Industrial Instrumentation
Prof. A. Barua
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 27
Measurement of Magnetic Field

(Refer Slide Time: 00:30)

Lesson 27 of industrial instrumentation, in this particular lesson, we will study basically measurement of magnetic field. Basically 2 sensors will consider here though the title of the lesson is measurement of magnetic field. But you will find that especially the sensor second sensors which we had. So, we will study the measurement of current measurement of power all those things. But the first sensors we that is the search coil is basically used for measurement of magnetic field. And second one is the Hall Effect transducers that will that can be used for measurement of magnetic field as well as current.

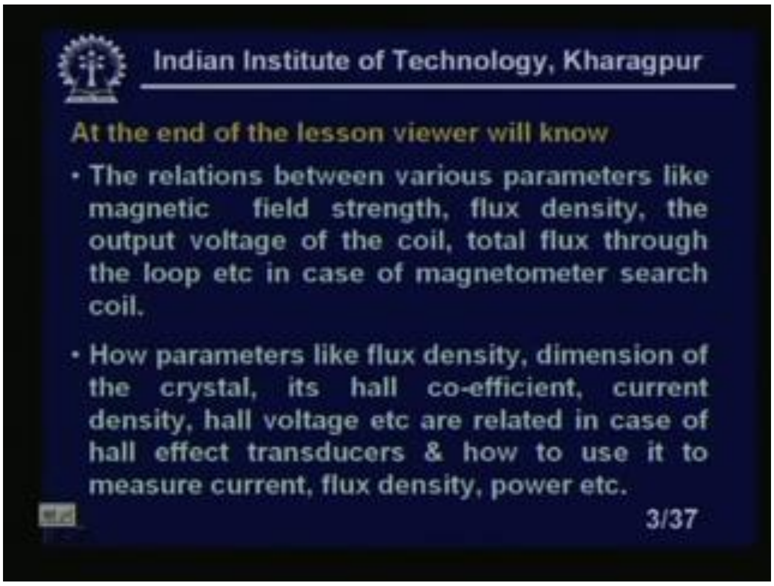
In fact, we will find that this particular sensors is extensively utilized thought it is named that it is used for the measurement of magnetic field. But you will find that it is extensively used for the measurement of currents especially the high current as well as the measurement of position of the proximity sensor. Measurement of power multiplications of the 2 signals these all those things we will see the, what of the different application areas of these hall effect transducers?

(Refer Slide Time: 01:54)

(Refer Slide Time: 01:56)

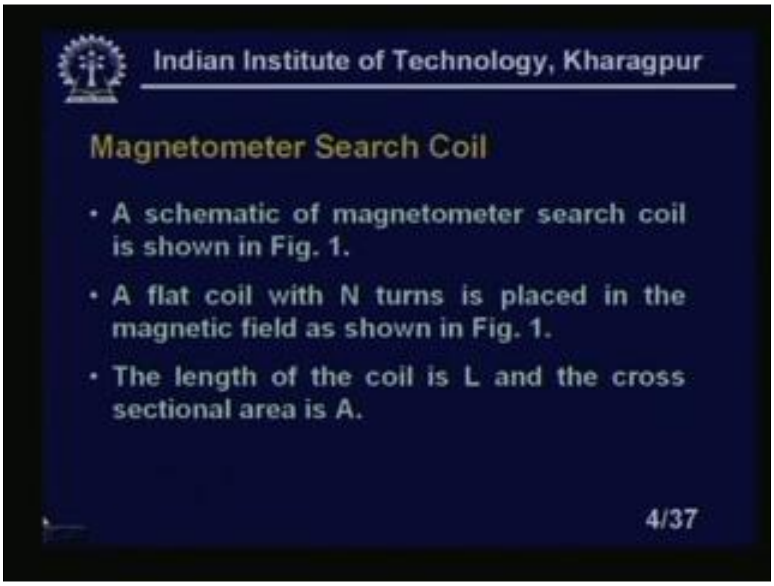
Let us look at the contents and all those things. Contents are search coil magnetometer search coil will basically discussed here. So, magnetometer search coil looks like this that you have a as we know that if a magnetic field that if you move some coil anywhere some voltage will be developed. So, using that, principles that voltage will be measured and that voltage will be calibrated in terms of terms of the magnetic field right. If the other things remains constants; obviously, we will find that the output voltage will be directly proportional to the magnetic field. So, that is the search coil or magnetometer search coil sometimes people called magnetometer search coil sometimes we call it simple search coil right. And second transducer we will considering in details is the hall, effect transducers right.

(Refer Slide Time: 02:51)



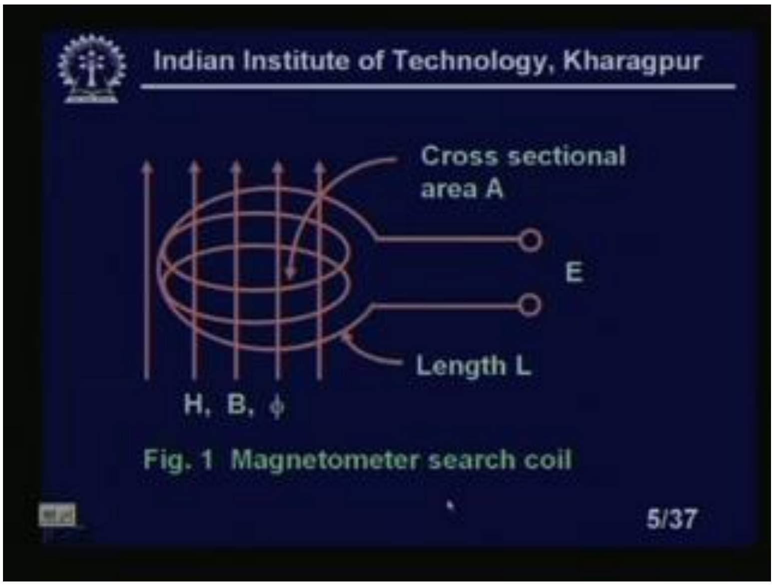
At the end of the lesson the viewer will know the relation between various parameters like the magnetic field strength, flux density. The output voltage of the coil total flux through the loop etcetera in case of magnetometer search coil right. So, this thing basically will know and in the case of in the case of Hall Effect transducers. We will know the how parameters like flux density, dimension of the crystal, its hall coefficient current density, hall voltage etcetera are related. In case of Hall Effect transducers and how to use it to measure the current flux density power etcetera will also study in this particular lesson.

(Refer Slide Time: 03:41)



Now, magnetometer search coil is basis principle is something like this a schematic of magnetometer search coil is shown in figure 1. A flat coil let us go back and see this one then will this come again here.

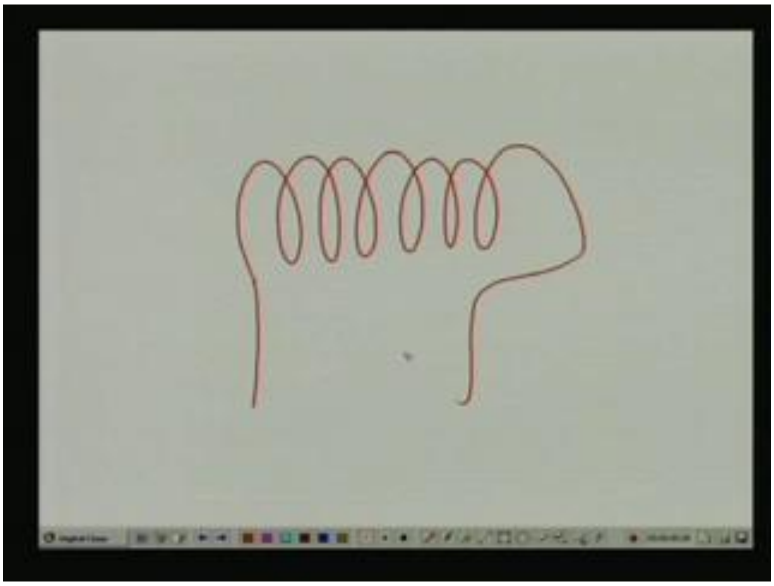
(Refer Slide Time: 04:00)



See this is the a coil which is and it is placed under magnetic field right and its cross sectional area is A length is L, and I am getting output voltage here E. Actually these output voltage is to be to get some output voltage, please go the 2 things is important either the magnetic field must vary or this coil was change its position. There should be some movement of the coil there is 2 option by which I will get a nonzero output voltage. One is that either H or B if the H varies, because as you know B equal to mu H H or B will vary or the position of the coil will vary.

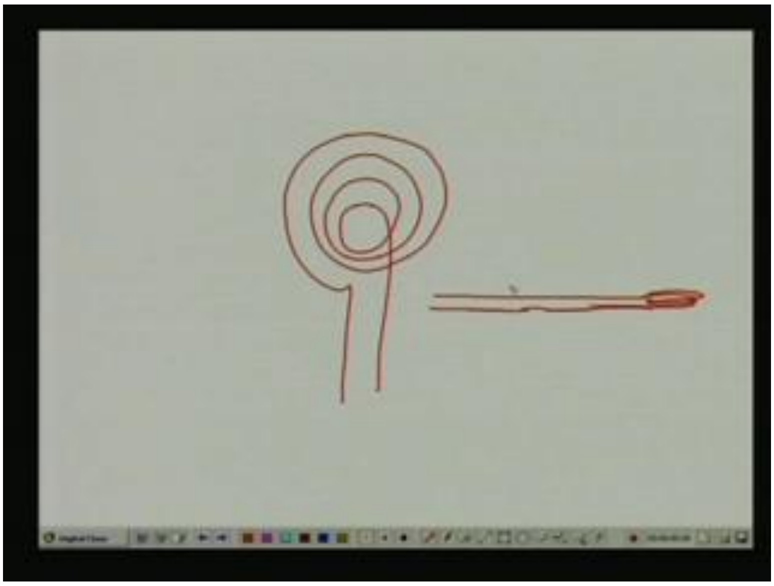
Then only I will get a nonzero output voltage this output voltage can be calibrated in the terms of the magnetic field. So, that is the basis principles of the magnetometer search coil. Let us go back to the previous slide right. So, schematic of magnetometer search coil is shown in figure 1 that is already we had shown right. A flat coil with N turns is placed in the magnetic field as shown in figure right is a flat coil please note its coil can be 2 types as you know. What is that flat coil placed let us go back and see a flat coil means like this.

(Refer Slide Time: 05:28)



The, you know the coil can be wound on a and it have a shape like this one. It can be I will usually before making inductance you make like this one right and a coil can be like this one also.

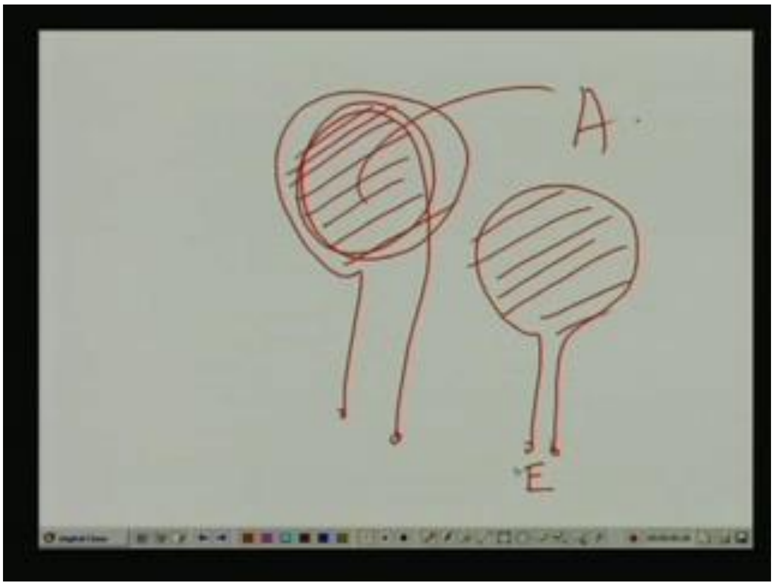
(Refer Slide Time: 05:46)



That insole a same I mean plane I can have the several turn; that means, I have can have a several turn of the coil. If I look from the side it will have a just a several length of the wires and which is coming right. So, it will look like this one that is the reason we calling it flat coil there is some reasons why we are calling all these flat. If it is the dimensions of the coil is very important to properly predict the output voltage. If though we will calibrate the instrument, but that is very important.

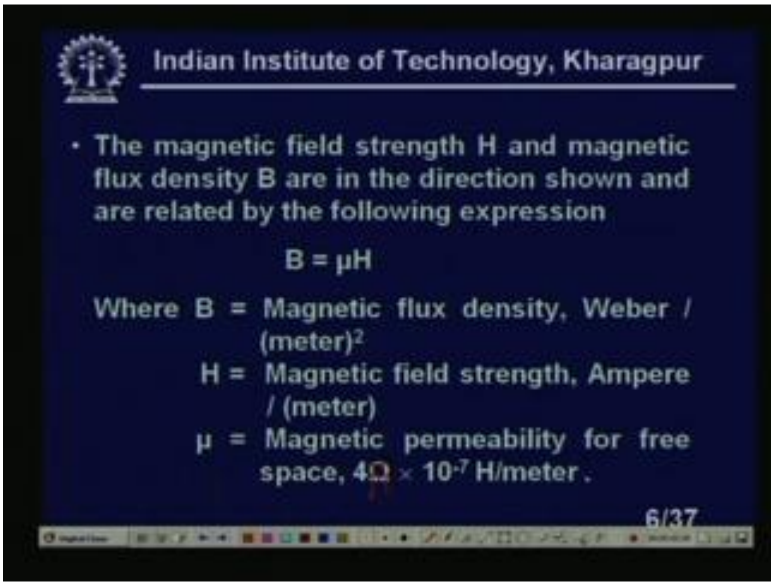
A flat coil with N number of turns is placed in the magnetic field as shown in figure 1 right N numbers of turns of there it is a flat coil. Obviously, the more number of turns I will get more output voltage that is also very important. But as we increase the number of turns the size of the coil also will increase the whole flatness. Whatever we are assuming that will be valid and more over the weight of the coil also will be quite large. So, that creates other problems. The length of the coil is L and the cross sectional area is A right. What is this cross sectional area let us again look at.

(Refer Slide Time: 07:12)



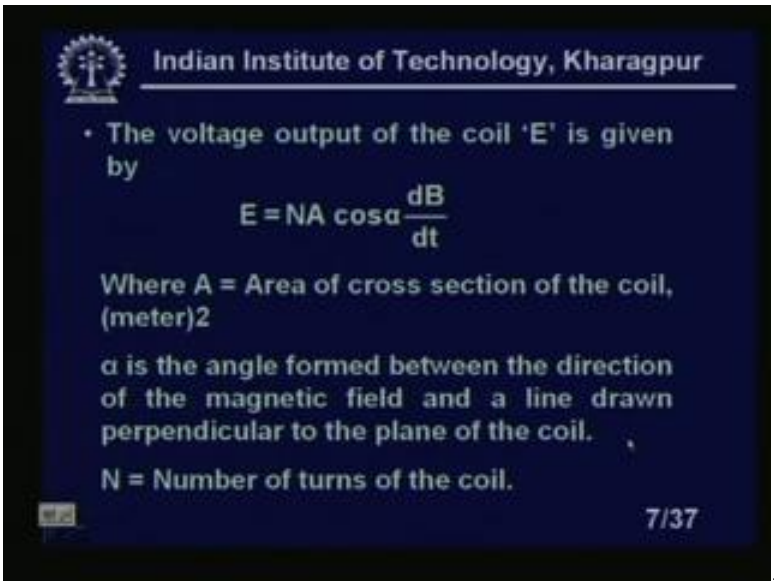
I want to mean that suppose I have a coil of N turns. So, this filled up area I am taking of the cross sectional area. A right this cross sectional area of the well. And it is not the cross sectional of the wire by which I am making the coil it is a cross sectional area of the coils; that means, if I just simply drown 1 simply look like this one right. So, I am taking of the this cross this is our cross sectional area this is the output voltage I will measure right which will be calibrated in terms of magnetic field. So, length of the coil is L and the cross sectional area is A will all talk about SI unit A. So, this is the all we will talked about. It is a flux density corrected to magnetic field H by mu and this is the cross sectional area A this E output voltage which is coming from the coil.

(Refer Slide Time: 08:21)



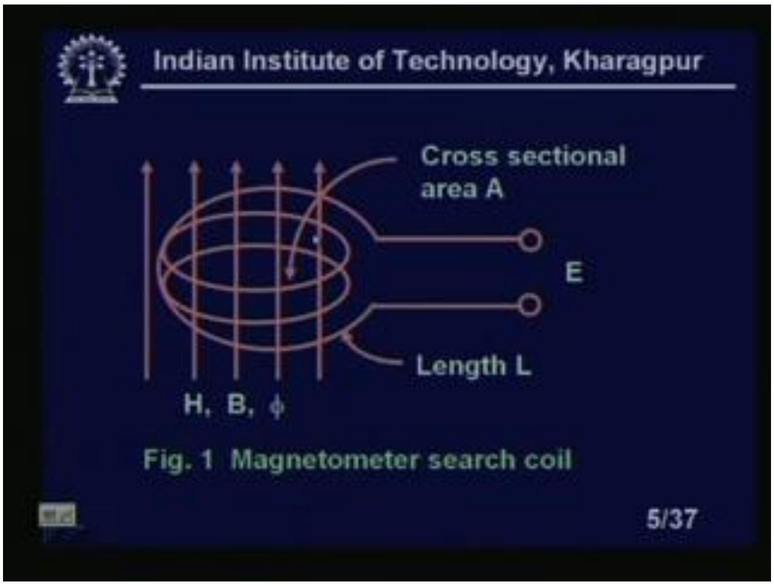
The magnetic field strength H and magnetic flux density B are in the direction shown and are related by the following expression. We have already shown the same direction it is working you see magnetic field is also working in this directions flux density is also; obviously, work in the same directions right. So, the magnetic field strength H and the magnetic flux density B are in the direction shown, and are related by the following expressions B equal to mu into H. What are these where B is a flux magnetic flux density which is in Weber per meter square Weber per meter square. And H is a magnetic field strength which we want to measure that is ampere per meter right. We are interested to measure the magnetic field strength and mu is a magnetic permeability for the free space which is 4 pi. I am sorry this will be 4 pi. This will be 4 pi into 10 to the power minus 7 Henry per meter 4 pi 10 to the power minus 7 Henry per meter right.

(Refer Slide Time: 09:44)



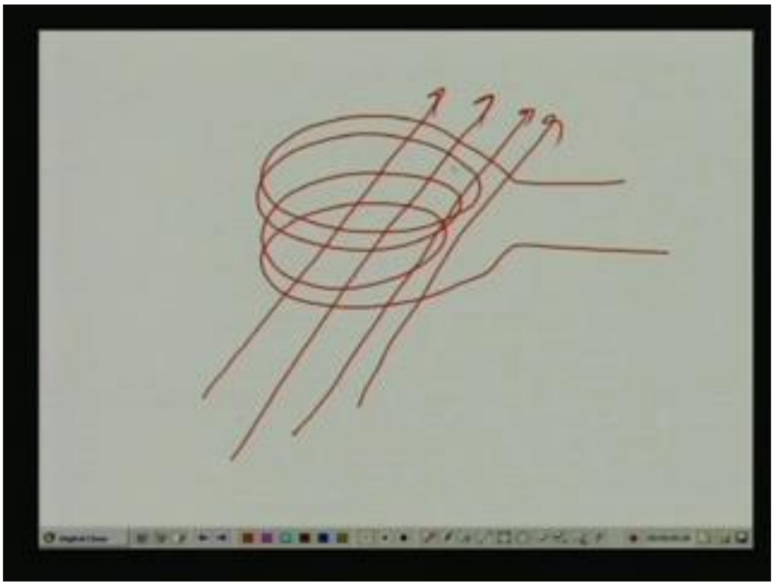
So, the voltage output of the coil E is given by now you see one thing is very important you see here in the previous slide we are interested in the measurements of H right. The how much is the magnetic field actually the value of B this point be constant this coming from some magnetic material. The value of H depending on the medium whatever the mediums, which we are applying these, magnetic field I will get a value of B. So, B B may vary depending on the particular medium suppose in water I have some difference value of B; obviously, mu will vary in the free space. We will have different value of B because mu will some other value, but H will remain constant is for some specific application. So, we are more interested to measure the H rather than the measurement of flux density, clear? The voltage output of the coil E is given by E equal to NA into cos alpha into dB by dt suddenly why how come this alpha came?

(Refer Slide Time: 11:01)



Actually we are assuming in the actual diagram you see if I go back to the diagram I have shown I have shown it like that. That H is perpendicular to the plane of the flat coil is not it. You see the H is perpendicular to the plane of the flat coil, but that is not the fact that be not be the fact though it is also less desirable, that it should be perpendicular that is output will be higher.

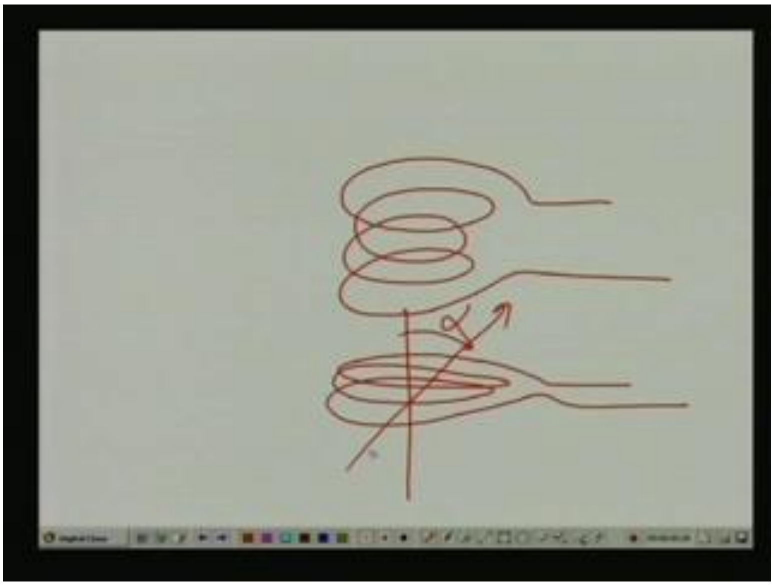
(Refer Slide Time: 11:32)



If it comes in an angle that; that means, I am saying if it comes in angle like this 1. So, I have suppose I have a. So, I am applying this magnetic field like this 1 suppose the magnetic field which is making an angle alpha right. So, I am taking of that alpha please note right. Again I am remain reminding this is pi naught omega the voltage output of the coil E is given by E equal to N into A into cos alpha into dB by dt.

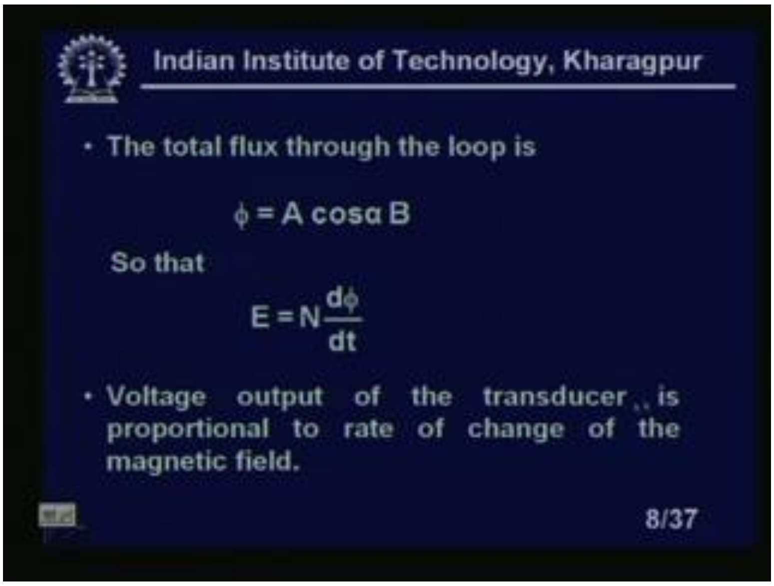
That is derivative of the flux density with respect to time. Now; obviously, it will be dH by dt, because mu will come out which is to be constant for a medium. Where A is the area of cross section of the coil, which is in meter square; obviously, in SI unit and alpha is the angle formed between the directions of the magnetic field. And a line drawn perpendicular to the plane of the coil just what I have whatever I have shown. What is that exactly like this one?

(Refer Slide Time: 12:54)



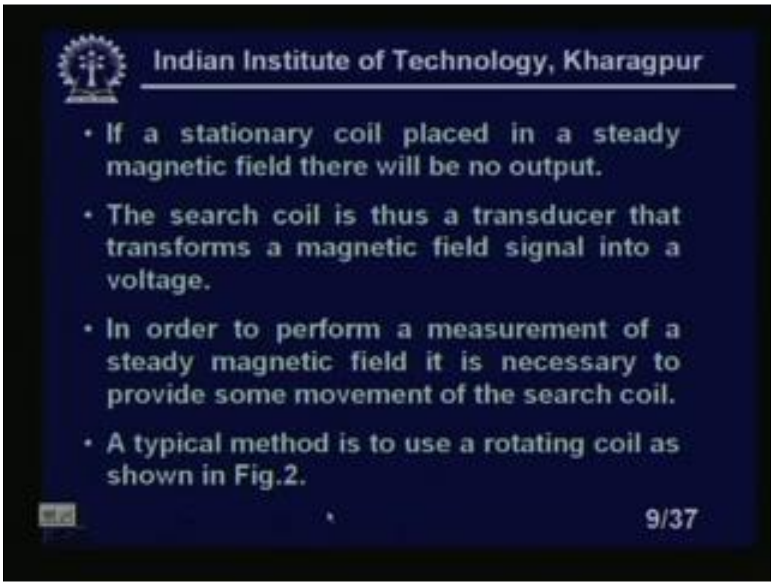
Just I have shown; that means, the I have a coil here even though I could not draw it in a single plane we assume that it is in a single plane. So, this is the perpendicular to the plane. So, this is our alpha clear or this is our now alpha is the angle formed between the directions of the magnetic field and a line drawn perpendicular the, to the plane of the coil, clear? N is the number of turns of the coil as we increase the number of turns; obviously, the output voltage will increase that I told you earlier also. If you A increase, because, but the magnetometer search coil is usually we are of this small dimensions. Because it is very easy to say that the, if you increase A, you will have the I mean larger value of the output voltage. But if you think of the large A keeping the shape of the, that entire coil intact I mean a large A and rotating it at a high speed it is not very task right.

(Refer Slide Time: 14:03)



The total flux through the loop is; that means, the loop of the coil is given by phi equal to A cos alpha into B right this is the total flux in the loop. So, that E equal to N d phi by dt; that means, derivative of phi into dt that is; obviously, always is not I mean voltage. That will be N multiplied by d phi by dt if it is an angle A cos alpha right. So, voltage output of the transducer is proportional to the rate of change of magnetic field as you rotate it in a high speed. So, the, you output voltage also will that mean rate of change of flux will be directly proportional to the output voltage faster the rate of change of flux through the coil; that means, faster rate if it is rotates I will get the larger output voltage. So, that is we are telling voltage output of the transducer is proportional to the rate of change of the magnetic field.

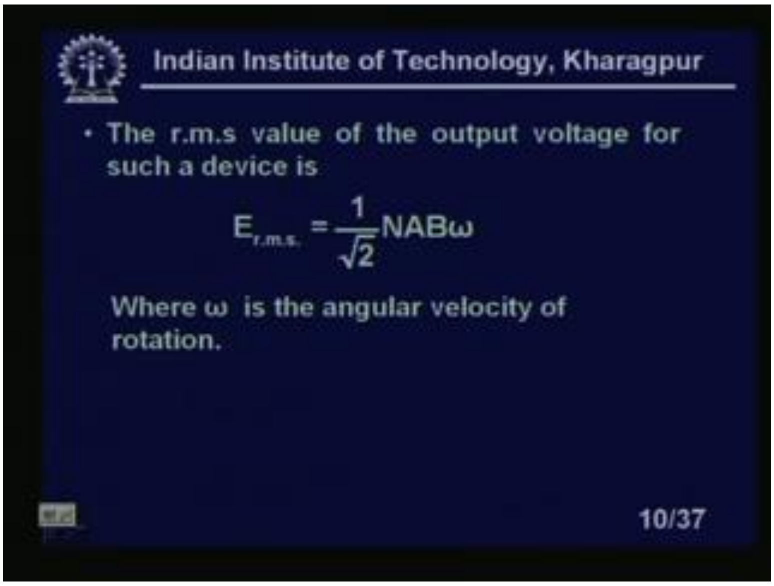
(Refer Slide Time: 15:02)



If a stationary coil now is placed in a steady state magnetic field; that means, a DC magnetic field. That means, a field which is produced by a DC voltage or a permanent magnate there will be no output voltage, because d phi by dt will be 0. So, there will be no change of flux no variations of the flux with respect to time. So, the output voltage will be; obviously, 0. That we can see, because we have seen this part will be 0. So, output voltage will be 0. The search coil is thus a transducer that transforms a magnetic field signal into a voltage. That means, it converts the magnetic field into z voltage which is can be easily transmitted can be converted to the digital domain. So, all those things facilities are already there which can be easily calibrated also if you have a standard magnetic field.

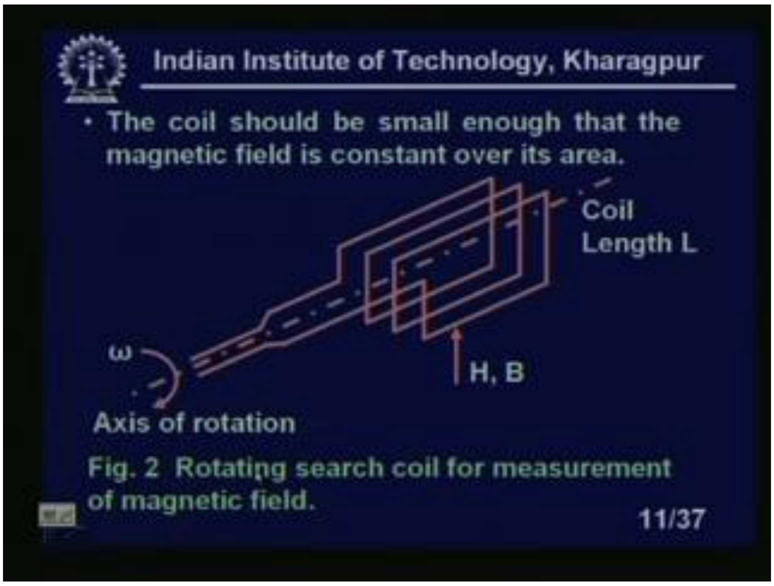
In order to perform a measurement of a steady magnetic field it is necessary to provide some movement of the search coil quite. Obviously, as I told you if it is steady that is the first bullet you see if this is a stationary. Obviously, if it is a stationary placed magnetic field no output or you will not get any output right. So, in order to perform a measurement of a steady magnetic field it is necessary to provide some movement of the search coil right. Some movement of the search coil will be necessary. So, I cannot change the magnetic field which I am going to measure. So; obviously, I have to make some movement of the coil. How let us look at how actually I am doing? A typical method is to use a rotating coil as shown in the figures with some motors and it will rotate at continuous speed.

(Refer Slide Time: 17:00)



So, let us look at that the rms value of the output voltage for such a device will be given by E rms 1 by root 2 NAB into omega. What are the other things, what are the regions where omega is the angular velocity of rotation of the coil the figures I will show you. Let us go back to figure first because it is very reticules if I see this is our coil.

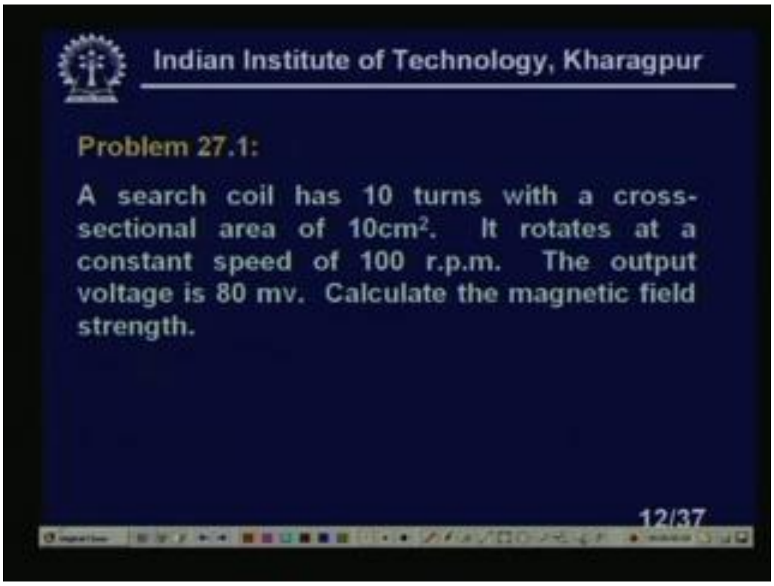
(Refer Slide Time: 17:28)



It is again flat coil in turn flat coils. So, it is rotating by angular speed of omega you see angular axis of rotation. So, it is continuously rotating I have placed. This entire coil is placed in a magnetic field of H with flux density B the coil is of length L. So, it will produce the output voltage which will be measured at this 2 terminals which term which are those terminals this terminals I will get the output voltage B, clear? So, this will be the output voltage E let us go back the search coil is thus a transducer that transforms a magnetic field signal into a voltage. And in order to perform a measurement of a steady magnetic field it is necessary to provide some movement of the search coil. So, some movement of the search coil is necessary that actually I am doing in the figure 2 as I have shown right. So, this is our coil now there is some constraint here please note 1 thing that the constraint is that first of all the coils should be of small size.

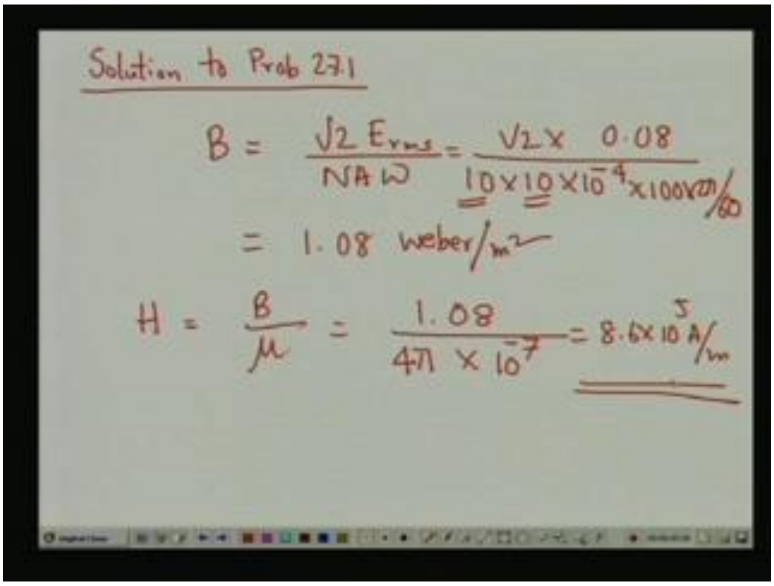
And the dimensions of the coil should be very well known. The exact precise geometry of the coil should be known to predict the value of the output voltage. And as I told you the smaller the size of the coil; obviously, you will get the better results. That you must be mention I mean it is worthy to mention that the size of the coil should be very, very small. So, this is the constraint that the coil should be small enough the magnetic field constant over its area. And this coil should move in a sufficiently high speed right this is another important thing to get a steady state value.

(Refer Slide Time: 19:58)



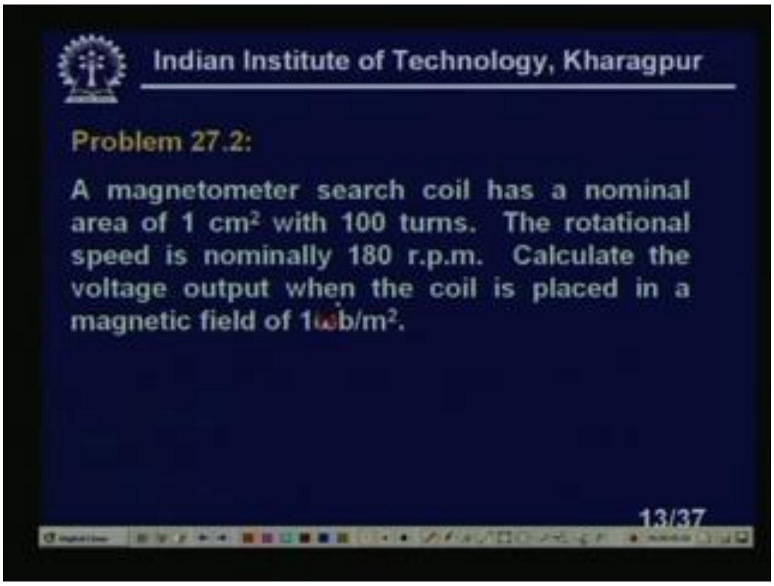
Now, let us solve some problem. So, that we will be more comfortable in the, so the problem is a search coil has 10 turns and with a cross sectional area of 10 centimeter square. It rotates at a constant speed of hundred revulsion per minute the output voltage is eighty mille volt calculate the magnetic field strength. Let us take a white page I will give the solution to this.

(Refer Slide Time: 20:29)



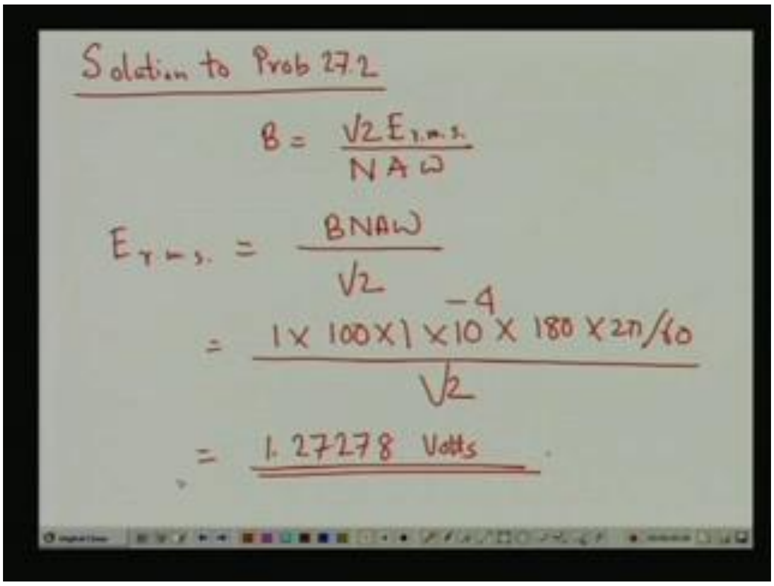
So, this is the solution to problem 27.1 like this 1 you see it is given that B equal to root 2 E rms by NA omega. So, which will be root 2 into 0.08 by 10 it is 10 centimeter square the cross sectional area number of turns 10 right. So, the, it is in the centimeter square. So, it is converted in the meter square. So, 10 to the power minus 4, so it you see this is the number of turns right this is the dimension in the problem it is given 10 centimeter square, clear? So, I convert it in the meter into 100 because it is 100 multiplied by 2 pi by 60. So, which will give you 1.08 Weber per meter square? So, the H will be given by B by mu which will be given by 1.08 divided by 4 pi into 10 to the power minus 7 10 to the power minus 7 into 8.6 10 to the power 5 ampere per meter right. This is the problem number solution to the problem number 27.1 right we have another problem.

(Refer Slide Time: 22:46)



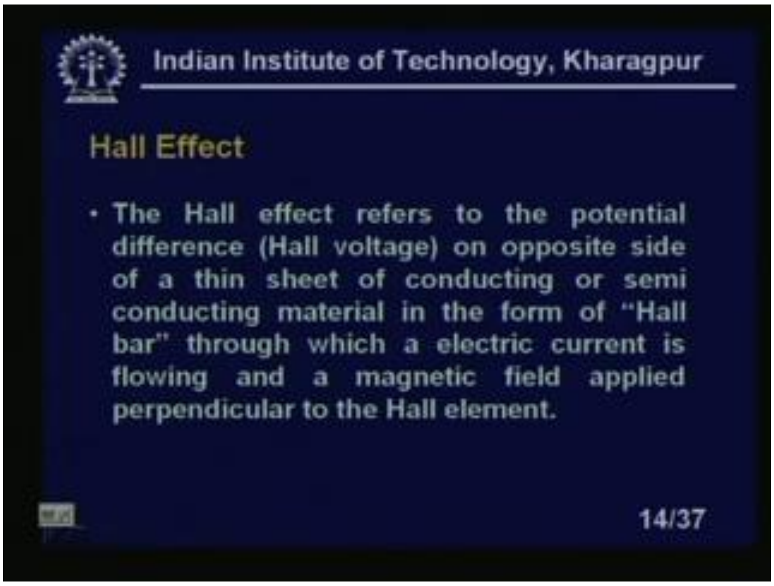
This is the problem 27.2. The problem is a magnetometer search coil has a nominal area of 1 centimeter square with 100 turns the rotational speed is nominally at 180 rpm. Calculate the voltage of output when the coil is placed in a magnetic field of 1 Weber by meter square please note it is not omega this is W right. And this will be simply W or I should take please note this is W right Weber per meter square. So, let us make the solution of this problem. So, again I am telling this is W.

(Refer Slide Time: 23:33)



So, again you see the solution to problem 27.2, B equal to root 2 E rms NAW E rms equal to BNA omega by root 2 you see it is 1 then, because it is 1 centimeter square. So, multiplied by 100 turns right into magnetic field is the this is the B is 1 Weber. So, it is 1 N is 100 into 1 converted into meter square 10 to the power minus 4 multiplied by 180 excuse me 2 pi by 60 divided by root 2. So, this will give you 1.27278 volts right. So, this is the solution to the problem 27.2 right. So, we have solved 2 problems.

(Refer Slide Time: 25:34)

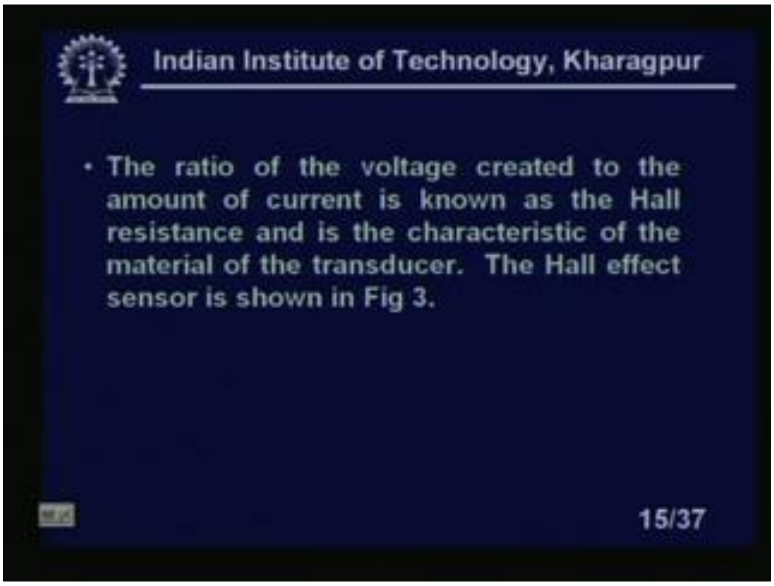


Now, let us come to the more I mean I mean the other sensors rather I should not I mean say this is the more important and that is the less important. We have this you see this is even though which is very easy to tell that you rotate the magnetic field I mean coil all those things. It is not very easy to do that and its dimensions everything is very I mean very difficult to predict all those values. So, people what they do, because we have much better sensors much better devices which is called the Hall Effect transducers. It is actually developed by the 1 scientist engineer I should say name is Edwin Hall.

So, the name also the sensor is also given Hall Effect actually this effect he discovered do while during the other experiment. And the sensors later came I mean came on. So, the sensors also named under him; that means, the hall effect transducers or hall effect sensor now what is hall effect let us look at. The Hall Effect refers to the potential difference which is calling? We are calling hall voltage on opposite side of a thin sheet of conducting or semi conducting material in the form of hall bar through which a electric current is flowing. And a magnetic field is applied perpendicular to the hall element. I will repeat it I am a bar looks like this 1, if I take this 1 as a I mean I mean many times amplified. So, something like that; that means, I will apply a magnetic field which is coming through this and going out this right.

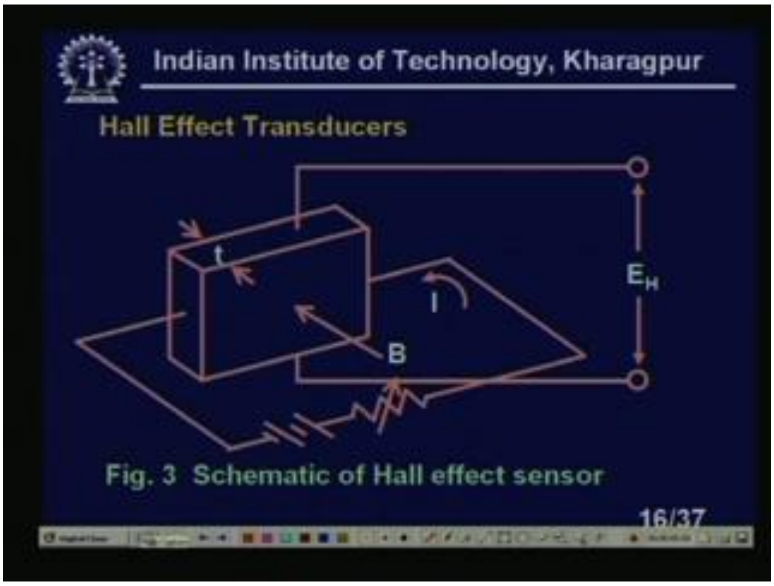
I am applying a current electric current, which is entering through this and going out of this; that means, I have applied some voltages. That is the reason the some current is flowing. If I apply a voltage I mean magnetic field here you will find that across these 2 surface these and this the potential will be developed. That potential is actually we are calling it a hall coefficient right hall voltage rather. So, the Hall Effect refers to the potential difference all hall voltage on opposite side of a thin sheet of conducting or semi conducting material in the form of a hall bar through which electric current is flowing. And a magnetic field applied perpendicular to the hall element.

(Refer Slide Time: 27:58)



The ratio of the voltage created to the amount of current is known as the hall resistance. And the characteristics of the material of the this is the characteristics of the material of the transducers and the hall effect sensors is shown in figure 3.

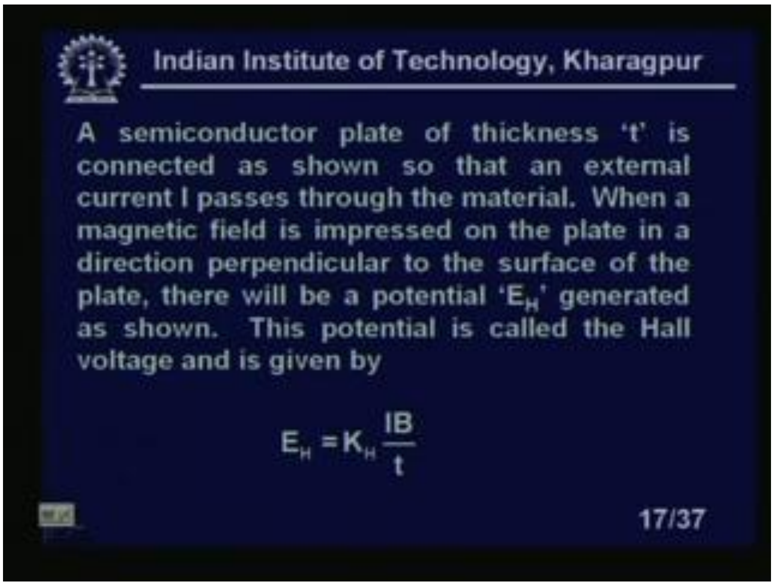
(Refer Slide Time: 28:16)



Let us look at Hall Effect transducers this is our Hall Effect transducer this is a thin metal plate of thickness t. So, I applied a voltage B sorry a potential B and you see this is a basically a Lorentz I mean Lorentz effect will come. In fact, some people say that the current carrying. That the current actually carrying by the electrons the actually that is first proved by the hall Edwin Hall right. So, I am applying a potential here. So, battery you see the current is flowing through this 1.

And some voltage will be developed across this that is I have shown like this 1, clear? Very clear, I will look at this 1 the same thing I am applying a magnetic field here. That means I am applying magnetic field here a current is flowing through this 1 applying current it is coming and it is going out through this right. So, hall potentials if you take these 2 terminals voltage will be developed that voltage is called as a hall voltage clear again right. So, it should be sufficiently thin.

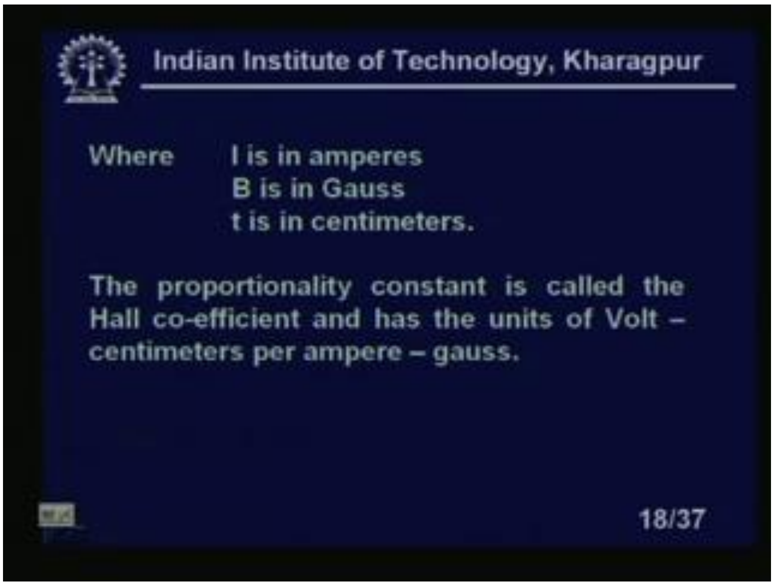
(Refer Slide Time: 29:35)



A semiconductor plate actually you will find that the hall coefficients or hall voltage is moved predominant in the case of semiconductor though in the all metals supposed to have some I mean hall voltage. But you will in the case of semiconductor this is more predominant. A semiconductor plate of thickness t is connected as shown. So, that an external current I passes through the material due to some battery voltage and when a magnetic field is impressed on the plate in a direction perpendicular to the surface of the plate. There will be a potential EH the, that is the hall voltage is subscript it generated as shown.

This potential is called the hall voltage and is given by EH equal to KH into I into B by t. This is our expressions of the hall voltage right. So, a semiconductor plate as a I told you it will have a larger value of the hall voltages the hall voltage of thickness t is connected as shown. So, that an external current I passes through the material when a magnetic field is impressed on the plate in a direction perpendicular to the surface of the plate. There will be a potential EH generated as shown and this potential is called the hall voltage and is given by EH and KH IB divided by t, clear?

(Refer Slide Time: 31:03)



Where I is in amperes B is in gauss and t is in centimeters right the proportionality constant is called the hall coefficient. And has the units of volt centimeters per ampere gauss right. So, it is a hall coefficients and is the characteristics of the particular material bar has the unit of the volt centimeters per ampere gauss.

(Refer Slide Time: 31:32)

Hall effect device produce a very low signal level. So, that it is to be amplified. So, it needs an amplifications, because the voltage is very, very small please note it it is not a very large voltage. So, it could amplifier known as amplifier is necessary though the voltage DC. So, that simplifies a lot of problem right. Hall Effect sensors are in fact, a device containing both the sensors described. And a high gain IC amplifier in a single package. Nowadays, these are made I think in 1000s and 1000s, because of the, because the hall effect transducers. We can see that if I know the, if I can predict that EH I can measure the current also it is not it if I know the potential let us go back it will be, clear? You see here if I know the EH of the material if I know the B if I know the, if I i know the EH if I can measure the EH. This EH can be calibrated in terms of I is not it if the, I is unknown.

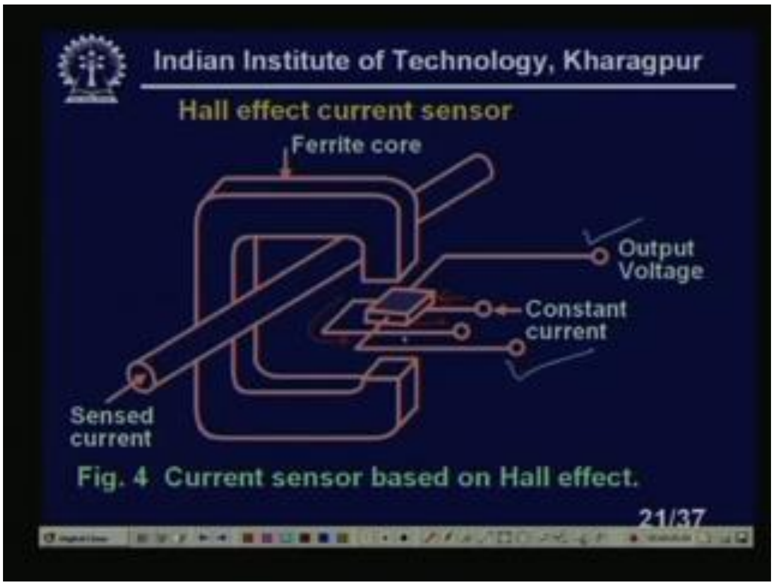
So, by measuring EH I can tell the, I clear because this is the only thing variable. So, it Hall Effect sensors the, that is the reason hall effect sensor are extensively used for measurement of current large current very large current around 500 amperes and all those things. There are various types of Hall Effect sensors are also used and more over suppose if this I is constant if I can vary B I can use this Hall Effect voltage EH to use it for proximity sensor, clear? How let us look at Hall Effect sensors are in fact, a device containing both the sensor and described and a high gain IC amplifier in a single package.

(Refer Slide Time: 33:33)

Advantage of the hall effect sensor hall effect devices when appropriately packaged are immune to dust dirt mud and water in many places in hostile environments I may use this. It does not depend on how much dirty it is, it will work same right calibration I do not have to recalibrate the instrument that is the great advantage of the. So, Hall Effect devices when appropriately packaged or immune to dust dirt mud and water. So, any is that type of environments I can use this Hall Effect sensor especially for the measurement of current. That is it is most extensive nowadays not for the used not for the measurement of magnetic field though we only just started this lesson. And, so I said that the, I mean measurement of we are actually we are discussing the measurement of magnetic field.

You please note this since it is Hall Effect transducers; we are actually discussing historically actually the all effect transducers are used for measurement of magnetic field. But it is nowadays extensively used for measurement of current excuse me. These characteristics make Hall Effect devices superior for position sensing. This is another important proximity sensing that I told you compared to alternative means such as optical and electromechanical sensing. Electromechanical sensing does not work in the dirt as you know, because dust will always block the of light. So, this optical system also does not work for a very, very small change. So, I can use this hall effect we will show that how would actually it works.

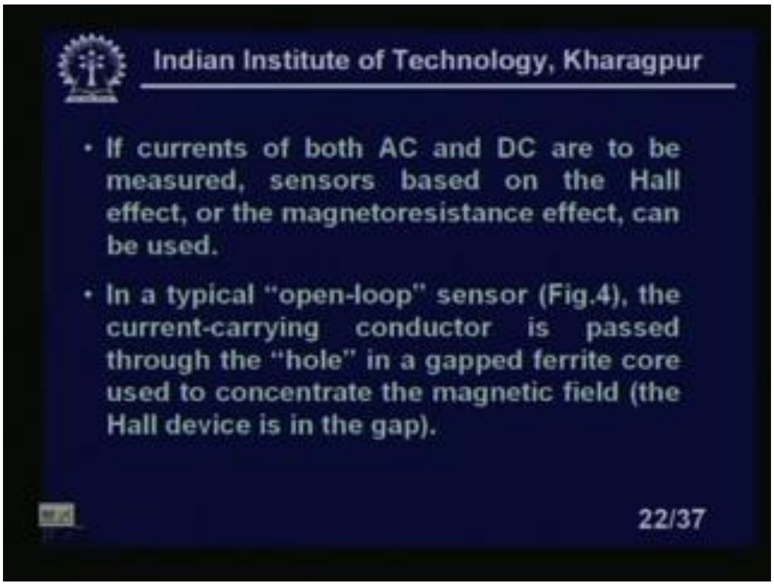
(Refer Slide Time: 35:07)



Hall Effect current sensor; this is the current sensor, based on Hall Effect you see the you see here a current. I want to measure this current, which is flowing through this wire. This is the section of the wire, which I have shown section of the wire you see this is the section of the wire it is placed under a magnetic field the ferrite core. This is our hall sensors right and I am sending a constant current through this where current is entering here current is coming out of this you see the current is coming to through the here. And going through this and coming out through this one right. I am measuring the output voltage across these 2 terminals these, this terminal and this terminal the output voltage. Let me, the take another colors I think this is not very, clear?

These hall and this I am measuring the voltage right. Now, what will happen? You see that this since it is a ferrite core. So, the amount of magnetic field also will depends on the current which is passing through this one. As we have shown that the, this EH the output voltage or hall voltage depends on the magnetic flux density. And this flux density will depend on the sensed current which is the current which is flowing through the wire right. Along with in conjunction with the ferrite core, so that will give you different value of B for different value of the current right. So, accordingly what will happen this output voltage will vary? So, this output voltage will be celebrated in terms of the sensed current. This is the basis principles of our Hall Effect current sensor, clear?

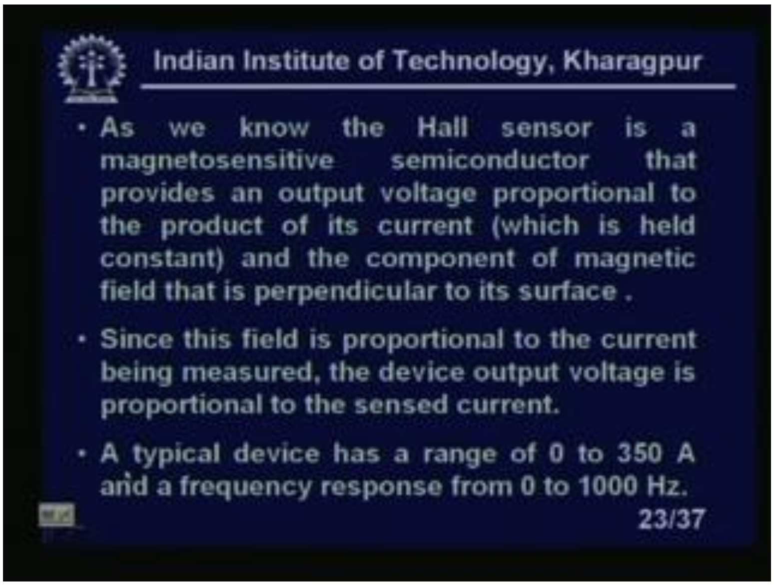
(Refer Slide Time: 37:17)



If currents of both AC and DC are to be measured sensor based on the Hall Effect or the magnetic I mean resistance magneto resistance effect can be used right. In a typical open loop sensor the current carrying conductor is passed through the hole in a gapped ferrite core used to concentrate the magnetic field that is we have shown. It is the gap ferrite core what is the gap you see it is not continuous it is there is a gap after this there is here. So, there is a gap. So, inside that gap we put this 1 why this gap to concentrate these magnetic field. And this magnetic field depends on the current which is flowing right it does not depend on the ferrite core only depends in the current which is flowing through the line right.

So; that means, B, so the B will change due to if the current changes. So, the output voltage will change. So, output voltage calibrated in terms of sensed current. So, in a typical open loop sensor the current carrying conductor, because it is a open loop sensors, because in the hall some hall effect sensors are used in closed loop control also. So, that is the reason we are using the term 2 different term open loop and closed loop. In a typical open loop sensor the current carrying conductor is passed through the hole in a gapped ferrite core used to connect concentrate the magnetic field. And the hall device is in the gap.

(Refer Slide Time: 38:42)



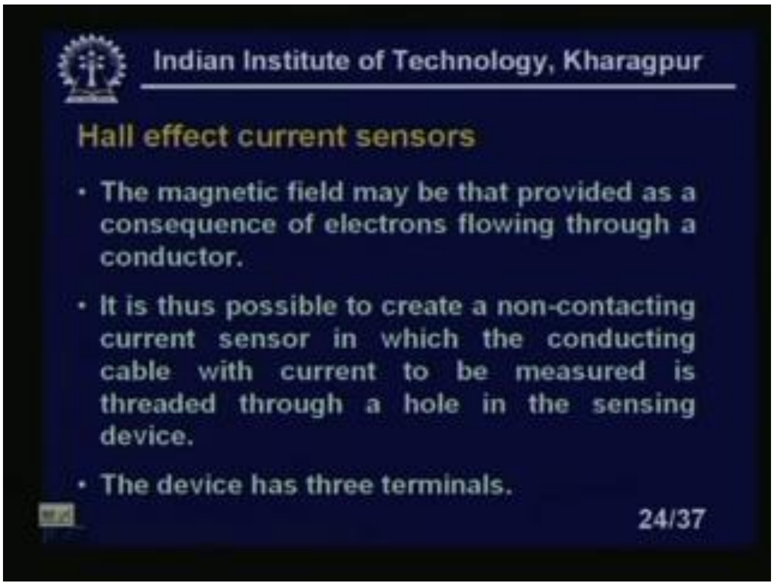
As we know the hall sensor is a magneto sensitive semiconductor that provides an output voltage proportional to the product of its current, which held constant. And the component of the magnetic field that is perpendicular to its surface. We have seen previously this is. So, many times right the hall sensor is a magneto sensitive semiconductor. That provides an output voltage proportional to the product of the current which is held constants. So, if I use a batter voltage constant, so it will remain constant and the component of magnetic field that is perpendicular to its surface right. Since this field is proportional to the current being measured that I told you several times twice the device output voltage is proportional to the sensed current. This is the most important this second point right. What is that since this field is proportional to the current being measured right field will depends on the current. And the device output voltage is proportional to the sensed current. So, using this principles we are making this hall effect current sensors as simple as that. A typical device has a range of has as I told you 0 to 350 ampere and a frequency response from a DC to 1000 Hertz.

(Refer Slide Time: 40:11)

Hall Effect current sensors is like this one. What is this DC? I am talking about suddenly a typical device has a range of 0 to 350 ampere that is understandable it can measure a current of 350 Ampere. And please note it is a non invasive device not contact device if you want to measure I i do not have to put nanometer I do not have to cut the wire right. That is the great advantage any meter measurement of current will be I mean is necessary we have previously the CT BT. And all those things current transformer potential transformer a little absolute that type of instruments. So, I can use the Hall Effect transducers there, clear? Totally you do not have to cut the wire to measure, because whenever you want to measure a current in the wirer you have to break the wire.

And connect a nanometer, but which is not necessary here right. So, when the online; that means, when the circuit is working fine you can bring a hall effect transducer set up like which I have described. And measure the current which is passing through the coil. Frequency response of 0 to 1000 Hertz what is this suddenly frequency response. That means, can I measure AC. AC current here yes why not the output voltage which will get that 1 also will be AC, but the magnetic field remains constant that is DC no that also will vary. Obviously, if this is AC that B will also vary. So, the output voltage will also will be AC.

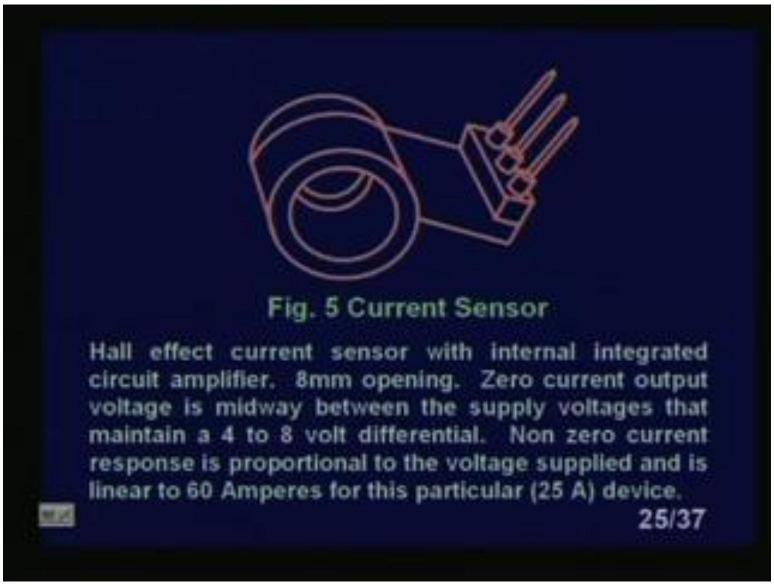
(Refer Slide Time: 41:51)



The Hall Effect current sensors the magnetic field may be that provided as a consequence of electrons flowing through a conductor. So, this is as I told you earlier, because this Hall Effect hall voltage actually developed due to the flow of electron in the semiconductor. In the conductor or in the metal or in the semiconductor, because some people say that the actually the metal that this the current flowing through the metal is due to electron was first established by the Edwin Hall.

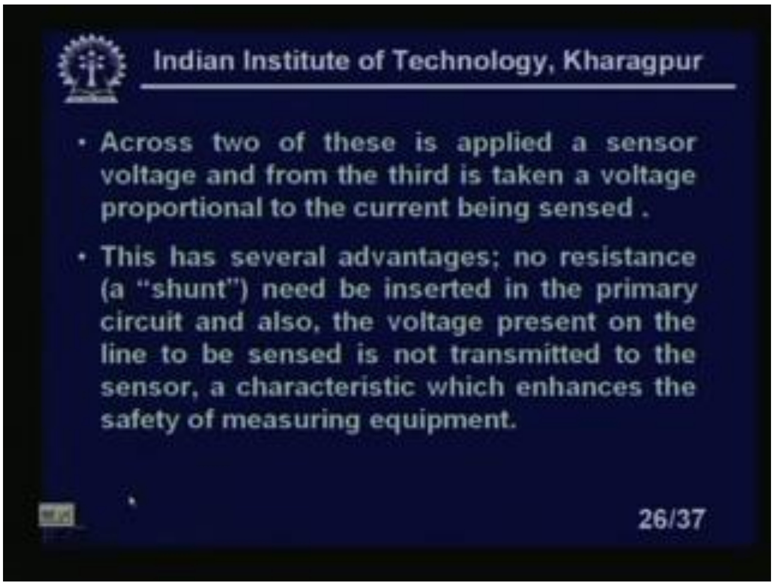
Magnetic field may be that provided as a consequence of electron flowing through a conductor. It is thus possible to create a non contacting current sensor which I told you sometime back in which the conducting cable with current to be measured is threaded through a hole in the sensing devices. Just through a hole in the sensing device. So, I will show you such a devices that more clear to you. The device has 3 terminals, let us look at this is our current sensors.

(Refer Slide Time: 42:54)



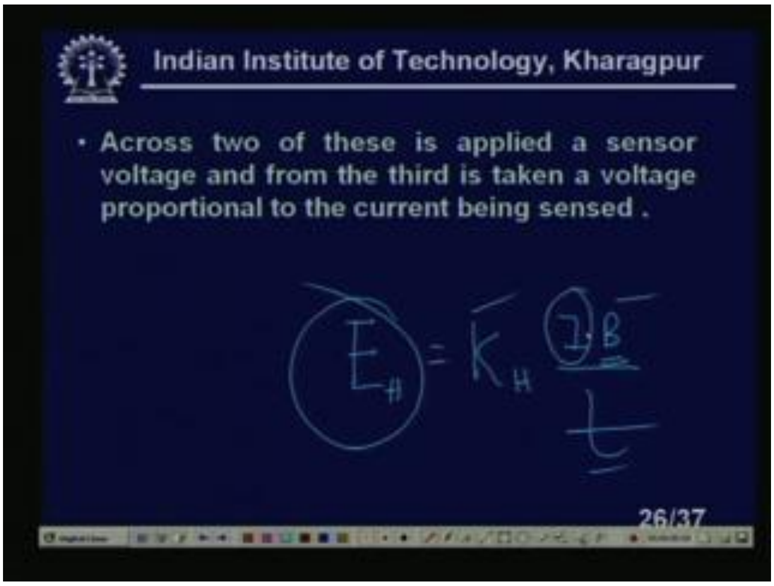
You see the the wire through I mean which will be in which we are interested to measure the current will pass through this please note. The wire will pass through this one. So, it will go out like this 1, clear? So, this should pass through this 1. So, this is our compact systems or our current sensor right. Hall Effect current sensor with internal integrated circuit amplifier this is total 8 mille meter opening 0 current output voltage is midway between the supply voltage that maintain at 4 to 8 volt differential. Non-zero current response is proportional to the voltage supplied and is linear to 60 ampere for this particular which it 25 ampere device.

(Refer Slide Time: 43:50)



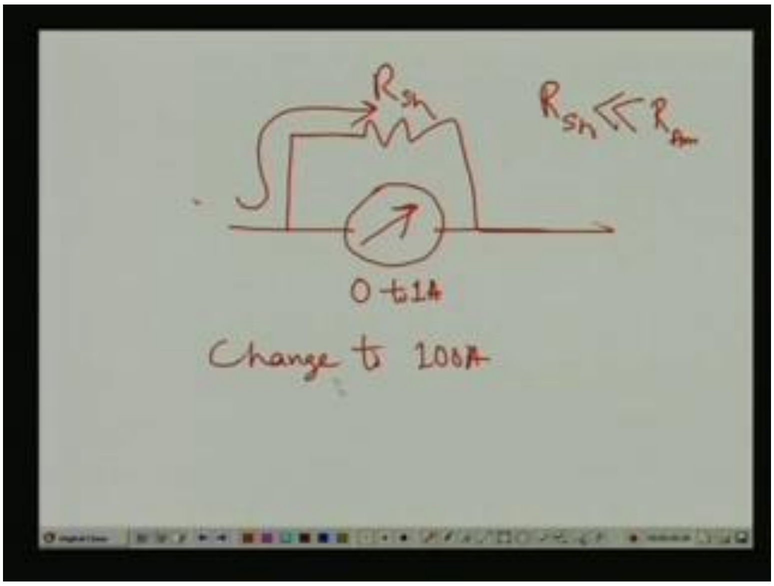
Across 2 of these is applied a sensor voltage because I have to give a voltage is not it. And from the third is taken a voltage proportional to the current being measured right. So, the across the 2 of these I have applied a sensor voltage which actually will give you the current I capital I you remember our basis expressions. What is that let us look at when I am telling that you see here KH IB into divided by t. So, this I is remaining constant across the 2 of these I have applied a sensor voltage. So, the sensor voltage will make this I constants KH B t everything remains same I have measured EH will measure the current.

(Refer Slide Time: 44:57)



So, current also will vary the B actually. This has several advantages. So, no resistance are shunt needed, because you see the typical measured of current high large current like 500 Ampere I mean 6 and 1000 ampere we are using a shunt. What is that shunt is basic principles all of you know form the first year classes.

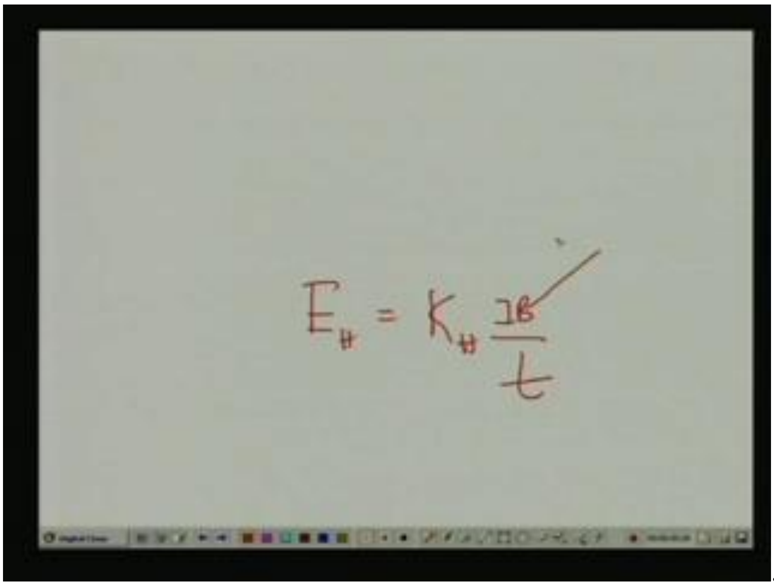
(Refer Slide Time: 45:20)



I have a nanometer, which can measure suppose I have a nanometer suppose it can measure only 0 to 1 ampere. But I want to measure a hundred ampere. So, what I will do? I will put a shunt a low resistance across this 1 R shunt. So, large current will pass through. So, this Rsh is much, much smaller than the resistance of the nanometer ram, so the large current most of the current if I want to measure. Now, we want to change it to 100 Ampere. So, most of the current will pass through shunt the small current will pass through this. Again the same problem the shunt and all that is not necessary in this particular case right.

So, this has a several advantage. So, no resistance a shunt needs to be inserted in the primary circuit. And also the voltage present on the line to be sensed is not transmitted. To the sensor and a characteristics which enhance the safety of the measuring equipment that is most important thing. You see what is I am saying also the voltage present on the line to be sensed is not transmitted to the sensor. So, the, whatever the voltage, because I am measuring the current, so that that is will be associated with the large voltage might be. So, that voltage will not come to the come to EH, because EH whatever we are taking about that will be these voltage what I am saying that you see these EH, I am sorry.

(Refer Slide Time: 47:19)



This EH KH IB by t B is changing getting changed due to the sensed current. This sensed current was associated with large voltage fatal voltage where the order of kilo volt. But that voltage is no way connected here is not coming to the measured I mean output voltage of the sensor, because that will give you some value of the B. So, that is the, I changes; that means, as the currents which I was sensing that is changing will you please do not confuse. These with the, I these I with the actually the current we are measuring. These current this small I this I sorry this I is actually the the DC current, which is established in the hall sensor by a steady voltage that is a very small voltage.

We are not measuring this current I we are a measuring a current which is changing the value of B right and we are measuring the EH. So, that would might be associated with large voltage fatal voltage, but that is not come to the picture that is what is that will not come to the sensed output. That means, the terminal which we are using for measurement of that voltage the hall voltage is no way getting that high fatal voltage is not it, because dangerous voltage I mean high tension voltage. So, that is no way connected, because it is no way totally non contact sort of devices. There is no physical connection between the current, which I am going to sense or I am going to measure and the output voltage right no mechanical connection nothing else.

(Refer Slide Time: 49:09)

Range of the current sensor the range of a given feed through sensors may be extended upward and downward by appropriate wiring. So, by I mean you can wiring; that means, I can make it larger and smaller. To extend the range to lower currents multiple turns of the current carrying wire may be made through the opening that, because there is an opening through which current sensors will go.

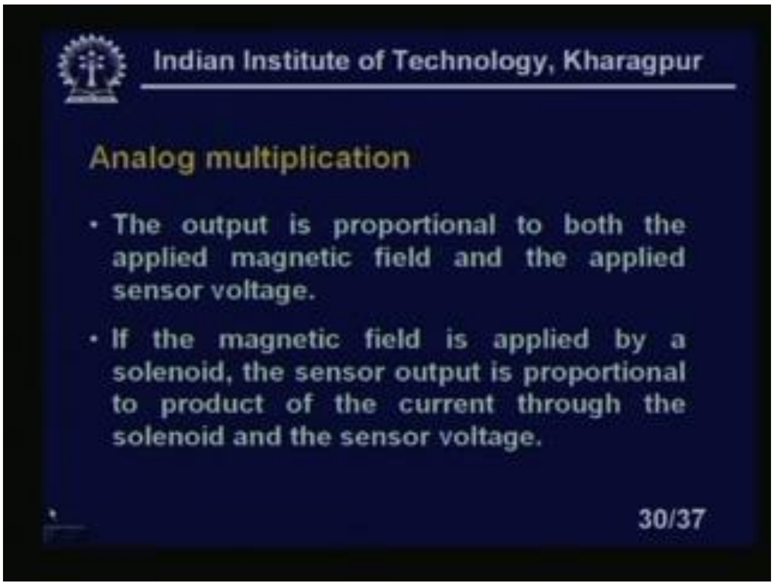
(Refer Slide Time: 49:42)

To extend the range or to the higher currents say current divider may be used with a portion of the current carried by a large wire flowing through a smaller parallel wire with the thicker wire passing through the sensor. This is the same principles of turn, but that is not very popular in that sense; that means. I have to take some other I mean is that same shunt business I am introducing again. So, I should not say it is very popular or usually typically you see the hall sensors are used for range. The same hall sensors which are used for measurement of current of 100 Ampere you are not using that hall sensor for measurement of 1000 Ampere for 1000 Ampere. You passed of different I mean all together different sensor assembly.

(Refer Slide Time: 50:30)

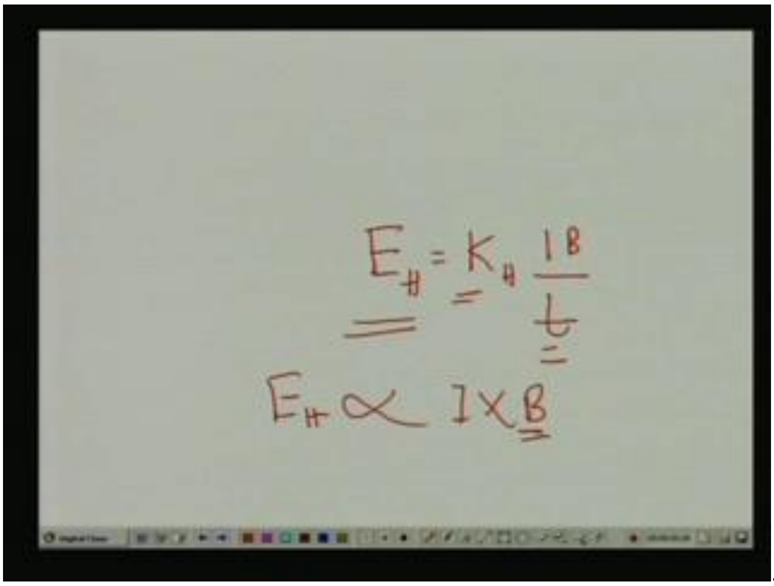
We can have a split ring on the clamp on current sensors also. A variations on the ring sensor uses a split sensor which is clamped onto the line rather than the threading the line through the sensor enabling. The devices to be included in the test equipment and it is not permanently installed in the device being tested excuse me. This also simplifies the permanent addition of current sensing to existing circuit as they need not to be dismantled to perform the installations. You do not have to lose I mean dismantle those thing right this is one way I mean though. It is I mean I mean we are using a clamp on sensor this is one way it is going to because you do not have to dismantle the entire system.

(Refer Slide Time: 51:25)



Now, analog multiplications because you see the, you will be surprised suddenly how come. We are come to the analog multiplication I mean we are taking about you see the analog multiplications is a, we are talking about, because though. It is a signals I mean I cannot I mean 2 signals can multiplied we are, so for taking about this excuse me. Suddenly how it can develop multiplication business let us look at the output is proportional to both the applied magnetic field and the applied sensor voltage right. Now, output is proportional to the both the applied magnetic field applied sensor voltage it is not it you see the applied sensor voltage, what is let us go back again, sorry.

(Refer Slide Time: 52:50)



.

Again we are telling that we are writing EH KH into IB into t right KH is constant t is constant. So, output voltage EH I can say that output voltage EH is proportional to I multiplied by B is not it that I can tell quite; obviously, if KH and t t are constant. But the is that you see that how I am saying that the, these 2 signals will be multiplied. What is B? Again B will depend on the magnetic field now if I can make B which is proportional to some other current to this. I we will be I I will depend on the current, which is flowing through the sensor B will. If I make the B proportional to some current so; obviously, I can say that the output voltage will be multiplied output voltage will be proportional to the multiplications of the 2 currents is not it? That is exactly what we are doing in the analog multiplication let us look at.

Now, let us go back to the output voltage output is proportional to the both the applied magnetic field and applied sensor voltage right. If the magnetic field is applied by a solenoid then the sensor output is proportional to the product of the current through the solenoid and the sensor voltage is not it? So, using that principles I am making the analog multiplication.

(Refer Slide Time: 54:37)

Power sensing: by sensing the current provided to a load and using the device applied voltage as a sensor voltage it is possible to determine the power flowing through the device right. This power is for direct current devices the product of the current and the voltage. With appropriate refinement and the devices may be applied to the alternating current applications where they are capable of reading, the true power produced or consumed by the device.

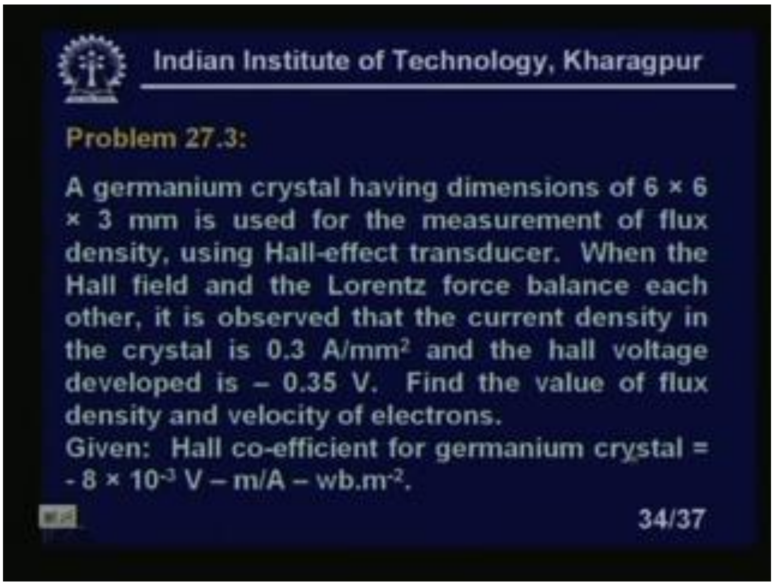
(Refer Slide Time: 55:10)

Position and motion sensing; that is most important thing which is when it is applied to the mechanical motion sensing and the motion limit switches, the hall effect device can offer enhanced reliability in the extreme environment. As there are no moving parts involved within the sensor or magnet there is a far greater useful life expected than from the electro mechanical switches right. So, again the, I mean position sensing is possible; that means, if I by some means I am changing the position I can change the value of B capital B we have capital B we have written. So, many times, so the; obviously, the output voltage will be proportional to the B. So, I can sense the position, so the position sensor will you make position sensors using this principle these all principle.

(Refer Slide Time: 56:03)

The sensor and the magnet may be permanently and completely encapsulated in an appropriate material.

(Refer Slide Time: 56:10)

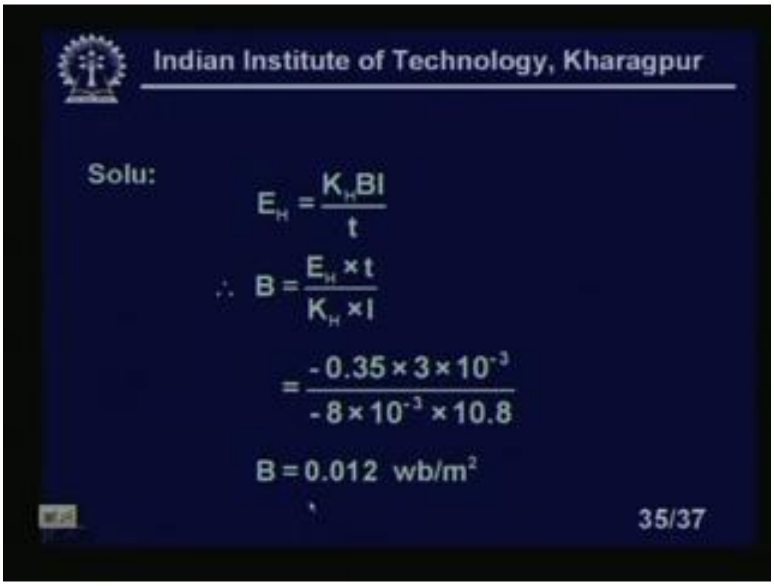


Now, let us look at the problem last problem 27.3. Let us read it which is the a germanium crystal having a dimension of a dimension of 6 into 6 into 3 millimeter is used for the measurement of flux density using hall effect sensor when the hall field and the Lorentz force balanced each other. It is observed that the current density in the crystals is 0.3 ampere per millimeter square. And the hall voltage developed is minus 0.35 volt we have to find the value of the flux density and the velocity of the electrons in the all sensor itself right. Now, suddenly I mean you can see that how we have induce a Lorentz force Lorentz force is basically a force which will try to oppose the which will try to oppose the basic I mean acquisition of the charges on the 2 extreme side of the plate.

We have seen that we have told several times that you see that when we apply some voltages on the opposite surface of the plates a voltage will be developed. Why this voltage was developed? This voltage is developed because there is a acquisition of the charges. Now, Lorentz force is basically when this Hall Effect and the Lorentz force will balance each other we will get a steady output voltage H right. Whatever the small it time might be 10 to the power minus 14 seconds, but within the short time it there will be balance will be achieved is it clear? That is I am saying that the when I applied a in a in a hall effect transducers when I applied a voltage I mean which will read will give me a steady current I and it is and on the steady magnetic field B.

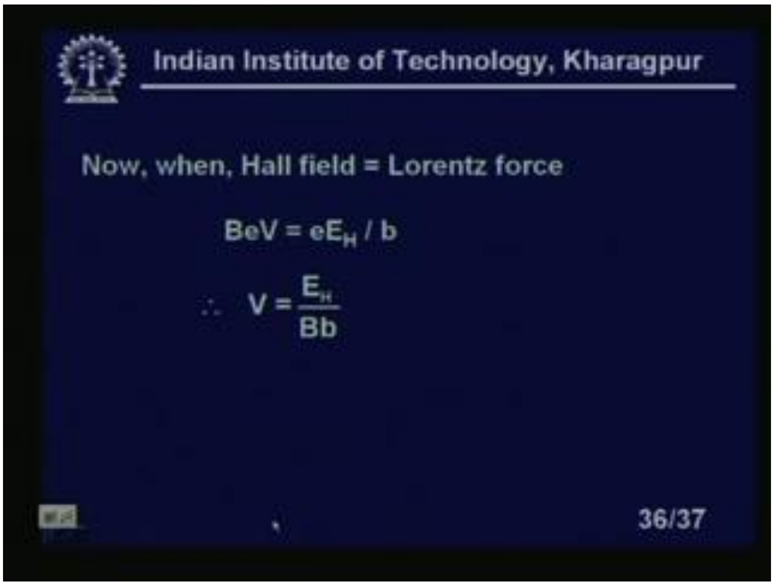
What will happen that there will be the redistributions of the charge of the charges or the electrons inside the hall to be 2 sides of the plates? And the Lorentz force will balance that thing and due to this acquisition of the electrons I am getting a a definite non-zero voltage which is we are calling it a hall voltage right. Let us look at the problem again this is our problem. So, given hall coefficient for the germanium crystal is minus 8 into 10 to the minus 3 volt meter ampere Weber per meter square.

(Refer Slide Time: 58:44)



Solution EH is equal to KH is BI by t we have seen. So, B equal to KH t by KH by KH by into I. So, this you just put all these value of B. So, B equal to 0.012 Weber per meter square.

(Refer Slide Time: 59:02)



So, now when the hall field a Lorentz force must be I mean balance. So, I can write it is the moment of the velocity B is the velocity of the electrons inside the hall sensors. So, e EH by b, so V equal to EH by B by small b let me go yes. So, which will give you the speed of the electron as 9 7 2; these are all the dimensions of the hall plates, B is a dimension of the hall plates 9 7 2 2 meter per second right. With this I come to the end of the lesson 27 of industrial instrumentation.