Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Applied Electromagnetics for Engineers

Module – 30
Faraday's Law

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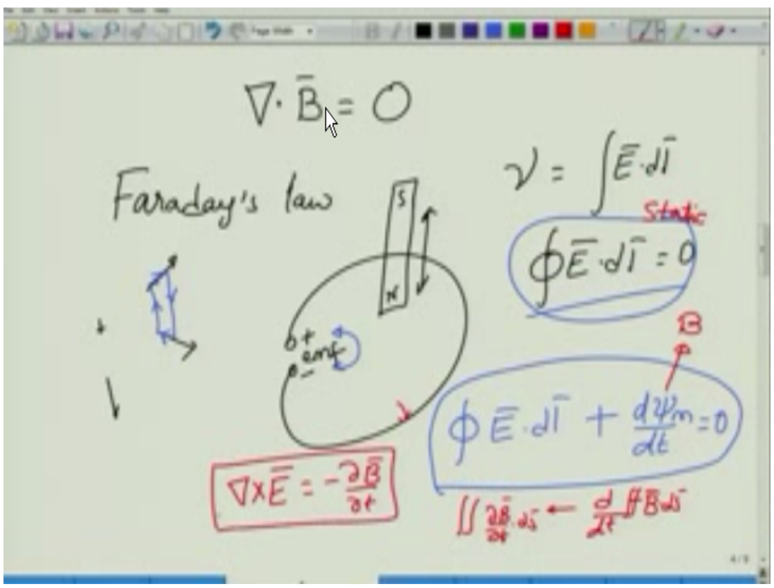

So continuing here with $\Delta B=0$ as one of the additional laws that we have written. These two divergence laws are called as Gausses law for electric fields, and Gausses for magnetic fields. Gausses law for electric field tells you that the source of the defiled is the charge and Gausses law for magnetic field, you know in the form of $\Delta B=0$ tells you that there is actually no source because we cannot isolate a magnetic charge.

Then we are left with one of the most important laws, you know which lead to the combination or which lead to the, you know synchronization between or kind of inter relationship between electricity and magnetism. And this law is called as Faraday's law. Faraday's law was, you know is a very interesting law. It tells you that if I have a conducting path or a conduction loop and let me open up first you know small piece here ψ open this conductor path here.

So this is a conductor okay and then I let this two terminals go out there and if I take a magnate okay may be the north is going here and then the south pole of the magnet is here and if I move this magnate vigorously right so if this magnet vigorously then I actually see that there will be a EMF generated.

Now it might not make so much sense to you unless you understand what an EMF is EMF was a you know very general term even today that is used to denote what is called as electro motive force okay it is the force which actually move the charges around in a closed path is what we you know we had written or we had talked people had defined and this EMF is related to the electric field how is EMF related to the electric field so we relate this EMF you know which I am denoting by this quantity do not worry what that quantity is.

If I take a particular you know closed path or you know take a path then over that path whatever the line integral of electric field that I am going to obtain is what by definition is this particular quantity V if V is = 0 usually V = 0 if I were to go over a complete loop okay because you know integral of E or dl will = 0 as electric field is usually in a static case when things are not varying with respect to time, then this law.

Tells or this particular thing tells you that the EMF developed around the closed path would = 0 that is you imagine that there is charge here and this are the electric field lines are there around it and if you take this path which is shown in this blue path you are not doing any work as you move along this arc because every where the electric field will be perpendicular but when you move along the electric field then work will be done by the charge for you and then when you move against the charge work has to be done by you on the charge but the contribution of these two would be exactly equal and they would cancel out and essentially what you obtain is ∫ of E. dl = 0, okay.

So what faraday discovered was that this quantity E. dl would not be equal to 0 there will be a non zero EMF generated okay provided there is a changing magnetic field in fact he called it has changing magnetic flux linkage okay there is a certain flux linking to this circuit and if this flux linkage to this circuit is changing with respect to time then there will be a certain EMF induced. So in the modern vector notation you write this as ∫E. dl okay is equal to –d ψ/dt, okay.

What is this d ψ or dψ m, ψ m is the magnetic flux density okay it is related to the amount of magnetic field or the magnetic flux that is changing link to a particular circuit and the time rate of this change is what is given by the flux, so in fact the equation should be written not in this way but it should be written in this way to bring out the concept clearly it says that the none EMF around a closed path all the none sources if you were to add then the total EMF around a close path would be equal to 0 okay.

So one portion is coming from this $\bar{E}.d\bar{l}$ and the corresponding portion is coming from dψm/dt this is the mathematical way of thinking about it, but what ψ does said is that if I take you know one conducting path or just take a loop and if I change the magnetic field in you know with respect to or the magnetic flux associated with respect to that particular loop with respect to time then there will be an EMF intrude which you can tap and then use, okay.

This is of course the way in which you know most generators work they change the magnetic field associated with it, the corresponding thing is also true so if you work to you know take so you can actually do this by two ways right so wither you can take a magnet and then move or you keep the magnet fixed and then you circuit and then move it around in and around the magnetic pole.

So in either case you generate the same effect okay and it is most important to note that the source would be –dψm / dt so if I move instead of taking result 0 if I write this as integral of E. dl over a close path that would be equal to –dψm / dt and that –ψ is called as lenses law. So you have totally four charges the corresponding point form for this equation is very simple, that is given by the curl operation ∇x E = -d/dt and the magnetic flux is related to the magnetic flux density okay7 and what is the magnetic flex density so this equation would be d/dt of integral B. ds okay, or you can rewrite this one as integral of ∇d / ∇t.ds where ∂B/∂t is a change in magnetic field.

So changing in magnetic field integrated over the open surface of the contour that is formed by the conductive part will give you the electric field quantity or know it will tell you what is the electric field quantity. So this is the scenario were the electric field around the closed part is equal to 0 when it is static scenario but when there is a magnetic field linking that particular path change in respect to time then this integral of e.dL is not 0 there will be a non zero EMF generated and the corresponding point form as I was writing is given by -∂B/∂t okay. So this is given by -∂B/∂t and this is the faraday's law.

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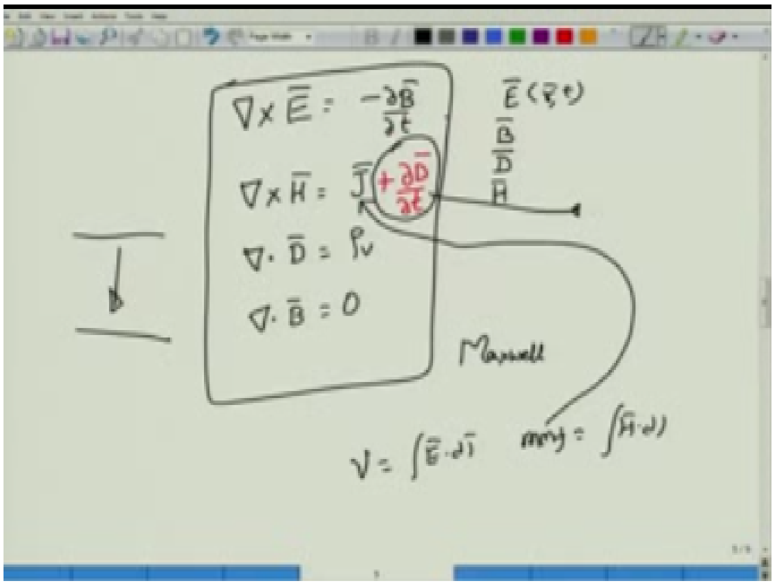

So finally let we just point out all the laws here okay you have the faraday's law which is curl e which is equal to -∂B/∂t okay please note that e is the function of r and t B is also function of r and t, D is also function of r and t, and H is the function of r and t, Ampere's law tells you that curl of h is equal to J the current density ∇.D is equal to ρv the source of the D field this is one in charge density ∇.B is equal to 0.

Because there is essentially know magnetic flux density okay there is no isolated magnetic charges do not exist so this for the equations which were known at the time of Maxwell of course they were not known in this form because vector notation was not invented by J.w.Deeps until of few years later so al the equations were there in the original partial differential form but by and large the physical interpretation the way to understand this equations was known by Maxwell.

So then why is this Maxwell equations which is now considered to be a corner stone it is considered to be a corner stone simply because the equation had they exist here are not complete, there is a problem with this equations, especially with the problem of this ampere law. So what Maxwell did was he introduced a term in which just as changing magnetic flux would induce, what is called as electric field okay or the EMF changing electric flux density which is δd/δt with respect to time would induce what is calmed has magneto motive force.

Just as you define the integral of E.dl over a path as the EMF right, so you define this one as EMF integral of E.dl. you could similarly define the mmf as ∫H. dl and what ampere said in the sense was that, the source of mmf is always the conductive current and it turned out it is not so because if you take capacitor there is no way there is current in this, if it is the ideal capacitor. So then what is happening?

Maxwell reasoned something else was happening and that something else is what he called as the displacement current and then you put this into the equation, and then completed this set. So they were all lying separately along with this vacuum or this lacunae Maxwell brought everything together and we will now study the ramification of these equations in the reminder of the course thank you very much.

<u>Acknowledgement</u>

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