Experimental Physics I
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Lecture – 58
Experiment to determination the permeability of air

So, we have a laser here. We have a laser here.

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So, this laser light is falling on this mirror laser light is falling on the mirror, right, you can see.

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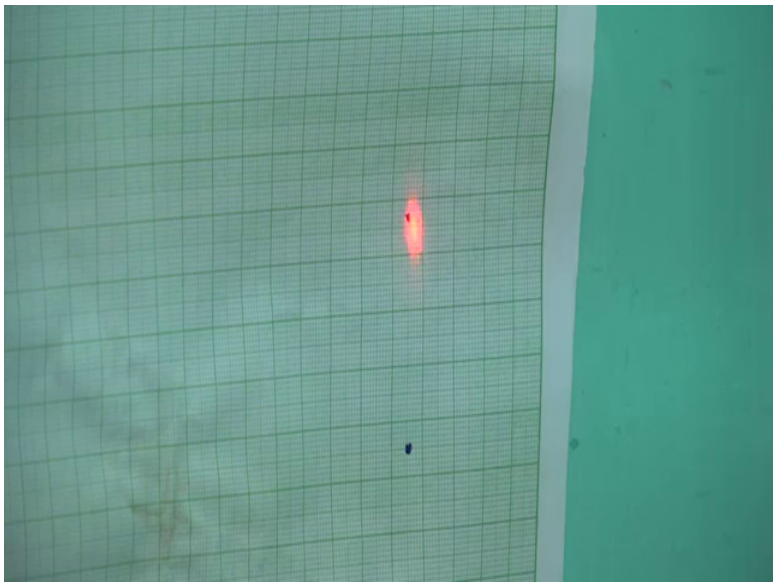

Now, this from this mirror now, reflected ray is coming back and is falling on a here we have put one graph paper. It is falling on a graph paper, right. So, we see on a graph paper you can see is oscillating.

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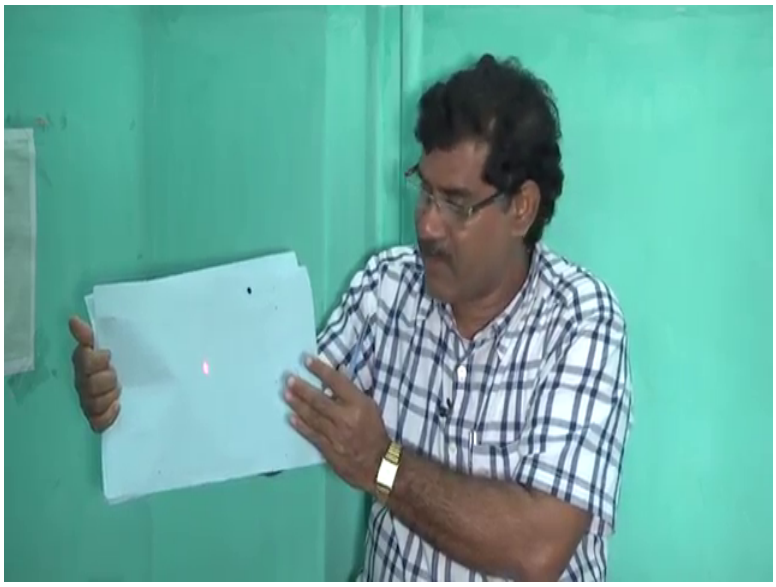

Here I can show you this in better way. So, you see this is oscillating. So, let it oscillate let it oscillate you can see this, ok. So, when that flame is oscillating a mirror is fixed with that, mirror also oscillating, right and a laser beam falls on this mirror and, this

reflected laser light is this one and this is also oscillating because you know that this is there is basically reflection, right.

So, change of ideal of mirror by theta the change of reflected angle will be by 2 theta. So, when mirror changes by theta reflected angle we change by 2 theta, ok. So, mirror is oscillating it is a changing angle, it is changing angle right. So, say by theta by theta. So, this reflected ray it is a oscillating by 2 theta or this angle of reflection we change by 2 theta, right. So, this we this laser beam is falling on this graph paper.

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So, now think that this what I can do for measuring d 0 so, I have to first it is a still oscillating I have to wait for or I have to make it in rest condition, ok; still oscillating I have to. So, I can take it in middle also just a slight change in angle. Now it is going on. So, I think I have to let it be there. So, I have to wait I think to stop it there is either no some tricks we can apply I think it may help just (Refer Time: 04:29),.

So, my hand is shaking. So, that is why also it is. So, I think one can I think let me try to make it steady, ok. Yes it works it works ok. So, actually you should not use any fan or I should not talk much also, ok. So, then it will start process. So, it is smallness steady ok. So, what I will do?

So, this is the steady position, I will mark it basically if slightly it oscillate that also it is a mean position of the oscillation you should find out. So, I will mark it, this position, ok.

So, actually I can take this the yeah I think this the I can take it, ok. This is the position I can take. Now, I do not know this whether I can see this mark or not let me check it. Yes, so, is there, ok. It is there see with respect to this marked point it is oscillating, right. So, this the original position in steady condition where this air gap that distance for d 0 this air gap we want to measure.

So, this the position of the light and when it will be at this position then this air gap that is we define that air gap is d 0.

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Now, what we will do? If we touch this two, ok, now, if I touch this two for touching this two I can put one weight I can put one weight. You see, I have weight box I can put weight say it is a 200 gram weight I will put 200 gram weight whether you can see. It is the 200 not gram milligram 200 milligram weight.

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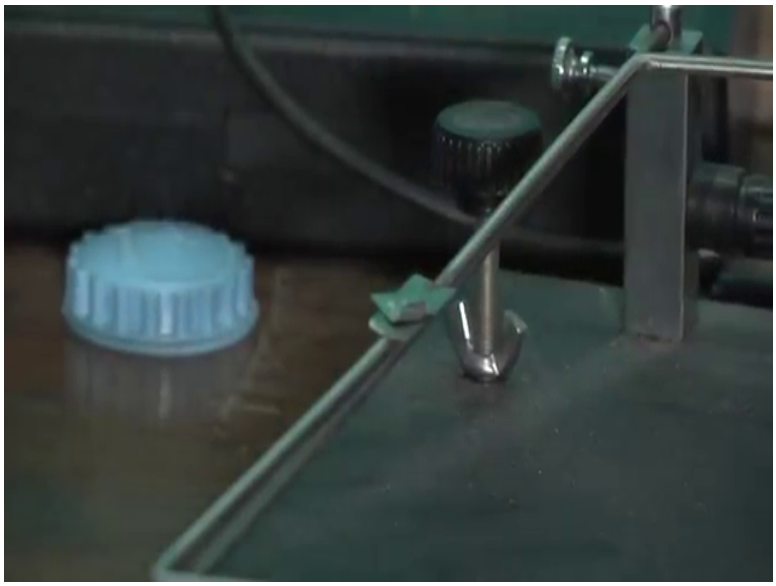

I have place to put the weight here I have place to put the wire put the weight on the wire. So, I think is I will here you see there is a place I think I will touch and holding and put this wire, ok. So, now this two wire touching each other just I put weight. So, a it is weighted down it is rotated down, it rotated down touch each other.

So, when they are touching each other then you see and it is touching with each other you will be sure that is not oscillating it is not oscillating, it is a just (Refer Time: 08:16). So, now, what I will do? I will just mark the middle point I will mark the middle point I will mark the middle point, I will mark the middle point, ok.

So, now, these distance between these two point that we will note down. So, here it is millimeter graph paper. So, how many points are there? I think this 1 2 3 ok, three complete one this 30 millimeter and then here 7, I think I will I will take 6, 36 and here it is 5 here it is a 5 when I will take out this mass when I will take out this mass I can say it is at 5. So, 30 plus 6 plus 5, 41 millimeter, ok. So, this what is 41 millimeter, but this is not d 0. So, we have to find out d 0 from this geometry.

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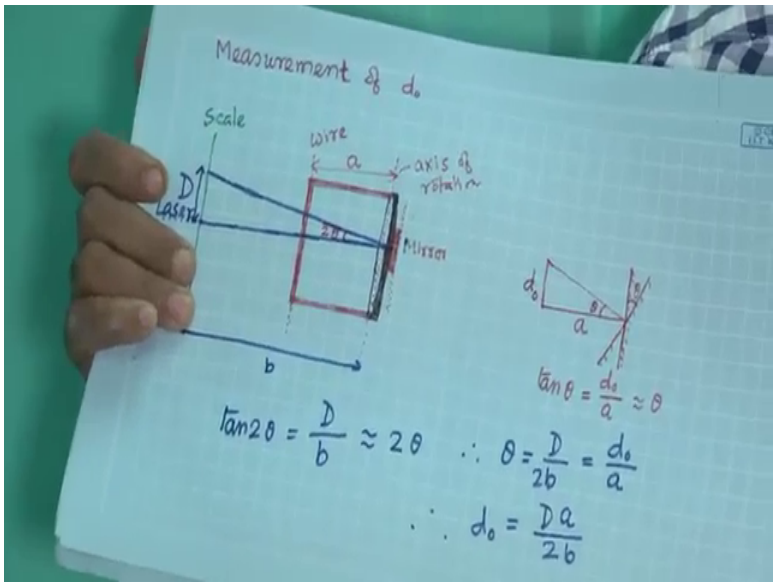

So, that I will basically tell you, that measurement of D measurement of D. So, you see. So, this upper part I have drawn upper part I have drawn, upper part this I have drawn. So, here mirror is here, mirror is here. So, and I put weight here I put weight here and then you touch this bottom wire. So, when it touch this bottom wire; that means, it is rotate, and then mirror also rotate.

So, if mirror rotate by when it was here when it was here with respect to this now mirror rotate by angle theta because of that then this light is basically reflected one now angle of reflection is change by 2 theta and because of this 2 theta change of angle of reflection. So, this reflected ray now it came here, ok. So, now, this when it was in this position in this so, this you can take one line ok, 1 distance. So, this distance is basically this distance is basically mirror to this scale graph paper.

So, distance if we define b and this. So, at this deflection here so, this the displacement of this of this light spot reflected light spot if it is capital D this is b. So, basically what happens? So, this the original position; now, then it is rotated by angle 2 theta because of that the ray is come down and it is falling here and you add this two. So, this tan 2 theta tan 2 theta will be that this divided by this. So, that will be this D divided by this distance if it is b D by b will be will be tan 2 theta is equal to D capital D by b, right. So, since this angle is very very small. So, tan 2 theta we can write 2 theta, right.

Now, you see here this level this axis of rotation is this axis of rotation is this where mirror is there. Now, and on this arm this wire this top wire whatever this arm, a distance between these two is if it is a distance between these two, ok, this is the axis of rotation and this arm this wire I have top wire basically if distance is a and mirror is here right mirror is here. So, if mirror is rotate by theta, ok. So, there will be deflection of this arm of this arm, ok. So, that because it is fixed with this, ok. So, forget light. So, live with light we have done, ok.

Now, without light also here you can see this something is rotating something is rotating. So, with respect to this axis, now this distance now this another things fixed with this one. So, what will be a deflection of this one what will be a deflection of this one. Then this angle of rotation is theta say again the tan theta will be the deflection the deflection if it is say it is the basically in this case this one is basically d 0, because these two wires this top wire touches this bottom wire, ok.

So, it is a deflection is basically d 0, whatever the air gap this d 0 tan theta will be this d 0 by that distance, ok. This arm distance, sorry this distance from the axis of this of this wire top wires, ok. So, this if it is this a so, basically here mirror is rotated with by theta, right. So, this part this distance is a then if this is d 0. So, tan theta will be d 0 by a.

So, for small angle of theta tan theta we can write theta. So, from here we can we can get that theta equal to D by 2b equal to equal to d 0 by a. So, d 0 from this two, d 0 is equal to D capital D small a divided by 2 small b, ok. So, so, you will get the d 0 if you know capital D; I know capital D hat is the 30 41 millimeter. Now, I have to measure a.

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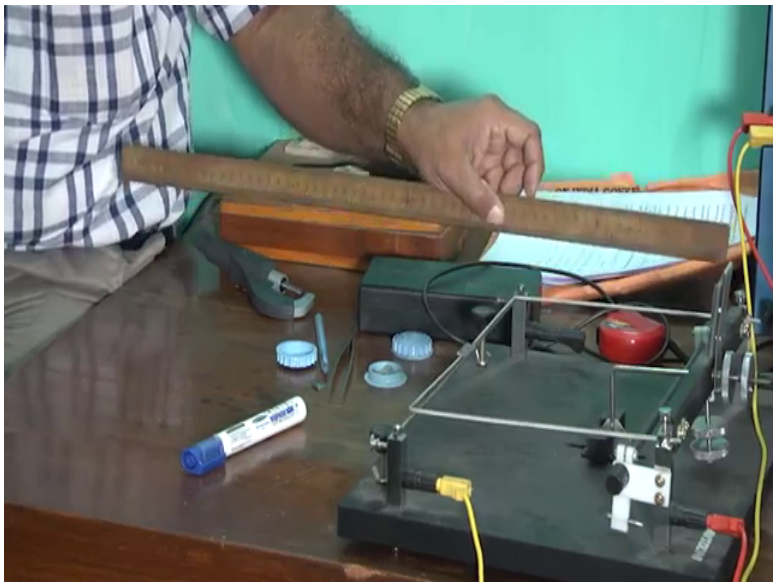

So, I will measure a, this what I have meter scale I have meter scale, ok. I have meter scale. So, I will use it and I will measure this length of the arc ok, ok. So, this one can take one should take this reading, ok. Since I am speaking so, is difficult to just read the reading, but this the you can take this reading. So, this is a and what I need? I need b. What is b? B is the distance of this graph paper from this mirror this, ok. So, for that I think this not error.

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So, I have tape, ok. I have tape measuring tape. So, I will use this one I will use this one from here I have to take. So, since it is a very long distance so, it is one should take the reading, whatever. So, that will be the b.

So, now, b is measured using the measuring tape. You need least count. So, least count of this tape you should see, find out, and noted down this is 1 millimeter. This is 1 millimeter I have used meter scale, ok. So, this also 1 millimeter least count then so, for capital D also I have used millimeter, ok. So, this the least count of this graph paper is millimeter 1. So, for all of length measurement, so, we have use the scale which is having the least count is 1 millimeter that we should note down.

So, this is the way will find out d 0 will find out d 0. So, thus this part is done.

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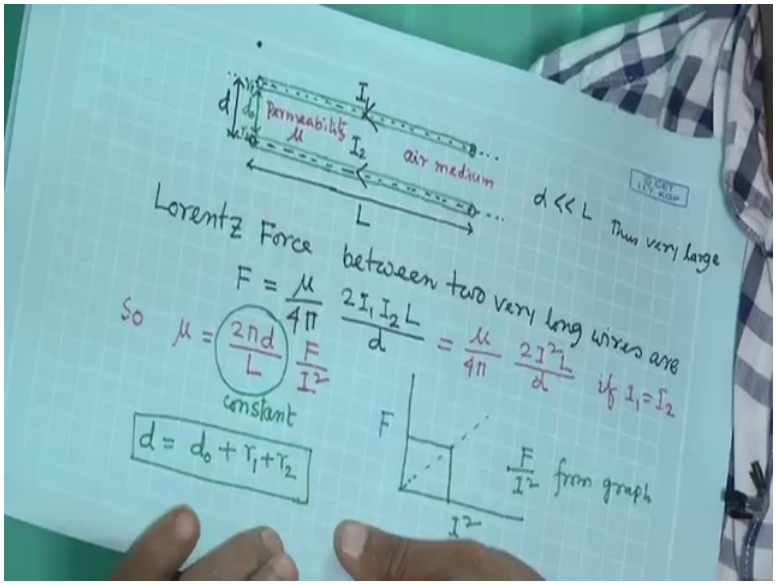

So, what is left in our formula working formula what was there is a mu equal to 2 pi d capital L divided by capital L f by I square. So, this d I have measured this d I have measured r 1, r 2 as I showed from using slide not slide calipers using screw gauge and d 0 using this optical method. This is you tell light mirror arrangement light mirror or light lens scale arrangement. So, from here view as able to measure the measure the d whatever we need in our working formula.

Next we have to measure L, length that is that is easy again I will use this one, meter scale.

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And, what is the length that we have to measure. Yes, this way just take reading and find out what is the length. So, L also using this meter scale we will measure this length because it is a 1 millimeter and this length looks to be it is a more than 20 centimeter means 200 millimeter. So, that is why error 1 millimeter least count. So, just you can take ok. So, you do not need to be vary cautious because error, error you know this delta l by L, ok; delta l is 1 millimeter by L that if it is l is very small if it is 10 millimeter then you have to very carefully. If it is 200 millimeter so, then fine will casually you can just take reading.

So, so, d and L, that is done. Now, next part is this F by I square that we have measure. So, this also we have discussed how to measure d 0 air gap. So, that is done, ok. Now, let me discuss is how to what is F and I square. So, that how we can measure that I will discuss so, basically you see. So, force is here Lorentz force, force between two force between two wires and that is because of the current flowing in this two wires in opposite direction so, that will be repulsive force, ok. So, the attracting or repulse that does not matter, but here we are considering repulsive force,.

So, now, you see in this so, this is the position when the air gap is d 0 so, this is the position that we have mark it, ok. Now, if I put a weight on this as I put earlier to 200 milligram I put and then it is touching the bottom wire. Now, I will put, I will put less weight I have to make sure that this top wire should not touch the bottom wire, ok.

So, in top wire I will put weight say 50 milligram, ok. So, when I will put 50 milligram then it will rotate it will bend rotate right not bend here to rotate, free oscillation, free rotation; it will rotate. So, so why it rotate because it is axis is here it is axis is here with respect to this axis since it can rotate freely. So, now, at these distance at this perpendicular distance I have put mass, say 50 milligram. So, m g that force is acting downwards so, force is acting downwards and this distance from this axis is this one. So, there will be torque, there will be torque. This torque is basically this force, cross product of force and this distance from the axis.

So, if force direction is this at distance the direction is say this way. So, in other third direction that will be the axis of that will be this top direction will be this third direction. So, that is basically the axis of rotation ok. So, that is why if I put weight so, it will rotate, due to torque, ok. Now, now it will come down because it is rotate. So, it will come down so, I will mark that position. When it will come down I will mark that position.

Now, from that position ok, now if I apply current now this gravitational force is acting downwards now, if I apply current in opposite direction then there will be repulsion. So, it will act in other way force between these two air you acting other direction, ok. So, then again torque, but in opposite direction so, it will rotate back it will rotate back ok. So, when it will rotate back mirror is rotating. So, this reflection rays also will moved up. So, I will apply current I will change current to bring this spot to this original position, ok.

So, when it will come at original position, then this two force will be equal one force is this Lorentz force F, this Lorentz force; that F will be equal to gravitational force m g. So, F will be equal to m g, ok. So, this is the way we will find out we will basically measure the F measure the F Lorentz force due to current I. So, that current we have to find out for which current this force Lorentz force will be equal to F g, ok. So, this is the techniques we will use and this is the main part of this experiment.

So, let me demonstrate that one.

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Now at this position air gap is d 0 right air gap is d 0. Now, let me put a weight that is I think to find out I do not want to put one to put 200 gram then it will touch then it will touch. So, let me put 50 gram 50 milligram, of course.

So, I have this maybe 20 it is a 20 I guess. So, this will be 50. So, this is a 50. So, basically we will use we later on we will measure this weight we check this weight using our digital balance. So, it is accuracy I think it is in micro microgram this accuracy of the balanced list count is microgram.

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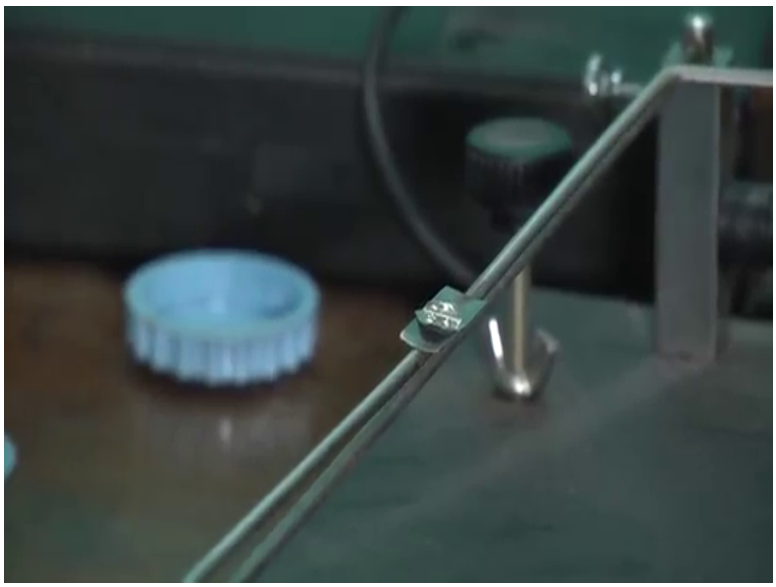

So, using that one we will we will verify this weight and actual weight we will take later on. I will not show here, but we have arrangement, ok. So, using the micro balance we will take we will later on take this. So, now, approximately we can tell this is the 50 milligram. So, this 50 milligram I will put. I will put this 50 milligram, I will put this 50 milligram, it is falling down. So, I should put, ok. I have put I have put. So, I think it should I do not know, but I do not here it should come it should come to the I should come to the static position. Yes, more or less it is static, ok. Ok, still I have to ok.

So, it is, but that does not matter I have to I have to just you see it. So, it has not reached at this point; that means, it is not touching, ok. So, it has to be after putting weight it has to be above this point then we are sure that these two parallels lines are not touching each other, ok.

So, now, it is at this position, ok. So, I do not need this reading once again. But, you can mark it you can mark it right without marking also right because my task is to bring it back to this position bring it back to this position and for that how much current I have to apply. So, now, 50 milligram I have put. So, that is the downward force is m g that is there now I will apply current.

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Now, you see I am applying current o it is the out current source I will switch on I will switch on, ok. I will switch on, ok. So, it is 0 current now 0 current now. Now, I am in just applying current I am applying current I think yes, 1 ampere I have put 1 ampere

then 2 3 I am changing reading you see it is going up now. It is going up now, ok. I have to increase current and I have to take it you see it is going up. So, one has to see I have to give slightly more current I have to give slightly more correct slightly more I will give, ok.

It is oscillating with respect to this point slightly more I am preferred to give I am preferred to give slightly more. Yes, no I need slightly more. Yes, now it is in middle, ok. So, here at this just it has exactly slightly I am touching. So, that is why it is slightly misaligned. So, it is the so, what is reading of the current? 11.1 ampere this current is 11.1 ampere. So, I have to note down this current I have to note down this current I have to switch off because of otherwise it will be hot.

So, now I know the reading I know the reading. So, I reduced and then switch off because ok. So, you have to take you have to you have to reduce current within very short time because otherwise if current passes through this wire high current 11.1 ampere very high current, ok. So, this things this rod will be hot and yes, it may bend also, ok. So, this gap now then it will change. So, the precaution one has to take.

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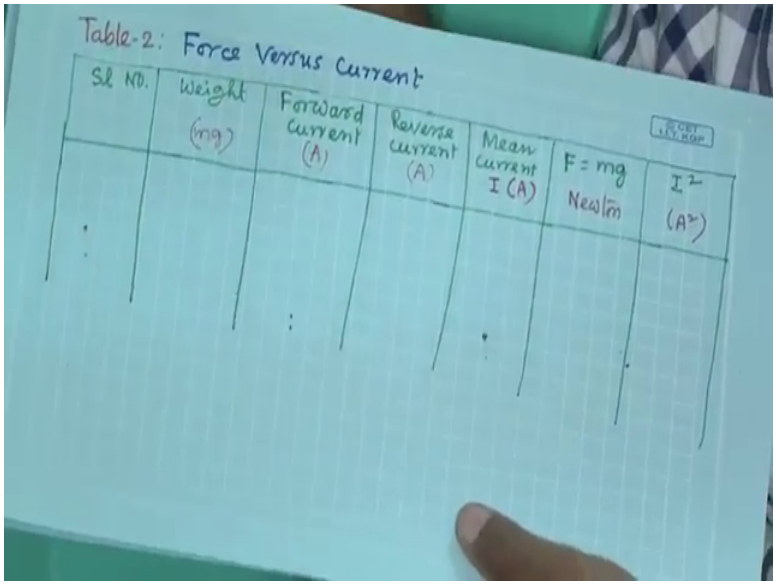

So, this the let me show you the table here let me I think this table you can see the serial number. This weight I have put this 50 milligram right I will write this one. Then, here I have written forward current reverse current forward current the reverse current to bring it back how much current I have to apply. So, if it is we take forward current, ok. So,

then I have to write here 11.1, then I will reverse the current or in opposite direction that is there. So, what about the in top whatever the direction was this and bottom direction was this or vice versa ok, now I will just do opposite.

So, this current will be reversed and the automatically the other one will be reversed, ok. For that what I have to? I have to just here I have to change the polarity. So, this I will change this to ok. So, I will just exchange this. So, thus I change the polarity, ok. Now, if I switch on and this apply like this I think just check how much I think let me check once more. So, this weight is there already ok. Now, in reverse for reverse current I will.

Student: (Refer Time: 33:48).

Yellow wire?

Student: (Refer Time: 33:53).

So, yes. So, now, I will apply current you see. So, I know this it will be around 11. So, let me go quickly ok. So, this reading is 10.2; for 10.2 I think slightly more I should give, yes. So, 10.8 earlier it was 11.1. Now, it is 10.8 or slightly reduce I should slightly reduce I should slightly reduce ok. So, it is around 11 10.6 or 10.8. So, we have to take reading note down this we are telling current reverse current ok. So, there I will I will note down 10.8 or 10.6, ok. Now, mean current I will take this plus this by 2 mean current and force id mg. So, I square I will find out I square.

So, F and I square this one set of data I got. So, then I will put 2 20 milligram I will increase by 20 milligram I will let me reduce these current let me reduce this current, ok. I reduce the current to 0, then switch off ok. So, you should switch off. So, this way I will such this 50, then I will take 70, I will put weight 20 more, 70, again I will repeat the experiment then 90, then 110, then 130. At least five data I need and then I now I have F versus I square graph I can plot. So, I will plot F versus I square graph and yes and then basically all things are in your hand all things all data are in your hand and you can calculate I think, yes. I do not, I have not written.

So, now, what will be the formula just let me go to the working formula. Yes, working formula as I told that I will plot this F versus I square graph from there I will find out the slope and the slope I will put here and d is already I have measured d already I have

measured and L also I have already measured and then we will find out the mu, ok. So, this is the one nice experiment, how to find out the permeability of air medium, ok. So, I think I will stop here.

Thank you.