Electrical Measurement And Electronic Instruments
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Lecture - 46
Flux density measurement with Ballistic Galvanometer (Contd.)

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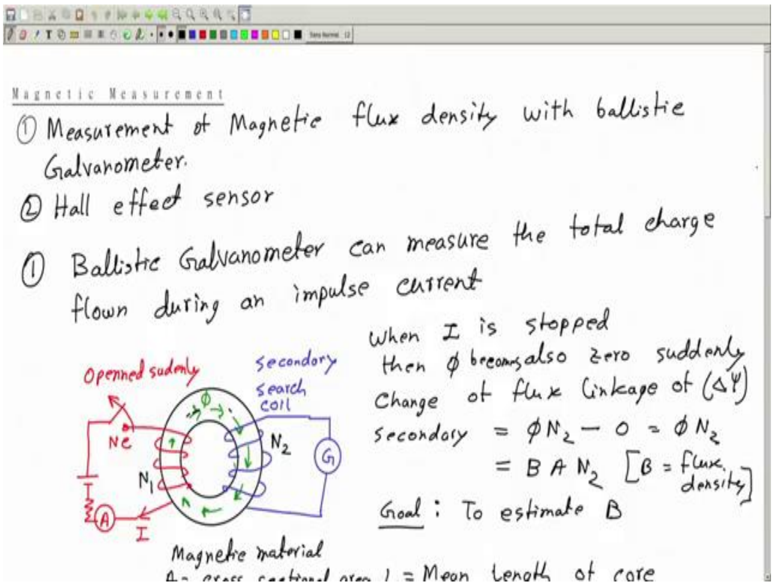

Magnetic Measurement

① Measurement of Magnetic flux density with ballistic Galvanometer.

② Hall effect sensor

① Ballistic Galvanometer can measure the total charge flown during an impulse current

When I is stopped then ϕ becomes also zero suddenly

Change of flux linkage of ($\Delta\psi$) secondary $= \phi N_2 - 0 = \phi N_2$

$= B A N_2$ [B = flux density]

Goal : To estimate B

A = cross sectional area, l = Mean length of core

We have so far seen how to measure flux density in a core using Ballistic Galvanometer.

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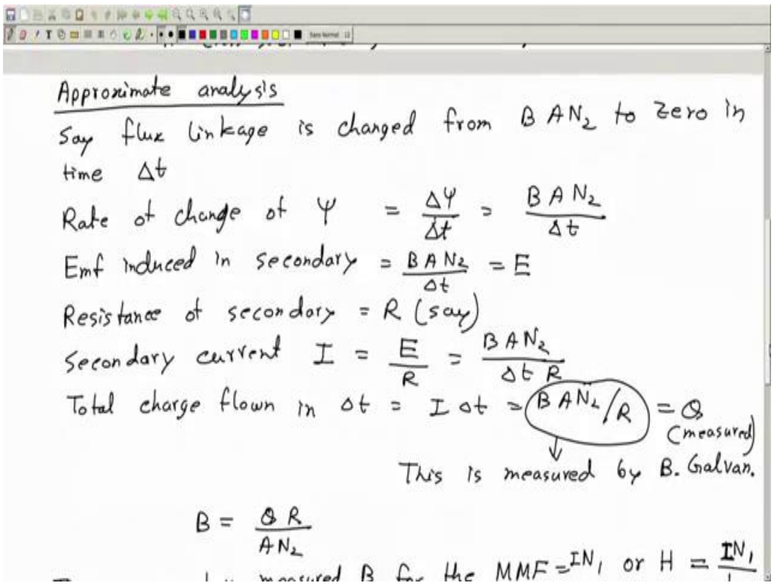

Approximate analysis

Say flux linkage is changed from $B A N_2$ to zero in time Δt

Rate of change of $\psi = \frac{\Delta \psi}{\Delta t} = \frac{B A N_2}{\Delta t}$

Emf induced in secondary $= \frac{B A N_2}{\Delta t} = E$

Resistance of secondary $= R$ (say)

Secondary current $I = \frac{E}{R} = \frac{B A N_2}{\Delta t R}$

Total charge flown in $\Delta t = I \Delta t = \boxed{B A N_2 / R} = Q$ (measured)

This is measured by B. Galvan.

$$B = \frac{Q R}{A N_2}$$

measured B for the MMF $= I N_1$ or $H = \frac{I N_1}{l}$

And so far, I have said that the derivation that we did is an approximation; approximate one. It is not very accurate. Can you guess why did I say so? The reason is here say in this line, I am estimating the current in the secondary or the search coil by dividing the E m f induced with the resistance of the search coil. But what about the inductance of the search coil? Is there no inductance? Definitely there is.

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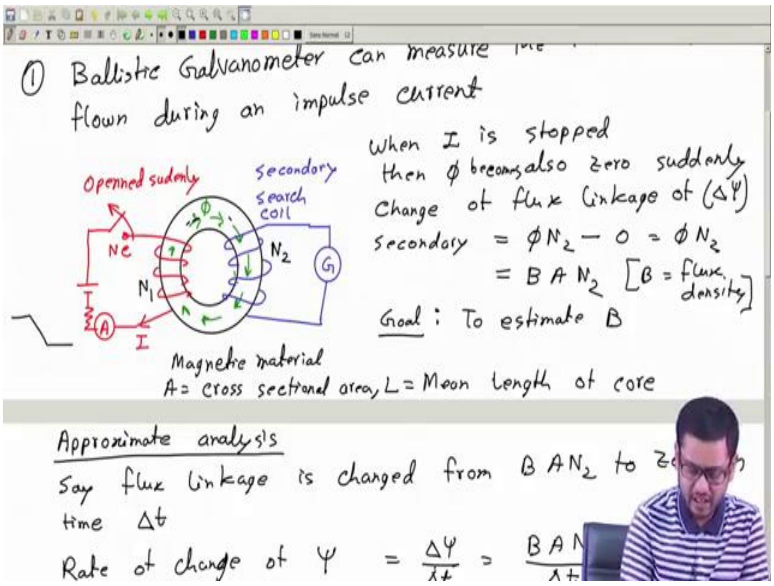

① Ballistic Galvanometer can measure
flown during an impulse current

When I is stopped
then ϕ becomes also zero suddenly
Change of flux linkage of $(\Delta\Psi)$
secondory $= \phi N_2 - 0 = \phi N_2$
$= B A N_2$ [B = flux density]

Goal : To estimate B

Magnetic material
A = cross sectional area, L = Mean length of core

Approximate analysis

Say flux linkage is changed from $B A N_2$ to
time Δt

Rate of change of $\Psi = \frac{\Delta\Psi}{\Delta t} = \frac{BAN}{\Delta t}$

And because, after all this is a coil. So, a coil with a magnetic core must have some inductance; can we neglect it? We can neglect it possibly if the inductance is low, but that will also mean the E m f induced in the secondary will also be low. Because when will we have low inductance maybe if the number of turns is low or maybe if the permeability of the core is low so on and in either of these cases that will mean the E m f induced in the secondary is also low. So, we have to also ignore the E m f. But then, then I mean then we cannot do this measurement at all.

Secondly, is this E m is this current that is flowing is it DC? So, that we can neglect the inductance. It is not necessarily DC because the E m f generated is not necessarily DC, because the rate of change of this current or rate of change of this flux, they are not necessarily constant. So, this derivation is an approximate one ok. So, yeah maybe if this rate of change of current is constant, if the current is changing like this, initially constant and then it goes down to 0 with a constant slope ok. Then, flux is also going down with this constant slope, then the E m f is constant and possibly then, we can follow this type of analysis.

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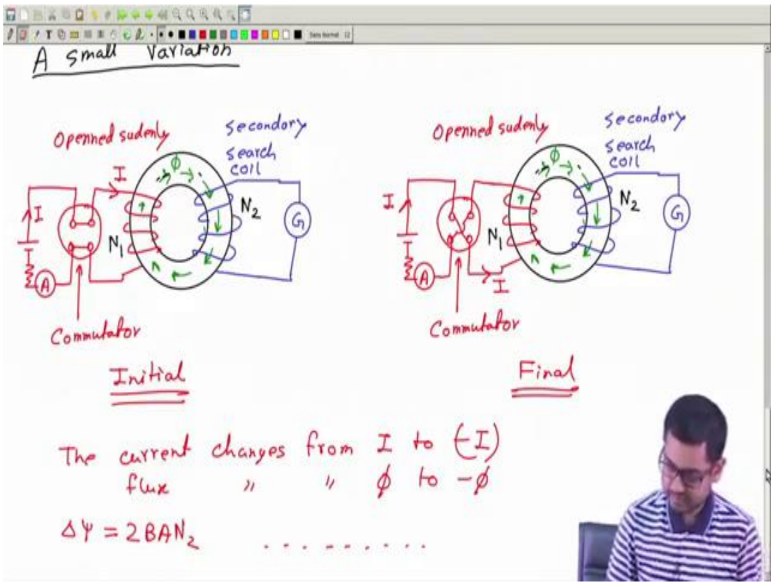

A small Variation

The current changes from I to (−I)
flux " " ϕ to $-\phi$

$\Delta\Psi = 2BAN_2$ . . . .

So, let us do a more precise calculation which is also simple.

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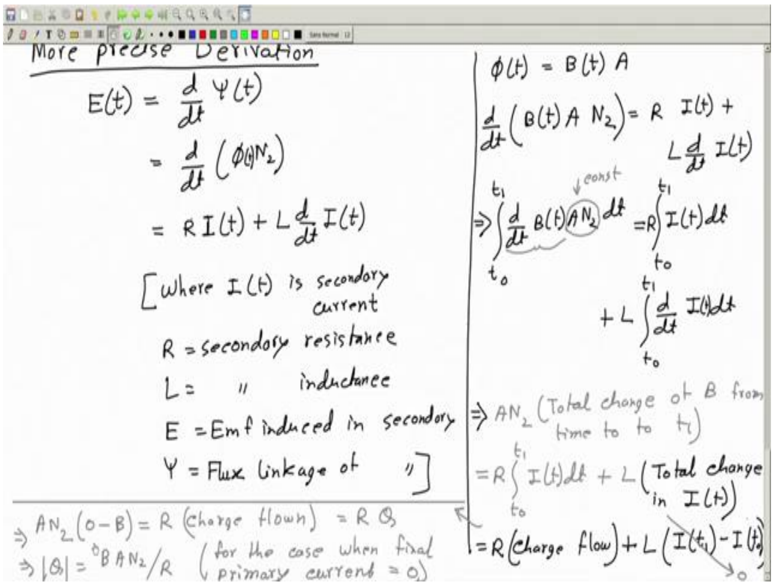

More precise Derivation

$$E(t) = \frac{d}{dt}\Psi(t) = \frac{d}{dt}\left(\phi(t)N_2\right) = R\,I(t) + L\frac{d}{dt}I(t)$$

[where I(t) is secondory current
R = secondory resistance
L = " inductance
E = Emf induced in secondory
Ψ = Flux linkage of "]

$\Rightarrow AN_2(0-B) = R$ (charge flown) $= R\,Q$

$\Rightarrow |Q| = BAN_2/R$ (for the case when final primary current = 0)

$\phi(t) = B(t)\,A$

$$\frac{d}{dt}\left(B(t)\,A\,N_2\right) = R\,I(t) + L\frac{d}{dt}I(t)$$

$$\Rightarrow \int_{t_0}^{t_1}\frac{d}{dt}B(t)\overset{\text{const}}{\boxed{AN_2}}\,dt = R\int_{t_0}^{t_1}I(t)\,dt + L\int_{t_0}^{t_1}\frac{d}{dt}I(t)\,dt$$

$\Rightarrow AN_2$ (Total change of B from time t_0 to t_1)

$= R\int_{t_0}^{t_1}I(t)\,dt + L$ (Total change in I(t))

$= R$ (Charge flow) $+ L\left(I(t_1) - I(t_0)\right)$ $\rightarrow 0$

E(t) = $\frac{d\varphi(t)}{dt}$ = $\frac{d\emptyset(t)\ N2}{dt}$ = R I(t) + L $\frac{d\ I(t)}{dt}$

$$\emptyset(t) = B(t)\ A$$

$$\frac{d\,(B(t)AN2)}{dt} = \mathrm{R\ I(t) + L}\ \frac{d\,I(t)}{dt}$$

$$\int \frac{d\,(B(t)AN2)}{dt}\ \mathrm{dt} = \int_{t0}^{t1} R\,I(t)dt + \mathrm{L} \int_{t0}^{t1} \frac{d\,I(t)}{dt}\,\mathrm{dt}$$

$$=\int_{t0}^{t1} R\,I(t)dt + L\,\big(total\ change\ in\ I(t)\big)$$

= R (charge flow) + L (I(t1)- I (t0))

= AN2 (0-B) = R (charge flown) = RQ

So, then I have from this Q is equal to the magnitude of Q is equal to B A N 2 divided by R and that is what we got here as well ok. So, it is written here; here. So, Q is B A N 2 /R. So, the approximate derivation gives the same result as the as this rigorous derivation, but the approximate derivation we did initially because I thought that is maybe easier to remember, easier to see the things fast. I mean realized realize what is happening ok, but this is a more rigorous derivation and it gives the same result ok.

And yeah, and let me also write that this is for the case when final primary current is 0. We can have a factor 2, if the final primary current is reversed ok. If that means, this circuit if we use this circuit, then the final primary current is reversed. So, total change in flux density will be doubled. So, we will have a factor of two here; here ok, at this point if we use the other circuit ok. So, that is it about ballistic Galvanometer based measurement of flux density. Now, let us move to our second topic in this chapter which is Hall Effect Sensor.

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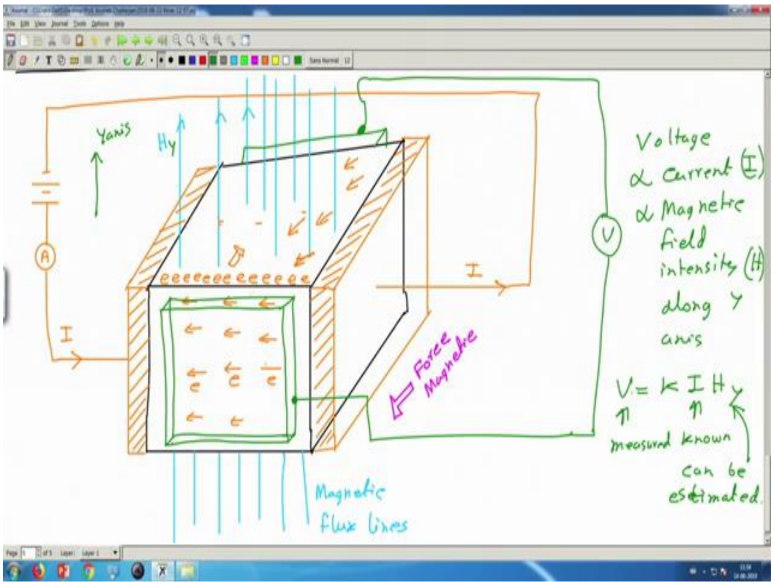

Voltage
$\propto$ Current (I)
$\propto$ Magnetic field intensity (H) along Y axis

$V = k I H_y$

measured known can be estimated

This is also small and easy topic I believe. Let us first understand what is Hall effect? Suppose, I have a block of some material which is called hall material and what I do is, I have this made this this this block in a magnetic field and say the magnetic field is in this direction. So, the magnetic field is let us take magnetic fields vertical like this and they continue through the through this block.

Although, I am not drawing through the block, but they continue these are continuous flux lines these are magnetic flux ok; so, magnetic flux lines. They can be upwards or downwards. Either it is fine for now ok. And then, what I do? I take say I connect; I pass some current through this block from one side to the other side. So, let me connect a metallic plate on this side. Similarly, on this side and I pass some current from one plate to other call this current I. So, the current is entering through this side and is leaving through the other side.

Now, when this current flows from one side to the other ok. So, suppose I also have a close circuit here. So, that current can flow like this and if you want you can put an ammeter to measure this current. So, this is the arrangement ok. Now, charge is flowing from left to right in through this block and that means, also the electrons are flowing from right to left ok. So, now, when this charged particle say electrons, if they are flowing through a magnetic field, they will experience some force. What kind of a force? They that force will try will be perpendicular to both the direction of this magnetic field and the velocity of this charged particles ok.

So, this if this are the electrons. So, electrons are normally flowing like this. But this magnetic field will cause a force on this electrons which and the direction of that force will be perpendicular to both the field and the velocity ok. So, we can find we can find this by using left hand rule ok. So, for example, let us assume if this is the direction of the field H upwards and if we had positive charge, if we had positive charge plus q flowing from say left to right because the current is from left to right.

Then, what will be the force on this positive charge? So, let us find that out. So, the direction of current is left to right field is upwards. So, I am applying left hand rule. Field is upwards. Direction of current is this left to right, direction of positive charge and my thumb is pointing towards me, I mean out outwards upwards ok. So, this this will be the force on the positive charge

Now, if you think in terms of the electrons, then the then they are they are charges negative. So, the force will be should be in the opposite direction, but their velocity is also opposite. So that means, two opposite things will cancel each other and the force will remain still in this direction ok. So, force. So, this is the direction of force. So, therefore, what will happen ok? So, the electrons are where normally flowing like this. Due to this force, they will they will come towards this side ok. So, the electrons will have a force which will cause them to deviate in this direction and then so if electrons are flowing in this direction ok, it is possible that there will be some accumulation of electrons on this side ok.

So, because of this force so, there will be some accumulated or store, I mean accumulated electrons on this side and there will be some there will be a situation when the these accumulated electrons will repel the flowing electrons and thereby equilibrium will be reestablished; magnetic force, this is the magnetic force is in this direction and this accumulated electron will give a force in the opposite direction. So, we can have a equilibrium established. But in this process, what will happen? There is some stored charge on this side and some less charge on the other side.

So, now, if we measure the potential difference between this side, between this side and the other side which is behind which we cannot see, then we will see there is a potential difference. Because there is an accumulation of electrons due to this magnetic force ok.

So, now, what we can do? We can actually say put a metallic plate here on this side and similarly, another plate on that side ok. So, this is a plate that is another plate and now, what we are going to do?

We are going to measure the potential difference between these two plates. Take a voltmeter. So, we will see some voltage appearing here and this phenomenon is called Hall Effect. So, what is the phenomena? The phenomena is that we have a magnetic field, in that field we have some current flown and if when this current is flowing the magnetic field will give some force on this on this charge carrying charge carriers and therefore, they will they will get diverted on one side causing a potential difference between this two plates ok.

These two plates should not touch these orange plates of course, then there will be there can be some sort. So, there can be some problems ok. So, well have some potential difference between these two plates. This is called Hall Effect and this voltage, what does this depend on? This voltage depends on of course, the velocity of these electrons which in turn depend on the amount of current. More the velocity that means, of course the current is more. And it is also proportional to the field intensity magnetic field intensity ok, magnetic field intensity H.

Particularly, in the direction perpendicular to the, to both this to the current and this where we are measuring this voltage. So, the component of H along say Y axis ok. So, this is say this is Y axis ok; magnetic field intensity H along Y axis. So, this voltage depends on these two factors. Now, if we know, if we know ok. So, the that before that so that means, we can write that this voltage V is equal to some constant times this I and H; you can call it H y in the direction along Y axis ok. Now, if we say no this I because this is the current we are passing this is in our control.

So, I is known; therefore, this quantity H can be estimated from these two values V and I. And by this, we can measure the component of H or H y in in this particular direction. So, this is an phenomenon called Hall Effect with which we can measure magnetic field intensity and then, this measurement is directional sensitive ok. So, if I put this block in different orientations, the voltage generated here will depend solely on the component of H in this direction; not on any other H ok. So, this is what Hall Effect sensors are.

Thank you.