Lecture (4)

Electricity and Magnetism II

First Stage
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Example: Calculate the magnetic field due to a wire in the shape of an arc that is one sixth of a circle of radius 0.2 m at the center of the circle when it carries a current of 4 A in a clock wise direction. Assume the arc lies on the xy-plane.

Sol.

Amperes Law for the magnetic field

Let us discuss some of the properties of static or time independent magnetic field.

Consider an infinite rectilinear current (**I**) the magnetic field $\vec{\boldsymbol{B}}$ at a point **A** is perpendicular to **OA** as in the figure below, and given by the equation:

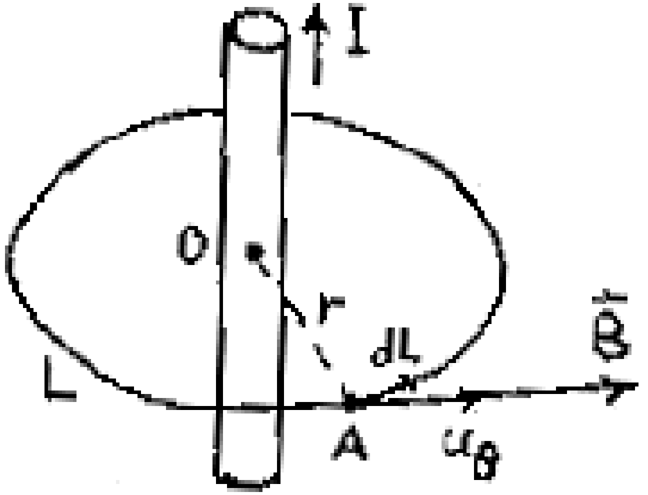
$$\vec{\boldsymbol{B}} = \frac{\boldsymbol{\mu_o\, I}}{\boldsymbol{2\,\pi\, r}}\vec{\boldsymbol{u}}_{\boldsymbol{\theta}}$$

To compute the circulation of $\vec{\boldsymbol{B}}$ around a circular path of radius **r**. the magnetic field $\vec{\boldsymbol{B}}$ is tangent to the path, so that:

$$\vec{\boldsymbol{B}}.\overrightarrow{\boldsymbol{dL}} = \boldsymbol{B\, dL}$$

and is constant in magnitude, therefore the magnetic circulation (designated by $\boldsymbol{\Lambda_B}$ and some times called the magnetomotive force **mmf**).

$$\Lambda_B = \oint_L \vec{B}.\vec{dL} = \oint_L B\, dL = B \oint_L dL = BL$$

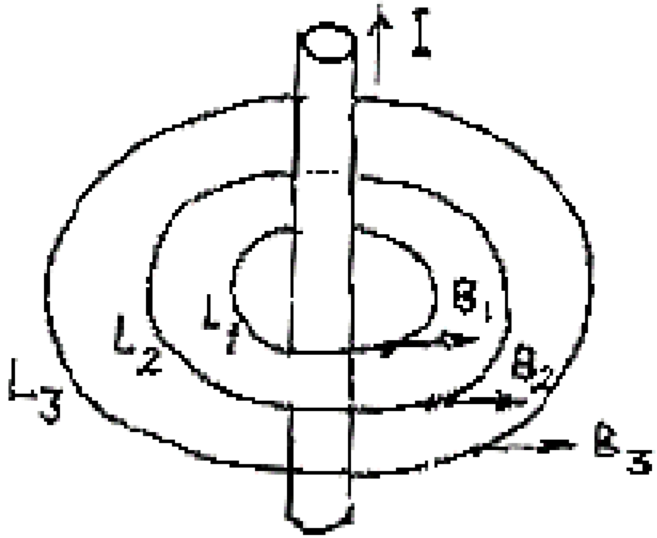


$$\Lambda_B = \frac{\mu_o\, I}{2\,\pi\, r}(2\,\pi\, r)$$

Because $L = 2\pi r$

$$\Lambda_B = \mu_o\, I$$

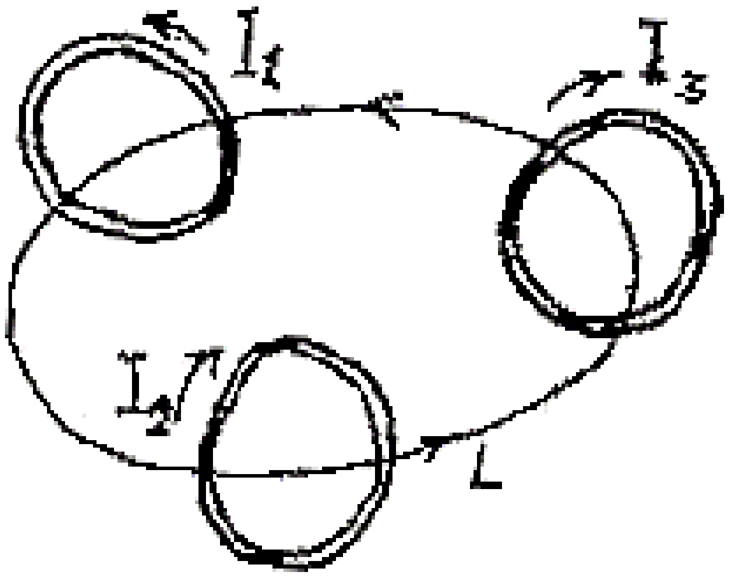
The magnetic circulation Λ_B is proportional to the electric current (**I**) and is independent of the path of the radius. Therefore, if around the current (**I**) we draw several circles $L_1, L_2, L_3, \ldots$ (as in the figure below), the magnetic circulation around all of them is the same, and is equal to ($\mu_o\, I$).



Amperes Law: the circulation of the magnetic field or (**mmf**) along a closed line which links current $\boldsymbol{I_1}, \boldsymbol{I_2}, \boldsymbol{I_3}, \ldots$ is

$$\boldsymbol{\Lambda_B} = \oint_{L} \vec{\boldsymbol{B}}.\overrightarrow{\boldsymbol{dL}} = \boldsymbol{\mu_o}\, \boldsymbol{I}$$

Where, $\boldsymbol{I} = \boldsymbol{I_1} + \boldsymbol{I_2} + \boldsymbol{I_3} + \cdots$ stands for the total current linked by the path (**L**) see figure below.



Examples on Amperes Law

Example 1: magnetic field produced by a current along a circular cylinder of infinite length.

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Consider a current **I** along a cylinder of radius **a** (as in the figure).

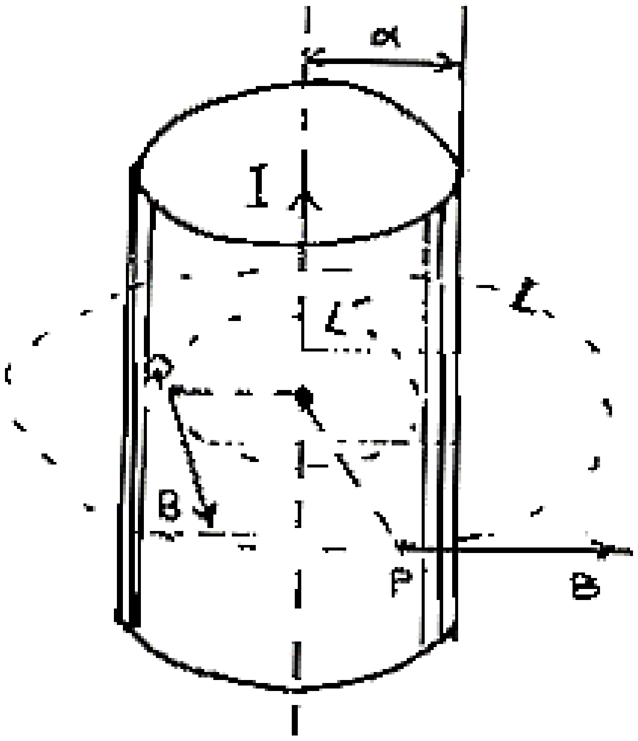

Figure magnetic field of a cylindrical conductor

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Example 2: Magnetic field produced by a toroidal coil.

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A toroidal coil consists of a wire uniformly wound on a torus, as shown in figure below.

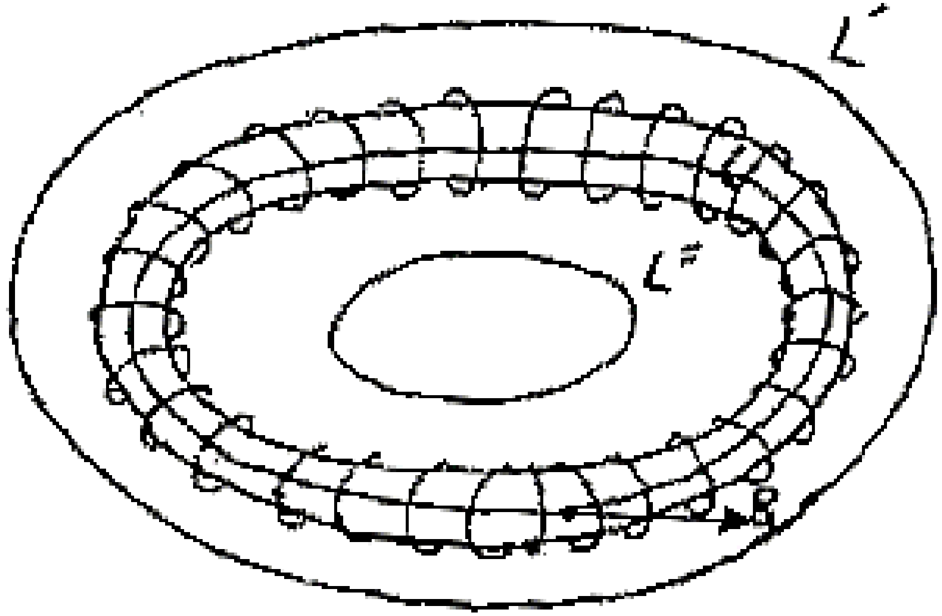

Figure magnetic field of a toroidal coil

Example 3: A toroidal coil with a circumference 0.2 m is wrapped with 1500 turns of wire that carries a current of $\mathbf{1.5}\ \boldsymbol{s^{-1}}\ \boldsymbol{C}$. Find the magnetic field within the toroid.

Example 4: find the magnetic field in air 1 cm from a wire that carries a current of 1A (as in the figure below).

Sol.