Magnetism

Magnetism Equations

Point Charge

$\vec{B} = \frac{\mu_0}{4\pi} \frac{qv\sin(\theta)}{r^2}$

$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$

1 Tesla $= N/Am$

Infinite Wire

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

Current Loop

$B = \frac{\mu_0}{2} \frac{NI}{R}$

Solenoid

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

Current Segment

$\vec{B} = \frac{\mu_0}{4\pi} \frac{I\Delta\vec{s} \times \hat{r}}{r^2}$

Long, Straight Wire

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

Coil Center

$B = \frac{\mu_0}{2} \frac{NI}{R}$

Dipole

$\vec{B} = \frac{\mu_0}{4\pi} \frac{2\vec{\mu}}{z^3}$

$\vec{\mu} = AI$

Current is in the direction of curled fingers.

Ampère's Law

$\int_{surface} \vec{B} \cdot d\vec{s} = \mu_0 I_{through}$

Positive currents are ones flowing in direction of thumb when curled with current.

Field Inside Current-Carrying Wire

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

Solenoid

$B = \frac{\mu_0 NI}{l} = \mu_0 nI$

Magnetic Force

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

Notice force is in the opposite direction if the charge is negative

This also implies cyclotron motion by showing that the force is perpendicular when initially traveling straight in a field.

Cyclotron

Radius

$r_{cyc} = \frac{mv}{qB}$

Frequency

$f_{cyc} = \frac{qB}{2\pi m}$

Hall Effect

Voltage

$\Delta V_H = \frac{IB}{tne}$

Forces Between Wires

$\vec{F} = I\vec{l} \times \vec{B}$

Parallel Wires

$F = I_1 l B_2 = \frac{\mu_0 l I_1 I_2}{2\pi d}$

d is distance between them.

Same direction attract. Different repel.

Torque

Current Loop

$\vec{\tau} = \vec{\mu} \times \vec{B}$

μ is the vector defined earlier.

Electromagnetic Wave Velocity

$v = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$

Transformer

Coil ratio:

$V_2 = \frac{N_2}{N_1} V_1$

Inductor

Henries

$L_{solenoid} = \frac{\mu_0 N^2 A}{l}$

Potential

$\epsilon = L|\frac{dI}{dt}|$

Potential across inductor is opposite of circuit polarity.

Energy

Stored

$U_L = \frac{1}{2} L I^2$

Density

$u = \frac{1}{2\mu_0} B^2$

LC Circuits

Oscillation frequency:

$\omega = \sqrt{\frac{1}{LC}}$

$f = \omega / 2\pi$

or

$I = I_{max} \sin(\omega t)$

LR Circuits

Discharging

$I = I_0 e^{-t/\tau}$

$\tau = L/R$

Lenz's Law

The direction of induced current *opposes* the change in magnetic flux through a loop.

Faraday's Law

$I = \frac{\epsilon}{R}$

$\epsilon = |\frac{d\Phi_m}{dt}|$

$\epsilon_{coin} = N|\frac{d\Phi_{per\ coil}}{dt}|$

This can also be used to describe flux in a circuit by subbing in Φ for the flux equation and then realizing change in area is related to velocity of movement.

Induced Electric Fields

$\int_{surface} \vec{E} \cdot d\vec{s} = A|\frac{dB}{dt}|$

So $d\vec{s}$ is length of loop, then solve for $\vec{E}$.

$d\vec{s}$ also ensures that this vector is tangent to the curve.

Inside a solenoid

$E = \frac{r}{2}|\frac{dB}{dt}|$

Induced Currents

Motional EMF

$\epsilon = vlB$

Induced Current In Circuit

Current Created

$I = \frac{\epsilon}{R} = \frac{vlB}{R}$

Power Dissipated

$P = I^2 R = \frac{v^2 l^2 B^2}{R}$

Magnetic Flux

$\Phi_m = \vec{A} \cdot \vec{B}$

$\Phi_m = AB \cos\theta$

Units of weber: 1 Tm^2