Experimental Physics - II
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Lecture – 05
Summary of Experimental Physics – I (Contd.)

What are the experiments we have demonstrated in Experimental Physics I on electricity and magnetism.

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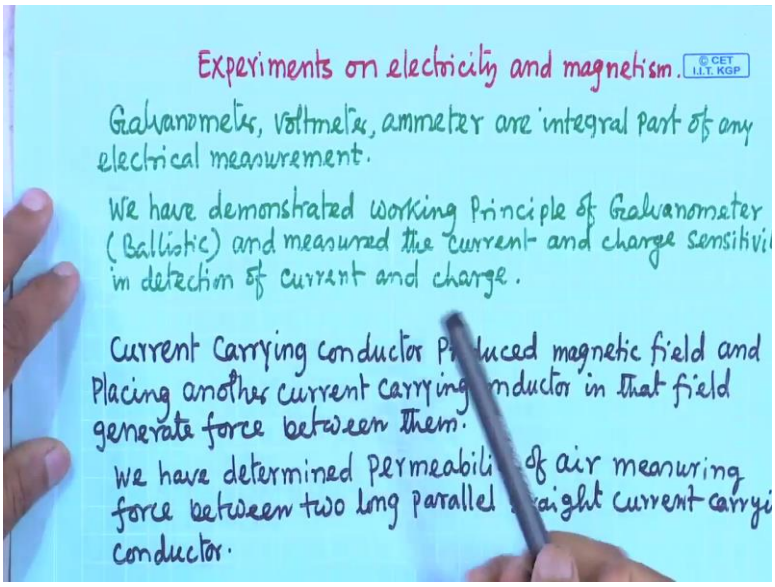

Let me just discuss them briefly. We have seen that galvanometer, voltmeter and ammeter are the integral part of any electrical measurements. We have demonstrated working principle of galvanometer: basically ballistic galvanometer and measured the current and charge sensitivity in detection of current and charge.

We have discussed about the working principle of the galvanometer and I think I opened the table galvanometer, voltmeter and ammeter. What are the things inside, how it works. One experiment, we have demonstrated that is ballistic galvanometer and measured the figure of merit that is basically sensitivity: charge sensitivity and current sensitivity of that galvanometer. We have also seen that the current carrying conductor produced magnetic field, and placing another current carrying conductor in that field generate force between them; that means, basically two parallel current carrying conductors, long conductors, straight conductors. Depending on the direction of the current, they feel

force; they apply force on each other. Either repulsive force between these two wires or attractive force depending on the direction of the current, that is because, when current flows in a conductor it produce magnetic field; as if another current carrying conductor, it also produces some magnetic field. So, two magnet, they will repel each other or they will attract each other depending on the polarity or pole direction of the pole.

So, based on this principle, we have determined the permeability of air measuring force between two long parallel straight current carrying conductors. This experiment we have demonstrated and we have measured the permeability of air. Then the resistor, inductor and capacitor: these three are very important components in electronics, in electrical circuit right.

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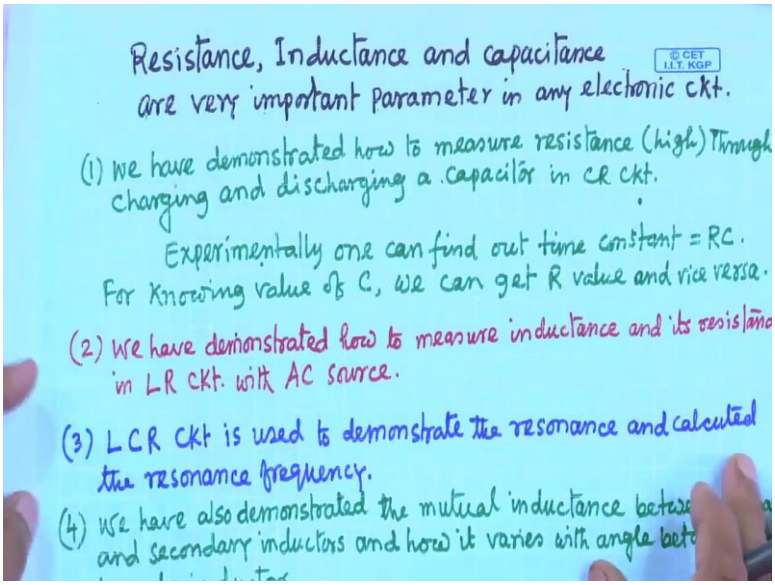

We have demonstrated how to measure resistance, basically high resistance through charging and discharging a capacitor in CR circuit or RC circuit. This experiment we have demonstrated and experimentally one can find out time constant that is RC.

Now, for knowing the value of C, we can get the R value and vice versa. If you know one of them, you can get the other one. Generally for this method, we use for measuring the high resistance in mega ohm resistance. It is very convenient method to find out the high resistance, very high resistance. Also we have demonstrated how to measure the inductance and its resistance, means inductor (Refer Time: 05:19) in a coil form, it has

resistance; how to measure the inductance and its resistance in LR circuit with AC source; this experiment also we have demonstrated.

Also we have used LCR circuit to demonstrate the resonance and calculated the resonance frequency. Here basically, at next experiment, we have demonstrated this; the mutual inductance between primary and secondary inductors; primary inductor, you pass current through it and the flux from this coil, it passes through the second coil placed near it. If there is a variation of this flux, then there will be induced emf in the second coil and again it will generate current in the second coil. So, because of that current again it will generate flux; that flux will affect the primary coil.

So, basically between primary and secondary coil, there will be mutual exchange of flux. That we tell the mutual inductance; that we have demonstrated this experiment and also have seen the variation of the mutual inductance with the angle between the two inductors. Here this experiment we have demonstrated to be familiar with the important components for electrical or electronic circuits. So, that is basically a resistor, inductor and capacitor right.

This experiments is really a very useful to be familiar with them and of course, without these three component we cannot think of any circuit in electronics and electrical purposes. So, these are the nice demonstration of the experiment in the laboratory and that we have seen in the experimental physics I course.

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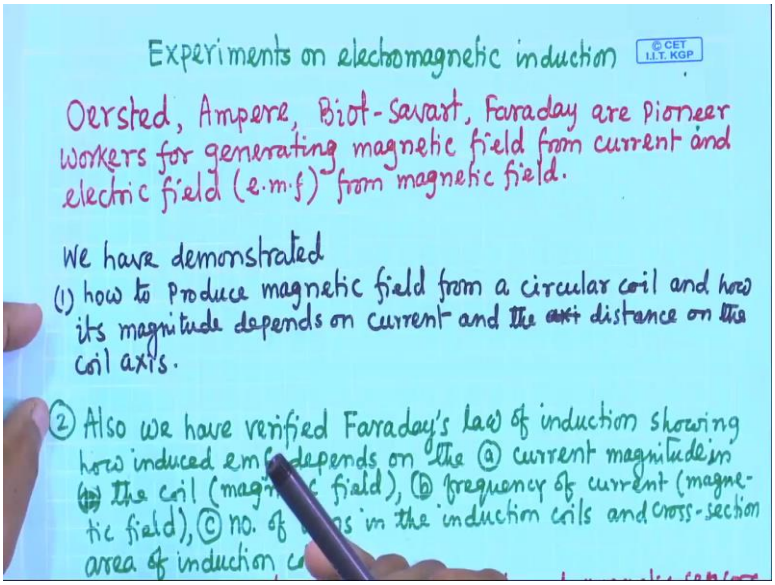

Next experiment we have demonstrate on electromagnetic induction; this is very important phenomenon: electromagnetic induction. Basically Oersted, Ampere, Biot-Savart, Faraday are pioneer workers for generating magnetic field from the current and electric field or that is basically emf or equivalent to emf, that is from the magnetic field.

From magnetic field to the electric field in terms of the electromotive force, you can say and vice versa. We have demonstrated in laboratory, how to produce magnetic field from a circular coil and how its magnitude depends on the current, magnitude of current and the distance on the coil axis. So, this experiment we have demonstrated. What will be the magnetic field; how this magnetic field varies; how magnetic field depends on the current in the circular coil; also it depends on the distance from the coil along the axis, a coil axis.

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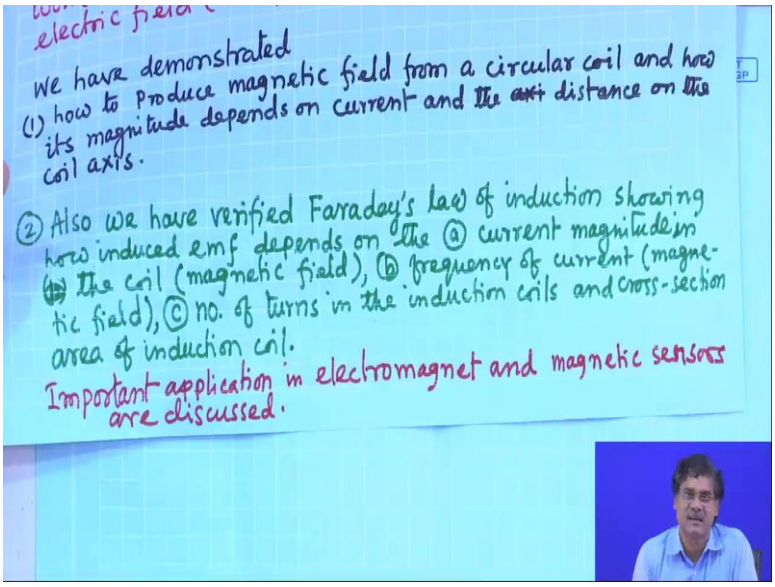

This is a very nice experiment because of its importance, as I will mention here, the important application of this phenomena that is electromagnet. So, electromagnet you can see in any laboratory; these are very useful magnet which you cannot get from the permanent magnet. So, advantage of electromagnet that you can vary the magnetic field just varying the current in it, but in case of permanent magnet that is not possible for a particular permanent magnet, you will get particular field.

Also we have verified Faraday's law of induction showing how induced emf depends on the current magnitude; current magnitude in the coils that is basically magnetic field, and

the frequency of the current. Again it will be same for magnetic field; the generated magnetic field physically and number of turns in the induction coil and cross section area of the induction coil.

Faraday's law of induction, that we have verified, that we have demonstrated and this induced emf basically, due to the variation of magnetic field. it depends on the frequency of the magnetic field or current in the coil; it depends on the number of turns in the coil, it depends on the cross sectional area of the coil. So, all these things we are able to demonstrate in a laboratory.

And based on this Faraday's law of induction, the magnetic sensors are produced, magnetic sensors are fabricated and this sensors are used in many experiments; in many industries, these sensors are used to sense the magnetic flux.

One experiment VSM, Vibrating Sample Magnetometers I discussed in experimental physics I; I think it was the last class. There is the magnetic sensors, I told you that this magnetic sensor is used to sense the change of the magnetization with the magnetic material.

These are very useful experiments and I think lot of experiments we have discussed; these are the basic experiments. All these experiments generally in our department of physics, B Tech students as well as integrated MSc students, also 2 year MSc students, they perform these experiments. They perform many experiments, some of them I have shown, in first year and second year whatever the experiments they perform, that I discussed in experimental physics I and in experimental physics II, in second year and third year whatever the experiments they perform that I will discuss in experimental physics II, whatever the course I am taking now.

Out of these experiments, also I have discussed how to write the data and how to write the result that is very important. That is basically error analysis. In details I have discussed in the experimental physics I and it is important for experimental physics II as well as experimental physics III or for any experiment, it is compulsory. Let me summarize what we have learned about the error analysis in module I; that also we need in module II, in experimental physics II

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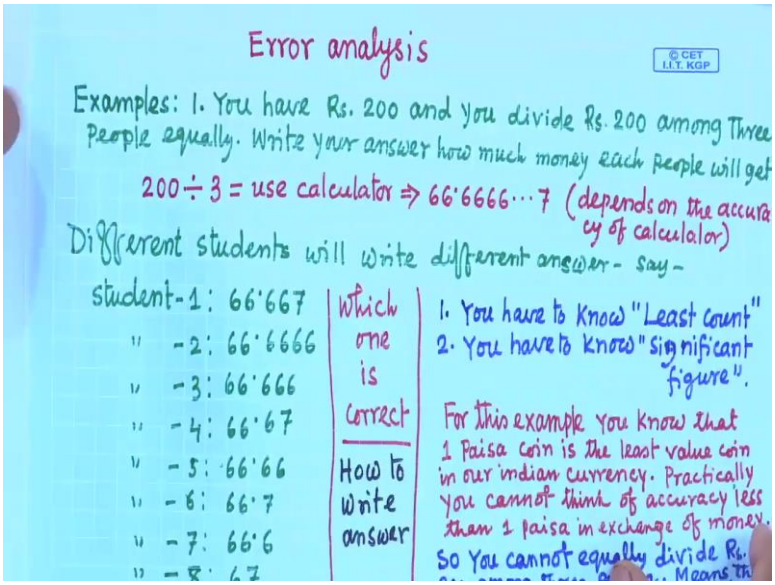

Error analysis: let me start with example, the example-1. Say, you have rupees 200 and you divide rupees 200 among 3 people equally. Write your answer, how much money each people will get. You have 200 rupees and you want to divide equally among the three people. Each people how much will get. That is the problem; now you have to tell me right answer, scientifically right. It is very simple; what you will do? 200 divided by 3; then you will use calculator, then calculator will give reading 66 point, decimal point 66666667. So, how many digit it will give, it will depend on the accuracy of the calculator, right.

Now, this is the result given by the calculator or manually if you calculate, divide, also you will get like this. So, you will stop somewhere. Now, question is: it is obvious that this accuracy of calculation will depend on generally, we think, it will depend on how many, upto how many digit you are able to calculate. This is the theoretical value; this is the theoretical value, but practically you cannot write your answer like this. So, what we can write? If I give this problem to the students, different students will write different answer. Say student one will write 66.667; another student, next students, student 2, he will write 66.6667 or third student will write 66.666; fourth one 66.67; then fifth 66.66 sixth student can write 66.7, seventh student can write 66.6, eighth student can write 67 ok.

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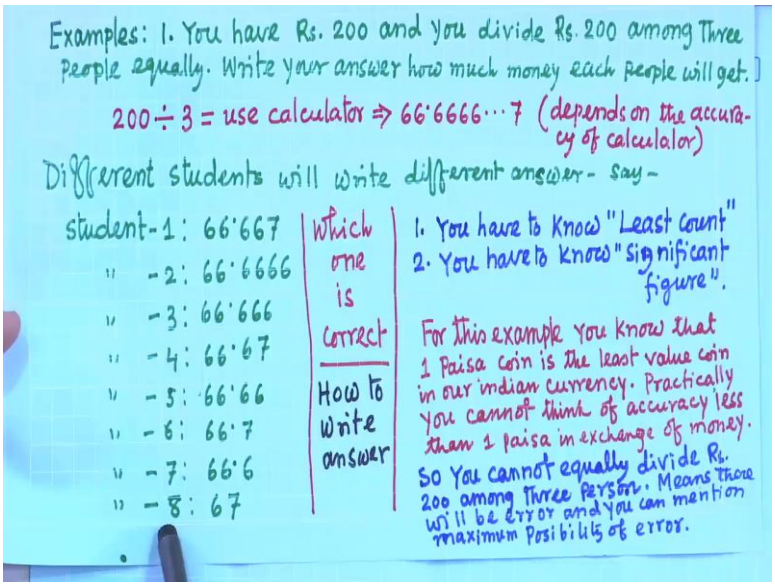

Now, question is which one is correct; which one is correct and how to write the answer. Can we write any one of them or there are some procedure to write the answer; that is what if you want to write answer properly. You have to know the least count and you have to know significant figure; if you understand, if you know these two then you can write the answer properly. You know that 1 paisa coin is the least value coin in our Indian currency, right, one paisa. Now-a-days I cannot see one paisa, but earlier in our childhood we have seen the 1 paisa.

I feel, I think, now it is not in market, but it is there. So, 1 paisa coin is the least value coin in our Indian currency. So, I cannot give to anyone the less than 1 paisa. 100 paisa is equal to 1 rupee. In rupees it is 0.01, right; so, I cannot give less than 0.01 rupees, ok. So, least count is 0.01 rupees or 1 paisa, ok.

If you know, for your problem, this is the realistic problem, it is the money we are dividing among three people, ok. So, you have money in 10 rupees, 20 rupees then 1 rupees then 50 paisa etcetera is up to 1 paisa. When you know the least count for your case, then practically you cannot, as I told, you cannot think of accuracy less than 1 paisa in exchange of money. In our currency, cannot think of accuracy less than 1 paisa in exchange of money, right. So, that is the fact that we have to keep in mind. That is we tell the least count.

Next we cannot here, we have seen that it is coming in decimal point and from this example that you can see that you cannot equally divide rupees 200 among three persons, 3 people right; means, there will be error and you can mention maximum possibility of error, right. So, when problem is given to you that you equally divide the 200 rupees among three people; you cannot equally divide; it is impossible, ok.

That means, there will be error, possible error, probable error in this distribution; in this distribution of money. So, in our answer there will be uncertainty that one can express in terms of error and in terms of maximum possible error. To express the result, keep this in mind that need to write the error, ok. As I told that one has to know the least count, significant figure.

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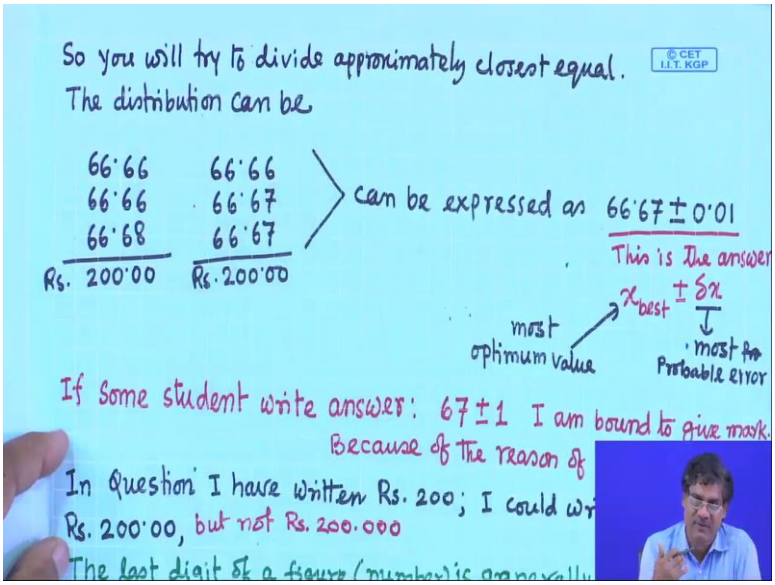

We will try to divide approximately, closest equal. We will try to divide approximately, closest equal, ok. I think, this one could not say properly probably. So, you cannot perfectly, you cannot divide, you cannot give them, but we will try. People generally will try to divide, it may not be equal, but it will be close to equal, that is what I want to mean. So, the distribution can be; now, it is clear that this since 0.01 so, that is the least count. So, you can keep only up to two decimal point. Whatever this 66.6667, you can keep only up to two decimal, right. So, you can divide this 200 rupees like this 66.66 one person, another person 66.66 and other person 66.68, this total is 200.

Or you can distribute like this 66.66, 66.67, 66.67. So, two people will get 66.67 and another people will get less than 1 paisa; 1 paisa less another person will get; so, total 200, ok. So, this can be expressed as your result; how we have divided, how we have distributed? So, your result you can express like this 66.67 plus minus 0.01, ok. If you express that three people, they will get money from 66.66 to 66.68, ok. That will be; so that is what here I tried to show, you cannot get better than this; that is why I told closest equal, ok.

Your result will be whatever here calculation we have done; calculation we have done from calculator is showing 66.666; whatever the calculator is giving? So, immediately what you will write 66 and you will keep two digit 0.66. Now, this 6 is followed the next 6; so, if it is more than 5, 1 will be added, ok. So, it will be 7; so, 66.67 ok. So, that immediately you can write now, what in this answer this is the absolute answer if you do not; if you write this one; that means, you are telling that everyone will get 66.67 rupees, but that is not the case; that is not the case so, there will be variation. So, one people may get 66.66 or one people can get 66.68 equal distribution is not possible.

Uncertainty is there so, that is expressed as a; what is the answer the maximum answer in the distribution ok? That is expressed with this as I showed you here this plus minus least count 0.01. This will be the answer of your example of your problem whatever I ask that you have rupees 200 and how you will distribute 200 among 3 people equally.

Your answer you have to write; your answer you have to write 66.67 plus minus 0.01. This is the answer and so, for any parameter generally we write x best value plus minus delta x. This is the most probable error; delta x this is the most probable error, plus minus delta x.

This is the way to express the quantity. Where and how to find out this error. Most probable error for different case; for single parameter, it is easy to find out, that is basically the least count of the instrument that is taken as a most probable error, but when some parameters are derived from other parameters, which are measured. That time, error of that parameter whatever we are calculating from the other parameters which are measured. It will depend on the error of the measured parameters. So, we tell this is basically propagation of error, that also I will discuss.

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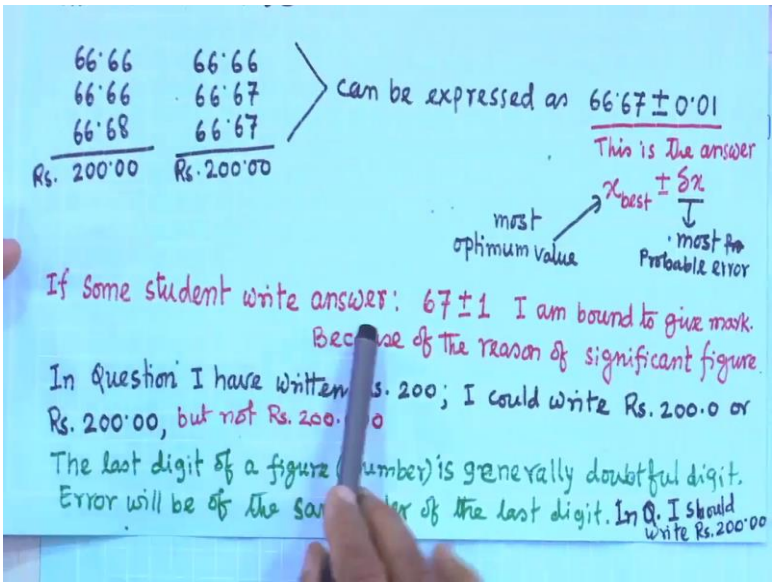

Now, this fine, but one thing here if some student write answer 67 plus minus 1. If someone, some student write answer 67 plus minus 1; actually I am bound to give him marks because of the reason of significant figure; because of the reason of significant figure. What is that? In question I have written rupees 200; I could write rupees 200.0 or I could write 200.00, but I cannot write rupees 200.000. Actually the last digit; the last digits of a figure of the number is generally doubtful digit; generally doubtful digit is an error will be of the same order of the last digit.

In question I should write actually, I should write rupees 200, 200.00 because in our currency the accuracy in our currency the accuracy is 1 paisa ok. We can give exchange money in terms of 1 paisa; if so, then I should write 200.00. When I am writing this one this will itself tell what is the uncertainty; what is the uncertainty in this number.

Actually last digit tells, basically doubtful digital and it tells the degree of uncertainty. If I write 200 simply then this is telling that the uncertainty is in the last digit here that is 0. So, it can be 200 one, it can be 199 ok. So, uncertainty or least count here, people will think that it is one if I write 200.00; then uncertainty is basically least count is basically 0.01.

So, if some student write this one also, I have to give marks to him also. So, writing a number is just; it is not the just like to write with 200 and 200.00 both are same right, 200.0 also same, 200.000 also same; but scientifically they are not same they are

different. That is what I tried to tell you. I will continue the error analysis more. Today let me stop here.

Thank you.