Magnetic field intensity due to straight conductor, circular loop

H due to straight conductors

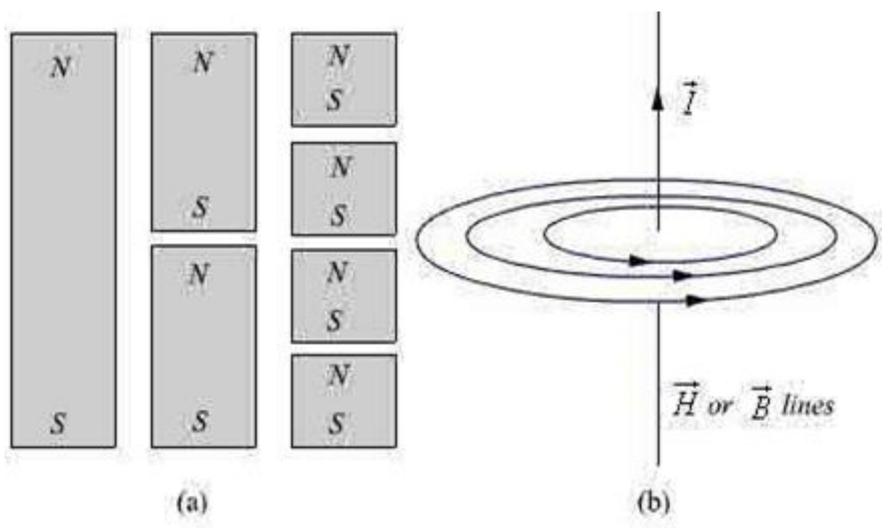
In simple matter, the magnetic flux density $\vec{B}$ related to the magnetic field intensity $\vec{H}$ as $\vec{B} = \mu \vec{H}$ where μ c alledthe permeability. In particular when we consider the free space $\vec{B} = \mu_0 \vec{H}$

where $\mu_0 = 4\pi \times 10^{-7}$ H/m is the permeability of the free space. Magnetic flux density is measured in terms of Wb/m ^{2} .

The magnetic flux density through a surface is given by:

$$\psi = \int_S \vec{B} \, d\vec{s} \quad \text{Wb}$$

In the case of electrostatic field, we have seen that if the surface is a closed surface, the net flux passing through the surface is equal to the charge enclosed by the surface. In case of magnetic field isolated magnetic charge (i. e. pole) does not exist. Magnetic poles always occur in pair (as N-S). For example, if we desire to have an isolated magnetic pole by dividing the magnetic bar successively into two, we end up with pieces each having north (N) and south (S) pole as shown in Fig. 4.7 (a). This process could be continued until the magnets are of atomic dimensions; still we will have N-S pair occurring together. This means that the magnetic poles cannot be isolated.



Similarly if we consider the field/flux lines of a current carrying conductor as shown in Fig. 4.7 (b), we find that these lines are closed lines, that is, if we consider a closed surface, the number of flux lines that would leave the surface would be same as the number of flux lines that would enter the surface.

From our discussions above, it is evident that for magnetic field,

$$\oint_S \vec{B}.d\vec{s} = 0$$

which is the Gauss's law for the magnetic field.By applying divergence theorem, we can write:

$$\oint_S \vec{B}.d\vec{s} = \int_V \nabla.\vec{B}dv = 0$$

Hence,

$$\nabla.\vec{B} = 0$$

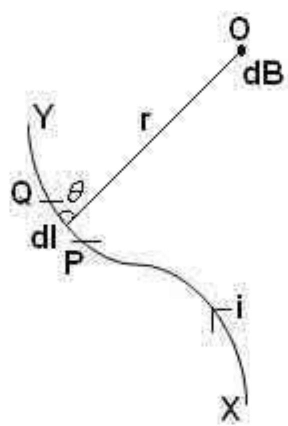
which is the Gauss's law for the magnetic field in point form.

3.4.1 H due to circular loop

A current carrying wire generates a magnetic field. According to Biot-Savart‟s law, the magnetic field at apoint due to an element of a conductor carrying current is,

Directly proportional to the strength of the current, *i*

1. Directly proportional to the length of the element, *dl*
2. Directly proportional to the Sine of the angle θ between the element and the line joining the element to thepoint and
3. Inversely proportional to the square of the distance *r* between the element and the point.



Thus, the magnetic field at O is dB, such that,

$$dB \propto \frac{i\,dl\,Sin\,\theta}{r^2}$$

$$dB = k\frac{i\,dl\,Sin\,\theta}{r^2} \quad dB = k\frac{i\,dl\,Sin\,\theta}{r^2}$$

Then,

where,

$$k = \frac{\mu_0}{4\pi}$$

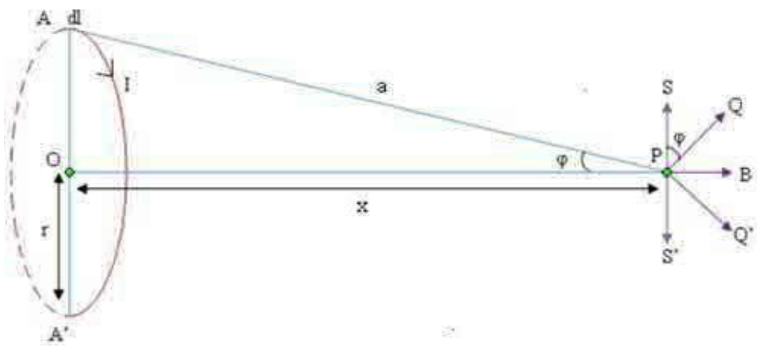
.

$$dB = \frac{\mu_0}{4\pi} \frac{i\, dl\, Sin\theta}{r^2}$$

In vector form,

$$d\vec{B} = \frac{\mu_0}{4\pi} i \frac{d\vec{l} \times \vec{r}}{r^3}$$

Consider a circular coil of radius r, carrying a current I. Consider a point P, which is at a distance x from the centre of the coil. We can consider that the loop is made up of a large number of short elements, generating small magnetic fields. So the total fieldat P will be the sum of the contributions from all these elements. At the centre of the coil, the field will be uniform. As the location of the point increases from the centre of the coil, the field decreases.



By Biot- Savart‟s law, the field dB due to a small element dl of the circle, centered at A is given by,

$$dB = \frac{\mu_0}{4\pi} I \frac{dl}{(x^2 + r^2)}$$

This can be resolved into two components, one along the axis OP, and other PS, which is perpendicular to OP. PS is exactly cancelled by the perpendicular component PS‟ of the field due to a current and centered at A‟. So, the total magnetic field at a point which is at a distance x away from the axis of a circular coil of radius r is given by,

$$B_x = \frac{\mu_0 I}{2} \frac{r^2}{(x^2 + r^2)^{3/2}}$$

If there are *n* turns in the coil, then

$$B_x = \frac{\mu_0 nI}{2} \frac{r^2}{(x^2 + r^2)^{3/2}}$$

$$\boldsymbol{B}_x = \frac{\mu_0 \boldsymbol{nI}}{2} \frac{\boldsymbol{r}^2}{(\boldsymbol{x}^2 + \boldsymbol{r}^2)^{3/2}}$$

$$B_x = \frac{\mu_0 n I}{2} \frac{r^2}{(x^2 + r^2)^{3/2}}$$

$$B_x = \frac{\mu_0 n I}{2} \frac{r^2}{(x^2 + r^2)^{3/2}}$$

where μ_0 is the absolute permeability of free space. Since this field B_x from the coil is acting perpendicular to the horizontal intensity of earth‟s magnetic field, B_0, and the compass needle align at an angle θ with the vector sum ofthese two fields, we have from the figure

H due to infinite sheet of current

In this case symmetry and the infinite extent of the sheet insures that **B** will have no components toward or away from the sheet nor will be any components in the direction of the current. Thus B will be in the directions indicated in the figure. Ampere's law can be used easily here provided the line integral is evaluated along the rectangular path of the figure.

$$\int \mathbf{B} \cdot d\mathbf{s} = \mu_0 I,$$

becomes, since the line integral is $\int \mathbf{B} \cdot d\mathbf{s} = 2lB$, and the current through the integration loop is $I = lJ_s$, where J_s is the current per unit length in the z-direction,

$$2lB = \mu_0 l J_s,$$

or

$$B = \mu_0 J_s / 2$$

in the direction indicted. Note that B is independent of the distance from the current sheet. In a real situation, with a non-infinite sheet, the derived result is still close to being valid as long as the distance from the sheet is small compared the the extent of the sheet. o