The Magnetic Field

- like with charges & $\vec{E}$ one magnet produces a magnetic field (field lines)

So far we talked about electric charges & $\vec{E}$ where el. charge is a fundamental property of matter & its interactions were explained by the concept $\vec{E}$

Magnetism is also based on electric charge.

But there is a crucial difference:

The phenomena of magnetism involve moving electric charge.

Moving electric charge is the source of magnetic field $\vec{B}$

Some $\vec{B}$ properties:

1) $\vec{B}$ is created at all points in space surrounding a current carrying wire

2) $\vec{B}$ at each point is a vector. It has a magnitude whic we call

magnetic field strength B or $|\vec{B}|$ & direction

3) $\vec{B}$ exerts forces

Remember that so far $\vec{F}_E = q\vec{E}$

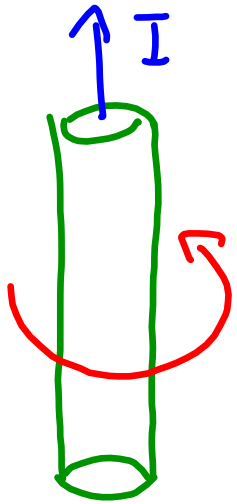
$$\boxed{\vec{F} = q\vec{v} \times \vec{B}}$$

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

Right hand rule for magnetic field

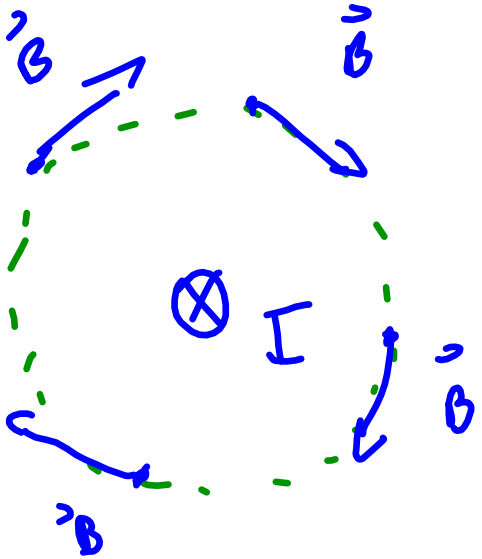
1) point your right thumb in the direction of the current

2) curl your fingers around the wire to indicate a circle



3) your fingers point in the direction of the magnetic field lines around the wire

- easier to draw if a current is pointing in or out of the page $\vec{F}_{wire} = I\vec{\ell} \times \vec{B}$



at every point of a circle $\vec{B}$ is a tangent to a circle

⊗ current into the page

⊙ out of

Biot - Savart Law

- analagous to Coulomb's law

$$\vec{B}_{\text{point charge}} = \left(\frac{\mu_0}{4\pi} \frac{q v \sin\theta}{r^2}, \text{ direction given by right-hand rule} \right)$$

SI unit for magnetic field is

Tesla [T]

$\mu_0 = 4\pi \cdot 10^{-7}$ Tm / A is

permeability constant

(similar to ε_0 permittivity etc)

typical $|\vec{B}|$ strengths:

surface of the earth $5 \cdot 10^{-5}$ T

refrigerator magnet $5 \cdot 10^{-3}$ T

superconducting material 10 T

Superposition of magnetic field

$$\vec{B} = \vec{B}_1 + \vec{B}_2 + \ldots$$

All charges create $\vec{E}$, but only moving charges create $\vec{B}$!

The magnetic force on a moving charge

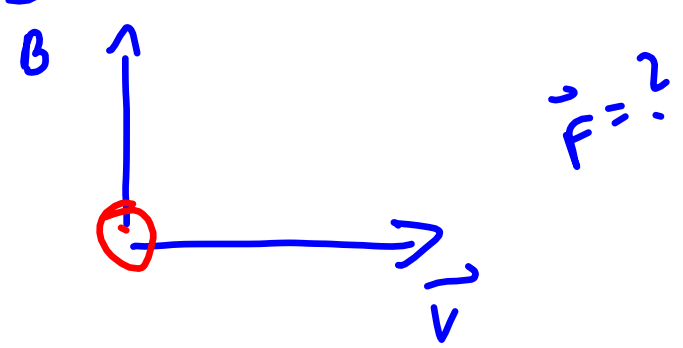
$$\vec{F} = q\vec{v} \times \vec{B} = qvB\sin\alpha$$

$\vec{v}$ thumb

$\vec{B}$ pointing finger

$\vec{F}$ middle finger

α angle between $\vec{v}$ & $\vec{B}$



$$\vec{F} = q\vec{v} \times \vec{B}$$

$$\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$$

$$\vec{F} = q \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_z \\ B_x & B_y & B_z \end{vmatrix}$$

$$F_x\hat{i} + F_y\hat{j} + F_z\hat{k} = q\left[\hat{i}(v_yB_z - v_zB_y) - \hat{j}(v_xB_z - v_zB_x) + \hat{k}(v_xB_y - v_yB_x)\right]$$