FARADAY'S LAW

In 1831 Michael Faraday in England performed a series of experiments and discovered that if a closed circuit moved across a magnetic field, a current flowed even though there were no batteries present.

Faradays gave two laws:

First Law:

When the flux of magnetic induction through a circuit is changing and electromagnetic force is induced in the circuit.

Second Law.

The magnitude of this emf is equal to the negative rate of change of the flux, i.e.,

$$\mathcal{E} = - \frac{d\phi}{dt}$$

This equation is known as Faraday's Law of induction also known as Neumann's Law.

It is fond to be independent of the way in which the flux is changed the circuit may be moved or destroyed & the value of B at various points inside the circuit may be charged.

If ϕ is the instantaneous value of the magnetic flux, then,

$$\phi = \int B \cdot ds \quad \text{——— (1)}$$

The induced emf $\mathcal{E}$ around the closed path C is given by the line integral of the induced electric field E around C, i.e.,

$$\mathcal{E} = \oint_c E \cdot dl \quad \text{——— (2)}$$

If the circuit C be bounded by an open surface S, then.

$$\therefore \quad \mathcal{E} = \oint_c E \cdot dl = -\frac{d}{dt}\int_s B \cdot ds \quad \text{— (3)}$$

Thus the Faradays Law tells us that the line integral of the electric intensity around any fixed closed path is equal to the time rate of decrease of flux of magnetic induction through the surface enclosed by the curve.

In addition of eqn (3), there are other equivalent statements of Faraday's law. Since $B = \text{curl}\, A$, hence

$$\oint_c E \cdot dl = -\frac{d}{dt}\int_s (\nabla \times A)\cdot ds$$

$$= -\frac{d}{dt}\oint_c A \cdot dl \qquad (4)$$

by using Stoke's law. This relation shows the induced emf can be calculated directly from the vector potential A.

The different form of the Faraday's Law is obtained by using Stoke's Law to replace line integral into surface integral,

$$\oint E \cdot dl = \int_s (\nabla \times E)\cdot ds$$

$$= -\frac{\partial}{\partial t}\int_s B \cdot ds$$

or. $$\int_s \left(\nabla \times E + \frac{\partial B}{\partial t}\right)\cdot ds = 0$$

Since S can be an arbitrary surface hence the integrand must be zero and we have

$$\nabla \times E = -\frac{\partial B}{\partial t} \qquad (5)$$

This eqn relates the space derivatives of E at a particular point to the time rate of change of B at that point, and shows that the electric field induced by B is not as the electrostatic field for which the curl is zero.