Experimental Physics I
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Lecture – 54
Experiment regarding the magnetic field along the axis of a circular coil

So, we are in second year lab of Department of Physics, IIT, Kharagpur. So, today, we will demonstrates one experiment, basically how to produce magnetic field in laboratory. So, you know this magnetic field, we can get from permanent magnet, this is one option.

Another option is electromagnet. So, if you pass current through a conductor, if conductor is straight or circular or spiral, it gives electromagnetic field, so following the Biot-Savart law right. So, today if in electromagnet basically we use circular coils, so two coils are separated by a distance, and then we use some core between these two coils.

And so there we tell this pole pieces, these two faces of these pole pieces between the two faces of the pole pieces, we get the magnetic field. So, this pole we use these are made of magnetic material. So, it helps to intensify the magnetic field. So, without pole also basically magnetic field is generated from this from the current carrying conductor, current carrying coils ok. Now, to intensify this field, we have other arrangement in electromagnet, so that is the basically electromagnet. So, mainly in laboratory we use electromagnet or producing magnetic field ok.

So, another of a way to produce magnetic field that is basically superconductor using superconductor, so this will tell superconductor magnet, so this is different. But, mainly we use electromagnet in our teaching laboratory, in our research laboratory to produce magnetic field. And what are the components in the electromagnets, so that I will show you many times in other experiment, we will use this electromagnet.

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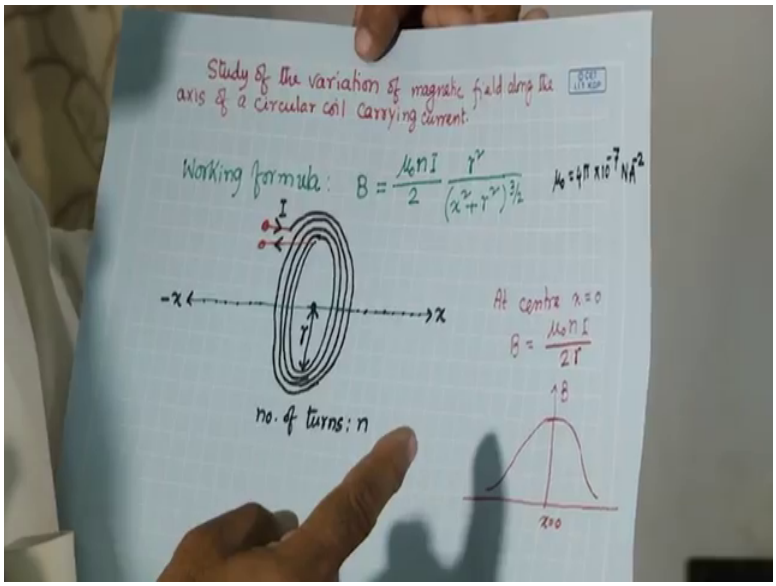

Now, today basically we will study, we will study the variation of magnetic field along the axis of a circular coil carrying current. So, if you have a circular coils, this coils I have say number of terms is n ok. And now if you pass current through it if you pass current through it, so there will be magnetic field. So, magnetic field, so we will measure here we will study, the magnetic field along the axis along the axis of the circular coil along the, this is the axis of the circular coil.

So, along the axis are different say I have put some points on this axis, so at different points what is the magnetic field that we will measure. So, basically we will for a particular current at different point on the axis, what is the magnetic field that we will measure. And then basically, if we look at the working formula as I already I have discussed in earlier class in last class that, this what is the working formula of this experiment.

So, working formula for this experiment is B, magnetic field produced by this coil on the axis at a distance X, coil this radius is r, number of turns is n. Then formula is mu 0 n I by 2 r square divided by x square plus r square to the power 3 by 2 ok. So, mu 0 is permeability basically air permeability. And so this is the formula, and if you plot this formula theoretically, this whatever the relation with the, this x and B, if you plot it, so this it is generally become like this ok. This variation of magnetic field is maximum at the center x equal to 0.

And if you just increase these distance, so it is a decrease, so decrease like this following this formula basically. And since it is x square, so in negative direction also for negative x also, so it will be this curve will be symmetry ok. So, basically in this experiment, we will vary this x, and measure the magnetic field, then we will plot magnetic field versus this x.

And from there we will so we will see these whether experimentally, we have seen this same type of profile or not, because theoretically this profile should be like this. And experimentally, we will see whether it is showing similar profile or not. Secondly, we can find out in principle the radius of this coil you know, this you see from this formula if you put x equal to 0 that means at the center, then B equal to mu 0 n I by 2 r.

So, if from this plot, I can find out the peak, and what is the peak value that is the B value at x equal to 0, so that means from this plot I will get B value. And mu 0 is supplied is known, n number of turns is known, and then current also known for a particular current, we are doing this experiment ok. So, from there we can calculate the radius of the square ok. So, this is the experiment.

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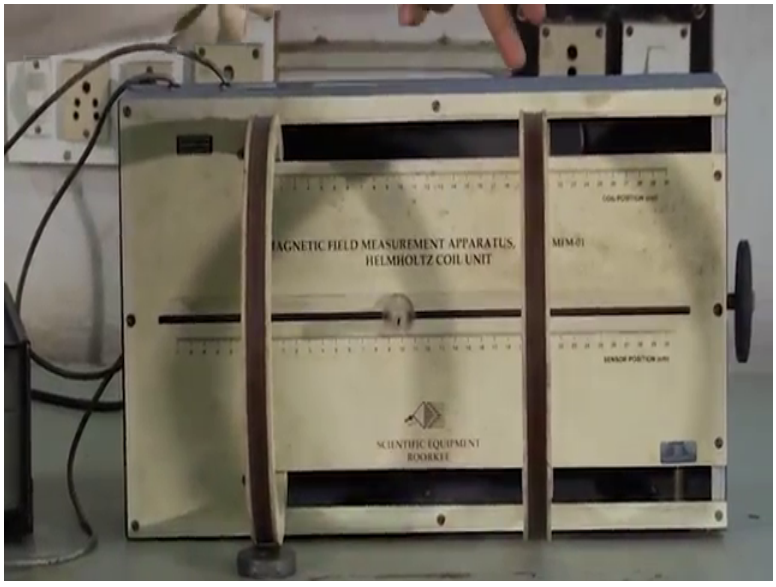

Now, this for this experiment this is the setup very simple setup this is the setup. So, here you can see this is the coil, we tell generally is the is a circular coil is the circular coil. So, basically here two coils are there, here two coils are there two coils are there ok. And this now in this coil, what is there basically here you cannot see, this basically this

number of turns it is in inside of this of this structure. So, you cannot see, but I will show you how to make this type of coil, I will show you.

So, this coil now these two coils are there. And they have arranged in this in these structures in such a way that one coil we have is the fixed with this. And another coil basically, we can move another coil we can move, because as I will tell you this why we need to move, so that I will explain.

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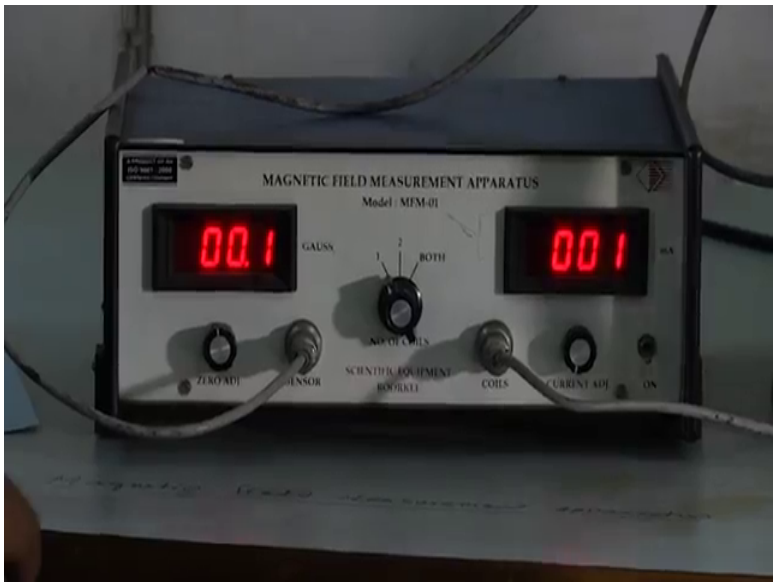

Secondly, we have to basically measure the magnetic field at different distance. So, for measuring the magnetic field at different distance, how we will measure. So, we use the gauss meter ok. So, this is the basically gauss meters here it has basically two part. One is here, you can see the sensor is written sensor ok. And here it is written coils current coils current. So, from this place, we are giving current to the coil we are giving current to the coil ok.

And for a particular current here you can see for a particular current in which coil you are sending current, here you see is written 1, 2 or both that means, if we set 1, you are sending the current in 1 coils coil 1, so say this is the current coil 1. So, you are sending current only in this coil. If you put it here, so means you are sending current to the coil 2. And if you set here, so this is basically you are sending current to both the coils ok, so this is the so that way circuit is made ok.

So, secondly after setting current, now what is the magnetic field at the along the axis of the coil that I have to measure, what this I need magnetic sensor. So, generally we use hall probe. So, later on probably, if not in this experimental physics 1, in experimental physics 2 another, so I will so in solid state physics basically we will demonstrate one experiment on Hall Effect.

So, depending on based on Hall Effect, there is a sensor is called hall sensor or a hall flow, so that sense the, that sense the magnetic field. And some calibration etcetera is there, so that is then as a whole we tell gauss meter. So, this is basically that is the gauss meter. So, this hall probe here this is the sensor, this is the hall probe ok. And this hall probe, we will tell you at this position, what is the magnetic field, and that reading will come here ok.

So, this experiment I will just how to do it, I will tell you. Now, here important is that as I told this inductors, this coil is nothing but basically inductor you know. Resistor, capacitor, inductor, these three elements are very very important; it is used in different form in different places ok. So, here this coil is very important for producing the magnetic field in the laboratory.

And making a coil is not difficult things, routinely we make the coil we make coil in our laboratory. So, our technician of our optics lab mister majumdar, really he is he is very expert in making coil. So, he will he will show you how to make this type of coil, he will show you one small small coil. So, mister majumdar we will tell you about the coil how to make it.

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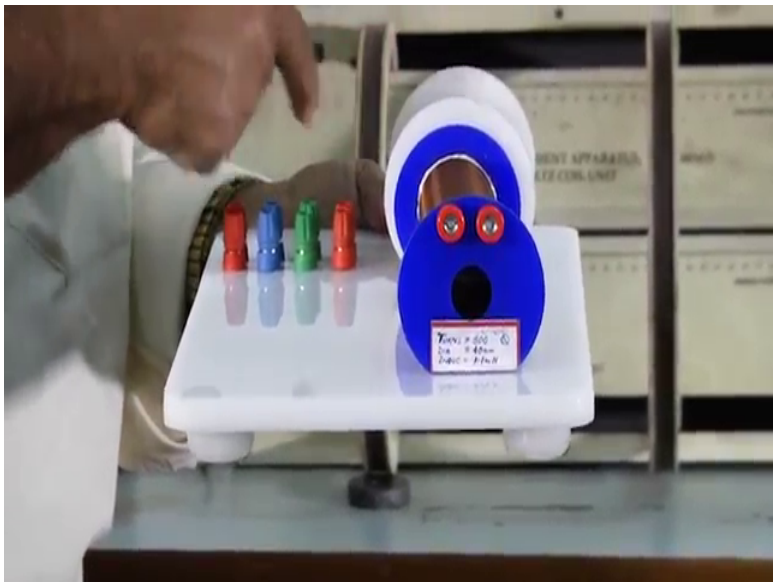

Now, here is a an inductor, it is a basically a PVC pipe. On the PVC pipe, we are winding of insulated enable insulated copper wire. Now, see here I made already 30 to 40 turns, none increasing the number turns. This type of wires are available in market in various gauges. According to the according to your (Refer Time: 11:58). I mean current in the coil current in the circuit you select the gauge of this wire.

Here it is 25 gauge, then again eighty eight 18 gauge, then 15 gauge various types of gauges are available. Then we would not this type of format this coil. Suppose if we own this one, then I shall show you later on. First here it is with 25 gauge, I am winding about 15 to 100 turns I have to complete up to this, then it will develop enough with a magnetic so magnetic force, then with the help of probe, inserting the probe inside, then we can measure the strength field strength like

So, this way you have to continue this

Winding.

Turns winding. And then

This.

Then we have similar type of

Similar type of.

It actually he has made many of them. I think these for various application or requirement in laboratory he has made this. So, these are just for to end up this coil. So, here this for giving power, so this part is there. So, I think, and then he said also here you see this I think he has made just a fixed on this plate. And from this plate, he has taken this connection ok. So, what I want to tell you, this is not very difficult, it is very easy.

Now, our problem is what is inside that we do not know. In inside nothing is there accept this one, this type of coil ok. Now, if I cover it with this you cannot see, then what is inside that is difficult to understand, so that is why this open things I was showing you. So, he will show you this one just yeah. So,

This type of coil.

This type of coil if you want to get, so you have to.

Again we can make a hole here, then this terminal will be will come out from this place, then again one turn, another turn.

Then 100s and 100s of turns, you can own. At this layer, you have to maintain the layer.

You have to maintain the proper layer in gauge, then we this slope we can accommodate 1000 turns of we get this small gauge. But, here.

For this gauge, we can turn 200 turns.

Around 200.

It will carry seven ampere, it is.

It is 18 gauge, it will carry 7 ampere.

Current.

For 7 ampere current, if you.

And in every layer, you give some.

Insulator.

Insulated paper, leather wood paper.

Ok.

And this insulation for a.

So, some insulation.

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All give for each after completing each layer.

Layer.

We put this, what is call this ah

Insulated varnish.

Insulated.

Varnish.

Varnish ok.

Then you can apply a 7 ampere, for 6 ampere, 7 ampere safely without it will not burn, safely you can use this. Apply continuously if for each layer, you have to apply this insulation.

So, this way we produce coil, this coil is used for you know these for electromagnet and in lab for different experiment, we use different different type of coils means its radius, its length etcetera different. You see coil also is very important, this coil produce magnetic field. And also this coil is used to detect magnetic field using we know Faraday law, Lenz law you know ok.

So, Faraday law, Lenz law actually Faraday law, Lenz law if you just to a bend this coil to a near magnetic field, and if it just vary you just move to the in the magnetic field, so then there will be induced emf in this in this coil. And form that induced emf, you can tell how much how much your magnetic field is there. So, you can sense the magnetic

field also. So, this coil is very important that is why I if I call mister Majumdar to show it to show it, so right like this you know here. ah

If you so, here this is the, we are using for producing magnetic field. So, if you put current, so you will get magnetic field. So, now, this another coil if you just bring close to it, and if is either you have to you have to vary the magnetic field apply ac current or you have to or you have to or you have to if it is dc current then you have should have option to vary this, this way this or this way ok. So, this magnetic field link with this coil, we will vary with time and that is what so this there will be induced emf on it, and measuring this induced emf or corresponding current you can correlate with the with the magnetic field of this coil.

So, these are very important for our experiment for our yeah I think in many places these coils are used. So, as I told this, this experiment here today using this coil what you want to measures we want to measure the variation of magnetic field along the axis of a circular coil carrying current ok. So, actually I will very I will vary the position x and corresponding magnetic field I will measure.

So, here you see this coil this position is a at is here scale is there is 0, 0 position ok. And this coil is basically I can move this coil basically I can move this coil you see there is a option to moving, this is fixed this move with (Refer Time: 18:53). Now, initially what I will do, I will take. So, this is the here this is the magnetic field sensors, and this sensor, this is the you see this high it will have taken in such a way, it is exactly on the axis of this on the axis of this coil, both coil actually. So, I can just initially what I have to do, I have to for this experiment I have to take it I have to take it basically at the centre, this magnetic field sensor should be should be I think here I put it at 10. So, here this also I have to put it at 10.

So, now forget this coil, just we are doing experiment using this coil. So, here you see this is the, this magnetic field sensor is at the centre of the coil of this coil ok. Now, I adjust here. Here you see I have to choose this is I think coil 2, this is coil 2 I guess, this is coil 2. This is also I set it at 2 position. And current now it is zero current zero current here. So, now, I will increase current ok. When I am increasing current, you see this magnetic field is you can see magnetic field it is in gauss, it is written gauss ok. So,

current I have given these are in milliamperes, unit is milliampere you see, can you see, milliamperes, it is the milliampere.

So, if I give say maximum probably 200 we can put here, but.

Student: 450.

450. So, so let us put maximum current around 450 around 450, because you have to know the limitation of your instrument you know here it is a four 500 milliampere you can get, but in if we if its limit is 500, we never go up to 500 we keep just slightly less than that. So, this is 450 milliampere current we have set ok. So, you have to note down current I is 450 milliampere ok.

Now, for this current at centre of this coil this x equal to 0 as I showed you that x equal to 0 at x equal to 0 this x is basically distance from the centre x equal to 0. Now, this is the or what is the magnetic field this 13.5 gauss. Now, I will change the position of this. So, both sides so this as a these are positive side x is increasing positive side.

Now, zero to positive side I am going, so I will change this is now 0, 10 is basically now zero position. Now, I will go to other side say 11, at 11, you see what is the reading 13.4, you have to note down for 11 means it is 1 1 centimeter, distance is 1 centimeter. Then I am changing to the 12, you see is the thirteen point thirteen point how much one ok. Then 12, then go 13; then go 13, it is 12.4. Then go thing go.

So, it got stuck anyway. Yes, it is fourteen, it is 11.5. Then 15, I think I have to go to 15, then it is 10.8. So, this way in continue up to say almost towards zero know zero of this magnetic field anyway. So, I am now at 18, then 19. So, for every one centimeter we have to just take a reading we have to take just reading. So, let us say up to let us say up to 21 or 25, so you take the reading ok. Then you go back to again to zero, zero means 10 ok, and take the reading in other side x equal to minus 1, minus 2, minus 3 up to this we have to take reading. So, then this then you have to plot this graph, and then find out the peak value ok. So, this how to analyze the data that I will explain in next class how to how to find out the radius of the of the curve as well as how to calculate the error. So, all things I will discuss in next class ok.

So, these are very nice experiment to demonstrate to verify very basic formula Biot-Savart law from Biot-Savart law this working formula has come. And you know these that in last class I have I have shown you how this working formula has come this is basically verification of Biot-Savart law you know. This also this two coil while two coil we are using. So, this you know this Helmholtz coil a theory of Helmholtz coil is basically this.

Now here what you saw this you have a coil now along the axis if you just move, then it magnetic field varies. But in electromagnet between two coil we use, between two coil we want uniform magnetic field. So, to produce uniform magnetic field what is the condition so that is the basically we tell Helmholtz coil. And you can we can show theoretically that when the distance between these two coil will be equal to the equal or less then the diameter of the one of the coil, two coil should be identical diameter of the coil. So, then you will get uniform magnetic field. So, that I can show you in fact it is not difficult. So, this coil I think it is a around.

Student: Radius.

Ah radius is 10 centimeter. So, let us keep at 10 centimeter. So, it is at 0. So, this one I will keep at 10 centimeter this I will keep at 10 centimeter this yeah, it is at centimeter ok. So, distance between these two coil is now 10 centimeter which is equal to the radius of the one of the coil ok.

Now, here you see magnetic field 13.6 ok, but now I have to pass current in both coil ok. So, here I have to take in this mode ok. Current is now in both coil, current is now both, coil now current somehow decrease. So, I have to I have increase it, yeah, no, no I think this it is a heated something anyway. So, it is a you see at this position it is around nineteen 19.1. Now, I am changing the position this is at the centre of this coil ok.

So, now let us go up to the centre of this upper coil, you see this it is a between 19 to 20 this distance 19 to 20, so it is a between these two coil you see this is a 20. So, almost constant I am varying, it is almost constant you see over this you know when it is coming to the near to the centre, then this is varying, but between these two coil you can see you see over this range, it is constant ok. So, this way this is the, we demonstration of a Helmholtz coil how to produce the uniform magnetic field. And for that these two coil one has to keep at a distance of diameter of not diameter radius of the one of the coil.

So, I think is a nice experiment to learn the theory verification of thereon how to produce magnetic field in the laboratory. So, this simple way input put showed you ok.

So, thank you very much I will discuss in next class about the data analysis and calculation results and the error analysis ok.

Thank you.