Experimental Physics - III
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Lecture - 05
Electro Magnet and Constant Current Power Supply

today I will discuss another basic tools and instruments in laboratory especially in solid state physics laboratory. first instrument I have discussed that is Cathode Ray Oscilloscope. Today second instrument that is Electro Magnet, how to produce magnetic field in laboratory, so that I will discuss today.

generally we use electro magnet in our laboratory for producing magnetic field for different experiment. I think more than 30, 40 percent experiment based on the magnetic field. I will demonstrate them, but that basic instrument for those experiment is electromagnet. you should have clear concept about the electromagnet.

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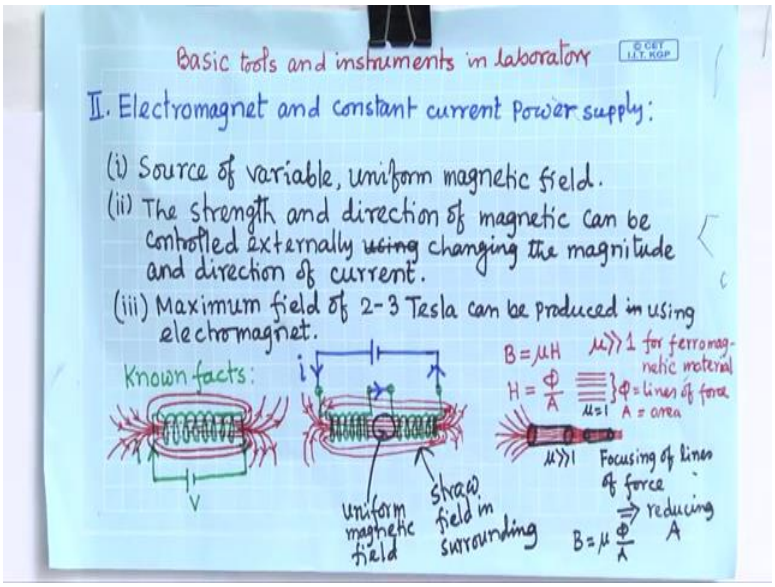

today's topics is Electro Magnet and Constant Current Power Supply, both we need for producing magnetic field. source of variable uniform magnetic field, electromagnet is is source of variable uniform magnetic field.

The strength and direction of magnetic field. here should be field magnetic field can be controlled externally changing the magnitude and direction of current. changing the

current it is magnitude and direction, we can change the strength and direction of the magnetic field using the electromagnet. that is the characteristics of electromagnet.

maximum field of 2 to 3 Tesla can be produced using the electromagnet in laboratory. But more than 3 Tesla is a is possible to produce using the electromagnet, for higher field we use other magnet that is a super conducting magnet basically. I will not discuss about that, but I will discuss about the electromagnet.

now in experimental physics two, there I have demonstrated some experiment using the using the coils. when you will pass current to the coils, then we produce we get the magnetic lines of force that is magnetic field flux per unit area that is the magnetic field.

this is the known fact was that if you have a coil and if current I passes through it then there will be lines of force magnetic lines of force. one end of the coil is n pole and the other one is s pole. magnetic lines of force will produced from this end generally from North end and it entered to the South end ok.

for uniform electromagnetic field to produce the uniform magnetic field, we use another coil, we use two coils here I have shown this is one coil like this and this is another coil ok.

between these two coils. we will get this South North; South North, it depends on the direction of the direction of the current in the coil. If this current is in same direction in both coils then you will get uniform field in the between these two coils, here this I marked with this circle. there we will uniform field.

And other field you see here it will it will always close the lines of force. this it will come from South North to South to close this magnetic lines of force. this part we tell the straw field we tell the straw field in surrounding ok.

electromagnet is based on this concept we take two coils and then this two coils we connect interconnect them each coil have two end; each coil have two ends. this end of this coil is connected directly connected with the other end of the this other end of the second coil ok.

And two other end of this each coil means this one and this other one ok, these are connected to the to the power supply. current will come and pass through it and then in

coil one then goes to the second coil, again it pass through it then it goes back goes back to the power supply ok.

so this is the this in electromagnet this coils are two coils are there. Now, there are other pins also we use in electromagnet, so that is called core. this type of; this type of material is used is a used iron material it is the is mu, mu is the magnetic material this it is a permittivity. It is a permittivity I always confuse with permittivity and permeability.

Anyway, so when this I think this is called permeability and this other one in electric dielectric constant that is called a permittivity whatever I always confuse. mu B induction field B equal to mu H; H is the; H is the field in here phi by a and b is the field in the material mu is the characteristics of that magnetic characteristics of that material.

this core if this material is used as a core, I will show you in the electromagnet to enhance the magnetic field to enhance the magnetic field produced by this coils that is because of it so it becomes mu times. whatever without this core whatever field, if we use core so it will be mu times and this mu is is a value in ferromagnetic it is a huge value, it is a I think sometimes it will be ten thousand times ok.

it be it will depend on the mu of that material. in near mu equal to 1 for other metal is very very greater than 1 so we can enhance the material and other factor you can seen this area. if we can reduce the area of the core. then area smaller area for the same lines of force for same number of lines of force. there is number of lines of force it will depend on the current it will depends on the current.

Now, whatever the lines of the force we will get. there that will be enhanced due to the this new value and further you can enhance these this field reducing. It will it will reduce the this area of the cross sectional area of the pole this is so this is whatever I had discussed here everything is necessary for the electromagnet to enhance the magnetic field and that concept is used to fabricate the electromagnet, so that I will show you in laboratory.

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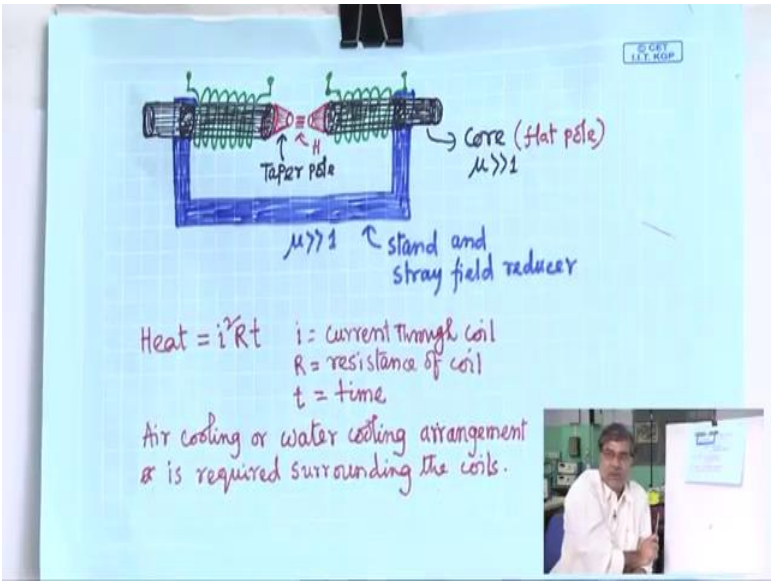

next other fact also as I discussed so here whatever I told here you can see. in laboratory in real electromagnet, so this shape is like this; shape is like this this coil you will not be able to see, but it is a covered with some insulating insulator. but inside that this coils are there now in the coil inside the coils. these core this is a material core of the circular is the is a circular bar kind of pin rod kind of pins of made of iron is there which is pushed inside the coil in both cases.

Now, and then sometimes this pole end the pole, when we tell pole that is it always it is the end of this core this end of this core here just forget the rate part end of this core it can be just flat it can be flat. then we tell flat pole and sometimes we use another piece of piece either separate piece or this we make it just like it is called tapered pole tapped tapered pole ok.

this way we reduce the area in area of the end of the pole. as I told so reducing the area in we can enhance the magnetic field at between these two pole in reality the shape of the magnetic magnet is like this and each part has; each part has significance you know.

here we will get enhanced magnetic field and also we have to hold this coil as well as this poles right, so for that this the base are there. Now, this base generally this electromagnet in reality it is heavy small magnet, but it is heavy due to core as well as this base.

Now, this base could be the wooden one, but this base also is made of made of iron ok, it is made up of same material or of similar material we could; we could make it with wood or light some light material. But we use the magnetic material to make this base. thus it is very heavy; so it is very heavy and so there is a purpose for using this one also magnetic material iron ok.

what is the purpose? As I told each part have some purpose. this part is used to for the purpose. What is the purpose? Purpose is to there is straw field as I show showed you straw filed The field here we want straw field is disturbed to the surrounding we do not want we want to reduce this straw field. But whatever the lines of force here, so that has to go back to the other end of that other end of that second pole second pole ok.

this is the magnetic path this is called the magnetic path, the conductive path this is the conductive path for magnetic lines. conductive path for current ok, so that is metal Current passing through a ear it is the very resistive path current passing through a metal it is the very is a very conductive path ok.

Similarly, for magnetic force of magnetic lines of force it is passing through the air it is resistive path and it can find the magnetic materials. that is conductive path for magnetic lines of force. all straw field so they will prefer to follow this path to close the lines of force. that is why; so that is why we use this one to nullify the straw field in surrounding. here there will not be any straw field in environment this is the purpose; this is the purpose for using this one is magnetic material not non magnetic material like wood or some something else ok.

another problem here why so here I is the I if we apply if we apply higher and higher current, you could apply 100 ampere 200 ampere. But problem is you cannot apply very high current because of heating there is a resistance of the coil so there will be it will generate heating heat will be dissipated ok.

we will try to minimize, we will try to optimize the current and also we will try to cool, sometimes we will try to cool we have to try to cool keep in cool condition cooling condition of this coils. for that also we need arrangement.

two types of arrangement one is the air cooling and other is liquid cooling water cooling in generally in our laboratory teaching laboratory we use the air cooling or just yeah for

that sometimes one can use fan or we do not need to use fan. Just in environment it will dissipate the heat and for bigger magnet where higher field you want.

in laboratory generally we produce we produce this in air cooling this less than 1 Tesla, I think even I think it depends on many factors the gap of the pole etcetera. less than 1 Tesla air cooling is find, but for a for a higher magnetic field. this we have to pass higher current also so water cooling is compulsory ok.

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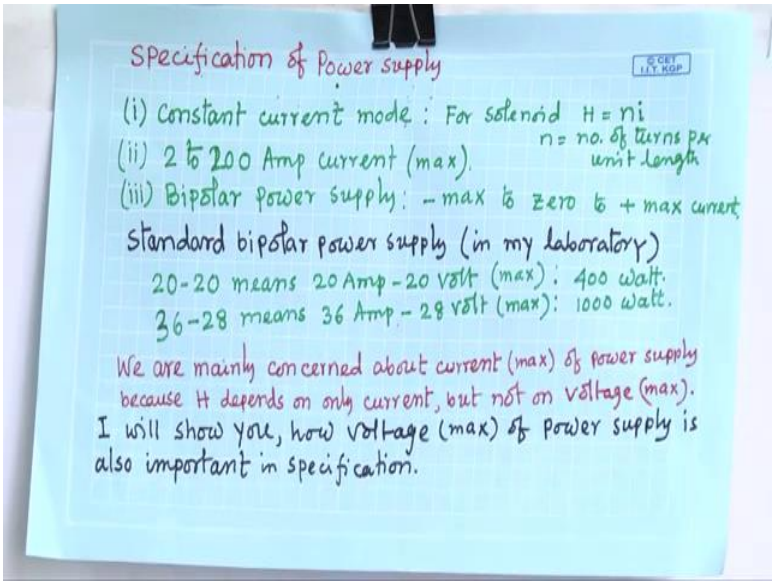

next so we have to we have to supply we have to we have to supply current you know so and that current should remain constant that is very important for electromagnet. If current fluctuate then magnetic field will fluctuate we want very stable magnetic field. that is why it is very important for electromagnet that current has to be constant all the time ok.

we need very good constant power supply, so we should we should we should get very good power supply constant current power supply. we should we should give importance for power supply also. Here let me tell you here why it is important. Say so you have to choose the specification of the power supply. what I am trying to say you think that coil is you can produce you can fabricate ok, core you can fabricate stand you can fabricate and make it uh this you make the arrangement for the you make the arrangement for the for the electromagnet.

Now, power supply you have to; you have to buy a power supply or you have to collect the power supply from the store of the laboratory huh. then what you will do how you will choose the power supply. that is what my aim to tell you.

specifications of power supply. constant current mode this power supply should have the constant current mode constant voltage mode, constant current mode voltage and current both will be there but in our experiment we need current I. we generally specify that power supply should get maximum 10 ampere current 20 ampere current or 5 ampere current that way you can tell you can choose.

But this so generally this current power supply whatever available in reality in market, so that is 2 to 200 ampere current maximum we can get and that power supply should be bipolar power supply. Means for changing the current for changing the direction of the magnetic field we have to change the direction of the current ok.

Changing the direction of the current we change the direction of the magnetic field. we prefer; we prefer bipolar power supply, means minus negative maximum ampere current to 0 to plus maximum current we can; we can vary from the power supply. if so then it is called bipolar power supply, otherwise what you have to do there are bi unipolar power supply means zero to some maximum current you will get ok.

to change the direction of the current, so you have to change the polarity in the connection you just change the polarity, then it will be 0 to negative minus maximum current but that is inconvenient, manually you have to put all into some relay people use. but there will be breaking at that point, but another.

bipolar power supply means it is a smooth variation from positive to negative. then we tell it is a bipolar, otherwise from unipolar you can that you can use as a bipolar. But there it need to use relay to switch just switching the direction of the current. there in connection using the relay you are changing the polarity of this of the two connection ok.

So that way also people do, but it is a it is not it is not smoothly variable. in our teaching laboratory generally because, bipolar power supply for smooth change from negative to positive or positive to negative is very costly. in our teaching laboratory generally we use this unipolar power supply, but for changing the direction of the current we just change the polarity in the connection ok.

standard power supply in our laboratory in my in my research laboratory generally it is the is the specification is like this you know 20-20 or 36-28. this type of specification of this power supply. 20-20 means from this power supply maximum 20 and ampere and 20 volt you can get you can apply ok.

that is why there are 400 watt power supply or 1000 watt power supply uh. so that here, so here mentioned as 36-28 means 36 ampere 28 volt. from this power supply 1000 watt power supply you can get 36 ampere and 28 volt maximum. 28 volt you can apply and you can get maximum 36 ampere.

this type of specification we see and we buy. what is the importance of this volt part? I should get 36 I should get 20 ampere ah, so that is enough for me because I need only current. why I should I, should I now question is should I bother about the this voltage, should I ask for no not 20 volt I need 20 ampere 50 volts ok.

Yes you can get but cost will be higher so and this cost will be lower why should I bother about this? that I have to bother that I will I will discuss. we are mainly concerned about current maximum current of the power supply, because h depends on only current, but not on voltage maximum voltage that is true. But I will show you how voltage of power supply is also important in specification that I will show you or tell you ok.

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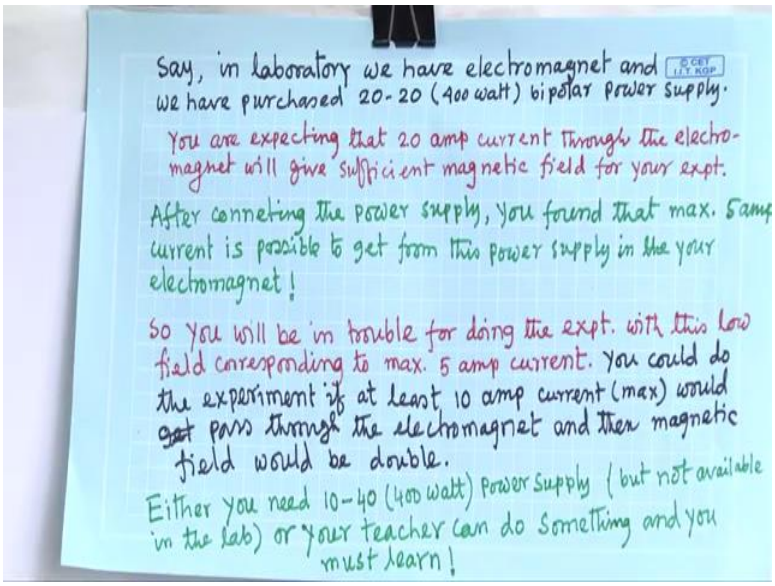

now you see say in laboratory we have electromagnet and we have purchased 20-20 means 400 watt bipolar power supply. you are expecting that 20 ampere current through the electromagnet will give sufficient magnetic field for your experiment; for your experiment. after connecting the power supply you found that maximum 5 ampere current is possible to get from the power supply in your electromagnet If this is the situation then what you will think that company has given the specification 20 ampere, but I am getting only 5 ampere current using the um. more than that I am not able to get.

you will be troubled for doing the experiment because you need 20 ampere current and corresponding magnetic field the using the current you have calculated It will give the that much field magnetic field and you can do the experiment. But practically you are seeing that this you are able to give get give or apply 5 ampere current of using their power supply.

you will be in trouble for doing the experiment with this low field corresponding to maximum 5 ampere current. Now, you could do the experiment if at least 10 ampere. you could do the experiment at least if you could apply the 10 ampere current through the electromagnet and corresponding whatever field you will get that will be the double of compared to the previous one corresponding this 5 ampere current. you could do the experiment now whether is it possible to do the experiment using this power supply or you have to search for power supply which will give you more current.

Now, more watt that power supply cost will be higher and the higher means it is the really higher, it is cost is very high with the watt if higher watt, then higher power lower watt lower power. that is the restriction otherwise you could you could use power supply for higher watt. But in this case I saw that this 400 watt power supply 20 volt 20 ampere for my electromagnet it is giving 5 ampere current. But at least I need 20 ampere current and corresponding field for doing the experiment.

Now, whether something can be done, so that we can get the 10 ampere current in passing through the coil in each coil and done the experiment that is when I will explain or you will think, in that case how this voltage importance that can be realized ok.

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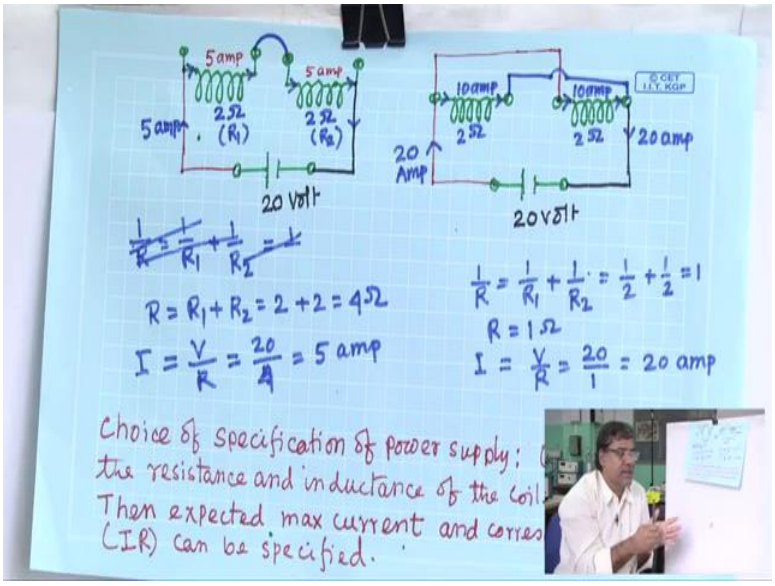

let me tell you; let you let me tell you. So electromagnet two coils are there, say each coil have resistance say it is a 2 ohm resistance each coil have same resistance say 2 ohm resistance. So now, you have 20 volt power supply. if these two are in series generally we keep in series the total resistance will be 4 ohm.

due to this 20 volt this maximum current passing through this resistance is 5 ampere ok, so why 5 ampere that is because of your coil resistance. depending on the coil resistance you have to mention to the company that I need this I need the higher voltage 20 ampere but higher voltage I need, because for getting the 20 ampere I need here it is a four this that means 80 volt. If your power supply is 20 ampere 80 volt that specification, then you will get using the power supply you will get in this electromagnet is 20 ampere. Otherwise you will have a for forty volt 20 ampere 40 volt, so it you it will give you 10 ampere current ok.

anyway for this 20-20 power supply you will get 5 ampere. Now you have to apply some tricks for getting the higher current, here you see if I connect this these two coil in parallel, then what will be the resistance of this total resistance of this two coils. this will be 1 ohm R will be 1 ohm.

now I equal to V by R so that is a 20 ampere. you can get current 20 ampere in this circuit, but now seems these two are in parallel. these two 20 ampere will be divided into two parts, since resistance are same. 10 ampere passing through this coil and 10 ampere

will pass through this coil and again come back and then this 20 and their current will be closed ok.

this connection changing the connection you can increase the current in the coils. if current is the double, then obviously it will it will it will give you double magnetic field. But one has to be careful when you are doing this connection series or parallel you have to be careful that the current in both coil has to be in same direction, then only you will get magnetic field between these two coil. magnetic field will be added from this coil and this coil And if you just connection is opposite current is flowing in anti clockwise direction in this coil and current is flowing clockwise in other coil.

then we will see that there will not be any magnetic field in the gap. The reason is that this it is the North pole phase South pole North pole, then South pole North pole. North to South lines of forces generally as I told come out from the North Pole and enter in to South.

now opposite direction if so happens, so South Pole North Pole then it will be current direction just opposite it will be North South North; North there will be repulsion means lines of force will not go there, lines of force it will just this way it will closed there will not be any magnetic field there ok.

this generally we do not bother about this one much because company just supplied the electromagnet and the everything is connected sometimes internally sometimes externally. we do not bother them just we just apply the current and get the magnetic field.

But I think today I tried to tell you this what is there and how we are producing the magnetic field and how why those different components are used for each component in this electromagnet it has meaning it has significance, so that is what I tried to tell you ok.

I think I will next I will demonstrate the electromagnet in the laboratory and also later on again I will discuss about the how to measure the magnetic field. Here in this class I am I just discussed how to produce the magnetic field ok.

Thank you.