Experimental Physics - III
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Lecture - 08
Gaussmeter/ Teslameter

in last class I was discussing about the one of the basic instrument in solid physics lab that is electromagnet. today in this class I will discuss about the about how to measure the magnetic field. electromagnet is used for producing magnetic field in laboratory. Now, how to measure to that magnetic field that I will discuss here.

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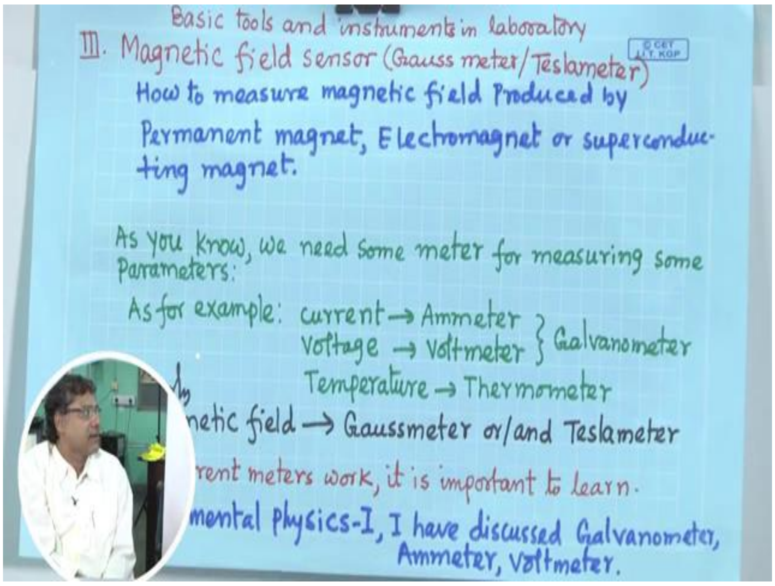

magnetic field sensor that is we tell Gaussmeter or Teslameter is used to measure the magnetic field produced by the permanent magnet or electromagnet or super conducting magnet. we know that for measuring current we use an ammeter, for measuring voltage we will use voltmeter. that is galvanometer.

And for and for measuring temperature we use thermocouple, thermometer ok; thermocouple is one of the thermometer. similarly for measuring magnetic field what is the what we use; that is called the Gaussmeter or and Teslameter this is this difference between this Gaussmeter and Teslameter is basically; you know this 1 Tesla equal to 10 to the power 4 Gauss ok.

1 Tesla equal to 10000, Gauss, 1 Tesla equal to 1000 millitesla. 1000 millitesla equal to 10000 Gauss, 1 millitesla equal to 10 Gauss 1 Gauss is a very small field then Tesla is a very high filed. when we measure the magnetic field sensor which is which is made for the for measuring the higher field that is that we tell the Teslameter. And sensor which we use for the smaller ranger of field that we tell the Gauss.

both are same, but it's the sensitivity wise one sensor it cannot be sensitive in the lower range or in very high range. that is why for different range this different sensor, same sensor but in different way they are fabricated. that is why this both Gaussmeter and Teslameter both are same, work on same principle, but only range wise it's this two different name

in experimental physics I I have discussed about galvanometer and ammeter voltmeter and the way I have discussed that I wanted to tell you that this the instrument, this basic tools are very simple, is they are based on very simple principle It is not difficult to understand, but one has to try to understand.

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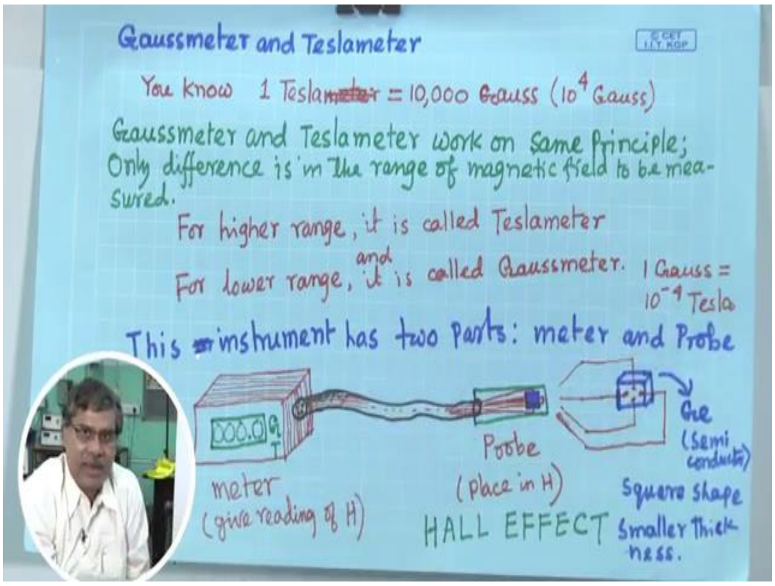

Gaussmeter and Teslameter is another important sensor for the laboratory. as I told that what is the difference between Teslameter and Gaussmeter. this instrument has two parts; this meter and probe. Teslameter or Gaussmeter it has two parts this instrument has two parts: one is called probe another is meter.

Meter you know voltmeter in the where scale will be there, where scale will be there scaling meter we use in the sense scaling. And probe which is sensor which will sense the which will sense some parameter like magnetic field or temperature or humidity which can sense them then this as we tell the sensor. here probe also whatever probe we are telling that is sensor Here magnetic field sensor, that we are telling probe why it is called probe you will understand ok.

this as I mentioned that meter and probe: meter means as I told is this this, there is a scale you can take the reading. And probe; probe means you want to probe you want to send something somewhere, there you can put it that is why it's called probe locate with; probe means in its a localized localizing point these are. probe this is probe and this is meter this two; this probe is connected with this meter. probe will sense some parameter and that meter will give reading of that one ok.

that is all. this probe this probe is called is based on the is based on the Hall effect. all of us we know the what is Hall effect, I have talked this one Hall effect in solid state physics NPTEL course Solid State Physics. this probe is nothing but the Hall probe, we tell Hall probe. it depends on the Hall it is based on the Hall effect what is Hall effect? You know that, but still let me tell you once more.

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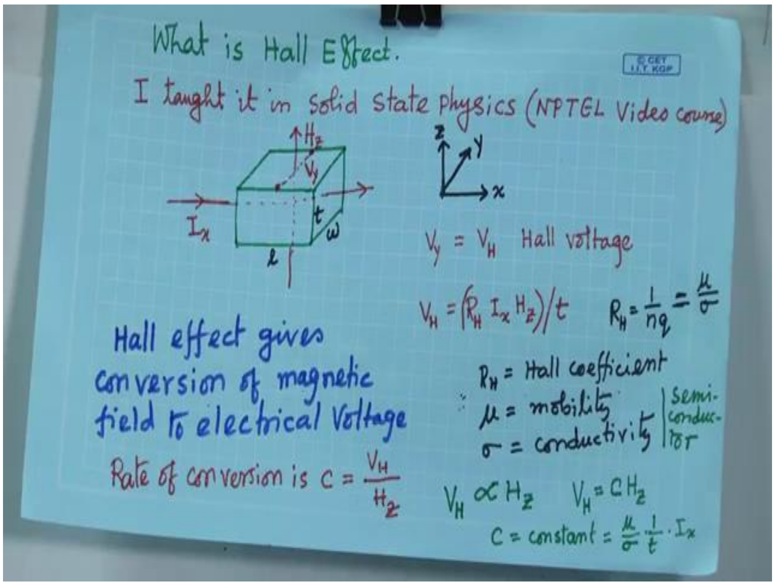

what is a Hall effect? Hall effect it will have a sample say rectangular shape sample. See, in one direction say z direction current constant current I x is going through the sample.

And if we apply magnetic field say along z direction; along z direction say this is the along the thickness of the sample, if this x direction is the length of the sample then along z direction it says its thickest of the sample.

If you if magnetic field is applying along the z direction, then along the y along the y direction along the y direction means along the width; if you along the width there will be its a there will be voltage. voltage developed along the width if you measure voltage along the width along the y direction you will find that you will get some voltage and that voltage is called the Hall voltage, and this is called the Hall effect ok.

a current flowing through the sample along the x direction, then if you apply magnetic field along the z direction. there will be; there will be voltage developed along the y direction that voltage is called a Hall voltage. And this Hall voltage if you; this derivation is very simple I am not going to do that.

this Hall voltage this Hall voltage along the y direction how whatever voltage is developed that is Hall voltage V H. That Hall voltage expression is here I have written R H I x H z by t It will be the very simple derivation you can derive it, I have derived in solid state physics NPTEL course solid state physics, it was running this last semester Again it will run this solid state physics is next autumn semester in 2020.

this; here R H is called Hall coefficient, I x is the current constant current along the x axis along the length, H z is applied magnetic field along the z direction and divided by t that is the thickness of the sample. along the y along the z what is the dimension of the sample that is say thickness t.

And Hall coefficient what is Hall coefficient R H; is it 1 by nq what is or you can write for electron if carrier is electron then it is (Refer Time: 11:23), the carrier is whole then it is (Refer Time: 11:25). Hall coefficient is 1 by any or it is mu by sigma; mu is mobility and sigma in the conductivity. R H equal to mu by H ok.

here we know that, from this expression we know that Hall voltage it depends on; it depends on the sample conductivity and sample mobility. It depends on the current how much current we are applying or how much current is passing through the sample. And it depends on the magnetic field Alit depends on the thickness of the sample.

we are not interested about the current because and you cannot apply any high current then sample will be hot. you have to; you have to optimize the current and we can keep it constant. And when we will choose a particular sample of a particular material then R H also constant because it depends on the material mobility and conductivity.

it depends; this also for a particular sample its concerned. for a particular sample R H constant and t thickness of the sample is constant. I cannot I will not use I would not like to (Refer Time: 13:12) I a x I will optimize it to; because higher current it will give troubles because of hitting of the sample. I H I will keep some optimum value.

Now H z, if H is higher there is no difficulties all other things will remain constant when remain constant then Hall voltage will be proportional to the magnetic field. if magnetic field increases Hall voltage will increase. it depends linearly, Hall voltage is proportional to the magnetic field I can write this Hall voltage proportional to the magnetic field ok, then proportionality constant V H Hall voltage equal to C H z right.

C is a constant and in this case C is mu by sigma 1 by t into I x for any z if you want to design a device it is important to note that; you have to see that how we can how we can make sensitive, how we can make the sensor or the device sensitive to the measuring parameter Means, what is the sensitivity? Means, for small change of that parameter sensors that corresponding electrical signal in the sensor should change more

What does it mean? I am telling in this case if I change slight magnetic field slightly then Hall voltage should change sufficiently then that means, then we will tell that this is sensitive this device will be sensitive how we can make it sensitive?' if C is large if C is large then V H by V H by H z means Hall voltage divided by magnetic field ok, that is C.

C is change of Hall voltage rate of change of Hall voltage will be the expected magnetic field. For even if we change the magnetic field how much Hall voltage is changed If this change is more, C will be more. for that C has to be higher. higher the C better the sensor ok, sensor will be more sensitive

now we have to think that, if I want to fabricate you want to design a device here now task is we have chosen all parameters in such a way C has to be we have C has to be maximized. here I x as I told we will take optimize one at higher end, because there is a limitation to take to increase the I x. I will take optimized value I x. Now this t is in my hand, when I am fabricating then it is in my hand.

When this instrument is in my lab it is not in my hand it is made by the company, but how companies made how. what is they have to consider that I am discussing. C will be higher C will be higher if thickness is lower ok; if t is low because it is in its a 1 by t ok.

this sample I have to if I take this is the rectangular shape and this thickness is very small compared to length and width then C will be higher. And also I can what I can do here I have to choose the sample material of the sample plus that is mobility higher and conductivity lower ok; is the conductivity lower mobility higher.

metal, if you take metal then metals conductivity is higher. conductivity is higher. it will not be suitable. comparatively semiconductor will be suitable. You see semiconductor this conductivity smaller and mobility is higher. Again, there are different semiconductor you have choose the semiconductor in such a way its conductivity will be lower and mobility should be higher, ok.

generally, we in our lab whatever is that the germanium semiconductor is taken. from here, metal why company do not choose the metal for this Hall sensor they choose the semiconductor, because the reason is these. if you take semiconductor then C will be higher. if now; this to maximize the C one has to take semiconductor as a probe sensor and it has to be its thickness has to be very small compared to the other dimension

based on this principle this Hall volt Hall probe is made. what is there? I have to take a semiconductor; a piece of semiconductor with thickness of that one has to be very it very small and then I need arrangement this 2 probe for the for current passing through the that sample along the length, and I need another 2 probe for measuring the voltage Hall voltage along the y direction along the width and third condition is, this sample I have to put in the magnetic field in such a way that the field has to be in along the z direction along the thickness ok.

this sample in magnetic field I have to put in transverse mode you know that magnetic field will be perpendicular on the sample; along the z direction along the thickness. magnetic field has to be along the thickness. this is the condition to fulfill the; fulfill the Hall effect and corresponding will.

depending on the voltage depending on the volt depending on the magnetic field voltage will be generated. Hall voltage is proportional to the magnetic field; C is the proportionality constant this proportionality constant it is one can know from the parameter as I mentioned here from the parameter or one has to yes. here remember this I x that has to be kept constant because C is constant ok, that arrangement has to what has to be made

these are the condition for fabricating the Hall probe, Now, as I mentioned that when I will put, this sensor is what is going this probe or sensor what it is whether I will put in magnetic field. the sensor is producing the voltage corresponding to the magnetic field; now that voltage.

it is magnetic field is converted into electrical signal, now that electrical signal in terms of voltage, that electrical signal I can measure using the voltmeter right; using the voltmeter I can measure and that voltage is proportional to the magnetic field, proportionally constant C one has to calibrating with known magnetic field one has to one have to has to find this constant calibration constant C.

Now in the meter, in the meter that probe is connected with the meter in that meter there should be provision for applying constant current in the sample to the 2 electrode; to the 2 2 electrode as I told 2 probes and 2 2 will be and 2 will be 2 electrodes will be of probe will be used for the measuring the voltage Hall voltage

in this meter for there should be there will be provision for applying the applying the constant current along the length and there will be voltmeter there. it will, it is connected with the along the width to other 2 probe and it will reach the voltage. Now there will be there the electric electronic circuit for multiplication. C constant will be given there ok.

with voltage C will be multiplied no; yes, no with voltage this C will be divided with this voltage division, because H z will be V H by C. this voltmeter what about the reading that will be divided by the that calibration constant C and then whatever result is will come that is the magnetic field: H z. that reading will be shown in the meter that reading will be shown ok

in meter, that arrangement is there applying for constant current measuring, or reading the voltage, that voltage in converted into the magnetic field, multiply with the or divided by the constant C. That constant C is given by the company or given by who is given by the manufacturer; if I manufacture I have to give the constant value that I have to find out from the calibration with known magnetic field, ok.

now meter here two part: meter and the probe. it is clear. I think meter that is a box there, there is a provision for applying current and measuring the Hall voltage. And also electronic electronically, this that Hall voltage will be divided by the calibration constant there is a given calibration constant is depending on the sample as I told, then that is giving me field electric field ok; sorry magnetic field and that reading will be displayed by the by that meter, ok.

this is the Hall Gaussmeter or Teslameter and that is used to measure the magnetic field. And I have shown you in last class that I was using this Hall probe to just to measure the magnetic field, and I told I will explain about it. this is the theoretical part of this meter. Next class I will demonstrate the Gaussmeter in laboratory, ok.

Thank you.