one. So, actually you should write this one here. So, actually this unit is 10 to the power minus 3 cm cube per second ok. So, what about this in bracket we are writing what about this is 200, what about the unit is it is cm cube per second that is what the meaning right.

So, now if I write this way so, then 200 into 10 to the power minus 3 cm cube per second. So, instead of here you can write here this one 10 to the power minus 3 means 0.2 and here 0.8 ok. But so, here 0.1 you can (Refer Time: 28:00), but if it is 10 to the power say minus 17 or minus 21 ok, so that you cannot here either you can write yeah. Here, itself we can define 10 to the power minus 3. But here 0.2 into 10 to the power minus 3, 0.8 into 10 to the power minus 3 ok, sorry 0.2 this point or 0.8 or you can write 200 into 10 to the power minus 3, 800 into 10 to the power minus 3 ok.

So, but then you need longer space. So, or always here you are repeating the same thing. So, to avoid that one and it is the convenient way to represent ok. So, people prefer to write this way. So, so this is the another way just I am I am showing another way to write or labelling this axis ok. The same is valid for x-axis also, y-axis also. So, depending on your data you have to decide how to write ok. So, this just that is why I have I have I have just noted down this reading to tell you about this the way of writing.

So, so, just then you have 5, 5 data point. So, we have to plot this 5 data points. And then we have to it is a basically it will be from equation one can see this it will be straight line. So, you should you should draw a straight line, average straight line ok. And from there you find out the slope, from there you find out the slope you know. So, this two points we have taken. Now, this difference of this y-axis, this two value is V by t and this difference x-axis this two points. So, you can find out and then that will be del P, so the slope. So, one has to find out the slope and then from the slope. So, now, already you have the slope.

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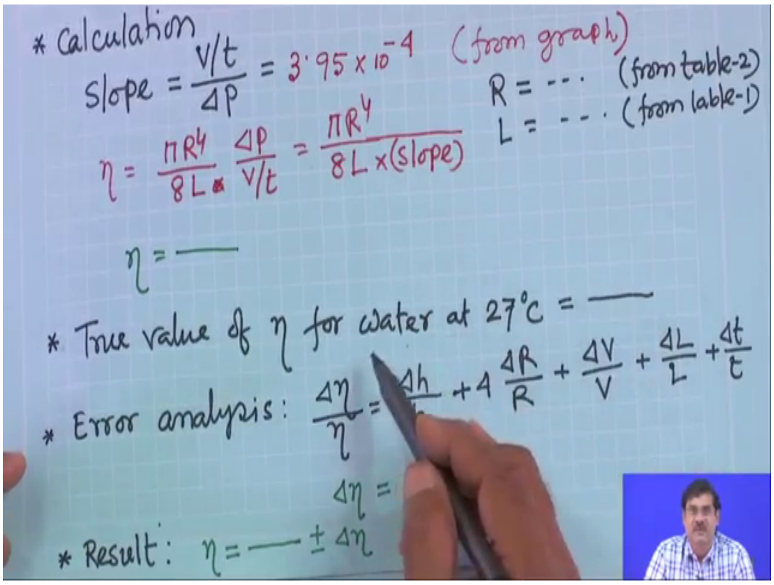

Now, this is the slope we will use for calculation, so then we are basically next step is to is calculation. So, slope this you note down. So, I have not plotted the points, but I know this from the data we have plotted and these we calculated the slope is say this. So, we have to write this value from where I got this from graph ok. Now, eta value was this. So, this I can now write. So, our slope is V by t by del P ok. So, here del P by V by t. So, it is a basically inverse of slope. So, I have written slope one by slope ok. So, slope from graph I got R and L from table two just noted down here and from table 1 ok.

So, now, I can calculate the eta value ok. Now, this it is universal constant this viscosity of water at a particular temperature. So, that is available from data ok. So, that value true value of this eta for water at 27 you should write and then compare how good your result ok.

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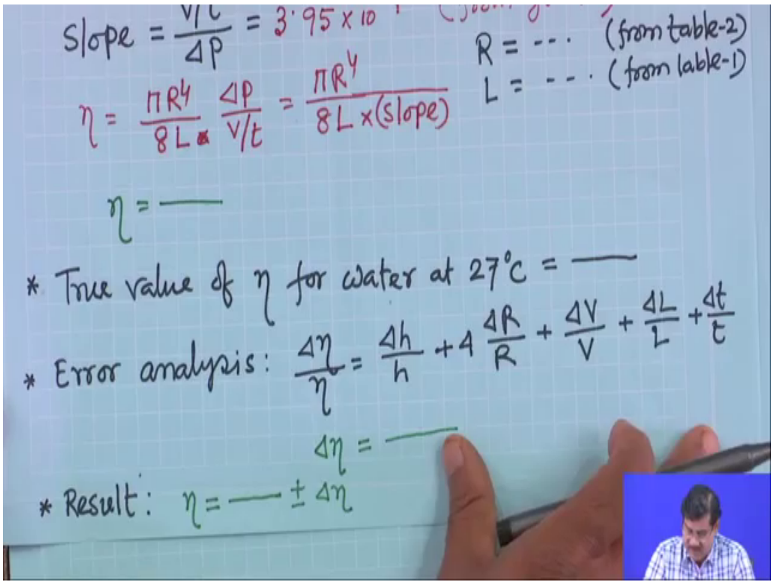

So, next is error analysis see it is very simple and you know already I have discussed many times for other experiments. So, here just simply it is the formula for the errors. And from there you find out the eta because del eta, eta is already here. Here so other also all data you have. So, you find out del eta. So, now write result eta equal to this whatever value you got here plus minus del eta ok. So, this is the systematic way you have to proceed. And so this is for true for all experiment.

So, just last three four experiment I discussed and everywhere I am telling the same things. Later on after that whatever experiments we will do I will not tell much about this because already you know, otherwise it will be just boring ok. So, initially for few experiments, I told in details, but next for other experiment I will just mention ok. So, same way you should proceed.

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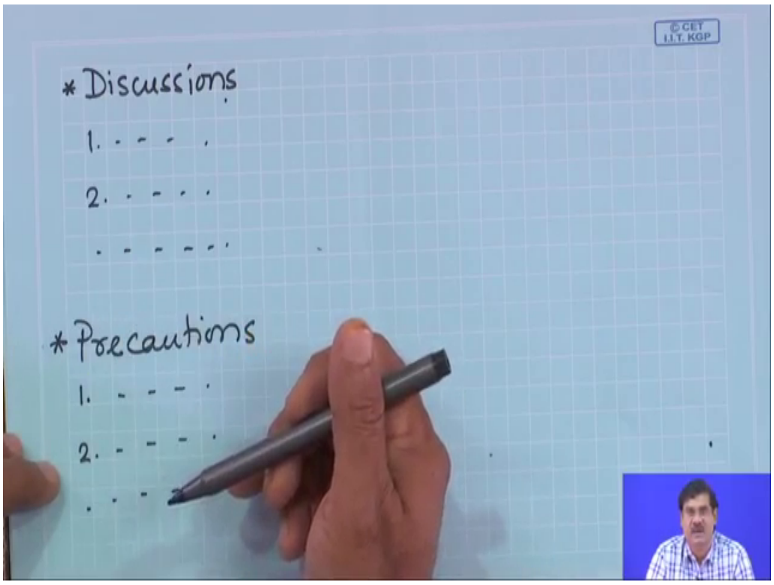

So, then I have not told earlier for other experiment, next important step it should be discussion ok. So, discussion they have point 1, 2, 3. One point could be these whatever true value standard value of the viscosity ok, but your value is deviated, it is the if it is very close to that then you should in discussion. You should you need a place where you should tell your words right, so you can write that your whatever experimentally you got this eta value that is very close to the true value.

So, your experimentally your measurement is very very good or there may be deviation from the true value. So, then you have to tell that one. And you can discuss why this deviate from where this deviation is coming ok. So, these things this is the place where you have to mention and the some precautions ok. Like here R to the power 4 in radius in formula the radius R to the power 4. So, in error you have seen this or if error in the measurement R if this is del R it is not del R by R, it is the 4 del R by R. So, whatever the del R in your this least count of the your instrument, so you have to take better instrument means this it is least count should be very is small, otherwise error will be higher.

So, here you should use better least count to, so that is what we can discuss in the so, you have taken precaution for measuring the radius of the tube. So, your least count is 0.001 centimetre. So, this very small least count so, because here error depends on the is the error will be four times basically of the least count not error means whatever, so, error in the measurement. So, there is the four times of the least count so, one has. So, this type of precaution you have to you have to you have to tell you have to write ok, so that is the next that is the item generally we keep (Refer Time: 36:17) precaution ok. What precaution one should take during this experiment, so that is what you should write ok.

So, yes, I think I have analyzed in details ok. And for other experiment I think this I will tell about more about discussion and precautions more ok. Because I have not mentioned for other experiment previous experiment experimental discussion, so but about (Refer Time: 36:54) I told I discussed in detail, so that I reduced time there, but I will spend more times on discussion precautions for other experiment. So, I will stop here.

Thank you for your attention.