**The Biot - savart law in vector form:**

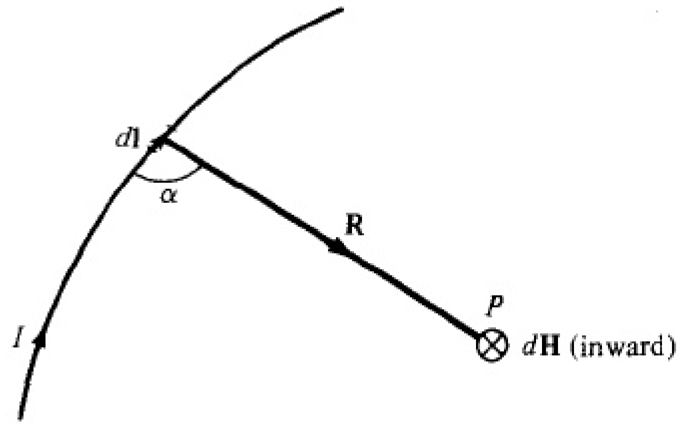


Fig 1: Magnetic field dH at P due to current element I dl

$$dH_2 = \frac{I\, dl_1 aR_{12}}{4\pi R_{12}^2}$$

Consider a conductor carrying a direct current I and a steady magnetic field produced around it.

The Biot-savart law states that the magnetic field intensity dH produced at a point P due to a differential current element Idl is,

i. Proportional to the product of current I and length dl
ii. Sine of angle between line joining pointP to the element dl
iii. Inversely proportional to the square of distance between point P and dl.

$$dH \propto \frac{I\ dl \sin\theta}{R^2}$$

dH = $\frac{K\, I\, dl\, sin\theta}{R^2}$ K=constant,K=$\frac{1}{4\pi}$

dH = $\frac{I\, dl\, sin\theta}{4\pi R^2}$

Now express this equation in vector form. dl = magnitude of vector length. a$\bar{R}$→ unit vector in the direction from the differential current element to point P.

Then d$\bar{l}$ x a$\bar{R}$ = dl $|a\bar{R}|$ sin $\theta$

= dl sin $\theta$

dH = $\frac{I\, d\bar{l}\, X\, aR}{4\pi R^2}$A/m

$$d\bar{H} = \frac{I\, dl\, X\, R}{4\pi R^3} \text{ A/m}$$

The entire conductor is made up of all such differential elements.

Hence total magnetic field intensity H

$$H = \oint \frac{I\, d\bar{l}\ X\, a\bar{R}}{4\pi R^2} \text{ A/m}$$

The closed line integral is required to ensure that all the current elements are considered. This is because current can only flow in the closed path, provided by the closed circuit. If the current element is at point 1 and field is measured at point 2

$$d\overline{H_2} = \frac{I_1\, dl_1 X\, aR_{12}}{4\pi R_{12}^2} \text{A/m}$$

$I_1$= current flowing through $dl_1$ at point 1.
$dl_1$ = differential vector length at point 1.
$aR_{12}$ = unit vector in the point 1, direction from element at point 1 to point 2.

$$\overline{aR_{12}} = \frac{\overline{R_{12}}}{|\overline{R_{12}}|}$$

$$H_2 = \oint \frac{I_1\, dl_1 X\, a\overline{R_{12}}}{4\pi R_{12}^2} \text{ A/m}$$


Fig 2 a: Determine direction of dH using right hand rule
b: The right handed screw rule


Fig3a : H out of the page, b: H into the page

**Biot-savart law in terms of Distributed Sources:**

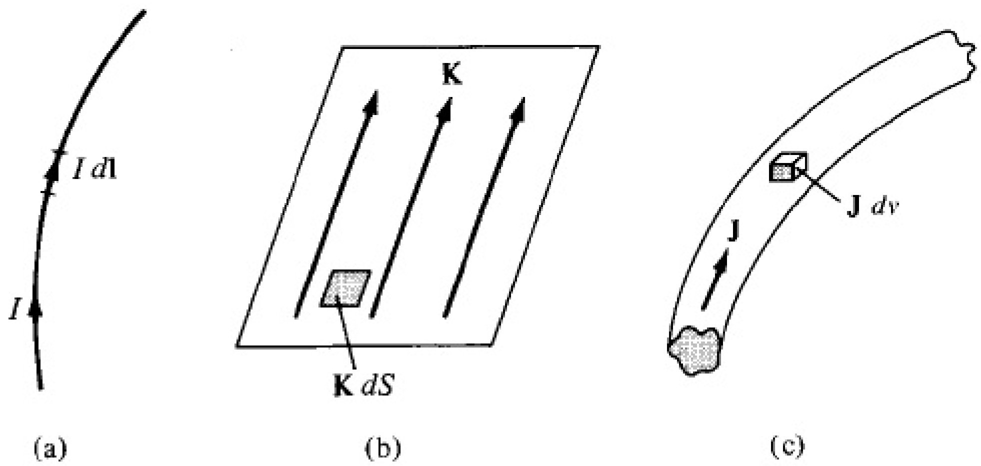

Fig 4: Current distributions a: Line current , b: Surface current, c: Volume current.

The surface current density is denoted as K and measured in amperes per meter. (A/m) Thus for uniform current density the current I in any width b is given by I = Kb.

Where the width b is perpendicular to the direction of current flow. Thus if ds is the differential surface are a considered a surface having current density $\overline{K}$ then,

$$I\, d\overline{l} = \overline{K}\, ds$$

If the current density in a volume of a given conductor is J measured in $A/m^2$ then for a differential volume dv.

$$I\, d\overline{l} = \overline{J}\, dv$$

Hence Biot – savart law can expressed for surface current considering $\overline{K}$ ds while for volume current $\overline{J}$ dv.

$$\overline{H} = \int_S \frac{\overline{K}\, dS\ X\ aR}{4\pi R^2} \quad \text{A/m.}$$

$$H = \int \frac{JdVX\ \overline{aR}}{4\pi R^2}\, dv \quad \text{A/m.}$$

The Biot-savart law is also called Amperes law for the current element.