Experimental Physics I
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Lecture – 14
Basic analysis (Contd.)

So, we will continue our discussion on Basic Analysis in laboratory. So, today, I will discuss about the calibration.

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So, basically when will do experiment, particular experiment are there our aim is to find out some parameter and for that we have to measure different parameters like temperature, like magnetic field, etcetera. So, there always we need to calibrate some instrument or instrument is there company has given the instrument but we should understand the principle of that instrument.

So, this calibration is a very common factor when you will do experiment in laboratory. And so, we should have clear understanding of the calibration. So, the simple example we can take that if you take a scale for measuring length right, so in that scale this is the meter scale, centimeter scale. So, it has this it has particular length say it is 1 meter or 50 centimeter scale length. So, in this so, how we know this, this is the length. It is 50 centimeter or this is the length, it is 100 centimeter means 1 meter. So, who has fabricated or made this scale. So, he has made how he has made. So, that we have to understand basically there is a standard scale ok, international standard scale. So, there this 1 meter is defined.

Now, if we want to make a scale, so we have to take help of this standard scale ok. So, what is the length of 1 meter? Now, that length you have to you have to take from that standard one, international standard one and now after getting that length ok, now we have you have divided this total length it to smaller division; each division it may be 1 centimeter or again in 1 centimeter again, you sub division you can make this 1 millimeter.

So, that is easy task to do because you know this the relation, 1 meter equal to 100 centimeter. So, in that total length here, I have to make 100 division. So, it each division length will be 1 centimeter. Again, I know that 1 centimeter equal to 10 millimeter. So, again in each centimeter that division, I have to divided in to 10 divisions. So, each division equally divide you have to take it. So, each division will be 1 millimeter. So, this is the basically you can make a scale ok, but you have to calibrate it. So, how to calibrate and what is the meaning of this calibration.

So, that with this example, I am trying to say that so, calibration means there is a standard length international standard length of 1 meter, ok. So, your scale whatever you are making, so that length first you have to decide the length for 1 meter or half of it may be 50 centimeter and that length you have to get. So, how much length you will take that length you have to take from this standard one ok.

So, you have to compare with that one and if it is compared comparable with that one, exactly same similar it has to be similar same length ok. So, that is you are calibrating if your scale length is not same as the standard one, there is a maybe there is a if slight difference. So, then your scale is not correct one or it is not calibrated one. So, this just one example I told you, but let us go for common device for measuring different parameters in our laboratory. So, this one is one parameter, most of the times one parameter we have to measure that is temperature.

So, for measuring temperature, so we use thermometer ok. Now, different kinds of thermometers are there. So, one common thermometer you know this is called this in, doctor use this thermometer ok. So, for measuring our this fever. So, fever we define in terms of temperature ok. There is a normal temperature of human body. If the temperature is higher than that, then we have a fever, we have fever. So, that we check with the thermometer right.

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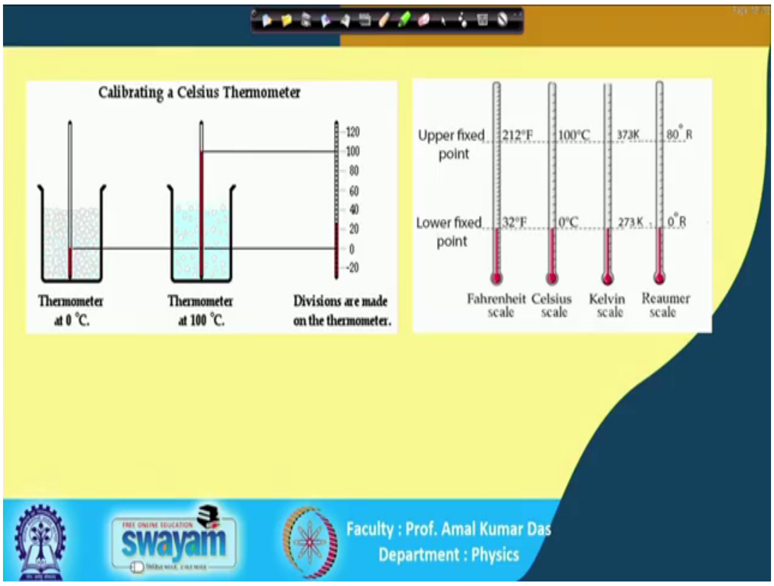

So, thermometer right, so we have seen thermometers and we have used also. So, this generally it is in doctor use this thermometer it is in Fahrenheit, this unit we use that is Fahrenheit and normally in our lab whatever we use that is in centimeter centigrade scale. And another scale Kelvin is there, Reaumer scale is there but Reaumer here where we do not use, but Kelvin we use, centigrade we use also if Fahrenheit we use. So, this scale is you know this not scale this thermometer. So, this thermometer is very simple one. How it works? We tell this mercury thermometer that means, in a glass tube we use this mercury.

So, here whatever rate, we are seeing rate part that is basically mercury, right. So, it if I take a glass tube with small radius and very very small radius and length is I think longer length and if I put the mercury ok, so this mercury position is say here. So, you can use any other liquid also but this mercury is very sensitive to the temperature. In which way, it is sensitive?

So, here mercury this one material, we are using for measuring for making thermometer because this mercury is very sensitive the temperature. If you increase the temperature of the mercury means, if we heat it, then what happens? It is one property changes discount thermal expansion. So, it is expand, it has property it expand with thermal energy when it gets thermal energy or when it is temperature is increased or decreased, it is length changes. It is volume basically changes since we have taken a fixed tube which is having a particular radius. So, this it is area is cross sectional area is fixed ok. So, only length wise, it can change length wise.

So, in this case, we are telling this sets ok. It is a, is linear we are observing linear thermal expansion ok, it is length only getting changed, but actually it is volume getting changed anyway. So, here it is length will change when it is temperature will decrease or increase. So,, so this is the principle.

So, this is the this is the principle of thermal expansion of mercury that is the that is we are utilizing for fabricating your thermometer and that mercury we have taken a tube having a particular cross sectional area and it is length will change in temperature,. So, so now, that is fine. If we put in a thermal bath and change the temperature of the, if we heat it, it is temperature will increase and mercury length upper, upper portion of the mercury upper part of the mercury when it is temperature increase, then upper end of the mercury it will go up.

So, that is means it is because of thermal expansion, it is going up and now trans is that I have to scale it, I have to make division for temperature. So, it may be 1 degree step or 5 degree step whatever. So, that I have to make a scale. So, that is basically scaling it, I have to make scale for temperature. So, you need as I if I mention that for meter scale, you need the standard length of for your one meter, then you can make division. So, in this case also you will you will need standard temperature ok. Now, standard temperature, so, taking help of standard temperature, we can make a scale we can make scale. So, standard temperature, so this ice temperature, let us consider only the Celsius scale and then there is a relation between Fahrenheit and this Kelvin, Reaumer. So, one can make it. So, let us just discuss the Celsius scale.

So, ice temperature that is standard one, international standard that is taken as a 0 degree centigrade and boiled water that temperature of boiled water. So, that temperature is taken as a 100 degree centigrade ok. So, this is the international standard ok. Now so, what I have to do? So, now, I will put, I will put this mercury that that mercury filled this tube in a bath having the ice. So, it is like this ok. So, then just wait for 40 minutes and when this mercury this upper end will be stabilized, it will be at particular, it will not change with time. So, this is stabilized. So, this I have to take as a 0, this I have to take as a 0. And then, I will put in a boiled water and then again I have to wait and see this when this upper end of the mercury will be stabilized means with time it is length it is it will not move upper or down see stabilized so, that I will take as a 100.

So, this is 0 and this is 100. So, this now length is basically 100 degree centigrade. Now, I will make divisions 100 divisions. So, this division will be 1 degree centigrade. So, information is that how I am making this thermometer that is not the important for me. It is the important is that how we are calibrating, how we are calibrating a system ok, it can be meter scale, it can be thermometer, it can be other thing magnetic field, electric field, resistance, etcetera.

So, so there we have to we have to compare with the international standard, it is defined ok. And then, we have to make scale making divided between this two upper and lower end ok. So, or this that is the total length will be this, 100 degree centigrade here 100. So, we can divide equal equally in to 100 division and each division will give you will become 1 degree centigrade, ok.

So, so this way, so this just we have I have one in lab frequent we use.

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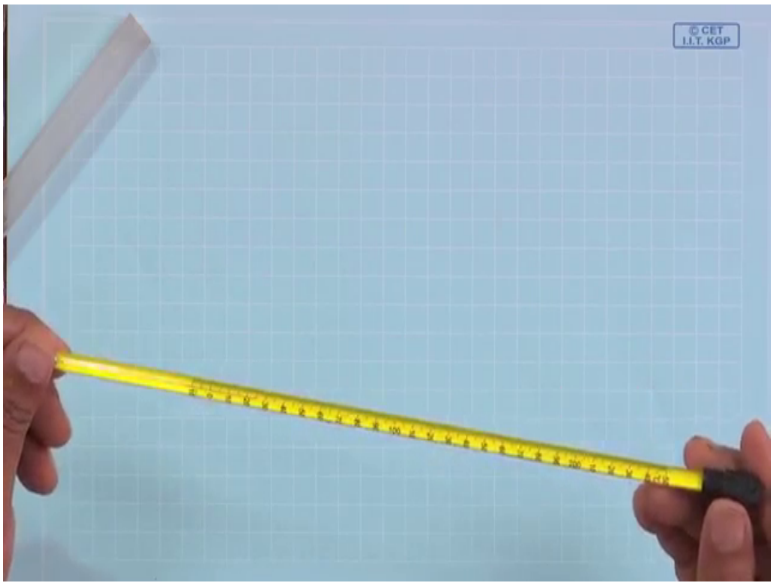

This is the thermometer, it is the scale is 0 to 50 degree here degree centigrade. So, now, question is how it is made here this, here I can see also minus 10 degree and in picture here I am seeing also minus 20 degree. So, I think that if you know this two, 0 and 100 and then you had division now this is 20, this division 0 and this 20, 40, 60, 80, this 100. So, this length is 20. So, below here minus 20, so I can take this equal this length down side, then it is a below 0 degree. So, it will be minus 20, ok.

So, so for calibration basically if you get the length and what is the value of that length and then from there you can extend it, it can be a 120, 140. So, that way you can extend it, ok. So, because you know already they are which for 1 degree what is the length? So, then for 20 minus 20 or 120 plus 120. So, that you can explain the scale, but you have to calibrate with the standard at least here in this case, you need this too ok; that one is ice temperature 0 and another is boiled water temperature that is 100. So, if you compare with these if you compare with the standard, this two temperature and then basically you will find the length for this 100 degree temperature and this other you can just calculate and divide the things and find out.

So, you see this length is not, this now here whatever I am showing you is very this quite big thermometer ok. It is the 50 degree centigrade. So, it is not like meter scale, this length is fixed for 50 degree centigrade ok, here. So, you can also make this same thermometer with the smaller size ok, with the small half of the size or you can make it as a double this, whatever the size you can make it double size ok, double length ok. So, in this case, this length is not fixed. So, for each thermometer if it is the tube that hole ok, it is diameter of cross section are different, then this length will be different for this 100 degree centigrade.

So, depending on the cross section if cross section is higher, then it is for same 100 degree centigrade, temperature length will be smaller because as I mentioned that it is a it depends on the it is expansion is basically volume expansion. Say if cross section area if it is fixed, then length wise it will expand ok. So, for different thermometer basically these cross section are different. So, length will be different.

So,, so for each temperature, one has to calibrate it. Now, I cannot take it is a now calibrated. Now, this I cannot take for calibrating the new another thermometer we have which I am fabricating and it is cross section may not be same as this one, ok. So, taking the length as a calibrated one, so that is not correct for this space. So, with that we have to understand because here length is not important, important is the volume expansion.

So, what will be the length for 100 degree or 50 degree? So, that will depend on the cross section of these holes. So, so this is the one example of calibration; why I am discussing? So, when we are teaching in lab, so there we have seen that when we are doing a experiments. So, there is the one experiment is basically is the assemble of many many small small components, ok. So,, so for what is the aim of the experiment? So, it could calculate to find out some parameter ok.

Thus that is parameter is basically defined the some properties of this of this say material and then for that we have to do different measurement and there this temperature measurement is there. So, as I told this temperature measurement, it can be for it can be for you can use for this commercial thermometer as this is the commercial thermometer or you do not have option to put this thermometer in that geometry experimental geometry.

So, you may need to use other thermometer ok. So, other thermometer you know this another thermometer we use in labs just that is thermo couple ok, thermo couple.

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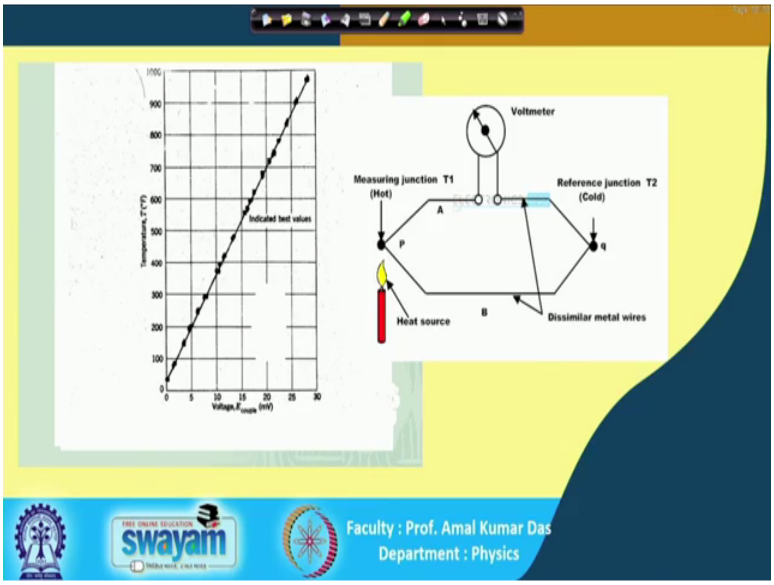

So, thermo couple basically what is thermocouple? This two dissimilar metal if we make two dissimilar metal if we make junction. So, this is may this is the wire of wire A and this wire B. So, it is a wire is made of some metal metal. So, may be copper and this where B is made of some other material. So, this it has to be dissimilar material. So, if you take this two dissimilar material and then this if you make junction here, ok. So, this wire then just squeezed it here. So, then this is one junction and other junction is this one and this. If this two junctions are kept at different temperature, so there is a induced, there is a EMF, thermal EMF produced generated in this in this in this case. So, basically there will be thermal, there will be thermo EMf or this there will be voltage difference between this two junction that we put called thermo EMF, thermal EMF or thermo EMF and if you can measure this thermo EMF if you put this 1 voltmeter here, ok.

So, this, so this is the, you say this is the principle of thermo couple. So, here thermo EMF will be generated if temperature depend between two junctions is there, ok. So, this property will be used for making the thermometer ok. So, this is the, so this one junction you have to keep that say some temperature here or this we are telling cold junction and other one will be at hot junction,.

So, company basically there they will give you this regulate thermocouple this base thermometer and we live it because just there will be meter and there it will show what is the temperature of your sample, but sometimes you can make yourself this type of thermometer, I will show you, I will show you just take two types of wire, this is one wire you see, this is one wire, this is one wire.

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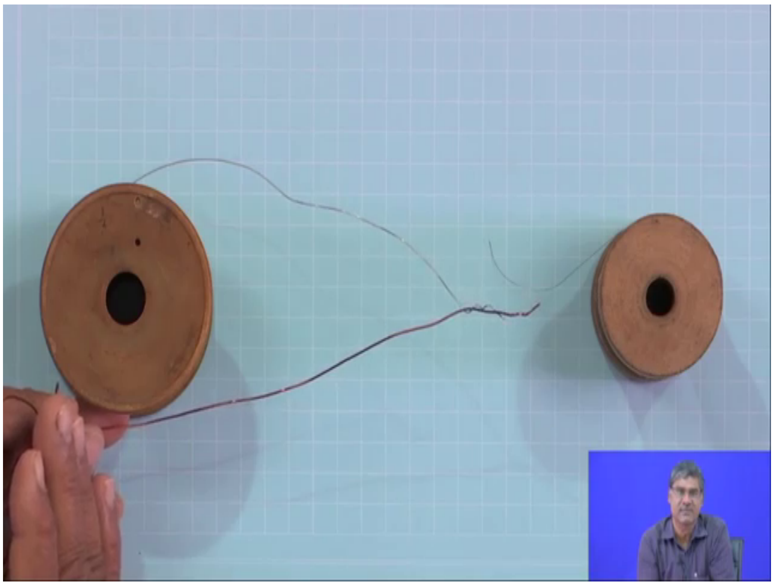

Just I have taken from my lab, this is one wire and you take another wire another type of wire this made of. It is a here, it is written I think from tungsten. There are different again another things we have to consider that your meter thermometer or yeah any whatever measuring instrument it has to be sensitive.

So, there is a combination of wire, chromel, alumel, then I think cons tungsten and this other cons tungsten and these are the copper wire may be. So, this copper wire may be is. So, there is a combination is a given one has to find out. So, if we take this these two type of dissimilar metal, your thermometer will be sensitive means for a small change of temperature ok, your EMF thermal, EMF or thermal EMF this will be that change will be higher ok. So, that way, so this people have given find out. So, that is come from research find out the combination of the dissimilar metal. So, just take two dissimilar metal and then you make it. So, one is copper wire another cons tungsten. So, just make it. This will be just one junction; this will be just one junction, ok.

So, we keep the junction at a low temperature at a low temperature. So, generally we can use as a this cold junction we can put in the ice and then you have to make other end. So, that other end we have to put in say boiled water ok. Now for temp, so or unknown temperature you will put. So, depending, so, then you have to measure the voltage in between we have to connect voltmeter, you will measure the voltage. So, that is a EMF thermal EMF we are telling. So, now, other end if you put, this is in ice and other end is in near to your sample.

So, we will get will get the thermo EMF or voltage in our voltmeter say you will take this reading voltmeter, but this voltmeter whatever reading it is giving, it is not giving temperature. It is giving voltage, but this voltage has relation with the temperature difference between this cold junction and your hot junction where you put which you put at the near your sample.

So, that temperatures, what about the temperature? So, this is 0 and this is some temperature say T. So, because of this temperature difference T, you are getting some voltage V ok. So, so this is the relation between this two, this temperature is change of this hot junction, then you will get the some voltage. So, we are measuring voltage, but I want to know the temperature of this end. So, how to know? So, that is that to know that one you need to do calibration ok. So, before use this thermo couple for measuring temperature, I have to calibrate. So, there it is easy, just you put it at for known temperature say ice temperature and this other end you are putting this say boiled water ok, boiled water then you know this temperature difference is 100 degree centigrade ok.

So, now for 100 degree centigrade, what is the voltage you are getting ok? So, if it is relation is linear, then if it linear this is linear relation is linear, then you can find out directly you can find out this from relation between the voltage and the temperature and calibration factor generally what can find out. So, then, what we tell this is the voltage V for temperature 100 degree ok.

So, for one degree, what will be the change of voltage ok? So, for 1 degree, so the you have to divide by 100 T, you have to divide by T. So, V by T. So, that equal to some c let us write c. So, that is the calibration factor. Now, whenever you will get voltage ok. So, for one degree, what is the voltage you are getting? So, that you know, now whatever the voltage you are getting. So, this actually I have to tell calibration factor whatever tell just it, it has to be opposite.

So, for some voltage V, we are getting the temperature difference is 100. So, this temperature T divided by V that will be that for 1 unit voltage, what is the temperature ok? Now, whatever voltage you will get for unknown temperature, so if you multiply with this calibration factor, then you will. So, that voltage will be converted in to the temperature ok. So, earlier whatever I told then, you have to basically in that case you have to divide it ok.

So, if it is linear so, but you say relation is not linear. So, it is something it is slightly different, linear is non-linear. So, in that case basically you have to take, it is not for only two temperature, one temperature difference. So, you have to take two temperature difference or three temperature difference ok. Generally, we have we take two temperature difference. So, you have to use another temperature, known temperature one can be boiled water; another can be, so other standard temperature.

We have to we have to take or one can take boiled water or not boiled water hot water, but you take help of standard thermometer mercury thermometer and this you keep this water temperature at say 70 degree and take the voltage you keep the temperature at 100 degree, take the voltage. So, so because in this case, you are using the standard thermometer which is already calibrated and taking help of this thermometer. So, your you are calibrating your thermocouple. So, this way one has to calibrate and this is very important because if it is commercially available, you have to understand how it works. If it is, it is you have to make it because experimental geometry sometimes it does not allow the standard thermometer ok. So, we have to, fabricate yourself and when you are going to fabricate here, you should have clear idea, ok.

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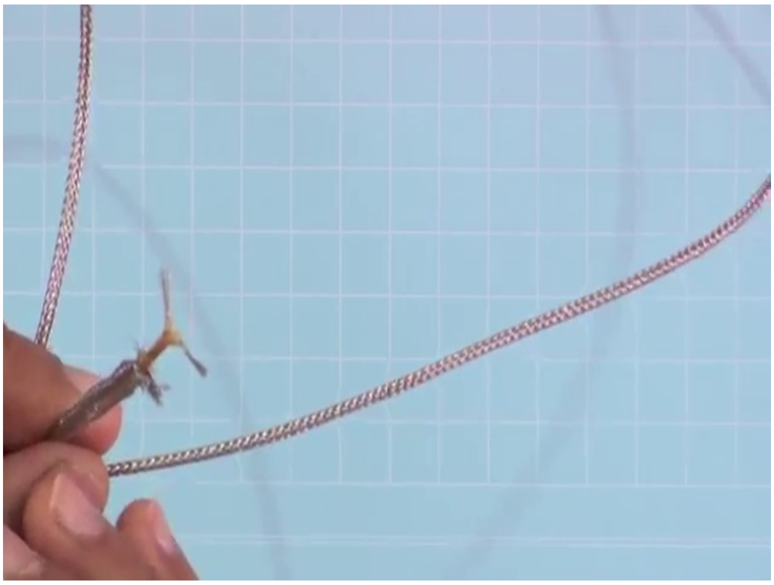

So, here they all commercial also thermo couple is used, but it is not thermo couple, it is not calibrated one. So, this commercially available thermo couple, so just it was in my lab I. So, here inside this two wires are there, two dissimilar wires wires are there. They are basically isolated one here you see this two. So, I do not know whether I can show you this no no, here I think. So, other end it is you say, it is you know probably can you see this I think I, is it two holes are there, this two you see is two holes are there yes, ok. So, two wires, two types of dissimilar wires you see here you know.

So, they are nicely they have this they are isolated, but they have make nicely with some coercive, there are some regions why they have use this type of wires. I say, there are some particular geometry experimental geometry where we have to put it and then there will be heat generations so that heat should transmit to the other place and so, that way this type of thermo couple this cohering with cohering will be helpful for that geometry. So, this is the commercial thermo couple is used is available. Now, this type of thermocouple we use in our lab but in this case again it is not calibrated one. You have to calibrate, you have to make this two junction; here one junction and other end here one junction, in between we should have. So, basically you have to, then you have to use your voltmeter.

So, one junction we made it ok, junction and other junction basically taking the third wire ok. So, if we put third wire, there should, there will not be change there is a theory. So, we use voltmeter to measure the EMF, ok. So, before using that one as I told once, you have to keep at different temperature at this and what will be the voltage for this known temperature and we have to calibrate first and then you can use it for measuring unknown temperature ok. So, this is the calibration of the instrument.

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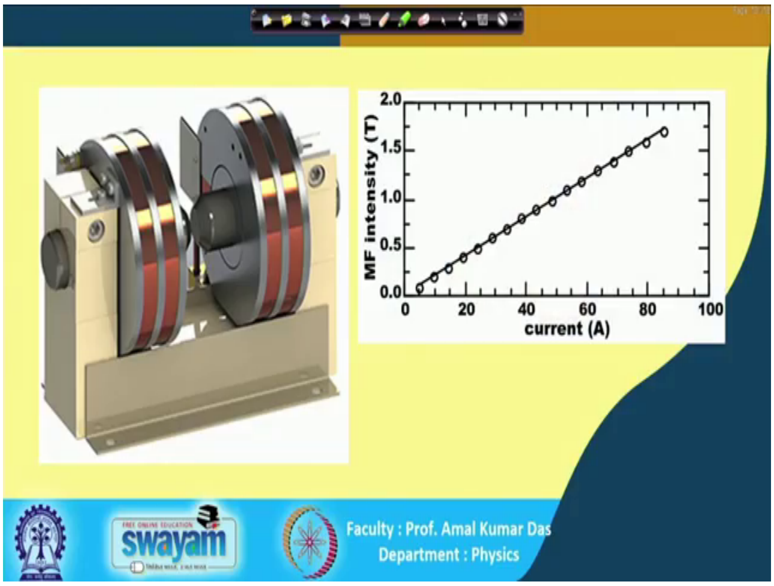

And another if you want is not magnetic field thermometer that this magnet electromagnet. So, how to again, there are two coils, there are two coils placed and this pole pieces are there. Now, if you first find through these coils and then there will be magnetic field between this two pole pieces again. So, what is the relation between the current and magnetic field?

So, to know that one, you have to you have to you have to you have to measure the magnetic field here. So, again you have to take some standard this as called Gauss meter of Tesla meter some standard meter which can measure the magnetic field. So, you have to place that meter here and that will give you the magnetic magnetic field for different current. So, so you have to calibrate here what you are calibrating? You are calibrating this magnet for a particular distance between the pole pieces. So, in that case, you are varying the current and measuring the magnetic field using some standard Gauss meter or Tesla meter and you are plotting plotting this in this graph and here it looks very linear. So, this way also we calibrate. So, it is not just one or two, three reading. There are many readings and then we plot with say here it is showing linear relation. So, if we plot then, next time you do not need this Tesla meter. So, because this magnet is calibrated means if I know the temperature know the current, then from here I can tell what is the magnetic field. So, this is the. So, frequently in lab frequently this type of calibration we have to do and we have to use because in experimental geometry, you will not be able to put the Tesla meter they are during experiment.

So, only you can change the current of this and in that field you have put sample. So, there you have no place to put this thermo Tesla meter or Gauss meter ok. So, because that is the restriction of this of the geometry of the experiment and in that case you have only option to calibrate this magnet first and then you remove this tesla meter and you start your experiment.

Then whenever you are changing the current and but you are not interested about the current, you are interested for that current what is the magnetic field. So, from this curve we will get the magnetic field. So, I just discuss few examples, but there are many things many examples and in laboratory, you will see this we will we need to calibrate this is very one important themes one should know.

So, that is why I separately I discuss this calibration of the instrument because otherwise this will be missing when we will we will do a particular experiment and there are many components and we will not be emphasize, we will not be able to emphasize on this on this calibration things, but this is very important ok. So, I think this about the calibration. I will stop discussion.

Thank you very much.