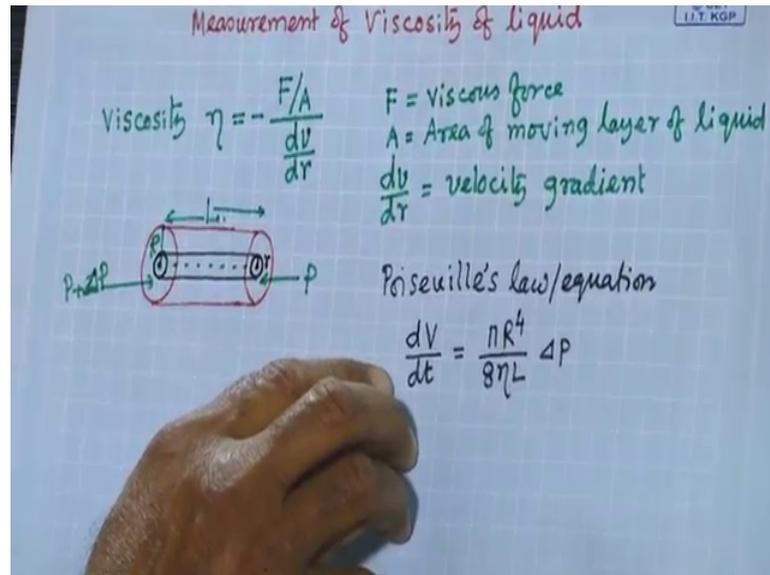


Experimental Physics I
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Lecture - 32
Demonstration on the experiment of viscosity

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So, today we will demonstrate how to measure the viscosity of liquid. So, as I discussed in previous class about the theory of the viscosity of liquid. So, this as I told that viscosity is defined by say eta equal to minus F by A dv by dr ok. So, what is F? F is viscous force. A is area of moving layer of liquid. And dv by dr is basically velocity gradient ok.

So, viscosity of a liquid that viscosity, you will feel when liquid will move liquid will flow then liquid basically when it flows it feel resistance, internal resistance that is called the viscous force it is. So, when it is moving in a particular direction, so this viscous force basically it is in opposite direction. So, as you know this in case of solid-solid in that case this frictional force. So, here also is the equivalent to frictional force ok

So, when a liquid column say here I have drawn this red cylinder ok. So, this either diameter of the cylinder is capital R; and this black cylinder that inside. So, this is the I have shown this as a liquid column, which is basically this liquid is flowing through this capillary tube basically. So, when liquid flowing through this capillary tube that tubes

internal resistance this radius is capital R, and here just I have chosen, here just I have chosen this black the cylindrical column of liquid. So, this, all liquid are moving, but just I have considered one column. So, this cylindrical column of this radius of the cylindrical column of water, in this case we have taken, we will use water for finding out the viscosity. So, you can use other liquid also.

So, this small l basically this radius of this of this water column, and which is basically these are a part of the liquid inside this cylinder, so that is basically moving and the velocity, if I consider from the center at distance r ok. So this velocity v and at distance v at distance r plus dr velocity is v plus dv or v minus dv actually v minus dv velocity decrease when velocity is maximum, maximum at the centre. When you are going towards the surface of the cylinder, then velocity will decrease, so that is basically minus. So, velocity difference will be minus dv at distance perpendicular distance dr.

So, that dv by dr is basically the velocity gradient ok. And this minus sign here because with distance here distance we are measuring from the centre, so their velocity is maximum. When we are going this perpendicular distance towards the cylinder surface, so this velocity is decreased. So, that is why dv by dr that we have to write minus dv by dr, so that minus is basically this minus. So, this is the velocity gradient.

And this force per unit area this is nothing but pressure. So, if pressure difference between this two end, water is flowing from this end to the other end. So, this pressure difference is in this end it is p plus dp and other end if it is p, so this direction in opposite direction. So, net pressure difference between these two end is basically dp. So, so F by A it is nothing but pressure. So, this, this one can replace F by A by dp ok. So, this is the velocity, viscosity, we tell coefficient of viscosity or simply viscosity, so that is nothing but the viscous force per unit area, per unit area of moving layer of liquid and per unit velocity gradient ok. So, this is the definition of viscosity.

So, we want to measure this viscosity of a liquid. Here we will choose liquid of this water ok. So, basically we will measure viscosity of water ok. So, we have to of develop theory for an experiment, so in which way you want to do the experiment. So, first you have develop to the theory ok. So, there is a Poiseuille's law or Poiseuille's equation. So, this equation is dv by dt equal to $\frac{\pi R^4}{8 \eta L} \frac{dP}{dx}$ ok.

So, here basically this geometry of the experiment is like this, if length of a capillary tube is capital L, and pressure difference between these two end is if it is ΔP , and the radius of the this capillary tube internal radius of the capillary tube if it is capital R ok. And viscosity of this liquid here it is water if it is η , then rate of change of volume of water which is passing through the capillary tube under this pressure difference, so then this dV by dt .

This v is volume rate of change of volume or the rate of change of volume of water which coming out from this tube, from this capillary tube that is equal to this relation $\pi R^4 \Delta P / 8 \eta L$ ok. So, this, so for our experimental setup this is the working formula. So, if this is the working formula, so what we will do this for a particular tube, it has particular radius R - capital R, and it has particular length L. Now, this part is constant for a particular tube. Now, experiment we can do what we have to do mainly we have to measure dV by dt form pressure difference ΔP .

So, here you can see if we plot graph of dV by dt as a function of ΔP , then we will get a linear curve. So, gradient of this linear curve will be this $\pi R^4 / 8 \eta L$. So, from graph I will get the gradient that will be equal to this, R of the tube I have to measure, length of the tube I have to measure, then from there I can find out the η ok. So, this is the working formula for measuring the viscosity of liquid for a particular this geometry experimental geometry. So, I will show this experimental geometry now.

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So, this is the experimental setup ok. So, here basically I have to take a capillary tube.

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So, this is the capillary tube; this is the capillary tube ok. So, to create pressure difference between these two end of this capillary tube, you see this, this is the, basically this is the length of the capillary tube ok. So, I have similar capillary tube here, not similar same exactly same radius and same length of the same tube.

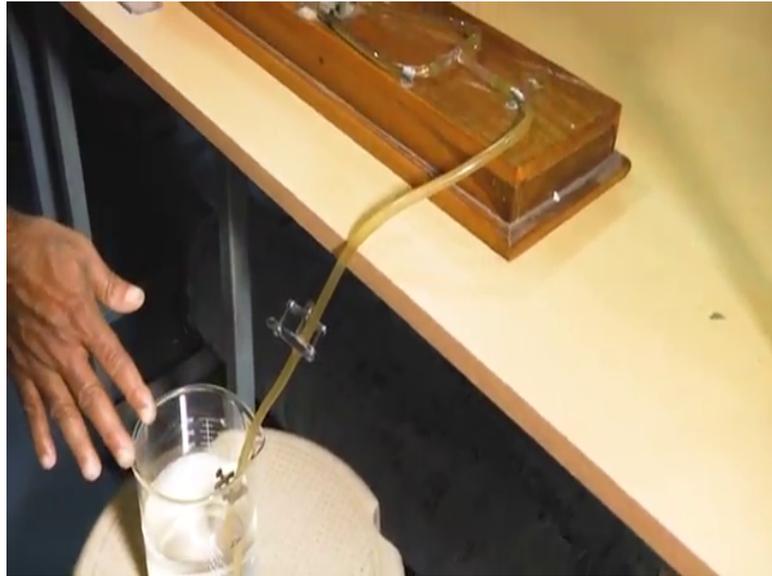
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So, I can show you that is the length is same exactly its length is same, and also its diameter also same. I think this is very small diameter ok. So, this capillary tube we have

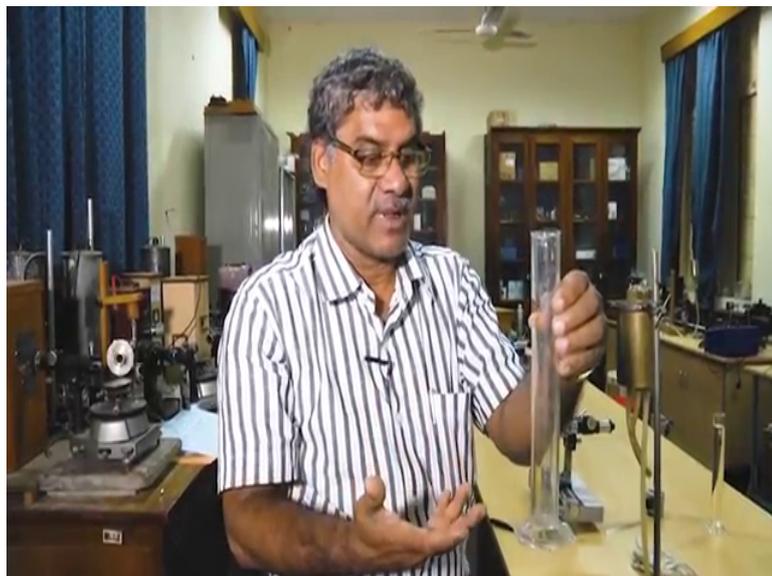
put here, we have put here ok. So, now this is the tube I have to measure the length of this tube and radius of the tube, so that we will do later on; that we will do later on. So, let me keep it here. So, I have this tube here now. Now, for the experiment what I have to do? I have to create pressure difference between these two end, and then I have to measure the water flow rate in volume that I have to measure ok.

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So, for this is the arrangement here, so water will flow and we will collect this water in a beaker.

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Or measuring tube, volume measuring tube, here this is the I think 50, no, this is the 100 ml tube ok. So, we will use this beaker or this measuring tube for measuring the volume of the water for a particular time. So, then this volume divided by that time that will be the basically dV by dt as we we have seen in the working formula ok. So, for now how we are creating the pressure difference between these two end.

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So, that basically this is the arrangement for this. So, creating pressure difference between these two end, this is the arrangement ok. So, this basically called manometer or manometer or manostat ok. So, this setup is manostat or manometer. So, here what is the principle of this to creating the pressure difference.

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Here you see so you know this water all the time it maintain the level ok.

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So, here we put water and here you can see there is a small hole actually continuously we should put water here, and then additional water will flow through this, it is go out.

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But here just we just kept, yeah closed it because manually just we will maintain this height during the experiment. Just we will put water and we will maintain this height, all the time we will try to maintain this height putting this water manually ok. And other option as I told this you can drainage out this water continuously and you can put the water continuously. So, if I maintain this level of the water, so here also here you can see this end, this is basically it is connected with this end ok, and other column is connected with the other end ok.

So, these two, water level of these two end, these two in these two column, it should suppose to be at the same level, but here you are seeing at the different level, that is because of this just there is a slight flow of water there is a slight flow of water. So, that is why this difference is there. If I just stop this flow of water, if I just stop this flow of water just you can see this water level are same, it should be same as this water level of this one ok.

So, initially water level of these two are the same. Now if there is a water flow, then there will be here pressure difference; so it is a vice versa. If pressure difference is there then there will be water flow or if water flow is there, then there will be pressure difference between these two end. So, here just we I am not disturbing this end because just we kept one constant water flow. So, just let it be there. So, some water is you see flowing, water is coming out drop wise, so that means, water is flowing through this. So,

there must be pressure difference between these two end, and that you can see here this pressure difference.

So, one has to take reading. So, one should wait for, one should wait and just let it be stable, and then you should take reading. Here it is this one is 44 more or less 44 or 43.9 ok. And this other one is 42 or it is 41.9, 41.9, 43.9. So, difference is 2 centimeter ok; difference is 2 centimeter, so that difference you can control just controlling the flowing rate of water.

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So, flowing rate of water, you can control either here or you can control here also ok. So, we will prefer to control at this end ok. So, you can just see if I control if I just yeah, if I just control the water flow this is coming down, it is coming down and, but anyway I need this basically difference between these two ok. So, yes, so I think this is the here reading is now ok. So, from here I think it is you cannot from here I think this yeah. So, one has to be yes. So, yeah, so only controlling here because this I just tightened it, so that is why this here this water coming in is very its rate is small, but here just it was opened ok. So, water was going out first. So, that is why this they came down, and again we just we just tighten it. So, then it has come up ok.

So, anyway, so controlling the flow of water in and controlling the flow of water out basically you can adjust the pressure difference ok. So, we have to first keep at a particular pressure difference. And then for that pressure difference, I have to measure

dV by dt means we have to collect water, volume of water for a certain time t , then we can find out dV by dt that is basically dV by t ok.

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So, for that I need stopwatch, I have this stopwatch. So, this start; so, this precision of this stopwatch is basically 0.01 second ok. So, this varying fast 0.01 second. And this one 12, 13, 14, 15, and other one is very difficult to read it, but so this precision of this stopwatch is 0.01 second. So, start, then I can stop it ok, then this is the reset ok, start, stop reset ok. So, watch is fine. This stop clock is fine. So, I will use this one.

So, here what I will do, now I have taken this reading, pressure reading. Here now this pressure is basically yeah so before starting, we have to maintain this water level ok. Then I have to see the pressure difference here that is reading is 44.3, and this is 43, and this is 44.3 ok. So, that is a 1.3 that is the pressure difference. So, for that there is a rate of flow of water, there is rate of flow of water.

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Now, what I will do I will collect the water. So, for this condition, under this condition ok, so I have to when I will take in, so I have to start watch. So, let us start, let us start, yes, I start this stopwatch. So, let it be here for some time. So, we can see also this water is poured in drop by drop. And from here I can see, so clock is running and also I think this water is water. So, we have to decide that how much water you want to collect. So, I think at least you should collect 20, 30, 40 ml water ok. And then when it will be around that 40, 30-40 or whatever, so then we will stop the watch.

So, you see now water level is here, water level is here. So, we have to wait. So, it is just 59 just 1 minute 3 second, 4 second, 5 second, 6, 7, 8. So, we are collecting water for sometimes when there will be reasonable amount of water. So, now, question is you are collecting water. So, how long you should collect, now I can stop it, but you have to think that this error you have to calculate error for this experiment. So, V by t that term will be there. So, you know this error is on this for ΔV and this Δt that will be additive and relative error ΔV by V and Δt by t ok.

So, ΔV by V . So, if V is more, ΔV is constant that is this is the I think 1 milliliter I think this least count of this measuring cylinder, so that is there. So, now, V is in your hand. So, if we collect more volume, so your error will be distributed over this volume ok. So, ΔV by V , if V is higher, obviously, ΔV by V will be less ok. So, similarly time also Δt by t , Δt is constant for this watch. Now, how much time you will take

that is in your hand. So, always it is better to take longer time, always it is better to take higher volume ok. So, then thus you can reduce the percentage error.

So, let us see how much here reading it is around yes I have to rotate it probably, I think to see the reading, and I can yeah its it is 50, it is between 40 and 50. So, it is now I can see. So, when it will be fifty just I will stop when it will be 50, I will stop, I will stop ok. So, it is yes, yeah I think this is the 50 I guess, yes. So, this is 50; I will stop it ok.

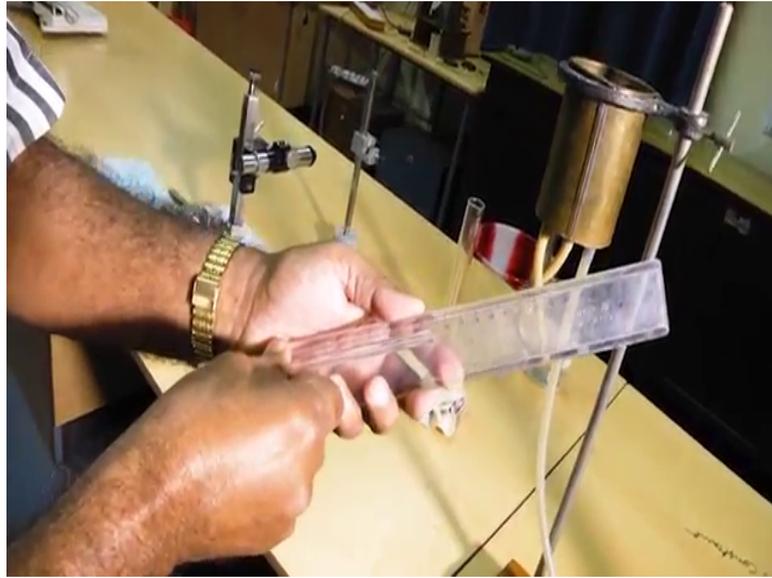
So, now for 50 ml, what is the time now, this 3 minute 40 I think this is the 3 minute 46 second, and this there is the 13.13 ok. So, 3 minute means 3 into 60, 180 minute plus 46.13 second ok. So, 180 plus 46.13, so that is the time t. And your volume is 50 ml. So, now, you can find out V by t, that is dV by dt you can do dV by dt ok. So, that is all this is the experiment. This is the one set of the experiment.

Now, you can repeat the experiment for other another pressure ok. So, here you see this pressure difference is increased because water level, no it is a water level more or less same, but you have to check whether no it is a 43 point now 4. And it is yes, it is changed. So, it should not change. So, you have to maintain the water level here. So, that is one has to be careful or also it may happen that it is a rate of water flow is very high, so one may deduce that one. So, anyway, so now, I can change the pressure difference, yes, I can change the pressure difference, I think this we should take out and ok.

So, here so we have to wait to stabilize it ok. We have to wait stabilize it ok. So, we have to take another pressure. So, here water level we have to keep yes more or less at the same height. So, we have to take another height. Here this time is height is yeah, it is at 41.7, and here 44.2, 44.5. So, it is now pressure difference is higher than earlier one. So, again you can repeat the experiment. So, at least you need to take this experiment for 4 to 5 set, because we have to plot the graph dV by dt versus the ΔP pressure difference.

So, for at least for 4 to 5 or 6 pressure difference, we have to repeat the experiment and then you will have the 6 data. Now, that data you plot on in the graph find out the gradient. And from that gradient as I told from gradient as I told we have to find out this one, this gradient this one.

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Now, this R and L we have to measure. So, L you can measure basically, just use scale for measuring L, just we use scale because this length is I think more than 10 centimeters I think it is more than 10 centimeter, one yeah it is 15 centimeter ok. It is looks exactly 15 centimeter fine.

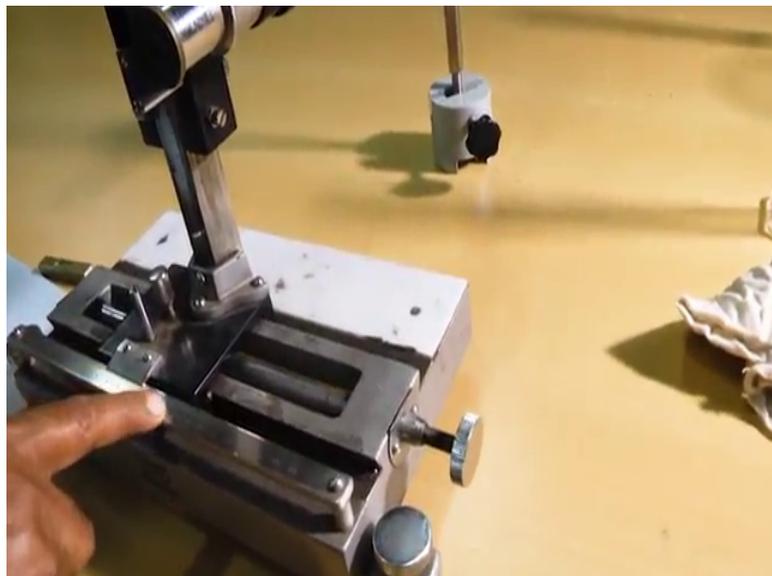
So, now, this radius we have measure either using the mercury, as I told in case of surface tension using the mercury you can find out the radius or using the travelling microscope; using the travelling microscope you can measure the, but you have to be careful just you have to tighten it careful because it is made of glass.

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So, using this travelling microscope you can measure the diameter ok. So, we have to focus this whole of this of this tube capillary tube. And then this cross wire of this vertical cross wire of this microscope that we have to just make coincide with the left edge.

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Take the reading of this horizontal scale on this original scale, and then shift it towards the right. And then again this vertical cross wire should coincide with this right edge ok, and then again you take reading. So, difference of this reading will give the diameter;

and half of it is the basically radius ok, so that way you have this now R as well as L. And from graph you have this gradient value. So, from three you can find out the eta ok.

So, in next class, I will explain I will show you data, and tell how to analyze the data, how to find out this eta value, viscosity value as well as how to calculate the error. So, I will stop here.

Thank you.