DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB101J-Electromagnetic Theory, Quantum Mechanics, Waves and Optics

Module I

Faraday’s Law and Ampere’s Law statement and Explanation

Biot – Savart Law

Biot – Savart law is used to calculate the magnetic field due to a current carrying conductor. According to this law, the magnitude of the magnetic field at any point P due to a small current element $I.dl$ (I = current through the element, dl = length of the element) is

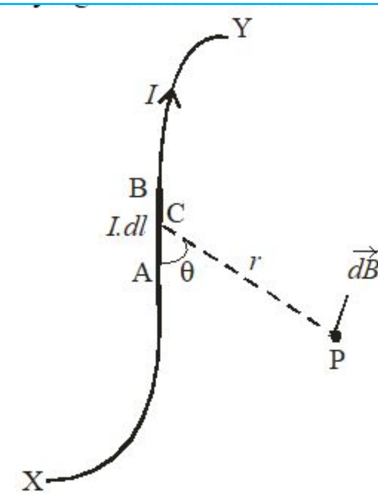


Fig. 2.5 Biot – Savart law

1. directly proportional to the current (I)

   directly proportional to the length of the current element (dl)

2. directly proportional to the sine of the angle (θ) between the direction of the current and the line joining the current element to the point P and

3. inversely proportional to the square of the distance between (r) of the point P from the current element

i.e. $$dB \propto \frac{Idl \sin\theta}{r^2} \text{ (or)}$$

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{Idl \sin\theta}{r^2}$$

In vector notation, $$\overrightarrow{dB} = \frac{\mu_0}{4\pi} \cdot \frac{\overrightarrow{idl} \times \vec{r}}{r^3}$$

The direction of vector dB is the direction of the vector $\overrightarrow{idl} \times \vec{r}$ (i.e.) perpendicular to the plane of the paper and inwards.

Faraday’s Law of electromagnetic induction

Michael Faraday found that whenever there is a change in magnetic flux linked with a circuit, an emf is induced resulting a flow of current in the circuit. The magnitude of the induced emf is directly proportional to the rate of change of magnetic flux.

Lenz’s rule gives the direction of the induced emf which states that the induced current produced in a circuit always in such a direction that it opposes the change or the cause that produces it.

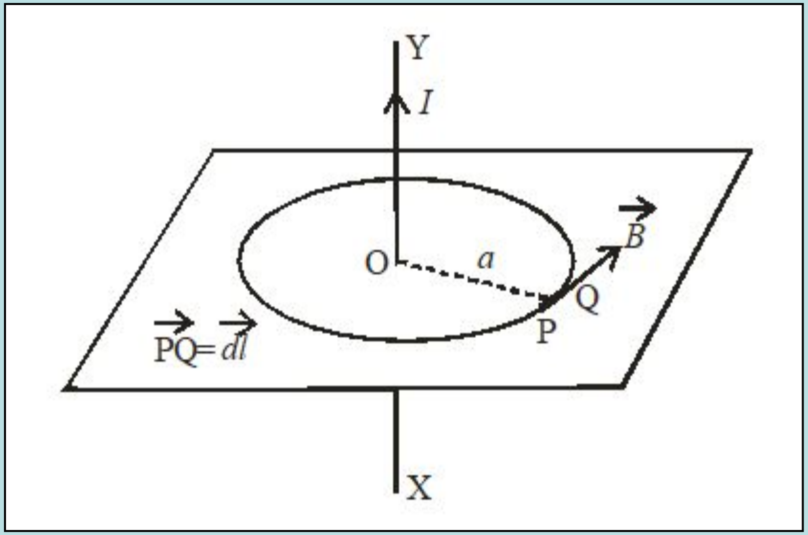
By combining Lenz's rule with Faraday's law of electromagnetic induction, the induced emf can be written as,

$$\text{induced emf } (e) = -\frac{d\phi}{dt}$$

where $d\varphi$ is the change magnetic flux linked with a circuit in a time dt second.

Ampere's circuital law

It states that the line integral of the magnetic field (vector B) around any closed path or circuit is equal to μ_0 (permeability of free space) times the total current (I) threading through the closed circuit. Mathematically,



Ampere’s circuital law

$$\oint \vec{B}.\vec{dl} = \mu_0 I$$

It may be noted that the magnitude of the magnetic field at a point on the circular path changes with the change in radius of the circular path but the line integral of vector *B* over any closed path will be independent of its radius i.e. equal to μ_0 times the current threading the circle.