Experimental Physics - III
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Lecture - 23
Susceptibility of paramagnetic substance by Gouy's method

I will use another method for measuring the Susceptibility of diamagnetic or Paramagnetic material. In this method, we have to use, solid sample; just unlike this Quinck's methods. In Quinck's method, we use the solution liquid sample; whereas, in Gouy's method, we use the solid sample, ok.

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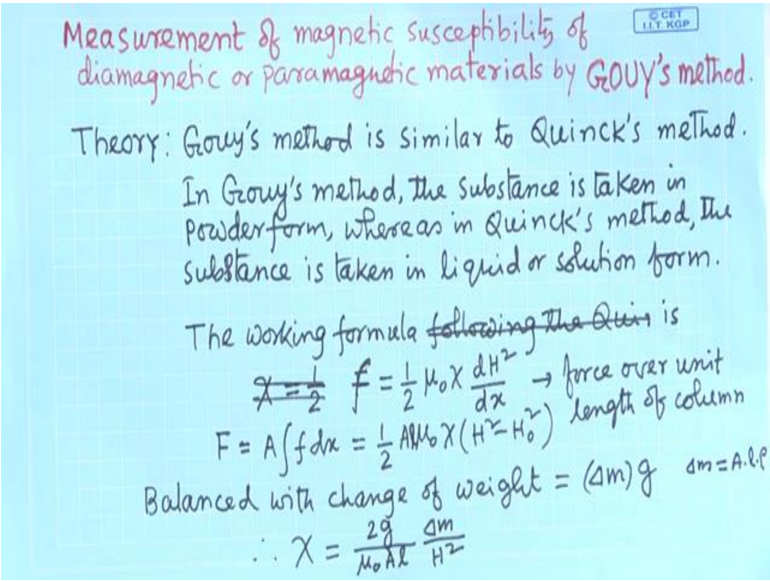

experiment are quite similar, only this force measurement are different; so measurement of magnetic susceptibility of diamagnetic or paramagnetic materials by Gouy's method, Gouy's method is similar to Quinck's method, as already I have, I have demonstrated this Quinck's method in laboratory. This we have measure, we have prepared the solution of manganese sulphate and using the solution how that experiment is done; they are height change of the liquid was the measurement parameter as a function of magnetic field.

That in this case, in Gouy's method the substance is taken in a powder form or solid form, it can be powdered form or this it can be solid rod also ok; whereas in Quinck's method, the substance is taken in liquid or solution form. This is the; this is the basic difference, but they are working formula, working formula this theory is same for same starting theory; but final form is slightly different. They are because in Quinck's method we are measuring the height change of the liquid and in this method, we will measure the weight change of the sample; we will measure the weight change of the sample, apparent weight change of the sample using the balance.

The working formula is f, here I have written small f, earlier in that case capital F I wrote. small f I have written, so that is half mu 0 chi d H 2 by d x. this is energy density I told, but this also one can tell force over unit length, over unit length, ok; force over unit length of column, column view, what is called column is either is sample in rod shape or powered sample put in a tube, so it will form a column, ok.

Why we need column from a tube kind of things? Because this condition is, we have to use the in homogenous magnetic field. some part of the sample has to be outside of the field magnetic field, then only we can use this we can use; we can think of this the variation of the magnetic field, ok.

so now, if it is if we tell this force over per unit length of the column; so now, if you have this, if you have this column, the sample having the length say l length l and this area, cross sectional area is A. now, the force; the force we can tell f per unit length, now that d x for d x length what is the force that may be the force. Now, with that if I multiply these with A, then it will be volume; A into an into d x it will be volume. If you integrate over this length where the magnetic field variation is there, so you will get this part, ok, you will get this part.

field from varying from the 0 H 0 to H over the over the, that length some say 0 to l, 0 to l length of the sample; so you will get this, f equal to this. this one can tell this as if this is the total force acting on the acting over the volume of the sample, over the volume of the sample now this force, because of this force the sample weight; so force, this weight of the sample how it come, because of the gravitational force you know, weight we get of the sample the gravitation m g. g, so that force is downwards, so weight and this force is equivalent.

now if some force is acting on these, so it will feel that, it is a it is weight will be; weight will be it is so lighter; it will feel lighter,. That is what it will have an if it is paramagnetic material; so force say it will be upwards; in diamagnetic material this force will be downwards, what will happen? this apparent weight of the sample will change, will change due to the force this force, or magnetic force. This magnetic force, so I can measure I can measure this magnetic force using the balance; using the balance; so initially whatever the weight now, this weight will change due to this force.

Now, to get back this original position ok, what is the weight I have to put in the balance so that; from there so that extra weight I am putting to get the initial position of the balance before applying magnetic field; so how much mass I have to put. That is if it is that Del m. Del mg, so that will be the weight change of the sample; weight change of the sample

In addition, this Del m as I told this, this A into l, so that will be the volume of this volume of the sample, and into rho density of the sample. that is delta m. balance with change of weight, so that will be, that is del m g is change of the mass and corresponding that change of the mass, so that mass, that change of the mass of what, change of the mass of what; apparent change of the mass of the that sample due to that force, ok.

So that that we have to take from these our sample, in terms of our sample dimension and this is density, here chi you are getting; chi equal to. this will be balance by this, this will be balance by this, from that chi equal to you will get 2 g; 2 g, 2 g del m by mu 0 A l H square. A part you can see these are all constant; these are constant that dimension of the sample,

If I can measure the change of the mass, apparent change of the mass of the sample as a function of magnetic field, so we will plot del m versus square of the magnetic field. Then from the slope of that curve; from the slope of that curve we will get this will be the slope, this will be the slope; so these will be equal to the this will be sorry, from the slope of the curve we will get chi into chi into, chi into mu 0 A l by 2 g.

This is the constant. chi by this constant will be the slope, that slope will get from the del m versus square of the magnetic field graph; so that from there, we can find out this chi, this susceptibility of the material. This Gouy’s method and Quinck’s method; see in both, in both method, we are measuring the susceptibility of the diamagnetic or paramagnetic material.

This in sample form is in is different. in Quinck's method it is a liquid form of the sample and in Gouy's method it has to be solid form and columnar form ok; either rod form or the powder in a tube. Because the sample in both techniques, so it has to be in length wise, this sample should have the length either in liquid column or the solid column; reason is that, there should be variation of the magnetic field over the; over the space.

So; that means, the in homogenous; in homogenous magnetic field, sample has to be in homogenous magnetic field; so that is the reason that the sample shape either in either liquid or solid it has to be in column form or tube form, And then in one method we are measuring the height change of the liquid and another method we are we will measure the mass change, apparent weight change of the sample over the magnetic field. In addition, plotting the plotting the graph with height or change of mass versus the square of the magnetic field, and from slope one can find out the susceptibility.

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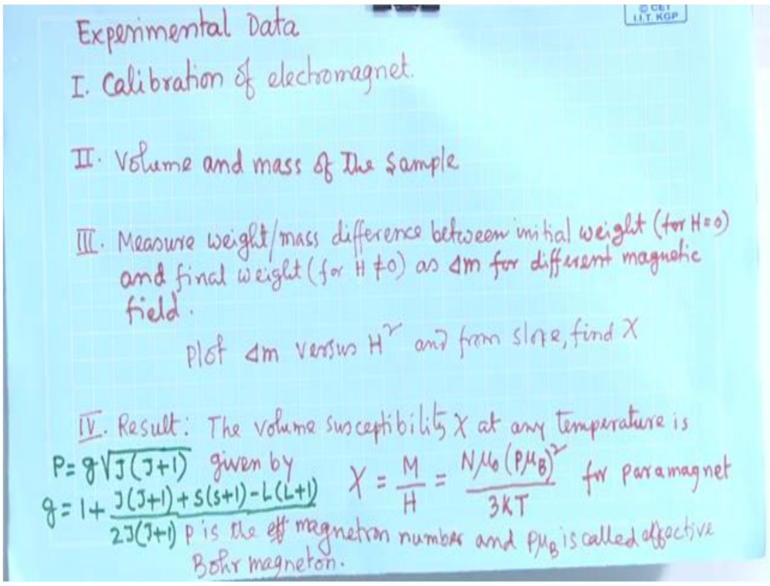

This for Gouy's method; so in Gouy's method, as I described these working formula, so we will take the, then we have to take the experimental data. in this experiment we did again magnetic field, so we will use electromagnet; whenever we will use electromagnet, we have to calibrate the magnet, this magnetic field versus coil current. first one has to do calibration of the electromagnet.

Then second we have seen that, we need the A l; means area and the length of the samples. volume of the sample and mass of the sample that you have; you have to measure or it has to be supplied, it has to be supplied; it has to be supplied by the lab. volume and mass of the sample that we need and then next this main part of this experiment measure weight or mass difference between initial weight for H equal to 0, When there is no magnetic field what is the weight and then final weight in presence of magnetic field that that is basically; that will be del m, del m for different magnetic field.

We will measure del m for change of mass, change of apparent mass; this not the real change, because this change looks because of the; because of the force coming from the magnetic sample in presence of in homogenous magnetic field. We have to take data just changing the magnetic field and measuring the del m. then we will plot del m versus H square, magnetic fields square and from the slope, we will find out chi.

Now, here in our laboratory we will use aluminum rod; aluminum rod for this experiment that is the, that is paramagnetic, paramagnetic material. from the after measuring this chi experimentally; then we can use this formula, this is the very well known formula, this chi that is M by H that is equal to N mu 0 P mu B whole square divide by 3 K T, ok.

K of course, Boltzmann constant that is known, mu 0 is this permeability of in vacuum. that is also known, known and N, this N, this N is; what is this N? N is Avogadro number, this N is Avogadro number that is also known, N is Avogadro number that is also known. Now. Here actually this is mu square, magnetic moment square; mu square.

that we have written P mu B square, mu B is the Bohr Magneton and P is called the, P is called the Magneton number and P mu B is called the effective Bohr Magneton, if I know this chi and this other Avogadro number, mu 0 other things is known, mu B also known Bohr Magneton; so then we can find out this P for this material P, P that is the Bohr that is the Magneton number, ok.

In addition, one can; one can compare with the theoretical value of P; so theoretical value of P one can; one can find out. using the this for aluminum what is the, what will be the magnetic moment, what will be the magnetic moment theoretically, so that one can find out. this P is theoretically, P is equal to g square root of J J plus 1 and g is (Refer

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For aluminum; for aluminum atom what is the; what is the L value total L, what is the S value and what is the J value? if you know then, you can calculate g. Now, from this, using this one g into this J J plus 1 square root of J J plus 1, so this theoretically you can tell what, what should be the P.

Now this P you can compare with your experimental value getting from measurement of this chi, so you can compare this experimental value with the theory value. If any discrepancy is there; so why this discrepancy is coming one can explain. Or if it is; if it is matching well with this theoretical value, then its fine, this experiment we will demonstrate in our laboratory. After this discussion, now I think in next we are going to demonstrate this in our laboratory.

I will demonstrate this Gouy's method for measuring the susceptibility of solid paramagnetic materials.

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In our laboratory we will take the aluminum, so this is the; this is the aluminum bar kind of things, this is our sample aluminum, it is made up of aluminum, is the it shows the paramagnetic property. this sample now in Gouy's method; so we will put; we will put this end at the center of the full pieces of electromagnet. this end will have the maximum magnetic field and this other end other side, it is outside of the magnetic field. this rod, aluminum rod or bar it will see the variation of the magnetic field along the length.

that is the condition in homogenous field; condition of in homogenous field for this experiment. And because of that it will feel force either downwards or upwards; thus the weight, apparent weight or mass of this, this sample will decrease or increase due to the force and that force because of in homogenous magnetic field. What I need? I need to apply the magnetic field and then for that magnetic field, there will be force acting on this sample.

Now, how much; how much equivalent mass changes; how much equivalent mass, equivalent mass of the force changes for a rod that we have to measure. In this method, balance is used, very sensitive balance it is in milligram sensitivity balance we need for this experiment and if it is if this set up is in a closure, so that no air should pass through it, and then it is better.

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Here this is the experimental set up for Gouy’s method ok; as I told we need electromagnet.

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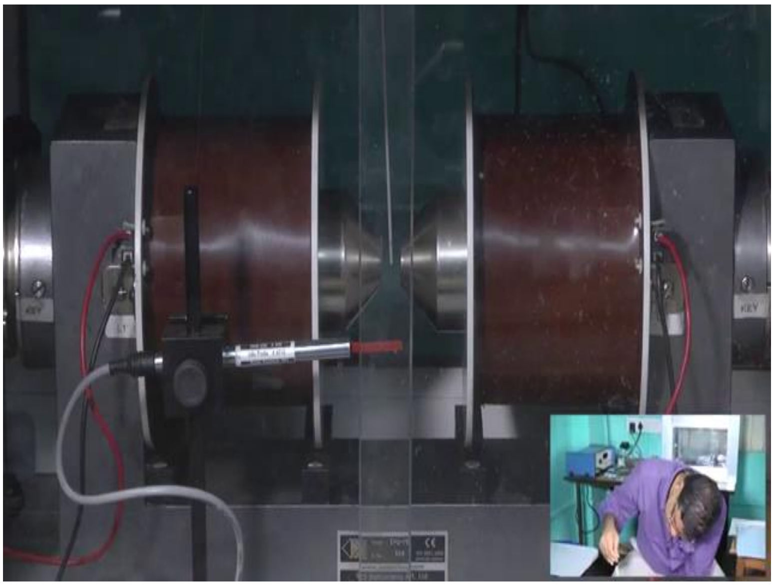

here you see this electromagnet and this, this rod is hanged from this balance, this is the digital balance, so from the bottom of this balance, this aluminum bar is hanged between the; you see this between the pole pieces, this here we have used tapered pole ok, so that field will be maximum at the center and then there will be; there will be if larger variation of the field along the; along the length of this rod. This end is between the pole pieces, you can see there between the pole pieces of the electromagnet and other end is attached with the balance.

This; this set up is very compact system, readymade system. what we have to do? We have to as I have shown you the formula chi equal to some constant parameters, where this dimension of the rod, this cause, this width, thickness and the length of the rod should be known, and density of this aluminum metal should be known, g value is known to us, one has to measure; this also here this the 10 millimeter, this width is 10 millimeter thickness is around 2 millimeter and length is 20 millimeter, 20 centimeter and it is a density of this aluminum, so from one can get from this from the literature, ok.

This we know so these parameters for this sample or we can measure and note down. Now, we have to hang from this balance, so this already there, because I cannot disturb that one; if you disturb, then it will make it, to be stable it takes time, this is the same sample we have put there.

Now, what we have to do? The we have to initially we have to take the reading of this rod. We have to note down that the initial reading and then that initial reading in mass. Now, I will apply magnetic field, I will apply different magnetic field and each magnetic field what is the reading of the balance, difference of this two reading; difference of this two reading will give me the del m, del m whatever we have seen in formula.

Your magnetic field versus del m or del m versus magnetic field that read that data I would get. in this balance here this facility is there. I can; I can initialize the initial mass as a 0, then what will happen? I need del m, so change of the mass, now, I will apply magnetic field, it is whatever the reading, so that is the directly I will get change of the mass del m. I will note down the as a del m, this whatever the reading I will see in this balance, ok.

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Now you see this, this reading is, here you can see a reading balance it is initialized this the; you can see a balance it is 0 reading 0.0000 gram. what does it mean? It means that, this I will get reading up to 4 digit; after decimal up to 4 digit means, it is a 0.1 milligram; 0.1 milligram is the least count of this balance, ok.

Now do you field is here you can see these electromagnet. I have Gouy's meter also there; hall probe and Gouy's meter here I have before starting experiment one should calibrate, this electromagnet ok; this current versus the magnetic field from this Gouy's meter, that calibration will be used for knowing the magnetic field for corresponding this, this coil current of electromagnet. now, you can see this reading now it is 0. Now, we will apply magnetic field; say I am applying magnetic field, some field I am applying it is changing ok, so 0.55, ok.

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This coil current is 0.55, Now here, so we have to give time, some time to stabilize it with very sensitive; very sensitive this balance, ok.

Here you see it has come a 0.0011 gram; that means 1.1 milligram. this is del m as I told this initially, so we have option here to this initial weight mass of this rod, weight of this rod to make it 0, so I have made it 0. Now, from that 0 whatever the change that is del m, so here this point. it is 1.1 now, it is showing 1.2. That is the for this for this field; for this field or for this coil current corresponding field you will get from the calibration, so you note down.

this coil current 0.5, I think 5 ampere; then it should give one column H corresponding H from the calibration curve one has to take, from the calibration curve one has to take, now I will write del m ok; del m is here it is a; it is a 1.1 to 1.3 this some variation is there, so one can take average 1.2 milligram, ok.

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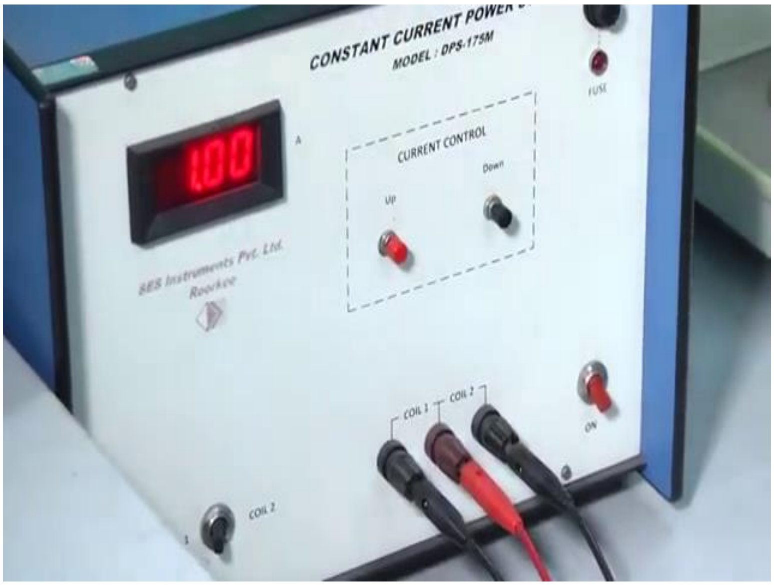

Now I will change to next values say, next value I will check 1 ok; it is a 1 ampere, ok.

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For 1-ampere coil current what is the magnetic field that I have to take from the calibration; then here you have to wait, here it is showing this 3.4 gram; it is showing 3.4 milligram not gram. we have noting down this change of the mass del m, ok.

This way for different field; for different field, I will go maximum field here, we can go up to 3 or 4 ampere current, up to that 3 or 4 ampere current I will go and then I will decrease again in step in step 0.5 step approximately and I will note down the reading.

During increasing the magnetic field during decrease the magnetic field, we can take data and take average for same field; we can take average of this two data or we can plot separately this for increasing of the magnetic field and for decreasing of the magnetic field.

Then we can actually find out the slope from the plot, delta m versus H square and then we will get from this two slope whatever we will get. We can take average of the slope or we will find out chi from this each slope and then we take we can take average of this this two value as a result, ok.

It is a; it is a very nice data, when I am increasing let me go to 1.5; then it is a 1.5 ok, so 1.5. Now, reading is this is one point 1.2 milligram; 1.2 milligram I will go to the next value 2. 2 ampere current and here this value is one 12.5 milligram, this way go up to the highest current and then again come back to the 0 value with step of 0.5 ampere current. In addition, we will get a set of data, important data for the, for this experiment and plotting the graph from the slope, we will find out the chi value.

After getting chi value as I told, you can calculate for aluminum what is the; what is the magnitude number P. And you calculate; you calculate from this using the experimental value of chi, using the formula as I showed you; N mu 0 P mu B square whole square divided by 3 K T, From there we can calculate P, if we know the chi value; then we can compare with this.

This is the experiment is called Gouy's method, which is used for measuring the susceptibility, magnetic susceptibility of paramagnetic or diamagnetic material in solid form. In liquid form we use the Quinck's method; this same thing for same thing for measuring the susceptibility of a sample in solid form. I will stop here.

Thank you.