Law of Electromagnetic Induction

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Abstract

In this paper the law of electromagnetic induction has been presented.
Keyword : Electromagnetic induction.

1 INTRODUCTION

Faraday observed that when a bar magnet is in relative motion with respect to a closed coil, a current is induced in the coil. Also the direction of current was opposite when the relative motion was away from the each other compared to when the relative motion was towards the each other.
In another experiment, he wrapped two wires around opposite sides of an iron ring (torus). He plugged one wire into a galvanometer, and watched it as he connected the other wire to a battery. He saw a transient current in the wire connected to the galvanometer at the moment he connected or disconnected the other wire to or from the battery.
From the first observation, it can be concluded that the current driving force is proportional to the magnetic field strength and the relative velocity between the coil and the structure of the magnetic field source.
From the second observation, it can be concluded that the current driving force is proportional to the magnetic field strength and the average relative velocity between the coil and the electrons present in the structure of the magnetic field source.

2 ELECTRODRIVING FORCE

Electrodriving force in a loop element **dl** will be

$$f = \frac{\mathbf{F.dl}}{dl}$$

where **F** is either an electric or a magnetic force.

3 MAGNETIC ELECTRODRIVING FORCE

$$f_m = \frac{\mathbf{F_m .dl}}{dl}$$

where $\mathbf{F_m}$ is a magnetic force.
Now by the law of Magnetic force

$$\mathbf{dF_m} = dq\,(\mathbf{v} \times \mathbf{dB})$$

where dq is the free charge present in a loop element **dl**, and **v** is the relative velocity of the loop element and consequently of the free charge dq with respect to the actual source of the magnetic field **dB**.

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$$\Rightarrow df_m = \frac{dq\,(\mathbf{v} \times \mathbf{dB}).\mathbf{dl}}{dl}$$

$$\Rightarrow \frac{df_m}{dq} = d\,(mef) = \frac{(\mathbf{v} \times \mathbf{dB}).\mathbf{dl}}{dl}$$

where mef = magnetic electrodriving field strength

$$\Rightarrow \int d\,(mef) = mef = \left(\int_B (\mathbf{v} \times \mathbf{dB}) \right) . \frac{\mathbf{dl}}{dl}$$

$$\Rightarrow \int_L (mef \times dl) = \int d\,(mep) = mep = \int_L \left(\int_B (\mathbf{v} \times \mathbf{dB}) \right) .\mathbf{dl}$$

where mep = magnetic electrodriving potential
so magnetic voltage in the loop

$$V_m = mep = \int_L \left(\int_B (\mathbf{v} \times \mathbf{dB}) \right) .\mathbf{dl}$$

4 SOLUTION FOR SOME SPECIAL CASES

Case (i) : When the size of the structure of the magnetic field source is negligible compared to the loop size and the magnetic field is steady with respect to the frame of reference corresponding to the structure of the magnetic field source.

$$mep = \int_L (\mathbf{v} \times \mathbf{B}).\mathbf{dl}$$

where **v** is the velocity of a loop element **dl** with respect to the structure of the magnetic field source and **B** is the total magnetic field strength at the position of the loop element.
In this case the effects of the velocities of the electrons present in the structure of the magnetic field source, get cancelled out.
Also in this case different elements of the loop can have different velocities with respect to the structure of the magnetic field source, therefore the loop can be rotating or deforming.

Case (ii) : When the structure of the magnetic field source (and consequently magnetic field) and the loop, both possess axial symmetry about a common axis and the magnetic field is steady with respect to the frame of reference corresponding to the structure of the magnetic field source.

$$mep = \int_L (\mathbf{v} \times \mathbf{B}).\mathbf{dl}$$

where **v** is the velocity of a loop element **dl** with respect to the structure of the magnetic field source and **B** is the total magnetic field strength at the position of the loop element.
In this case the effects of the velocities of the electrons present in the structure of the magnetic field source, get cancelled out.
Also in this case different elements of the loop can have different velocities with respect to the structure of the magnetic field source provided that axial symmetry of the loop about the common axis of symmetry still remains maintained, therefore the loop can be radially expanding.

Case (iii) : When the magnetic field source is a straight current carrying wire.

$$mep = \int_L (\mathbf{v} \times \mathbf{B}).\mathbf{dl} - \int_L (\mathbf{v_d} \times \mathbf{B}).\mathbf{dl} = \int_L [(\mathbf{v} - \mathbf{v_d}) \times \mathbf{B}].\mathbf{dl}$$

where **v** is the velocity of a loop element **dl** with respect to the structure of the magnetic field source, $\mathbf{v_d}$ is the drift velocity for the free electrons with respect to the wire and **B** is the total magnetic field strength at the position of the loop element.
In this case the effects of the velocities of the electrons present in the structure of the magnetic field source, do not get cancelled out.
Also in this case different elements of the loop can have different velocities with respect to the structure of the magnetic field source, therefore the loop can be rotating or deforming.

5 CONCLUSION

From this paper it can be concluded that the conventional Faraday's law of electromagnetic induction is not correct and it should be replaced with the law presented in this paper.

References

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