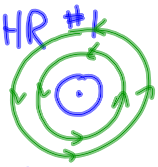
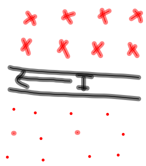
Magnetic Fields

Review:

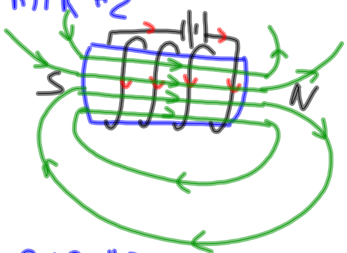
Magnetic field lines point in the direction that the north pole of a compass points.

RHR #1

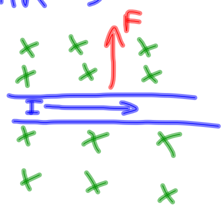




RHR #2



RHR #3



Motion of Electric Charges in Magnetic Fields

Cross product: $\vec{A} \times \vec{B} = \vec{C}$

$= |\vec{A}||\vec{B}|\sin\theta$ — angle between $\vec{A}$ and $\vec{B}$

On a wire of current, $\vec{I}$ and length, ℓ, in magnetic field $\vec{B}$...

$\vec{F_m} = \ell \vec{I} \times \vec{B}$

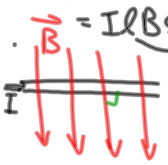
$= I\ell B\sin\theta$ — length of wire in B

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

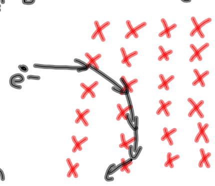
$= qvB\sin\theta$

$I = \frac{q}{t} \therefore q = It$

$v = \frac{d}{t} = \frac{\ell}{t}$



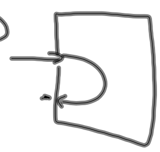
we get circular motion



$F_m = qvB\sin\theta = F_{NET} = F_c$ ($\sin\theta = 1$)

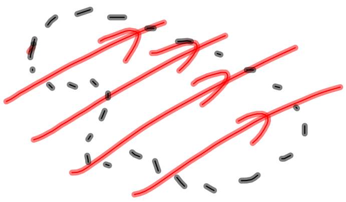
$qvB = \frac{mv^2}{r}$

$r = \frac{mv}{qB}$

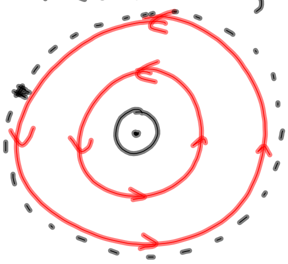


Ampère's Law

In any closed path through a magnetic field the sum of the dot product between $\vec{B}$ and the length of the path segment, $\Delta\vec{\ell}$, is proportional to the net current inside the closed path.



Ex. 1 : A conducting wire



$\sum \vec{B}\cdot\Delta\vec{\ell} \propto I$ $\quad \sum \vec{B}\cdot\Delta\vec{\ell} = \mu_0 I$

$\mu_0 \rightarrow 4\pi \times 10^{-7}\ \frac{T}{A}$

$\vec{B}$ is constant for the entire path

$\therefore \sum \vec{B}\cdot\Delta\vec{\ell} = \sum B\Delta\ell\cos\theta$

$= B\sum\Delta\ell\cos\theta$

But $\theta = 0 \therefore \cos\theta = 1$

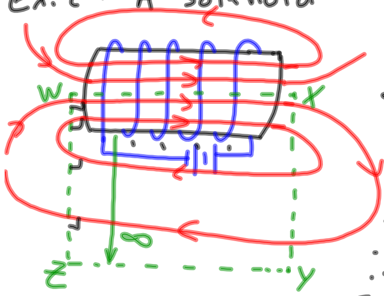
$= B\sum\Delta\ell$

$= B(2\pi r)$

$\therefore 2\pi r B = \mu_0 I$

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

Ex. 2 : A solenoid



$\sum \vec{B} \cdot \Delta \vec{\ell}$

For WZ

since $\vec{B} \perp \Delta \vec{\ell}$

then $\vec{B} \cdot \Delta \vec{\ell} = 0$

$\therefore \sum \vec{B} \cdot \Delta \vec{\ell} = 0$

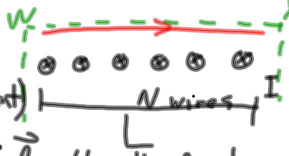
same for XY

For ZY...

$B = 0$

$\therefore \sum \vec{B} \cdot \Delta \vec{\ell} = 0$

For WX...



$|\vec{B}| = B$ (constant)

$\sum \vec{B} \cdot \Delta \vec{\ell}$ & $\vec{B} \parallel \vec{\ell}$ (length of solenoid)

$= B \sum \Delta \ell$

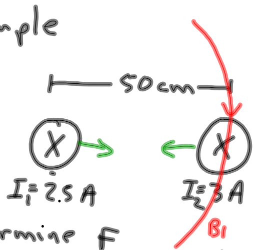
$= BL$

$\sum \vec{B} \cdot \Delta \ell = \mu_0 I_T$ — total current within path

$BL = \mu_0 N I$

$B = \frac{\mu_0 N I}{L}$ or $\mu_0 I ($

Example



Determine F (per unit of length)

$\ell \vec{I} \times \vec{B}$

$B_1 = \frac{\mu_0 I_1}{2\pi r}$

$F_2 = I \ell B \sin\theta$

$= I_2 \ell B_1$ ($\sin\theta = 1$)

$\frac{F_2}{\ell} = I_2 \left(\frac{\mu_0 I_1}{2\pi r} \right)$

$\frac{F}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi r}$

$= \frac{(4\pi \times 10^{-7})(2.5)(3)}{2\pi (0.5)}$

$= 3 \times 10^{-6} \frac{N}{m}$

1 A is defined as the current going through 2 parallel wires that results in a 2×10^{-7} N force between them when they are 1 m away.

Electromagnetic Induction

An electric current is induced whenever there is a changing magnetic field in the vicinity of a conductor.

Lenz's Law:

The induced current is created in such a way as to create a magnetic field that resists the motion (or change) in the inducing field.

Eg.