3–21 Ampère's Law

Note: Ampère's Law is needed for AP Physics C: physical science majors, calculus based.

Ampère's Law and The Magnetic Field Around a Current Carrying Wire (Case 1 revisited)

Previously we learned that a current carrying wire generates a magnetic field that circles the wire and varies proportional with the distance from the wire. If we integrate along the path of this circular field, by summing the magnetic field over very small distance it is found to be $\boxed{\oint B \cdot d\ell = \mu_0 I}$. The permeability of free space to the magnetic field is $\mu_0 = 4\pi \times 10^{-7}\, T \cdot m/A$.

It is useful for calculating the magnetic field around current carrying configurations that have a high degree of symmetry.

Example 21-1: Magnetic Field Around a Current Carrying Wire.

Solve for the magnetic field a distance r from a current carrying wire, in Fig 21.

Use Ampère's Law, $\boxed{\oint B \cdot d\ell = \mu_0 I}$. As it is highly symmetrical B can be removed from the integral, $B\oint d\ell = \mu_0 I$. The circumference of a circle is known, so integration is not necessary, $B(2\pi r) = \mu_0 I$. Rearrange to solve for B, $\boxed{B = \frac{\mu_0}{2\pi}\frac{I}{r}}$, and we arrive at the algebraic version of the equation, that was given previously.

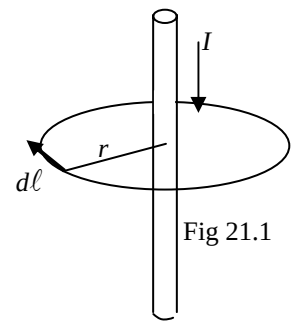

Fig 21.1

Solenoid: A solenoid is a wire wound in the form of a helix, as shown in fig 21.2

Magnetic Field of a Solenoid: A The magnetic field in a solenoid is strongest down the middle. The direction follows the right hand rule. The magnetic field is weak around the outside, and in many problems it may say that the field is negligible on the outside. The magnitude of the field is $\boxed{B_S = \mu_0 n I}$

n is the number of turns, N, in the solenoid per unit of length, ℓ. $n = \frac{N}{\ell}$.

A solenoid is a tightly wound coil of wire where each successive coil touches the next coil. This means that the diameter of the wire making up the solenoid is equal to the length of a single turn, $n = \frac{1}{diameter\ of\ wire}$, as shown in Fig 21.2.

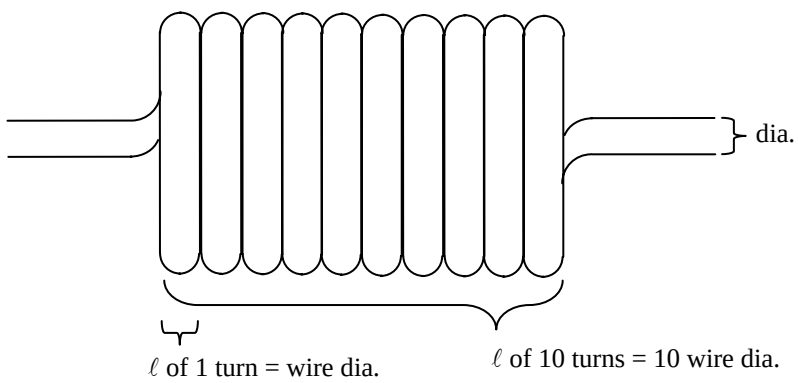

Fig 21.2

Magnetic Flux: The same principles and explanations apply to magnetic flux as they do the electric flux (see previous section on Gauss's Law). $\boxed{\phi_m = \int \mathbf{B} \cdot d\mathbf{A}}$. This is a dot product. The algebraic version is $\boxed{\phi_m = \mathbf{B} \cdot \mathbf{A} = BA\cos\theta}$. ***<u>Caution: remember that flux involves area. When referencing areas angles are measured from a normal (line drawn perpendicular to the surface).</u>***

Gauss's Law of Magnetism: The net magnetic flux through any closed surface is always zero. $\boxed{\oint \mathbf{B} \cdot d\mathbf{A} = 0}$

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