Experimental Physics I
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Lecture - 28
Theory regarding surface tension of the liquid

So, today I will discuss about the surface tension of a liquid. So, measurement of surface tension of a liquid so, that is the experiments we will discuss, but before experiment we should know the working formula and how this working formula has come, how to derive it. So, that is what first I will discuss before demonstration of this experiment in our laboratory.

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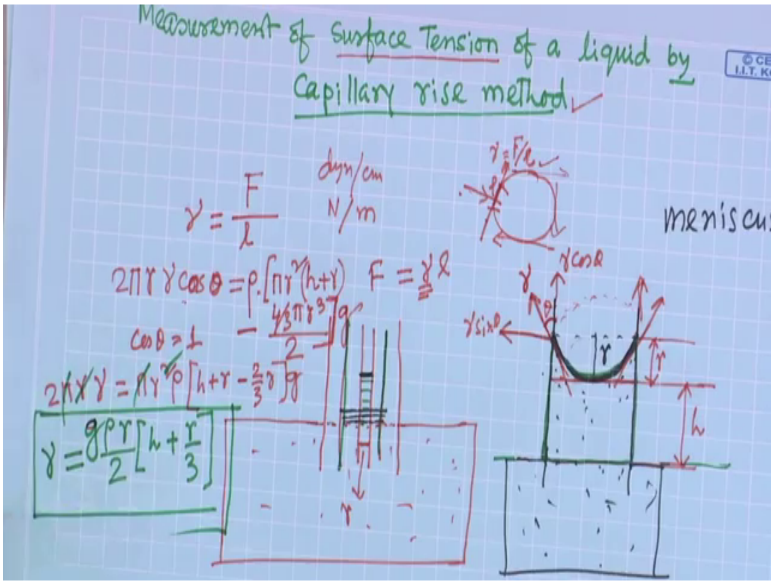

So, measurement of surface tension of a liquid so, when you will measure something some parameter. So, we use some method ok. There are different method, one can use to measure that parameter, but we have to choose one particular method in our laboratory and for that, you have to develop the working formula or develop theory for that method.

So, we will use this method that is called capillary rise method; so, by basically by capillary rise method. So, for this method we have to find out the working formula. So, let us just discuss what is what is surface tension, what is the origin of this surface tension ok. So, if you just put a liquid say mercury. Mercury is a liquid heavy metal if you put mercury on a glass plate, you see that it takes spherical shape; it is the spherical drops or spherical ball like things. If you put water on the glass plate so, generally it does not form the water droplets generally it spread over the glass plate.

So, in one case you are seeing this it is taking spherical shape, this mercury whereas, the water it is it spread over the what the glass, but if you put this water is on other surface. So, there it may form the droplets spherical droplets. So, this is because of surface tension. So, different surface have different surface tension. So, for any system energy system try to keep the total energy minimum. So, if you put mercury on a glass plate, surface tension of mercury is very high than the surface tension of the glass plate. It is not all the time it is surface tension is only exist for liquid, it is a for any surface there is a surface tension for solid also; that means, for glass plate also this it has surface. So, it has surface tension ok.

So, this surface is basically that is the air and the that material at the interface it is a that material is exposed to the air material the area of the material exposed to the air. So, that is the basically surface of that material and now its energy will depend on the area of the surface ok. So, incase of mercury's surface tension is very high, glass surface tension is low compared to mercury. So, now, when you put mercury on glass plate, if it spread over so, then area of the mercury surface will be whatever. So, that will be higher, then the surface of the mercury exposed to the air if it is in spherical form ok because spherical surface for same volume, spherical surface is always having the minimum area minimum area.

So, that is why any things is try to take it in spherical shape. So, what is the definition of surface tension? So, surface tension is definition is basically this force per unit length per unit length, that is basically is force per unit length that is the surface tension dyn it is a dyn per centimeter or Newton per meter that is the unit. So, this and this force basically is the tangential force on the surface of the of the liquid or any surface, tangential it is the if you have this surface this tangential force.

So, basically tangential force its not perpendicular force it is not perpendicular force its the tangential force. So, this is the F now over the length what is the length? So, this force acts over this length. So, if it is l. So, this f by l that is the definition of surface tension per unit length force per unit length. So, if then; obviously, if surface area is more so, length will be also more and it will be of course, in different direction. So, net force will be. So, one has to find out. So, this is the definition of surface tension now for any surface there is a force tangential force and per unit length for per unit length whatever the force there is the there is a surface tension there is the definition.

Now, total force you will find out this that acting on the surface tangentially. So, that will be if gamma into l. So, this is constant for a particular liquid or particular solid surface. So, now, we will do experiment for measuring the surface tension. So, this method we will use this capillary rise method. Capillary tube you know generally capillary tube is tube have very small radius this tube has a internal hole and that has very small radius. So, radius is very small compared to length very very small compared to length. So, if you take a tube if you take a tube if you take a tube.

And if you put in water if you put in water if you put in a water just drop into water partially drop. So, inside water is there. So, you know this water level your are expecting up to this whatever the water level on this container. So, in tube also we expect this see if you take higher radius. So, you will see this see this level, but if you just reduce the if you reduce the radius if you reduce the radius smaller and smaller, smaller and smaller and smaller. So, your changing the radius, its size basically radius of this of this capillary tube. So, if it is smaller and smaller then you will find out that it is a this liquid is for smallest 1 it will be it is rising it is rising liquid is up to this, and for others if this is the radius if this is the radius then it will rise say I think smaller height up to this.

So, this rise of the liquid in the capillary tube it is depend on the radius of the tube. If radius is higher height liquid height will be smaller and smaller. Now next is when water will come up here. So, this surface is not flat this surface is not flat see if I draw in larger scale. So, the surface of the liquid if you see. So, this surface of the liquid is in case of water of course, for different liquid it may be different it can be other way also. So, the surface is like this ok. So, we assume that is a spherical shape semispherical. So, this radius is. So, this meniscus we tell this is the meniscus ok.

So, it will take this form this meniscus form ok. So, it is a basically hemispherical shape. So, that means, this liquid is rising this way liquid is rising this way here you have container here we have container ok. So, here now liquid is at height if you take this bottom of this meniscus, if you take bottom of this meniscus this and this is the level this is the level. If this we take this is a height is h height is h and this is the this is the radius r is the it is the equal to the tube capillary tube radius this is r.

So, amount of water is on the is at height h pass r it is not exactly r ok. So, there we have to calculate what is the volume of this much what is the volume of this much water I think. So, this is the volume of water, this is the volume of water it is above the what is the volume of this water? So, water is now above this level above this level. So, now, there is if there will be gravitational force will act downwards and there is there is any something else force, which is taking it up. So, whatever the additional this some force taking it up, which is balance with this gravitational force of this liquid column. So, that would be balanced now whatever this force which is taking up that is basically that is nothing, but the surface tension that is nothing, but the surface tension ok.

So, as I told the surface tension it acts on the surfaces tangentially. So, this is the force will act. So, this force let us tell this surface tension gamma this force per unit length. So, if this contact this is called contact angle this theta this we tell contact angle this theta. So, you can take 2 component of this force one is vertical direction. So, that is gamma cos theta and another is horizontal direction that is gamma sin theta. So, this gamma sin theta basically perpendicular to this to this surface, not to the surface on the this perpendicular to this vertical direction.

So, this will be in all direction. So, that will be balanced, but this one vertical one is basically is the resultant force acting on this liquid because of this vertical force, this is coming due to the surface tension because of this vertical force. So, this liquid is now going up. Now that will be balanced by the gravitational force acting downwards ok.

So, here this what is the total force on this surface then what is the total force acting on the surface? So, that is this if it a radius is r this perimeter it is acting as a on the perimeter. So, that is I think 2 pi perimeter is 2 pi r 2 pi r, this is the length perimeter length and then for this gamma cos theta that is the vertical component per unit length this force per unit length vertical component of this gamma of course. So, this will be the force upward force due to the surface tension and that will be balanced by the that will be balanced by the by the gravitational force downward force.

So, that is m h gravitational force what is this gravitational force? That is mass basically m g that force. So, mass is; so, this volume and this density of this liquid. So, if density of this liquid is rho into volume, volume of this water. So, what will be the volume of this water? So, basically for this 1 this pi r square pi r square into this h this. So, I will take h plus r; I will take h plus r if liquid is full up to this. So, this is the volume this is the volume, but this part is not there is no liquid. So, I have to take minus of this volume.

So, this is the this volume is basically half of the half of the sphere half of the sphere. So, sphere volume 4 by 3 pi r cube, then divided by 2. So, that will be the volume of this hemisphere here. So, into of course, density has to be multiplied; so, from here so, this angle generally is theta is very very small ok. So, then it is a tends to 0 if we take then cos theta is 1. So, we will assume that theta is very very small. So, then basically cos theta equal to 1, then you are getting 2 pi r gamma equal to; from here I can take pi r square pi r square yes pi r square rho is there see inside there will be h plus r minus here basically 2 by 3 4 by 3 by 2; so, 2 by 3 2 by 3 r 2 by 3 r.

So, 2 by 3 r. So, finally, what you are getting? You are getting this gamma equal to gamma equal to. So, pi will go r will go and then this 2 is there. So, I will get rho r by 2 then h plus r by 3. So, this is the g is missing it seems. So, that was the mass and then this is the force now this is basically mass, then I have to multiply g I have to multiply g. So, there should be g there should be g here there should be g. So, I got this g rho r h plus r by 3 divided by 2. So, this is my working formula for this capillary rise method. So, this is my working formula.

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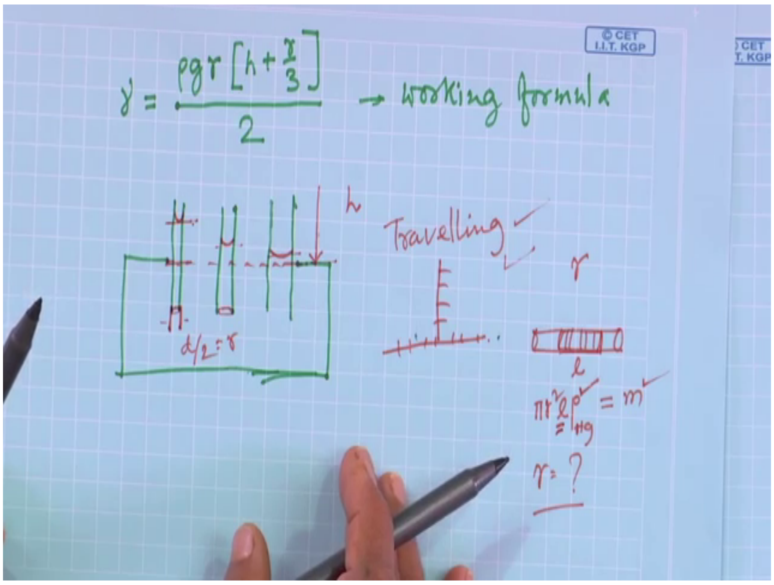

Now, so finally, what I got? I got this working formula for capillary rise method gamma equal to rho g r h plus r by 3 divided by 2 divided by 2. So, this is the working formula for this for the capillary rise method to measure the surface tension. So, in laboratory we will see the arrangement basically in laboratory we will take 3 we will take basically 3 capillary tube of different radius and we will put in water. We will measure basically in laboratory we will demonstrate how to measure this surface tension of water.

So, one can take soap water, one can take salt water ok. So, we will take this. So, here basically depending on r h will vary. So, in our hand only we can vary the for a particular liquid we can vary r for different r h will be different and so, this experiment will be repeated for different radius of the capillary tube.

So, we will take 3 capillary tube having different radius and we will do the experiment and there you will see as I mentioned. So, this kind of this kind of rise of the water you will see this kind of rise of the water you will see ok. So, now, we have to measure the height we have to measure the height. So, we will use one indicator it will touch the surface of the water here in the container and we will use travelling microscope; travelling microscope basically microscope we will use because without microscopic it is difficult to see this one and this meniscus. So, we will use travelling microscope. So, travelling microscope has vertical scale as well as well as horizontal scale vertical scale as well as horizontal scale.

So, in this case first we will set here. So, then using vertical scale we will measure this height this reading and we have to take this reading also difference of this 2 will be the h ok. So,. So, for this 3 cases we have to measure h using the travelling microscope and we can measure we will measure the radius r also now we have to measure radius r of this 3 capillary tube. So, that also this 2 ways one can measure. So, that if we take tube and then if you take this tube and then put some really mercury if you put mercury of length l and then volume of the mercury will be pi r square l into density of the mercury h g ok.

So, that will be the mass now you can. So, take out this mercury and measure it measure it means it is a what is the mass that you can measure using balance using balance you can measure. So, that is known this density also known l you have to what is the length of. So, few centimeter is l is taken. So, that also you can measure you not measure you have to take the measure this length using either yeah meter scale or slide calipers, I think this using slide calipers will be difficult you have to use meter scale.

So, then from here this is the. So, experimentally you are measuring m then l then you can find out r ok. So, this is the one method we used to measure the r; another method we will use this just travelling microscope. So, this travelling microscope has this you see this focused eye pieces, you can take you can take in horizontal direction, also you can take in vertical direction. So, there is a movement option for movement. So, here this tube now we put in vertically, now we will take it just make it horizontal arrangement and then focus using this travelling microscope and from there you will be able to see this able to see this hole.

So, that cursor that you have to take 2 reading basically putting cursor at this end what is the reading and then putting shifting the cursor at this end what is the reading. So, difference of this 2 reading will give you the diameter. So, diameter half of the diameter is will be radius ok. So, using travelling microscope also one can measure it. So, I think yeah this is about the method of measuring surface tension in a laboratory. So, we know the working formula and what are the parameters we have to measure that you know ok. So, I think in next class I will demonstrate in the laboratory how we are measuring the surface tension of water so.

Thank you for your attention.