Experimental Physics I
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Lecture – 57
Theory regarding permeability of air

So, today we are in our Experimental Condensed Metal Lab. So, here we will demonstrate how to determine the permeability of air. So, we have experimental setup, this the experimental setup for measuring the permeability of air. So, I will explain this set up, but before that let us see what is the working formula for this experiment.

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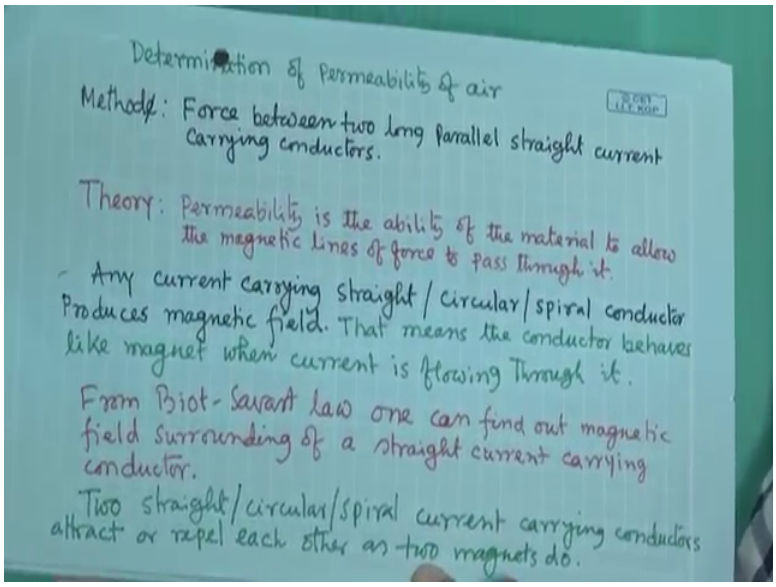

So, this you know this permeability is the ability of the material to allow the magnetic lines of force to pass through it to pass through it. So, to determine this permeability here method we will use that is basically force between 2 long parallel straight current carrying conductor.

So, any current carrying conductors, whether it is straight circular or spiral so, it produces magnetic field. So, if you pass current through conductor it will produce magnetic field right. So; that means, the conductor behave like magnet when current is flowing through it right. So, we are getting when current pass through a conductor it produced by a (Refer Time: 02:16) it behaves like a magnet. Now, if we take 2 conductors and placed in parallel and if you pass current through it. So, both of them will

be like magnet. So, 2 magnet if you bring them closer so, either they will repel each other or they will attract each other depending on the polarity right.

So, South Pole or North Pole, whether they are facing each other or this South North if so, then it will repel each other. South north will attract each other. So, , force between 2 long parallel straight current carrying conductors. So, that will be placed with some gap now if you pass current through these 2 conductor. So, either they will repel or attract depending on the direction of the current in the conductor. So, this from biot savart law 1 can find out the magic field surrounding of a straight current carrying conductors. So, 2 straight circular or spiral current carrying conductors attract or repel each other as 2 magnet pair's right.

When 2 magnets are close to each other, then what about the property phenomena we see. So, 2 current carrying conductor will behave in same way.

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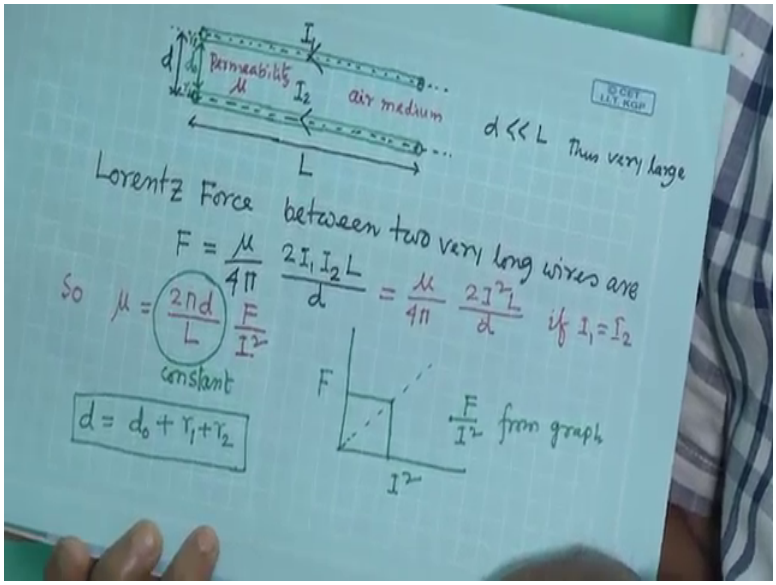

So, this the fundamental basic concept of producing magnetic field in a current carrying conductor. So, basically we use the biot savarts law to find out the magnetic field. So, here so, this a conductor it is a length say it is L and current is flowing this 2 conductors. So, they are separated they are this distance is d ok. So, this centre to centre this axis of this wire and this of the other wire.

So, distance between these 2 axis middle point for of each wire. So, the distance is d and. So, these basically these basically d 0 plus r 1 plus r 2 r 1 and r 2 are the are the radius of wire 1 and radius of wire 2 and d 0 is the d 0 here d 0 is the gap air gap between these 2 conductor. So, effective distance between these 2 conductor is d. So, that is d 0 plus r 1 plus r 2 right. So, Lorentz force between these 2 wire when they are carrying current I 1 and I 2, this 2 conductor.

So, this force between 2 very long wires are basically this the formula f equal to mu 4 pi 2 I 1 I 2 L divide by d L is the length, L is the length of the wire. This I 1 I 2 as I told this current passing through this 2 wires wire 1 and wire 2 and d is the distance between these 2 wires.

So, distance is taken from the axis; so, here we have air gap. So, basically we have air medium. So, air medium has permeability ok, whenever magnetic field passing through a medium. So, that mediums that property of this medium is expressed by permeability as I told earlier this, permeability is the basically is the ability of the material to allow the magnetic lines of force to pass through it.

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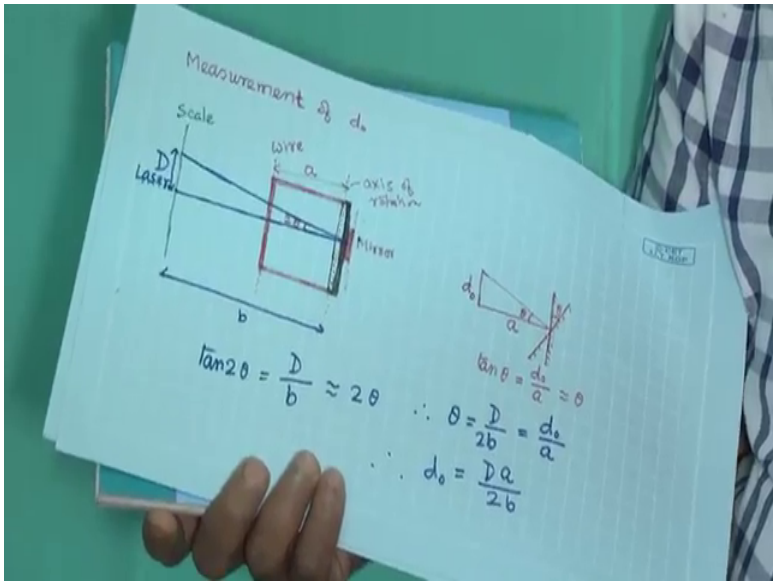

So, so, here so, here basically lines of force is produced by this magnetic lines of force is produced by this wire 1 and wire 2 ok. So, they are passing through this through this air medium. So, that is why this concept will be used to measure the permeability of air right.

So, in this formula this mu is the permeability. So, here medium is air. So, permeability is mu of the air right. So, this if current are same in this 2 2 wires I 1 equal to I 2 equal to I. So, then we can write 2 I square l by d and force mu by 4 pi it is there. So, ultimately then we can write mu equal to 2 pi d I L F by I square, F is is the Lorentz force.

So, so, this is the basically working formula for this experiment that mu equal to 2 pi d by L F by I square. So, this the distance between this 2 wires gap between these 2 wires and L is the length of the wires. So, , if this is the working formula. So, from this working formula itself we can see what we have to measure.

We have to measure d and in d there are 3 parts 1 is d 0 r 1 r 2. So, we have seen r 1 r 2 is the diameter radius of the wires r 1 wire 1 and wire 2. So, we will use screw gauge basically, we will use screw gauge in our so, one can use slide callipers also, but here screw gauge is convenient and more accurate. So, we will use screw gauge for measuring the r 1 and r 2 and d 0. How to measure this d 0, that I will tell you.

And, second you have to measure the length we have to measure the length of this wire. So, that we will use this we use this metre scale for measuring the length and main a part of this experiment is F by I square. So, will vary F we will vary f sorry we will vary I and measure the or we will vary F and measure the I. So, this F by I square basically we will at least we will take 4 to 5 to 6 set of data for each set of data.

So, we will for a particular F, we will find out the current how much current for that force. So, this we will select 4 to 6 force and we will find out the I. So, that is the main part of this experiment and then we will plot graph F versus I square, F versus I square graph and from that graph we will find out the slope.

So, if you find out the slope that that slope is basically F by I square. So, F by I square this will that slope will use here and then length, we know we have we will measure and d also we know for that d 0 we have to measure right. Now N let me show you let me show you first the this experimental setup and then I will tell you how to measure d 0 and how to do this part this work (Refer Time: 12:38) F by I square; so the slope how to find out the slope that I will explain.

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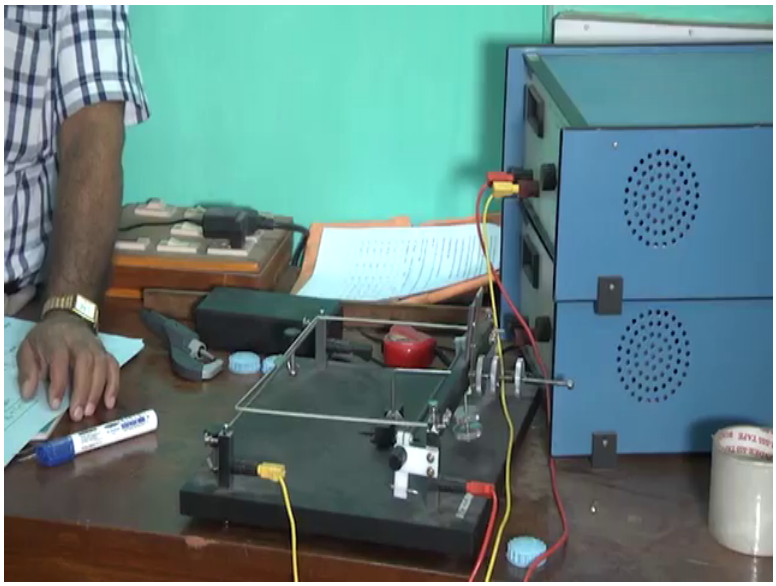

So, let me show you the setup for this experiment. So, here if you see so, this 2 wire 1 and wire 2, whatever I told during theory discussion. So, here this is the; this you can see you can see a rectangular a rectangular shape of a wire and below of it there is a another wire.

So, here this wire 1 and wire 2 is basically let us say this the this below 1 bottom 1 bottom wire ok. So, this the wire number 1 and this the; this top 1 this the wire number 2 ok. So, 2 parallel wires whatever we are telling. So, that length are same for these 2 wire. So, basically the common length of this wire will be taken as a capital L. So, here common L common L common length is you see between this length between these 2 2 end length between this 2 end.

So, this the; this part is the common common length for this 2 wires. So, these the 2 wires whatever we are speaking. So, it has it is a rod kind of things it is between rod and wires. So, this it is diameters or radius this between wire and rod. So, , these 2 wire it has radius. So, this radius is not very small, but it is reasonable radius. So, we will use screw gauge we will use screw gauge for measuring this wire.

So, let us just first take this data. So, this the digital screw gauge I have not shown you earlier. So, let me show you. So, this the digital screw gauge digital screw gauge it is on off is there yes.

So, this digital screw gauge ok. So, this reading is 0 you know this reading is 0. So, if you just rotate it is now here there is no gap, if you just rotate it then you see this is changing reading depending on the depending on the gap right. So, what is the reading now reading I can see this is 1.019 millimetre 1.0 1.019 millimetre ok. So; that means, it is least count is of the screw gauge is 0.001 millimetre ok; so 0.0001 centimetre. So, it is a our this manual screw gauge it is least count is 0.001, but this digital 1 even it is more accurate it is least count it is 1 order of magnitude is smaller 0.0001 centimetre.

So, we will use this one. So, just you should measure you should measure the airs yes, I should know here this we have to ok. So yes I think yes no it is got stuck it seems oh ok. So, this the tube 1 and this 1 the finer 1. So, I should rotate this 1 not I was rotating the wrong one. So, right yes ok. So, this more or less is giving reading 3.050 3.050. So, this way in 3 places we will take this reading for wire 2 and 3 places we will take reading for wire 1 this bottom wire.

So, here I have to just it is a I have to put here yes. So, this the this wire we will find out r 1 and r 2 whatever in formula I have shown I have showed you r 1 and r 2 here d equal to d 0 plus r 1 and r 2. So, this a we will find out r 1 and r 2. So, now, so, these 2 wires it has gapped between this air gap that is d 0 that d 0 how will measure that I will tell you. Now, we have to pass current through it we have to pass current through these 2 parallel wires straight wires.

So, we have here is we can see this high current power supply. So, , this here I can see this it can give maximum 20 ampere current 20 ampere current. So, this the you see this one connection and this the another connection, this the another connection here another connection here. So, this and then we since we will pass the same current in the both wires I 1 I 2 are same. So, if I pass current pass current connect current here from this source. So, this from this source I have to I think I have to check some arrangement is done ok.

So, basically here this yellow 1 is coming here and the red 1 is coming here. So, current is say entering here and then passing through I think this is connected here ok. So, passing through this passing through this passing through this and then here you can I can show you that is connection here and here. So, current will come out through this current will come out this and this is the current will come this way and enter here and

this will go this way and go out through this yellow wire; so this the complete circuit. So, same current is basically passing through this to the top wire and to the bottom wire.

So, the current will pass here. So, connection here made in such a way if current entering here. So, is current direction is this and then I told you this way it will follow the black wire is coming here and then current is flowing this way then it will come out through the yellow wire. So, here you can see this in top wire current is passing through in this direction and bottom wire current is passing in opposite direction. So, when current are flowing through the opposite in opposite direction then they will there will be repulsion between this 2 wire and if they are passing through the same direction.

So, then they will attract each other. So, but there is a reason why we are taking in opposite direction reason is that if they attract each other then what will happen they will touch each other then will be there will be short circuit. So, to avoid it just we have chosen the opposite direction taking in same direction also 1 can do the experiment, but as I told this we have to be cautious there is a there should be you should take precaution to avoid such accident that if they touch each other at high current is flowing.

So, then there will be maybe when they will go very close then there will be sparkling also. To avoid this it is better to choose current in opposite direction, then you will get you will here you will get this repulsion between these 2 wires, and they will go I think in opposite direction ok. So, there is no possibility to touch each other. So, now here so, this file these 2 parallel wires and we have arrangement for current passing through them in opposite direction. Now, this wire top wire say if bottom wire is fixed for a strength fixed, but top wire it this arrangement is done in such a way that this basically it can rotate freely.

This top wire can rotate freely; so it is a here we have basically here this lever kind of arrangement is there. So, this wire this wire if see it is connected with this other 2 wires and here we have made the arrangement lever arrangement. So, that this can rotate this can rotate or oscillate freely with respect to this axis with respect to this axis it can rotate freely it can rotate freely. So, then we have option to balance it is a if see to fix the air gap. So, there are options here one can increase the gap one can decrease the gap ok.

But, here we have fix that that gap this is the gap between these 2 wire. So, now we have to measure the gap between these 2 wire. So, for that basically we have taken light

mirror arrangement. So, 1 mirror is fixed with this levers here it is fixed. So, if it is rotate if we just oscillate you see it is oscillating, you can see it is oscillating right it just it is oscillating right and this mirror also oscillating, because it is fixed with this frame. So, it is also oscillating. So, it is oscillating it is a rotating with respect to this axis and on the yes on the axis itself near the axis it itself, we have mirror fixed with this; so that also oscillating with the same way.