Experimental Physics I
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Lecture – 60
Devices around us (Contd.)

So, this is the last class for this Experimental Physics I. So, but in next semester we will continue this course as you know that we have I have designed this course in three modules – experiment physics I and experimental physics II and experimental physics III. So, we here I am giving's few examples common Devices around us, whether we can understand the principle of them. There are many, but I am discussing few of them.

And you will see this there are some now whatever I will discuss one instrument all parts you will not be able to understand with your knowledge gathered from this experimental physics I, but to understand this completely. So, one has to complete this experimental physics course. So, that means, you should take this experimental physics II in next semester then in success semester probably we will continue the experiment physics experimental physic III. So, now this is the last lectures lecture this 60. So, again I will continue the devices around us.

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So, I have chosen a research equipment. This is the vibrating sample magnetometer this is an research equipment. So, we will I will discuss the principle of this vibrating sample magnetometer.

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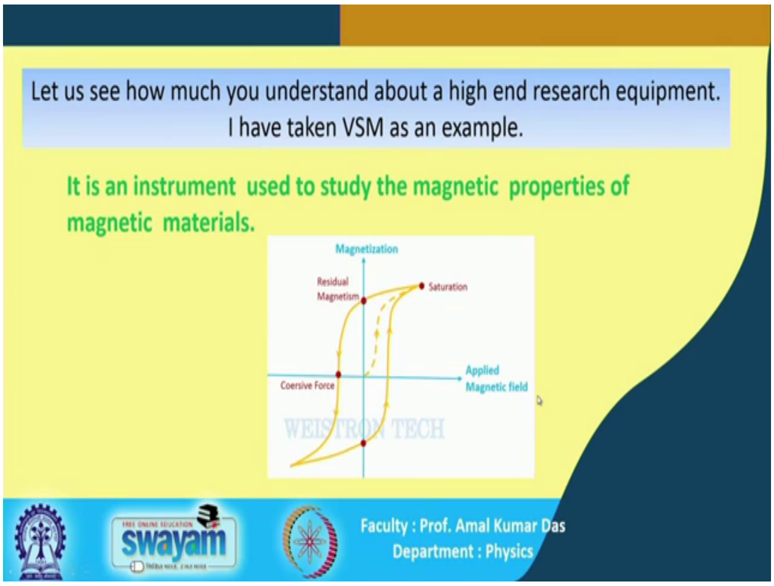

Again aim is to again aim is to check to see whether how much we understand about this high end research equipment. So, this you are quite familiar with this hysteresis loop I think in class 12 you have all of us have seen study this hysteresis loop. So, this is basically the magnetization this a here plot is magnetization and this the applied magnetic field; means if we take a magnetic material and if you apply field its magnetization changes right and magnetization changes like this.

So, when you are increasing the magnetic field the way the magnetization changes when you are decreasing the magnetic field the change is not following the same path it follows the different path. So, that is why this magnetic material is interesting and it has lot of application.

So, now, question is this how to experimentally how to measure magnetization of a magnetic material as a function of magnetic field. So, that is what the we need instrument we need experiment to measure such parameter. So, actually let me tell you this what are the properties of magnetic material we generally studying in our research.

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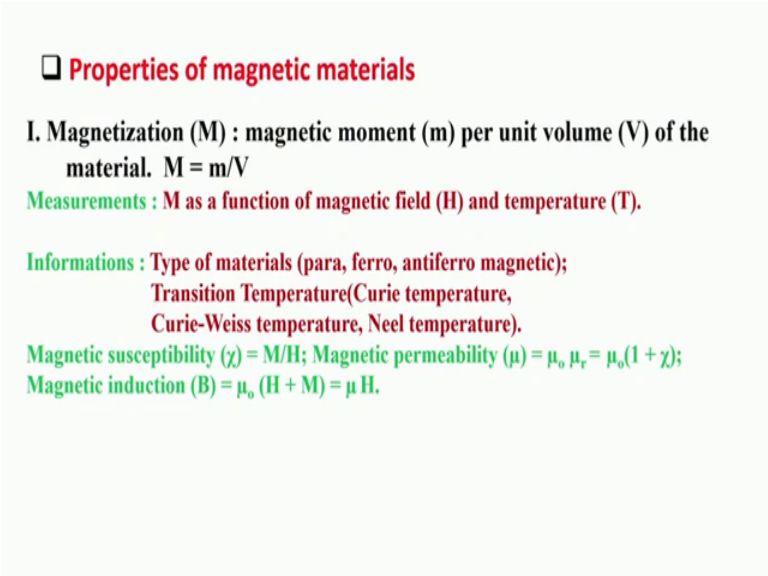

So, property of magnetic material this one is this basically it has magnetization; magnetization is nothing, but magnetic moment per unit volume of the material ok. So, now this magnetization we want to measure as a function of magnetic field we want to measure as a function of temperature. If we measure then we get information about the magnetic material which type of this magnetic materials whether it is paramagnetic or ferromagnetic anti ferromagnetic ok. So, different kind of magnetic materials are there. So, it is which type that we can find out from this measurement.

Transition temperature or Curie temperature of the magnetic material, Curie-Weiss temperature, Neel temperature if in case of antiferromagnetic material. So, this is call Neel temperature phase transition between antiferromagnetic and the paramagnetic and Curie-Weiss basically ferromagnetic and paramagnetic ok. So, that is what we can get information from the from the measurement of magnetization as a function of magnetic field and temperature.

And you know the selection this parameters magnetic susceptibility between it is nothing, but magnetization M by H. So, magnetization per unit magnetic field magnetic permeability that is mu equal to mu 0 mu r mu 0 1 plus chi, so, these are the relation. So, you are you are familiar with this relation. So, magnetic induction B, that is basically mu H.

So, my purpose is not to discuss this things. So, these are the these are actually with the magnetic material. Here I am discussing I want to discuss that how to measure the experimentally how to measure the magnetization as a function of magnetic field.

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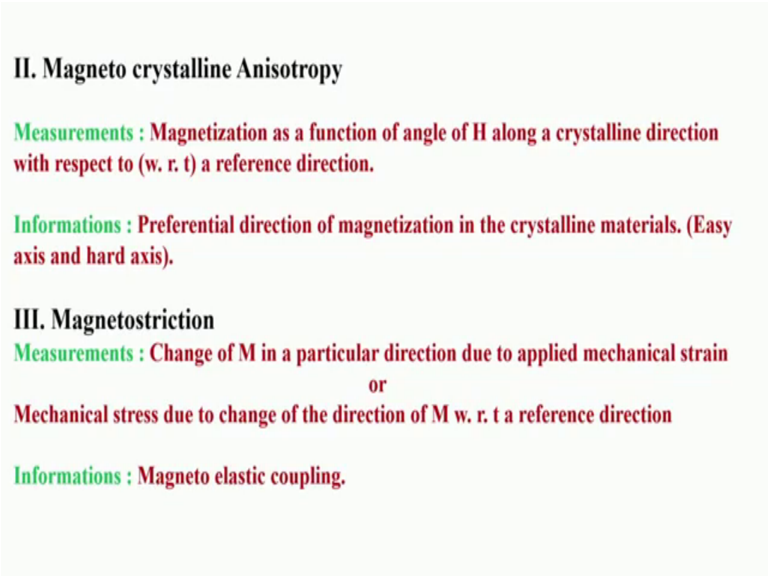

So, but here just I am telling you this in research what we study. Also we studied the there are another property magno magneto crystalline anisotropy and third one is magnetostriction ok. So, these also we study in research. So, using the so we need technique to measure to study this parameter, study this properties and in most of the in all cases mainly we have to measure the magnetization as a function of magnetic field, temperature, angle as a function of space ok.

So, so, measurement of magnetization is a is the only way, but as a function of different parameter to study the magnetic property of the material. So, but forget all these things as my purpose is different here. So, here let us just check see how to measure magnetization as a function of magnetic field. If I apply magnetic field how the magnetization changes and that how we can measure, which experiment we use for this measurement. So, that is what I want to tell you whether the principle of this of this research equipment we understand now.

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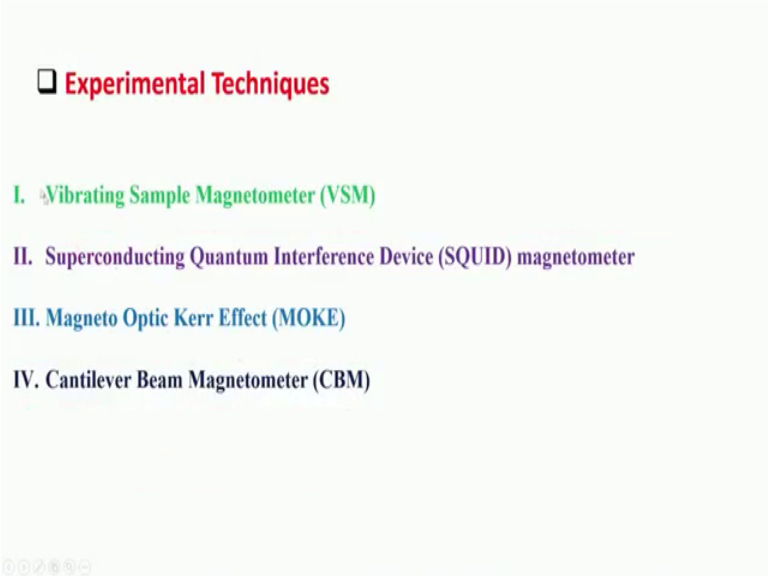

So, there are; there are; there are 4 method experimental technique and we used in research or measuring for studying the magnetic material. So, this one is Vibrating Sample Magnetometer this VSM; another is Superconducting Quantum Interference Device magnetometer ok, this is another magnetometer. So, third one is Magneto Optic Kerr Effect – MOKE; fourth one is Cantilever Beam Magnetometer. So, this four magnetometer can we used in research there difference among them, but all measures the magnetization all technique measures the magnetization as a function of magnetic field.

But, there are ok, they works on different principle ok. So, I have taken example of this one just to see whether we can understand the principle of this instrument high end instrument.

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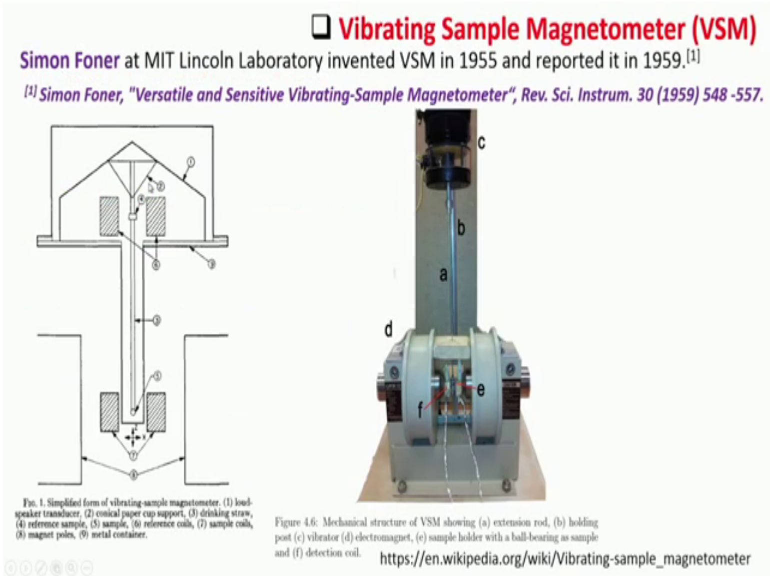

So, this is the schematic diagram of VSM. So, Simon Foner he was the he invented this instrument in 1955 and he publish this work in review of scientific instrument in 1959, from there. So, these are research paper. So, as I told these are research equipment and this is the schematic diagram ok.

What is there? Here is telling that this, this is a this 8; 8 means here this magnetic magnet pole. So, these are the magnet. So, in this setup experimental setup we need magnet ok. Second is telling this I think here it is 7, these two are telling its coil sample coils, I will tell the meaning of this sample coil. So, this two are sample coils and this here this 5 this means here this sample whatever you want to measure. So, basically this sample is placed here between two pole pieces of paper magnet ok. So, to apply magnetic field on the sample and these two coils is called this sample coils we tell nowadays we tell detection coil or pickup coil; I will tell the meaning.

So, it is there it is place near the sample ok, they are fixed. Now, basically this sample is put in a straw drinking straw this is the straw see drinking straw. So, in straw this is your sample say powder sample is put it is the at this end of this straw and the other end of the straw is connected to the is connected; is connected to the here this loudspeaker this drinking is the it is connected to the here one loudspeaker here you see this less than one is loudspeaker. So, this one so, this part is loudspeaker.

So, one end of the straw is connected to the loudspeakers other ended the straw is having the sample. Now, these two pick up coil or sample coils are here close to the sample and to apply magnetic field there. So, this in reality so, this is the; so, this is the electromagnet basically. These two coils are placed and this in between this pole whatever we telling this is the magnetic material we used to intensify the magnetic field, and here this sample is basically sample holders with a yes whatever sample basically this sample.

And, f; f here this is the whatever this pickup coil as I told this e is the pickup coil or detection coil her placed near the sample. So, here we can see the electromagnet then sample and then this pick up coil or detection coil these two the connection with the detection coil and the sample in a rod now at one end of the rod and other end of the rod is connect with the loudspeaker ok. So, this is the experimental setup complete set for VSM.

Now, what is the what we want to measure we want to measure magnetization of the sample at different magnetic field at different magnetic field. So, first question is then we have to make arrangements for the magnetic field, right. So, how to produce magnetic field that is what we have learned in this course.

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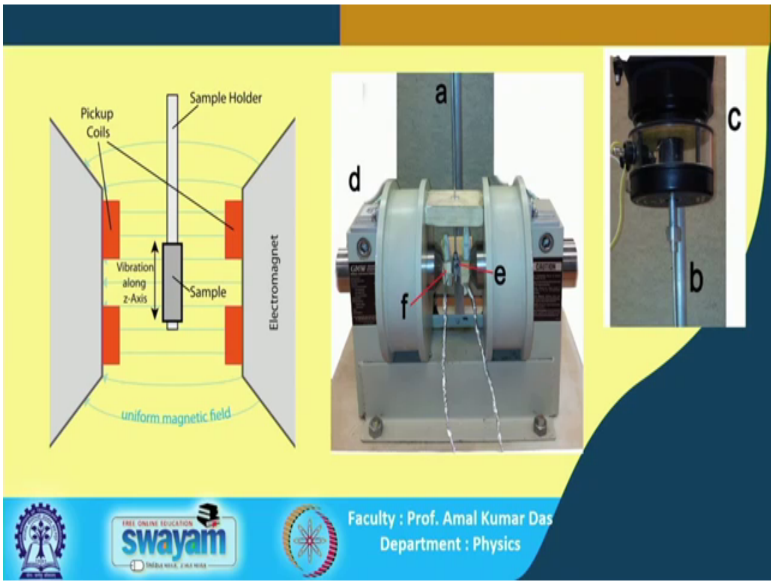

And you remember you remember that yeah so, this is basically magnifying way I have shown you.

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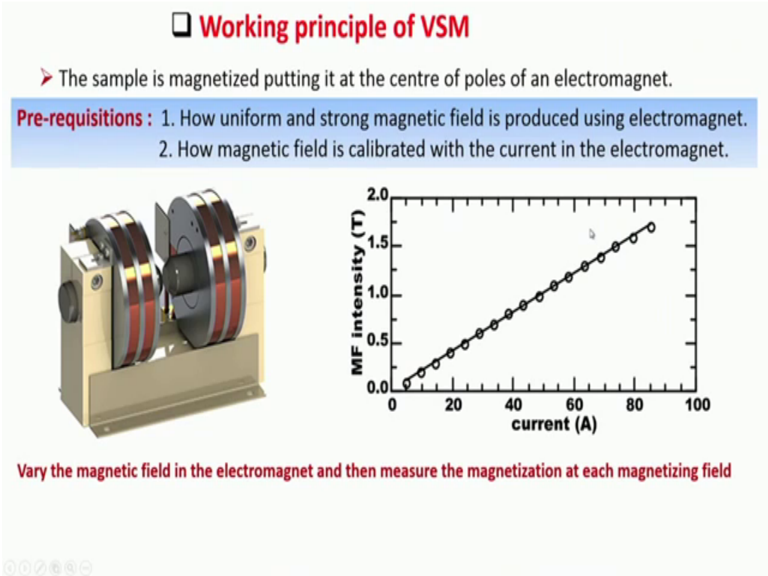

So, I have shown this picture, right. So, in case of when I was discussing calibration so, actually this is the electromagnet. It has pole pieces as I told pole pieces is nothing, but it is used to intensify the electric magnetic field; without pole piece also we can get magnetic field, but its a it will not be intensified as for same current same coil if we will we will get intensify it is field if we use this magnetic material as a pole ok.

So, but this how to produce magnetic field? Magnetic field is produced using the passing the current in a circular coil that is what we have learned from this course.

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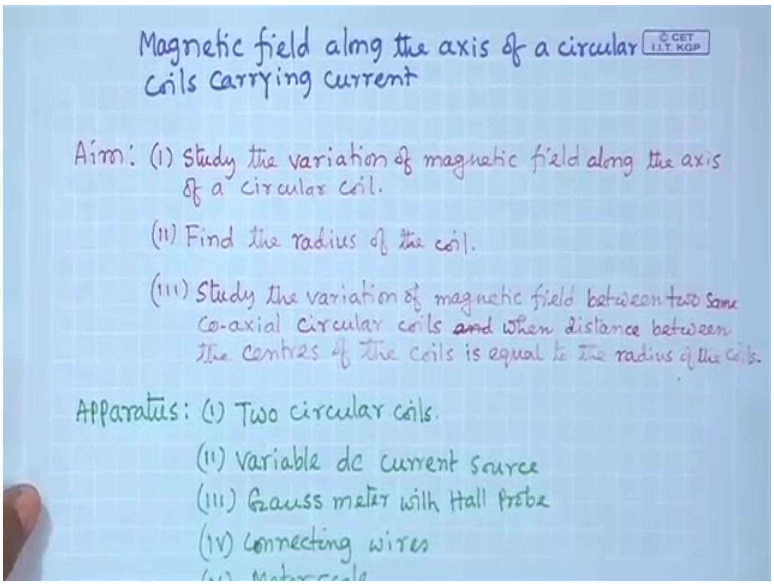

So, I have so, to probably yes, we have remember that I have discuss how to I think I have this experiment I have discussed this magnetic field along the axis of a circular coil carrying current, right. So, that experiment we have shown and we have measured the magnetic field at different distance along the axis right. So, this experiment so, basically told us that how to generate the magnetic field. So, this is the basically electromagnetic electromagnet basically is based on this principle.

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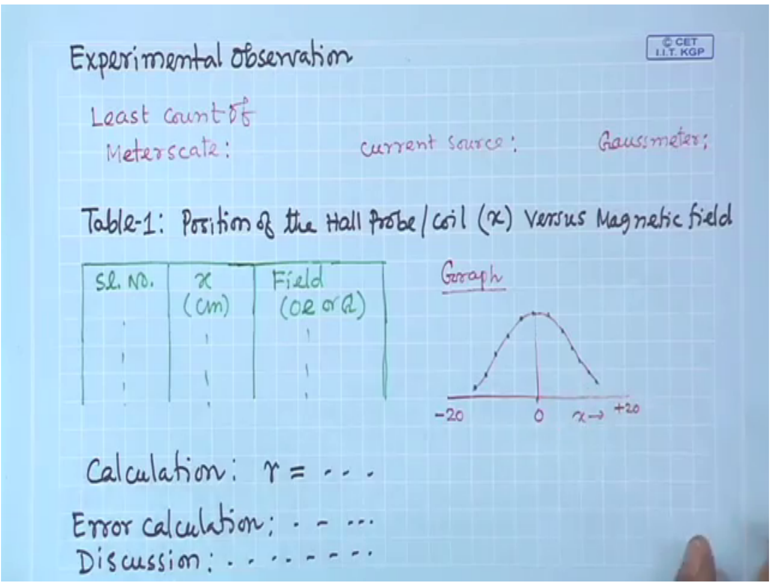

So, this experiment I have demonstrated, right. So, this along the axis how it varies. So, that plot the data, so, it varies like this. So, this is the 0 position means is the yes electromagnet this coil, if I start; if I start that is this is the distance we are taking this side is positive with respect to 0 and other side is negative.

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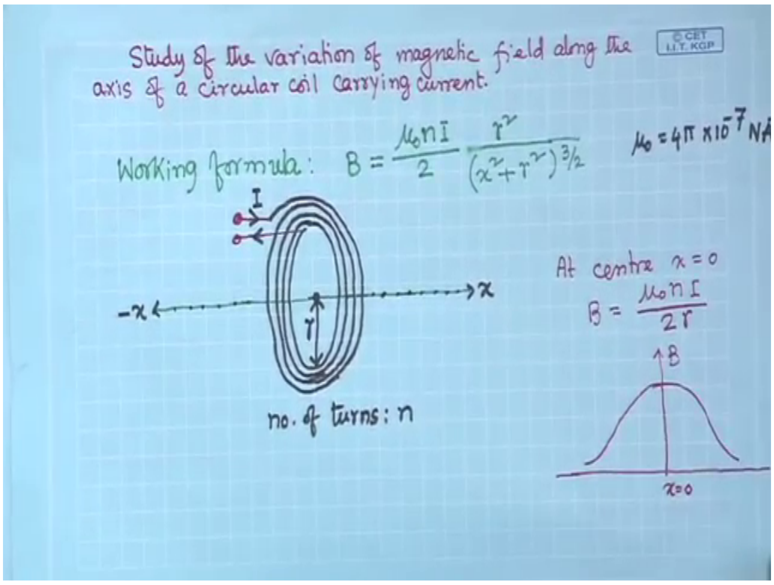

So, I think it will be in theory I discuss with you so, what is plus and what is minus. So, starting from the center if you go this sides we have taken class this side minus. So, whether if you go this side so, how it is magnetic field varies with the distance. How magnetic field is produced? Magnetic field is produced because of passing current through it and it depends on the number of turns.

So, that is why we have learned how to produce magnetic field for that we have to use coil. So, if you want uniform magnetic field between two between the in a place so, we have to use two coils. We have to use two coils and that is called Helmholtz coil that also we have learn from this course.

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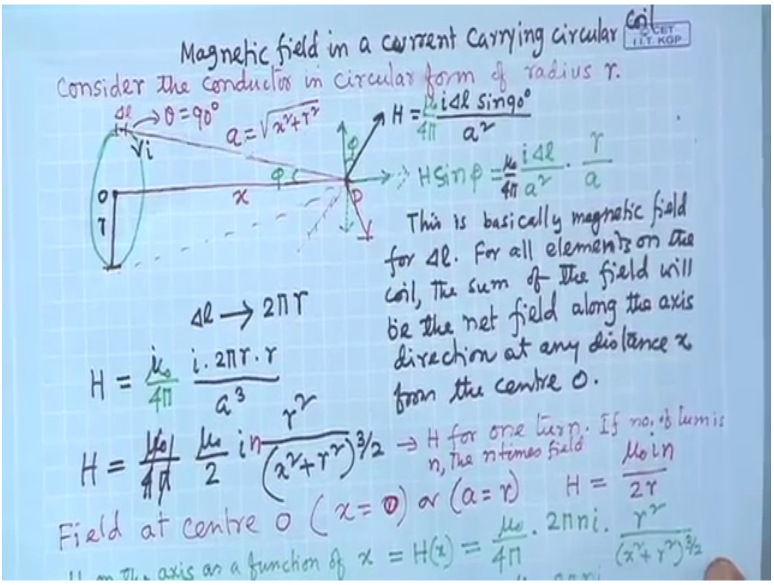

So, and that also theory wise I think I have also shown you this calculation of this magnetic field in a current carrying circular coils. So, in details we have studied in details we have studied and how to get this uniform magnetic field.

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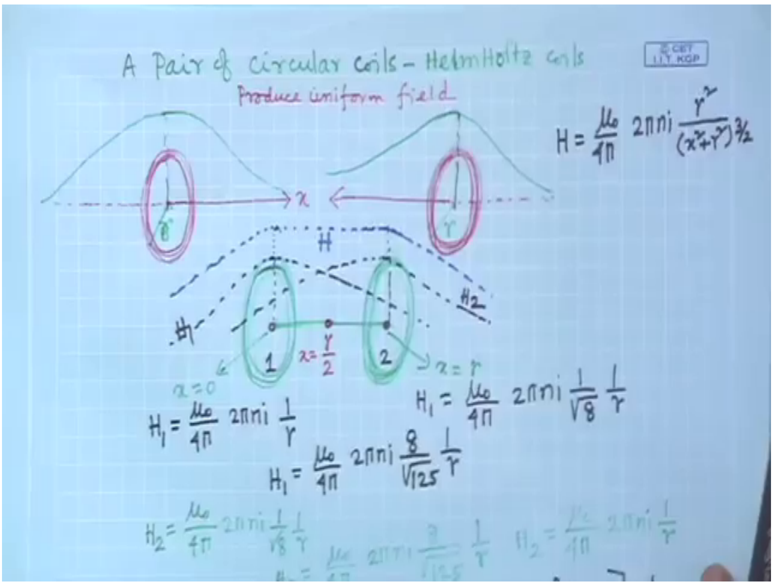

So, just I am showing you to connect with this. So, this also I have discussed earlier. So, these two coils here it is distance should be half of the radius. So, then you will get uniform magnetic field. So, these are the things in details we have learned how to produce magnetic field. So, this knowledge is useful, so, for understanding this one research equipment, whatever we are discussing that is VSM.

But, this I see this basically an equipment high end equipment is a symbol of the many small exponent whatever we are doing now. So, there are many experiments, ok. They are assembled in a in an instrument for a specific purpose. So, here that is why it is a composite system it is not a just ones one if this is the one part of this instrument, but is a one experiment whatever in this course we have learned. So, this and this how to so, we have to; we have to; we have to calibrate this electromagnet for that you need Gauss meter or gal we use hall probe Gauss meter.

So, that now this part I have not this experiment how to sense the magnetic field that about that sensor I have not discussed in this course. I think if you we. So, in successive experimental physics II, experimental physic III I think this part I will discuss in experimental physics III when I will discuss about the experiment of solid state.

So, then you will understand this the probe we used to calibrate the electromagnet. So, how that probe functions, but right now this about the probe you will not be understand you not be understand means whatever knowledge gathered from this course we will get knowledge you will not able to understand, but you know if we have already learned about it.

So, next one is so, what is there? So, here this we need electromagnet and we have to vary the magnetic field. So, that is why varying the current we can vary the magnetic field on our sample ok. Now, I am in a position we are in a position to vary the magnetic field to vary the magnetic field and the sample is magnetized for that magnetic field what is the magnetization. So, that I have to measure.

So, for that what principle is used let me tell you; so, here this is the samples. Here you can see here, this is the sample. Now, this name of the technique is telling this vibrating, sample, magnetometer; vibrating, sample, magnetometer; vibrating, sample; that means, here principle is based on the vibration of the sample. The principle of this instrument is based on the vibration of the sample vibrating of the sample, right.

So, why we need to vibrate the sample? So, if you so, you know the magnetization is basically equivalent to the it gives magnetic field you know this from this relation we can see this b equal to magnetic induction B equal to H plus M ok. So, basically H and M are same; H is giving lines of force. So, this magnetization also gives a lines of force. So, basically magnetization is nothing, but the it is lines of force, is same as the magnetic field,.

So, magnetization gives lines of force; magnetic field also gives lines of force. Now, if we see here these two coils we have kept close to the close to the sample means close to the magnetization this sample is magnetized it has magnetization close to the magnetization. So, this magnetization will give lines of force magnetic lines of force and this lines of force will pass through this coils; whatever sample coils or detection coils or pickup coils whatever we are telling, so, this flux from this magnetization we will link this coils ok.

And also this coils will be linked with the flux from these electromagnet because these coils are in electromagnet between the pole pieces of the electromagnetic. So, this magnetic field is passing lines of force are passing through this, like this. So, this magnetic field lines of force from this electromagnet will pass through this detection coils means this lines of force from the electromagnet will be linked with this coils as well as the flux or lines of force from the magnetization that will be linked of these with these coil also ok.

Now, flux or lines of force link with this coil if lines of force changes with time lines of force linked with the coil that lines of force changes with their time then there will be induced emf in this, induced emf of this. So, that is what we have learned from a experiment we have discussed in this in this course ok. So, let me remind show you what we have learned. So, we have learned that this experiment on electromagnetic experimental electromagnetic radiationn a induction, right.

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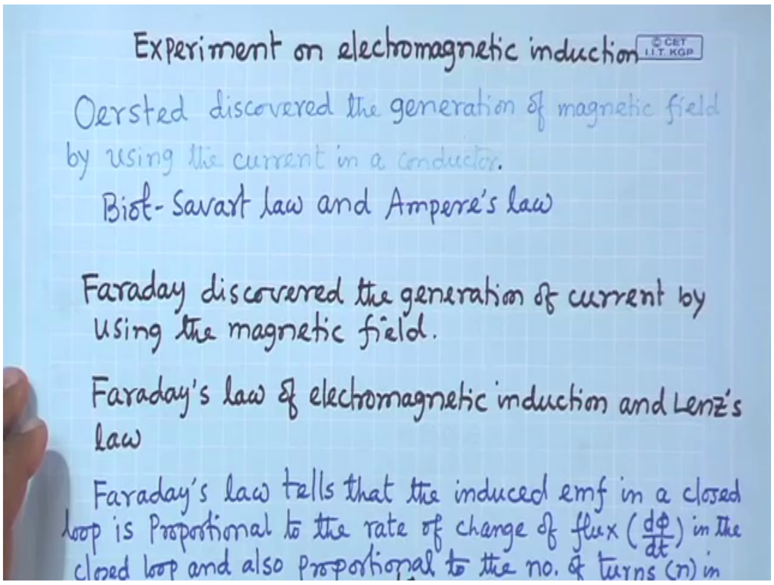

So, here there I have discussed and I have we have seen that this there will be induced emf.

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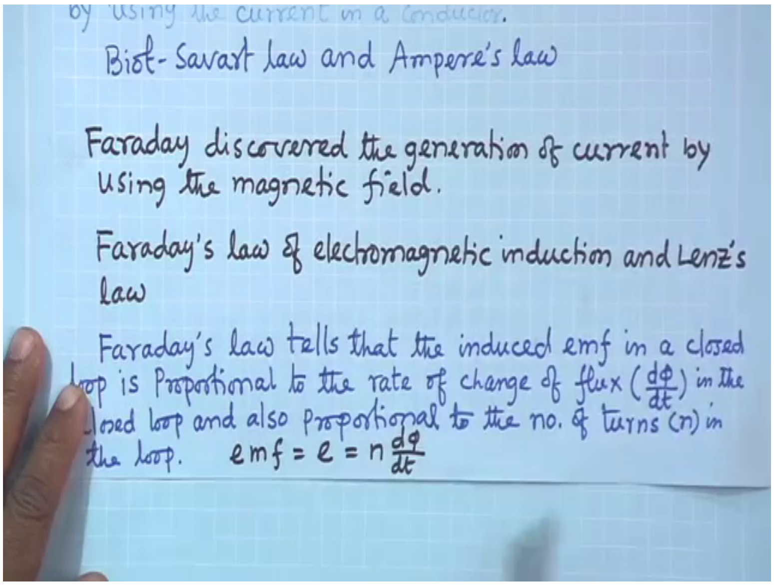

If induced emf if there is a change of flux linked with the coil ok. So, this I have discuss in details; this I have discuss in details in an experiment in our laboratory right you remember.

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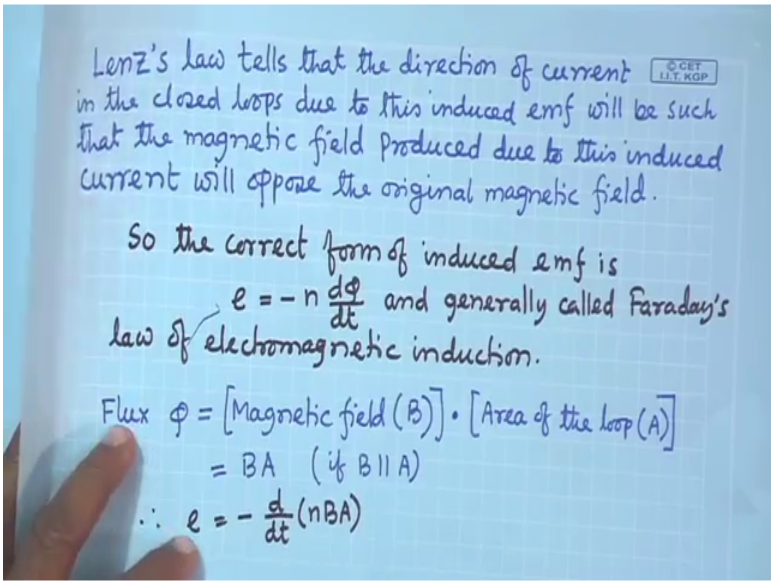

So, this I was discussing and this theory and also we have demonstrated the that experiment.

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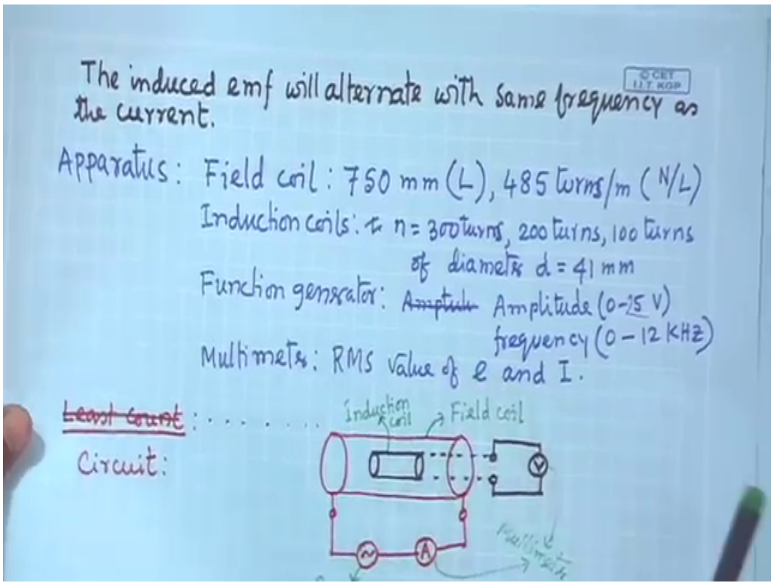

This also it is induced emf will alternate with same frequency as the current ok; this things we have discussed.

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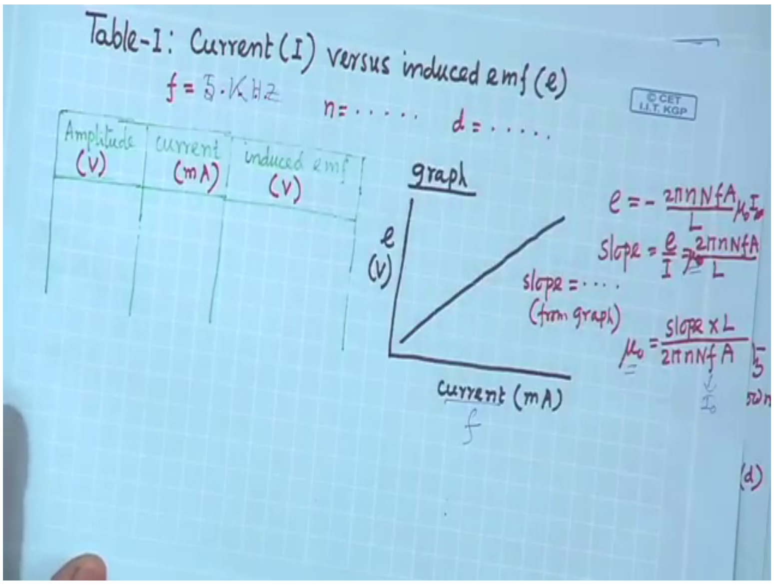

So, this is basically Faraday induction law Faraday law of inductions and then we have measure the current versus induced emf ok. So, we have learn this course we have learn that this experiment on electromagnetic induction, there if lines of force or flux linked with a coil and that flux varies with time. So, there will be induced emf in the coil and that induced emf is proportional to the rate of change of the flux, so, that is what we have learned.

Now, that same if we use this knowledge here, now you see here so, flux linked with these two coils or if you can consider one coil also, these two coils people use four coils so, to make it more sensitive. So, we can think that is so, in terms of one coil. So, flux link with the coil with the coil. Now, so, this coil is not changed, this coil is not changed. This sorry, this flux linked with the coil that will not change with time if this sample is static here ok. So, this electromagnet is static.

So, all the time flux whatever is linked it is not changing with time if we use DC current of course, in electromagnet we use DC current ok. So, it is the DC electric field, DC magnetic field ok. So, there will not be any induced emf due to this due to this magnetic field from the electromagnet all lines of force passing through the coil from the electromagnet ok.

Now, for a particular magnetization for a particular field there will be particular magnetization if this sample is static also its a that flux from this magnetization linked with the coil that also will not change with the time. Now, if I make a arrangement that this magnetization position of the magnetization will be will be vibrating. Position of the magnetization will be vibrating; vibrating along the z-axis like this vibrating. So, what will happen; what happe? This, magnetization basically this I this yes, basically this magnetization this magnetization of this sample this will go up and down.

The sample is going up and down going up and down. So, what will happen, the flux linked with this coil thus flux coming from the magnetization linked with this coil. So, when it is going out here so, this flux from the magnetization if you consider that it is going like this in this direction for a small distance. So, this flux when it is here so, this flux is now no more passing through this coil when it is here. So, no more it is passing through the coil. So, if this sample is going like this so, this flux linked with the coil that will that will change with time depending on the position of the sample. So, that is basically due to the vibration of the sample due to the vibration of the sample.

So, sample is going out of the coil sample is passing through the near the coil ok. So, that means, the flux from this magnetization link with the coil is varying with the time. So, there will be induced emf because this flux that is basically proportional to the magnetization, it will depend on the strength of the magnetization. Now, for a particular magnetization ok. So, the there will be induced emf there will be induced emf depending on the variation of the flux with time. So, whatever the induced emf I will get in the coil that is basically proportional to the magnetization ok.

So, here basically this now this magnetization is converted into electrical signal induced emf. So, we will if we can measure the induced emf if we can measure the induced emf then that induced emf is proportional to the proportional to the magnetization. Then after calibration basically I will get the matters magnetization measuring the induced emf I will get the magnetization. Now, that is the principle of this vibrating sample magnetometer. This is the heart. This part is the heart of this of this magnetometer. So, that part is easily understood by us after this course ok.

So, so, that is you see this is another part another experiment this is the; this is the another part another experiment whatever we have done. So, this is a; this is a part of this of this whole system. So, one is electromagnet; so, that we have learnt in experiment that is assembled here. So, this Faraday induction that part experiment we have done that is also indicated here. So, now, here I told you that we need to vibrate the sample.

So, now, next question how to vibrate the sample ok. So, the sample for to vibrate the sample the sample is connected this rod is basically connected to the loudspeaker. So, now we have to understand the working principle of the loudspeaker working principle of the loudspeaker.

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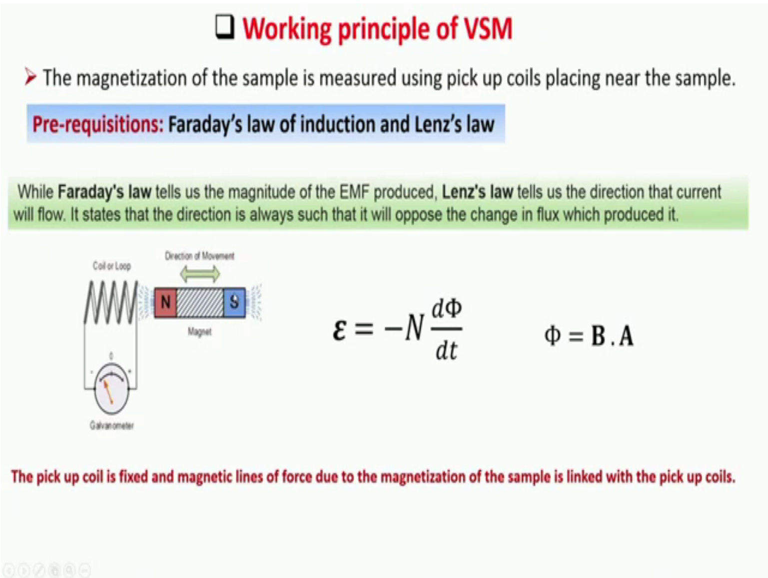

So, loudspeaker you know that microphone that we used. So, we whenever we speak that is that you can control the control the voice ok. So, that loudspeaker how it works you know? So, in loudspeaker the principle also is very simple. You see just here I tried to explain if you here have a this is the Faraday law in of induction that you know already we have done experiment.

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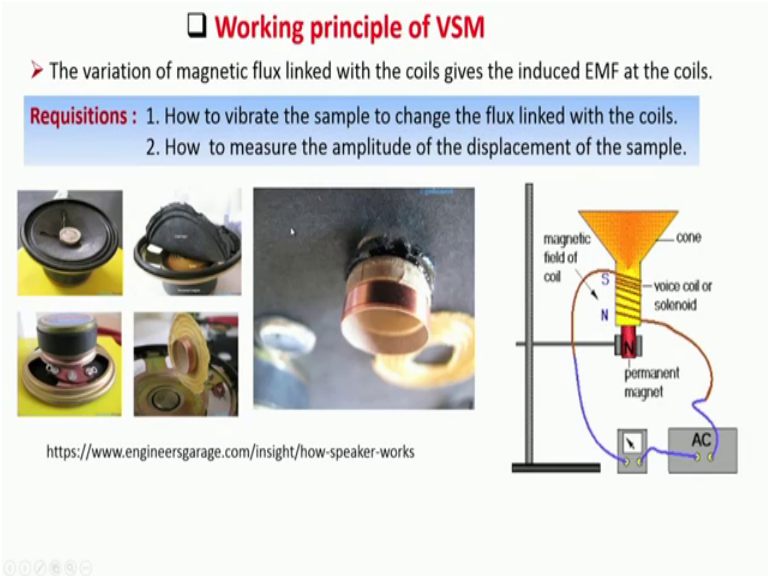

Now, in loudspeaker what happens there is a permanent magnet, ok. So, it has South Pole and North Pole. It has a South Pole and North Pole. Now, there is a coil; there is a coil. Now, this coil is placed on top of this on top of this permanent magnet South Pole and North Pole ok. So, you have a permanent magnet it has a South Pole and North Pole. Now, if you take another permanent magnet having South Pole and north pole; you know north pole – North Pole will repel each other, North – South Pole will attract each other.

Now, instead of taking to permanent bar magnet if you take one bar magnet and another if you take a coil electromagnet a coil where you are passing current through it and then this coil will act as a like magnet. So, it will have this coil will have South Pole and North Pole. Now, if you apply AC current now this periodically this South Pole and North Pole of this coil will exchange ok, but it is on top of a bar magnet where say it is this bar magnet this it is if it is North Pole then this other part will be South Pole other part will be South Pole.

So, if this coil is on South Pole so, when this end of the coil will be will be north then it will be attracted by the South Pole and when this will be just AC current so, it will be again it will become the North to South Pole. So, then south – south there will be repulsion. So, that means, this part because of changing the current AC current here pole are will change of this of this magnet, other magnet is fixed. So, this will vibrate or other way. So, one is fixed another will vibrate depending because of periodic repulsion and attraction between these two magnet; one is permanent magnet and other is electromagnet.

So, that means, here so, whatever attached with this magnet one magnet. So, this part which basically will vibrate and basically there is a there is there will be air this there will be air column here. So, that air column will vibrate and there is a on top of it there is a this pin which basically vibrate. So, vibration of air column is basically gives you sound ok. Vibration of the air column will gives you sounds you have seen the drum if you just vibrate it, so, it makes sound ok. So, this is the principle of the loudspeaker. So, this loudspeaker this principle is used here.

So, now, imagine so, if this is your; if this is your this part here whatever this cone we are using so, here the with this cone if we use this use if we attach the end another end of the sample rod, so, now this is vibrating means this sample which road is vibrating and your sample is vibrating. So, that is what; that is what happens that is what happens.

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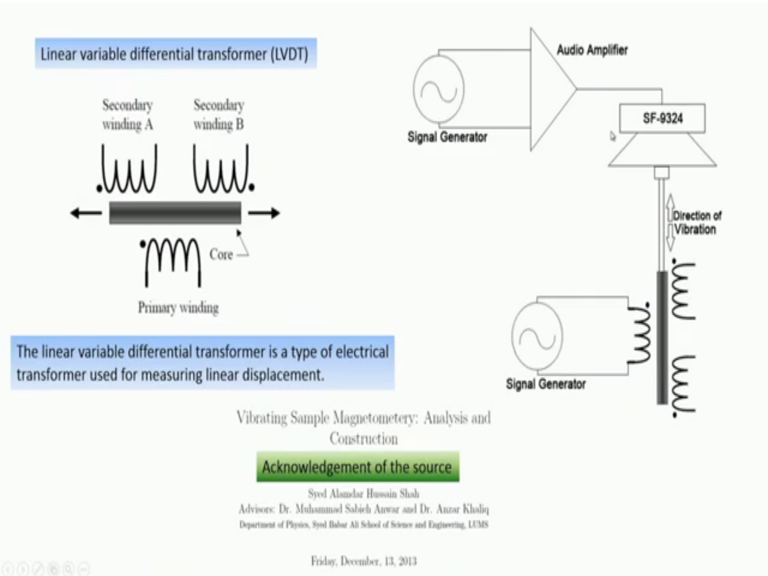

In this case, so, this principle is used here to vibrate the sample holder and this is the loudspeaker head. The sample holder it is attached with the loud speaker head. So, loud speaker head here this that mechanism is used. So, that head will vibrate and this rod is attached with the head and basically you are getting the vibration of the sample ok. So, now, if sample vibrates then there will be change of the change of the flux linked with the detection coil. And you will get the induced emf we are measuring the induced emf and you will get the.

So, what here I want to show; so, this part also it is well understood after doing this course, right. So, here another part is there basically one has to one has to find out the magnitude this amplitude of this vibration how much it should be. So, for that there should be mechanism to measure the amplitude of this vibration or to calibrate the amplitude of this of the vibration because this that one will vibrate with the loudspeaker, but depending on the amplification of this loudspeaker you know this amplitude will vary.

So, how much amplitude you want depending on the detection coil size etcetera so, that one has to calibrate for that basically one sensor is used it is called linear variable differential transformer.

So, this principal also not difficult, but this part you do not know this part you do not know. So, to learn this part to understand this part so, we have to; we have to; we have to gain the more knowledge so, that we will be discussed in the successive modules ah. So, this part is let us not discuss because my aim is not to teach you this VSM Vibrating Sample Magnetometer but, I want to tell you that how much you can understand.

So, there are some parts you are able to understand now, but there are some part you have to understand that part you have to learn more. So, that is why we have to; we have to basically take this complete course after module 1, we have to take module 2 and module 3 and hopefully then you will able to understand most of the devices around us.

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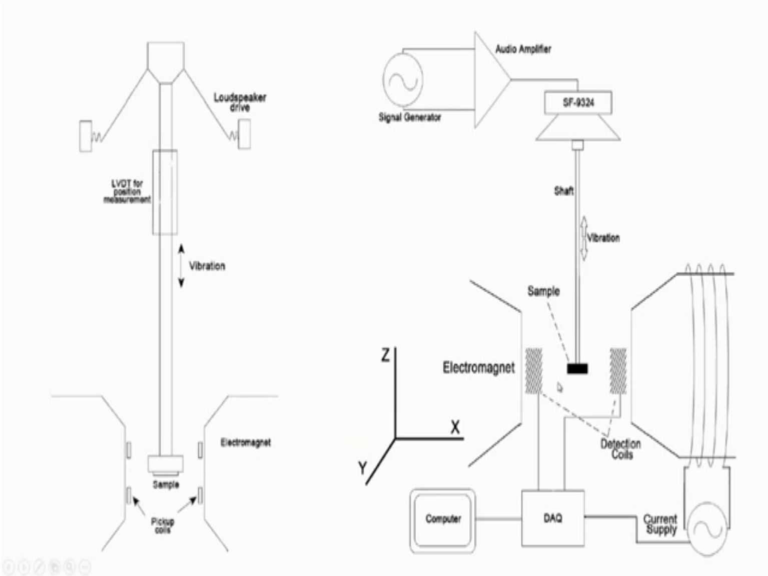

So, to detect this one so, there is one lock in amplifier that is that also used so, that also you do not know. So, I will not discuss. So, there are so, I think there are few things we need to understand for that we have to go further we have to go ahead. So, that is what I will do in some of them some of the things more things you will learn experimental physics II which we will give we will continue in next semester.

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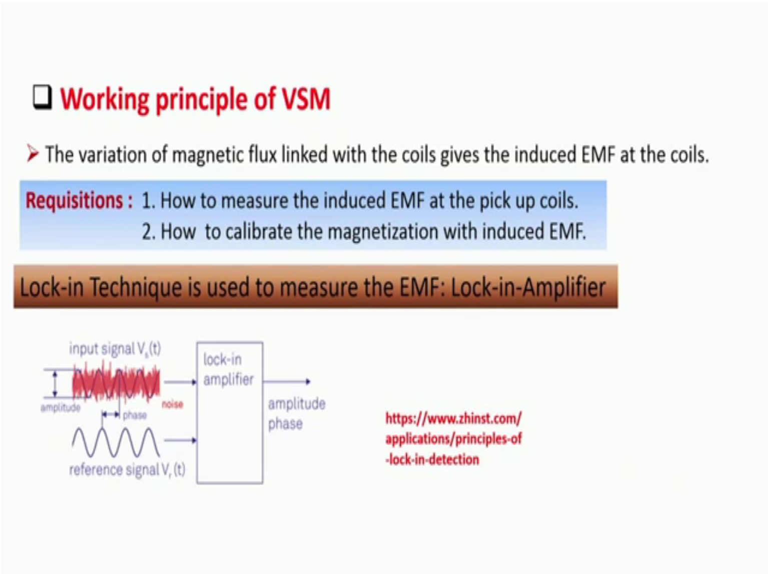

So, this about this lock in amplifier also we have to learn here we have not learnt in this course.

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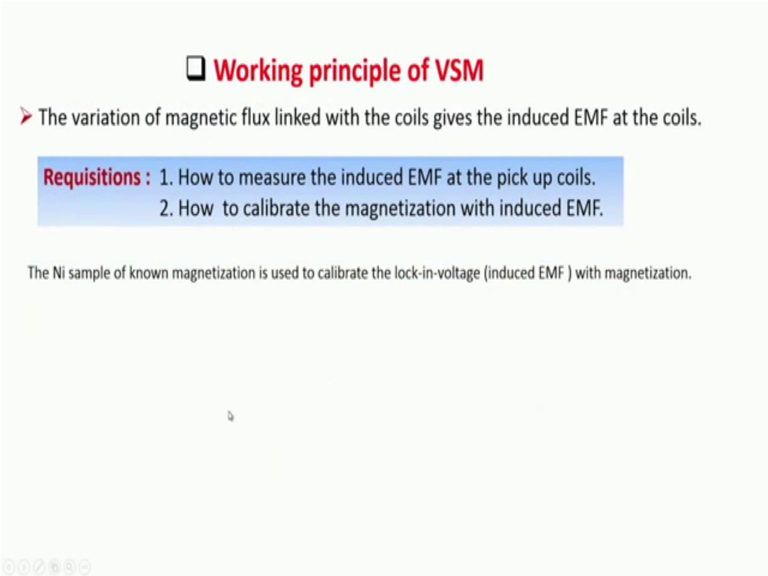

And, then calibration of this one there is a so, there are details. So, at least you should be happy that major most not major this is a research equipment and half of it already you are able to understand after doing this module I. So, to understand fully we have to take the other modules and hopefully we will be able to explain understand all devices around us after completing this three module. So, thank you for the attention and we will see you again in next semester.

Thank you.