Change in Voltage

Gordon Ng

17 August, 2012

Contents

1 Introduction to Magnetism

- The Magnetic field is similar to a electric dipole field.

2 Notation

- Into the page : $\times$
- Out of the page : $\bullet$

3 Field Strength

$$B \propto \frac{1}{r^2} \tag{3.1}$$

4 Biot-Savart Law

$$B_{PC} = \frac{\mu_o}{4\pi}\frac{qvsin\theta}{r^2} \tag{4.1}$$

Where

$$\begin{aligned}
\mu_0 &= 4\pi \times 10^{-7} TmA \\
q &= \text{Charge (C)} \\
v &= \text{Velocity of Charge} \\
\theta &= \text{Angle between velocity vector and position vector}
\end{aligned}$$

4.1 Magnetic Field For A Long Current Carrying wire

$$B_{PC} = \frac{\mu_o}{2\pi}\frac{I}{d} \tag{4.2}$$

4.2 Magnetic Field along a current loop axis

$$B_{PC} = \frac{\mu_o}{2}\frac{IR^2}{(z^2 + R^2)^{\frac{3}{2}}} \tag{4.3}$$

4.2.1 If z= 0

$$B_{PC} = \frac{\mu_o}{2}\frac{I}{R^{\frac{3}{2}}} \tag{4.4}$$

If There is N Rings:

$$B_{PC} = \frac{\mu_o}{2}\frac{NIR^2}{(z^2+R^2)^{\frac{3}{2}}} \tag{4.5}$$

5 Symmetry And Ampere's Law

They symmetry between Gauss's Law and
Gauss's law:

$$\Phi_e * = \oint EdA = \frac{Q_{in}}{\varepsilon_)} \tag{5.1}$$

Line Integral

$$\oint Tds = n_1 ds_1 + n_2 ds_1 \tag{5.2}$$

Ampere's Law

When Magnetic Field is perpendicular to the Line

$$\vec{B} \cdot d\vec{s} = 0 \tag{5.3}$$

When the Magnetic Field is parallel to the Line

$$\oint \vec{B} \cdot d\vec{s} = Bl = B(2\pi d) \tag{5.4}$$

If we combine it with Biot-Savart Law:

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I \tag{5.5}$$

5.1 Ampere's Law Inside a Wire

In here we assume constant current denssity.

Ratio of Area:

$$\frac{\pi r^2}{\pi R^2} = \frac{r^2}{R^2} \tag{5.6}$$

Hence:

$$\oint \vec{B} \cdot d\vec{s} = \frac{\mu_0 r^2 I}{R^2} \tag{5.7}$$

Replace Line Integral

$$2\pi r B = \frac{\mu_0 r^2 I}{R^2} \tag{5.8}$$

Rearrangement results in:

$$B = \frac{\mu_0 I}{2piR^2} r \tag{5.9}$$

6 Solenoid

The Solenoid should have a diameter which is fair smaller than the length of the coil. They have such properties:

- The magnetic field inside a solenoid is uniform.
- Infinitely Long

6.1 Ampere's Law

From Biot-Savart Law:

$$\frac{\pi r^2}{\pi R^2} = \frac{r^2}{R^2} \tag{6.1}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I \tag{6.2}$$

6.2 Ampere's Law Inside a Wire

In here we assume constant current denssity.

Ratio of Area:

$$\frac{\pi r^2}{\pi R^2} = \frac{r^2}{R^2} \tag{6.3}$$

Hence:

$$\oint \vec{B} \cdot d\vec{s} = \frac{\mu_0 r^2 I}{R^2} \tag{6.4}$$

Replace Line Integral

$$2\pi r B = \frac{\mu_0 r^2 I}{R^2} \tag{6.5}$$

Rearrangement results in:

$$B = \frac{\mu_0 I}{2piR^2} r \tag{6.6}$$

7 Solenoid

The Solenoid should have a diameter which is fair smaller than the length of the coil. They have such properties:

- The magnetic field inside a solenoid is uniform.
- Infinitely Long

7.1 Ampere's Law

From Biot-Savart Law:

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I \tag{7.1}$$

Replace with line Integral:

$$Bl = \mu_0 NI \tag{7.2}$$

Hence:

$$B = \frac{\mu_0 NI}{l} = mu_0 nI \tag{7.3}$$

n is the number of turns per unit length

7.2 Doughnut Shape

$$B = \frac{\mu_0 NI}{2\pi r} \tag{7.4}$$

8 Frequency of a Cyclotron

$$f = \frac{qB}{a\pi m} \tag{8.1}$$

9 Hall Effect

$$\Delta V_H = \frac{IB}{tne} \tag{9.1}$$

n= charge density. e= charge of an Electron.

10 Force on Wire Due To Magnetic Field

$$F = BIL\frac{\mu_o I_1 I_2}{2\pi d}$$

11 Magnetic Moment

$$IA = Il2 = \mu \tag{11.1}$$

12 Torque due to Magnetic Field

$$\vec{\tau} \times \vec{B} = \mu B sin\theta \tag{12.1}$$

13 Electromagnetic Induction

14 Eddy Currents

An current loop with a hole present acts like a capacitor with charges on either end of the hole. There IS Indeed an EMF even though no current will flow.

15 Faraday's Law

$$\varepsilon = \left|\frac{d\Phi_b}{dt}\right| = \left|\vec{B} \cdot \frac{d\vec{A}}{dt} + \vec{A} \cdot \frac{d\vec{B}}{dt}\right| \tag{15.1}$$

The direction of current is defined by Lenz's Law.

16 Induced Electric Field

If we divide the equation above into two parts. We can see that we have induced Electric-field which is non-Couloumbic.
This is generated by a **changing** magnetic field. Such force will still exert the force $F = qe$ on an charge. (Same as Coulombic Electric Field)

We know that :

$$W = q \oint \vec{E} \cdot d\vec{s} \tag{16.1}$$

Hence we can write that:

$$\varepsilon = \oint \vec{E} \cdot d\vec{s} \tag{16.2}$$

We can also conclude that:

$$\oint \vec{E} \cdot d\vec{s} = A \left| \frac{d\vec{B}}{dt} \right| \tag{16.3}$$

$$\tag{16.4}$$

If we have the pendulum we will have a Lorentz current which causes a Force.

17 Modified Faraday's Law

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\vec{\Phi}_B}{dt} \tag{17.1}$$

Where $ds = 2\pi r$ if the line is a circle.

18 Application of Faraday's Law

18.1 AC generator

18.1.1 EMF

$$\varepsilon = -N\frac{d\vec{\Phi}_B}{dt} = -N\frac{dBA\vec{cos}(\omega t)}{dt} = NBAsin(\omega t) \tag{18.1}$$

18.2 Transformer

It does not work with DC (DC current only causes a constant Magnetic Field.

Ratio:

$$\frac{V_1}{V_2} = N_1 N_2 \tag{18.2}$$

Current (Energy must be conserved):

$$V_1 I_1 = V_2 I_2 \tag{18.3}$$
$$\frac{V_1}{V_2} = \frac{I_2}{I_1} \tag{18.4}$$
$$\frac{N_1}{N_2} = \frac{I_2}{I_1} \tag{18.5}$$

18.3 Metal Detector

The Transmitter coil causes a current in the receiver coil, but the metal can reduce the current in the receiver coil due to eddy currents.

18.4 Inductor

EMF:

$$V = -L\frac{dI}{dt} \tag{18.6}$$

Inductance

$$L = \frac{\mu_0 N^2 A}{l} \tag{18.7}$$

The negative signs indicates that it opposes the change in current.

18.5 Maxwell's Equations

Gauss's Law for Magnetism

$$\oint \vec{B} \cdot d\vec{A} = 0 \tag{18.8}$$

Ampere-Maxwell's Law

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{through} + \epsilon_0 \mu_o \frac{d\Phi_e}{dt} \tag{18.9}$$

Lorentz's Force Law

$$F = q\vec{E} + q\vec{v} \times \vec{B} \tag{18.10}$$

19 Electromagnetic Waves

An oscillating charge will create a changing magnetic and electric field which generates an EM Wave.

Poynting vector:

$$|\vec{S}| = \frac{1}{\mu_0}\vec{E} \times \vec{B} = \frac{EB}{\mu_0} \tag{19.1}$$

Hence

$$\frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2\mu_0} B^2 \tag{19.2}$$