Experimental Physics I
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Lecture - 31
Theory regarding viscosity of liquid

So, today I will discuss about the viscosity of liquid, how to measure viscosity of a liquid, so that is what I will discuss today. So, you know viscosity viscous force basically when liquid move so it is does not move; it does not move freely what I mean this if liquid is in velocity in liquid ok. So, when it moves then it feels fiction force opposite to the motion.

So, its a very simple example if you put a ball small ball in a liquid, when that ball will go down means ball will move then this ball will feel fiction force due to the liquid, so that is the call the viscous force ok. So, whenever something is in motion in a liquid so it feels fictional force due to the liquid, so that force is called the viscous force. Now, we want to determine the viscous force, basically viscosity of a liquid in the laboratory. So, viscosity of a liquid it is that we tell the coefficient of viscosity of liquid.

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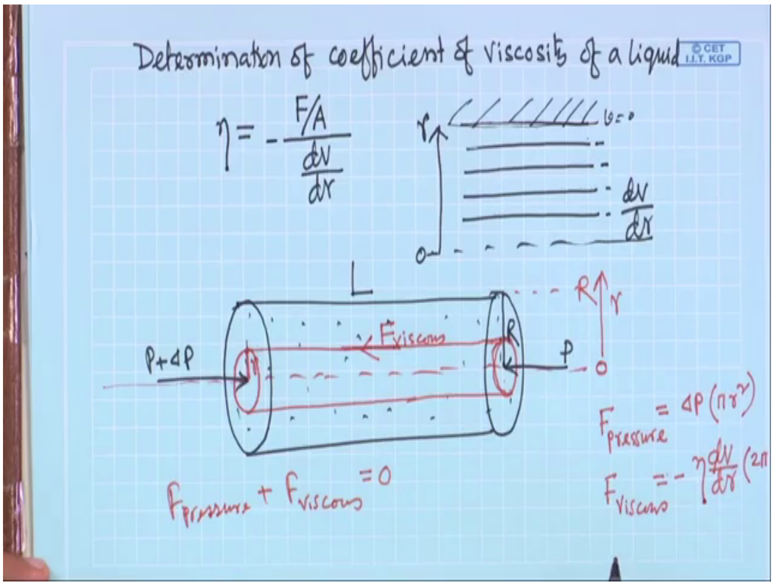

So, basically ours experiment is determination of coefficient of viscosity coefficient of viscosity of a liquid. So, basically in a laboratory we will measure the viscosity of water. So, so this definition of viscosity coefficient of viscosity say it is eta it is a equal to viscous force per units area divided by d v by d r there is the velocity gradient and one negative sign is there one negative sign is there ok.

Why negative sign because this actually d v by d r there is the velocity change between layer to layer. So, water is in moving water is in motion ok. So if you take different layer of water if at a certain layer say here it is a contact with a static surface, so here velocity 0 basically. Now, if you so this velocity of this layer velocity of this there is next layer are not same there is a velocity gradient there is a velocity gradient.

So, this we are telling this, this velocity gradient is d v by d r if I distance if I take from here. So, it is a if we measure distance from here. So, if we go up so it is a changing r changing r, so here r equal to 0 here r equal to 0. So, it is a velocity gradient is basically it is negative. So, when you are going in r is increasing velocity is decreasing and at the same time here we can take the velocity is maximum or some velocity V and while we are going to this statics surface.

So, velocity is going towards 0, so that is why this d v by d r is the is negative, so that is why this negative sign has come so this is the definition. Definition is the viscous force F is viscous force; viscous force per unit area per unit velocity gradient. So, that is the definition of coefficient of viscosity of a liquid. So, now I want to measure this coefficient in a laboratory. So, whenever you want to measure a parameter for a particular parameters it is which repairing the property of a material ok.

So, you have to take a particular geometry and further geometry you need working formula. So, it is a definition it is not the working formula for the experiment. So, for same for same I think this for the same measurement of this coefficient ok. So, in people can do in different ways means people can design its own experiment, so depending on the geometry of the experiment one has to find out this, this working formula for this eta.

So, here in a laboratory we leave this capillary tube, we will take a capillary tube will take a capillary tube it has say length L it has a length L and its a radius its radius is capital R and now liquid is flowing through this capillary tube liquid is flowing through this capillary tube.

Now liquid will not flow automatically right if it is perfectly horizontal liquid will not flow automatically we have to there should be pressure difference between these two face ok. So, you have to apply pressure difference, so here say pressure is P plus del P and here this pressure is say P. So, pressure differences is del P because of this pressure difference del P so liquid will flow.

Now when liquid will flow, then so you will get basically cylindrical so, this this liquid in this capillary tube it is in cylindrical form. So, you can consider concentric many cylinders cylindrical liquid ok.

So, its surface is basically cylindrical, so let us consider a surface let us consider a cylindrical one liquid surface at distance are small r from the centre. So, this is the centre so this is the centre this is the centre. So, from here this distance is r, so here we are taking basically this distance this origin here on this axis and this a this distance r will be changing.

So, it is maximum this distance is here it is R capital R. Now due to this pressure difference there will be so here what is the so when liquid is this layer it is not it is a basically cylindrical layer ok. So, when it is moving so there will be viscous force in opposite direction. So, we are writing that force is F viscous ok. So, F viscous so this F viscous force is in this direction and F due to this pressure difference there will be force in this direction in opposite direction because of this liquid is flowing.

So, this force if I write F pressures force due to this pressure difference a pressure. So, what will be the that force it is basically del P is the pressure into the area what is the area on this so pi r square pi small r square ok. So, this is the force acting on this liquid column due to this pressure difference del P now and then this due to this viscous force, so that will be that is in opposite direction. So, that viscous force so that is basically here viscous force as I told, so this will be eta minus eta a let me write d v by d r into A into A area.

So, this area is basically this is the surface area of this cylinder. So, it should be because this this eta this force per unit area is basically surface area of the of water of the liquid ok. So, is the cylindrical that surface 2 pi r and then L length is L so this will be the viscous force ok. Now, this force will be equal or net force on this will be equal when there will be steady state flow of water ok. In steady state flow of water so this F pressures plus F viscous is 0 ok. So, if we equate this two if we if we equate this two yes.

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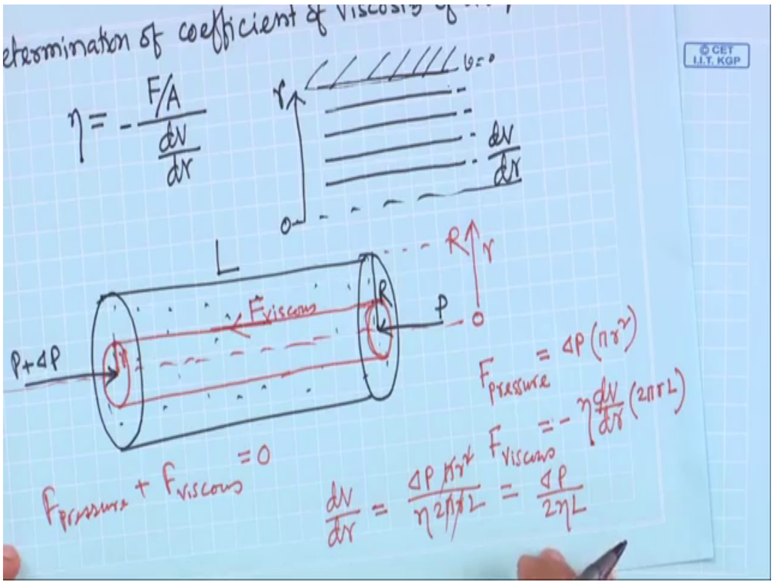

If we equate this two, so you can basically write d v by d r equal to, so minus sign will go this here this pressure. So, it take in opposite side d v by d r equal to del P pi r square divided by eta 2 pi r L right. So, this basically you are getting delta P pi pi will go r this will go by 2 eta L; 2 eta L. So, here d v by d r equal to del P by 2 eta L.

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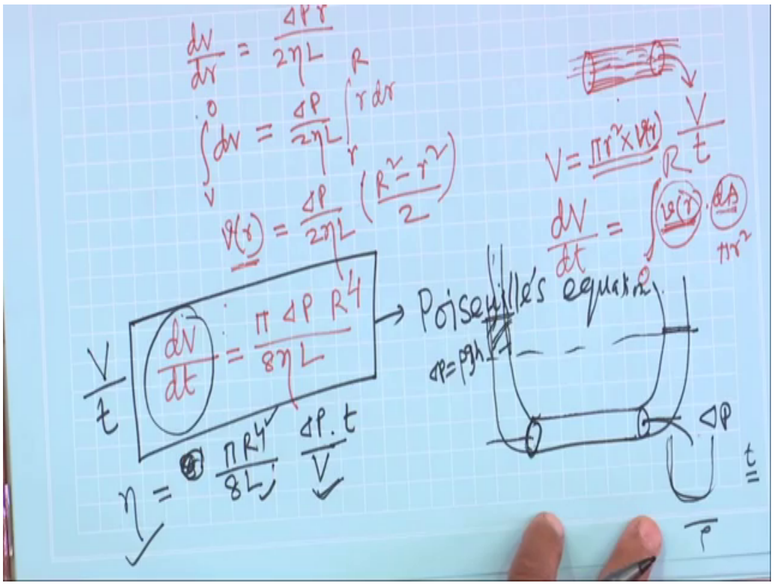

So, d v by d r equal to delta P by 2 eta L. So, del P file wherever the pressure we are applying between these two end of the capillary tube L also length is known we will measure the length. Now what is d v d r d v by d r how to measure is a directly we cannot measure it, so you have to we have to go further. So, here if I integrate this one let us find out the velocity of the liquid. So, if we integrate d v by d v del P by 2 eta L I think one r should be there yes I think here one r should be there one r is left.

So, there should be r 1 here there should be r one here there should be r here, so here r d r. So, now in cylinder velocity here is maximum at centre, but here at r distance it is some velocity v and at capital R distance velocity 0.

So, if I integrate over this say r to capital R, so capital R velocity 0 here velocity in general. So, then we have to integrate and if you integrate so here if we integrate, so I think v velocity as a function of r velocity are not same. So, from centre if you move towards the surface, so velocity will change velocity is will decrease basically know r will increase velocity will decrease.

So, here basically you will get del P by 2 eta L it is the eta and here you are getting r square by 2; r square by 2. So, I will get I think here so this there will be minus sign there will be minus sign any way we forget the minus sign just you right R square minus r square by 2. So, this is the expression we got so this v as a function of r is this, so this v is the velocity of the liquid. Now problem is again velocity of the liquid at different layer how I will measure so this the again difficulties.

So, further if we proceed this velocity, now if see continuity of basically if you consider the or continuity equation of continuity. So you can say think that overall there is a where there is a velocity distribution in this tube. But per unit time; per unit time whatever the liquid will come out volume of liquid say V it is the volume and it is and if you collect the water in time t ok. So, water is flowing for this tube now if I collect water for time t and see this volume of this liquid coming out that is V. Now this V is related to this V is related to this is the volume know.

So, volume is basically liquid here you can consider this area pi r square. So, liquid is coming out through this area pi r square and then, per unit time; per unit time what is the what is the length it is travels it is travelling. So, that is the basically velocity of the liquid. So, where is velocity of the liquid V r of V, if I write V is a function of r. So, here I can tell this is the volume of the liquid will come out per unit time; per unit time. So, this the volume of liquid will come out per unit time.

So, yes so this I can write basically so this is basically in integration formula (Refer Time: 20:08) change of volume here basically this whatever water is coming out this per unit times ok. So, this I can write d v by d t volume change per unit time or volume coming out per unit time, so this is d v by d t equal to I can.

So, through these tube I can write the velocity v velocity v this I should write like this to differentiate volume and this. So, this dot d A area and this integration because, here problem is this way I cannot write this because velocity is not constant it depends on the radius you know. So, that is why I have to take small so I have to take in differentiate form.

So, this and then basically that this velocity at this point and from the and area it will in that area in this region if I considered the small area and through this area what is the water is coming out per unit time. So, that is this now I will integrate over this over this whole area, so this a is basically pi r square pi r square. So, over the r 0 to R I have to integrate I have to integrate. So, if you integrate so this v r is basically this v r here, so if I put it pi r square is there if I integrate so I am not doing just you can do it.

So, I will get this relation I will get pi pi then dell P dell P divided by 4 eta L; 4 eta L and here r squares is there and here I think here this v r this R square minus r to the r square. So this R square r to the square 4. So, if you consider them so finally your result will be your result will be 8 eta L 8 4 and 1 and 2 will come here. So, this basically R to the power 4 , so this will be the final expression and based on what based on this formula based on that in capillary tube water is flowing between pressure difference dell P and then if it is length is L and radius is R.

Then the water volume of the water per unit time will come out from this tube is related like this and this dell v by dell t, so this I can write v by t over time t it is how much volume is coming so this is the rate of change. So, if I collect for the time t then what is the volume so this is the v. Now then eta you can write; eta you can write eta you can write I think 8 no here eta I will take eta then pi R to the power 4 dell pi then V will come V will come and 8 is there L is there and also t will be there t will later t will go out go off t (Refer Time: 24:38) t ok, so that will be the formula for this.

Now, here you see the basically this equation this equation this equation is called Poiseuille's equation; Poiseuille's equation ok. So, somebody has you see to determine the coefficient of viscosity of liquid. So, somebody has done has worked out this method and find out this working formula. So, using this working formula one can calculate or determine the viscosity coefficient of viscosity ok. So, what I want to mean so what is viscosity what is coefficient. So, their definition is there but to if you want to measure. So, in different way one can measure.

So, one can design itself and for that depending on geometry one has to find out the theory ok. So, here this Poiseuille's he suggested that if you design the experiment like this, so that will be the working formula for that geometry of the experiment. Now this is readymade it is in our hand given by Poiseuille's ok, now in laboratory we have to exactly whatever that now interesting thing is that we have to create or we have to find out or we have to build up exact geometry of the experiment depending on the condition of this of this expression ok.

So, in next class I will demonstrate this experiment in the laboratory. So, in the laboratory so we have to take a tube we have to take a tube ok, now we have to made arrangement to create pressure difference. So, manometer generally we use to we used to make pressure difference in this two end. So, this depending on the liquid height difference so we get this basically pressure difference dell P ok. So, from manometer we can take this reading so this dell P will be actually rho g h, so h is the basically difference of this two water level.

So, that way dell P we will get and then radius R. So, you have to measure the radius of this r of this of this tube this internal radius of course so will use either travelling microscope or we will use mercury to measure this radius internal radius of this tube. So, that we have to experimentally we have to measure and length also using metre scale we have to we will measure and then only now over taking the stopwatch we will collect water we will collect water for different time t we will collect water for different time t we will collect water.

So, then from the basically measuring cylinder volumetric cylinder you can measure the directive volume or you can measure the mass of this water and then just divided by this density of the water then that will give this volume ok. So, I will show you this the experimental setup in our laboratory and how we are measuring this parameters to find out this viscous coefficient of viscosity ok.

So, for any experiment this is very important to understand the working formula because, working formula is it has derived based on a particular geometry and using these working formulas. If you are going to do experiment so in so in laboratory we have to create same environment same environment in the experiment where this working formula was derived ok. So that is why derivation of the working formula is important to understand, so that is what I discussed and now we will follow each and every step in the experimental geometry to measure the individual parameters and calculate the eta so I will stop here.

Thank you.