

MAGNETIC FIELDS:

- Pointlike fundamental particles have an intrinsic “magnetic moment” and as a result an associated intrinsic magnetic field, just as they have intrinsic charge and an associated electric field.
- Any charge moving with respect to an observer has an associated magnetic field detectable by the observer.
- A magnetic field exerts a force on any charge moving with respect to that field.

Permanent magnets: In certain metals, such as nickel, iron and cobalt, the magnetic moments of electrons line up so that the entire piece of metal has a magnetic field \mathbf{B} . Our own planet earth, with an iron core, has an associated magnetic field. The south magnetic pole of the earth is currently near the north geographic pole.

Lorentz Force: $F = qvB \sin \theta$.

The vector \mathbf{F} is perpendicular to the plane containing velocity \mathbf{v} and field \mathbf{B} .

We can use the force law to define a unit for B : the Tesla (N/A m). An older unit is the Gauss (10^{-4} T).

A charge will move in a circle in a uniform magnetic field. If the momentum of the charge is p , the radius of the circle will be $r = p/(qB)$.

Force per unit length on a current carrying wire in a B field:

$$\frac{F}{\ell} = IB \sin \theta.$$

Torque on a current loop in a B field:

$$\tau_{\max} = BIA.$$

$$\tau = BIA \sin \theta.$$

The magnetic moment μ has magnitude INA for a coil of area A with N turns. Thus

$$\tau = \mu B \sin \theta.$$

Field of a long straight wire:

$$B = \frac{\mu_0 I}{2\pi r}.$$

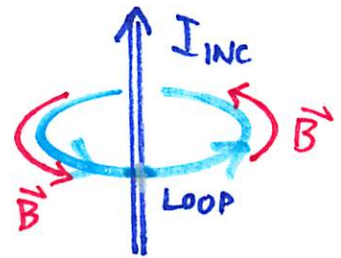
The constant $\mu_0 = 4\pi \times 10^{-7}$ T-m/A.

Magnetic fields *always form closed loops*. There is no known physical reason why “magnetic charges” should not exist, that act as sources or sinks of \mathbf{B} just as charges act as sources or sinks for \mathbf{E} , but none have ever been observed.



Ampere's Law:

$$\sum B_{\parallel} \Delta \ell = \mu_0 I_{\text{inc}}.$$



The idea is similar to Gauss's Law, we just look at currents passing through the loop we take.

Force between parallel wires:

$$\frac{F_{12}}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi d}.$$

Field at center of current loop:

$$B = \frac{\mu_0 I}{2R}.$$

Field inside a long solenoid (using Ampere's Law):

$$B = \mu_0 n I.$$

Main types of magnetic materials:

Paramagnetic: Internal magnetic moments align weakly with an external field.

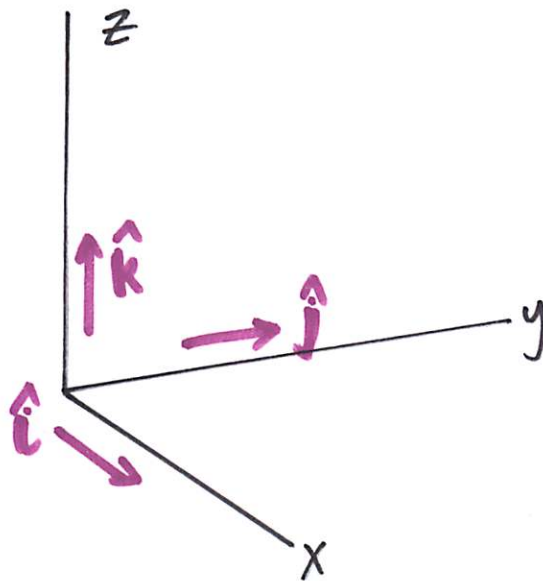
Diamagnetic: There is an induced weak internal **B** field that opposes an external field.

Ferromagnetic: Electron magnetic moments align strongly with any external field, and remain aligned after the external field is removed.

UNIT VECTORS:

One of the most useful concepts in vector algebra is the unit vector, which is a vector pointed in a specific direction, with magnitude 1.

The usual unit vectors encountered in elementary physics classes are $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$ and $\hat{\mathbf{k}}$. These vectors point along $+x$, $+y$ and $+z$.



The way these vectors are used is often just to specify a particular direction. By the way, Quest usually writes them in an incorrect notation as \hat{i} , \hat{j} , and \hat{k} .

For example if you knew the three components of a vector \mathbf{A} , namely A_x , A_y and A_z , you could write

$$\mathbf{A} = \hat{\mathbf{i}}A_x + \hat{\mathbf{j}}A_y + \hat{\mathbf{k}}A_z.$$