$\vec{B} = \frac{\vec{F_B}}{q\vec{V}}$ [Tesla]	$\vec{B}$ = Magnetic Field	$\vec{F_B}$ = Magnetic Force	V = Velocity	q = Charge
$\vec{E} = \frac{\vec{F}}{q}$ [N/C]	$\vec{F}$ = Force	$\vec{E}$ = Electric Field	q = Charge	
$\vec{F_B} = q\vec{V}\vec{B}$[Newton]	$\vec{B}$ = Magnetic Field	$\vec{F_B}$ = Magnetic Force	V = Velocity	q = Charge

A Circulating Charged Particle

$F = ma, a = \frac{V^2}{r}$	$F = m(\frac{V^2}{r})$[Newton]
$\vec{F_B} = q\vec{V}\vec{B} = m\frac{V^2}{r}$ $\vec{F_B}$ = Magnetic Force	$r = \frac{m\vec{V}}{\vec{B}q}$[Meter]
$T = \frac{2\pi r}{V} = \frac{2\pi}{V}\frac{m\vec{V}}{\vec{B}q}$, T = Period	$T = \frac{2\pi m}{\vec{B}q}$ [Second]
$f = \frac{1}{T}$, f = Frequency	$f = \frac{q\vec{B}}{2\pi m}$ [Herz]
$w = 2\pi f, w = 2\pi\frac{q\vec{B}}{2\pi m}$ w = Angular Frequency	$w = \frac{q\vec{B}}{m}\left[\frac{Rad}{Second}\right]$
$w = \frac{V}{r}$, $V = wr$	$V = \frac{qBr}{m}\left[\frac{Meter}{Second}\right]$

Magnetic Force on a Current-Carrying Wire

$L = \vec{V}t$[Meter]	$t = \frac{L}{\vec{V}}$[Second]
$i = \frac{q}{t}$[A] $q = it$[C]	$q = i*(\frac{L}{\vec{V}})$ [C]
$\vec{F} = qVBSin\theta = i\frac{L}{V}VBSin\theta = iLBSin\theta$ [Newton]	$\vec{F} = i(\vec{L}\times\vec{B})$[Newton] , $d\vec{F_B} = i(d\vec{l}\times\vec{B})$

The Magnetic Dipole Moment of Coil

$\vec{\mu} = Ni\vec{A} = NI\vec{A}$[Amper*Meter^2] $\vec{\mu}$ = Magnetic dipole moment N = Number of turns of the coild A = The cross-sectional area of the coil

Torque

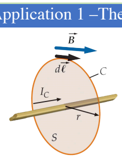
$\mathcal{T} = \vec{\mu}\times\vec{B} = \mu BSin\theta = Ni\vec{A}BSin\theta$ $\vec{\mu}$ = Magnetic dipole moment B = Magnetic Field N = Number of turns of the coild

$\mathcal{T} = \vec{p}\times\vec{E}$[Newton*Meter] E = Electric field p = Electric dipole moment

Magnetic Field due to Currents

$\oint\vec{E}d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$ → Gauss law	$\oint\vec{B}d\vec{s} = \mu_o I_{enc}$ → Ampere's law	$d\vec{B} = \frac{\mu_o}{4\pi}\frac{id\vec{s}\times\vec{r}}{r^3}$ → Biot-Savart Law
Magnetic Fields due to Current in a Long Straight Wire –Infinite	**Magnetic Fields due to Current in a Long Straight Wire –Finite**	**Magnetic Fields due to Current in a Circular arc of Wire**
$B = \frac{\mu_o i}{2\pi R}$	$B = \frac{\mu_o i}{4\pi R}$	$B = \frac{\mu_o i}{2R}$

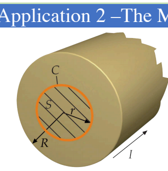
Application 1 –The Magnetic Field Outside a Long Straight Wire with Current



$\oint\vec{B}d\vec{s} = \mu_o I_{enc}$ $\vec{B}\oint d\vec{s} = \mu_o I_{enc}$

$\vec{B}(2\pi r) = \mu_o I_{enc}$ $\vec{B} = \frac{\mu_o I_{enc}}{(2\pi r)}$

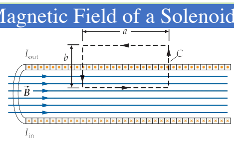
Application 2 –The Magnetic Field Inside a Long Straight Wire with Current



$\oint\vec{B}d\vec{s} = \mu_o I_{enc}$ $\vec{B}\oint d\vec{s} = \mu_o I_{enc}$

$\vec{B}(2\pi r) = \mu_o I\frac{\pi r^2}{\pi R^2}$ $\vec{B} = \mu_o I\frac{r}{\pi R^2}$

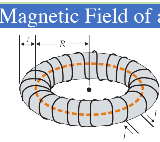
Magnetic Field of a Solenoid (Coil/Bobbin)



$\oint\vec{B}d\vec{s} = \mu_o I_{enc}$

$\vec{B} = \mu_o In$[Tesla] $n = \frac{N}{L}$

Magnetic Field of a Toroid

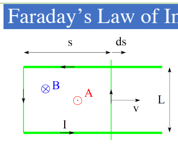


$\oint\vec{B}d\vec{s} = \mu_o I_{enc}$ $\vec{B}\oint d\vec{s} = \mu_o I_{enc}$

$\vec{B}(2\pi r) = \mu_o I_{enc}$ $\vec{B}(2\pi r) = \mu_o IN$

$\vec{B} = \frac{\mu_o IN}{2\pi r}$ [Tesla]

Faraday's Law of Induction

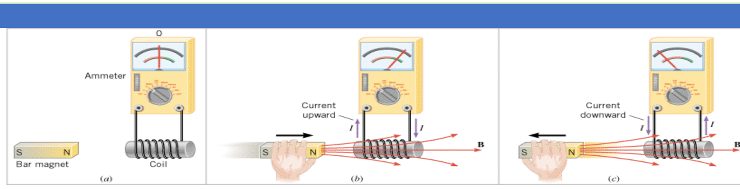


$\Phi_B = \int\vec{B}d\vec{A}$ [Tm^2] $\Phi_B = BACos\theta$ [Tm^2] $\Phi_B = BA$ [Tm^2]

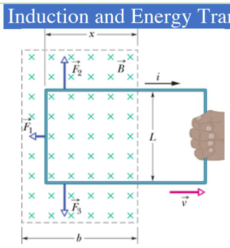
Φ_B = Magnetic Flux $\vec{B}$ = Magnetic Field $d\vec{A}$ = Closed Surface Area

$\varepsilon = -N\frac{d\Phi_B}{dt}$

Lenz's Law



Induction and Energy Transfer



$\Phi_B = BA$ $\Phi_B = BLx$ $\varepsilon = \frac{d\Phi_B}{dt}$ $\varepsilon = \frac{d}{dt}(BLx)$ $\varepsilon = (BL)\frac{dx}{dt}$ $\varepsilon = BLV$

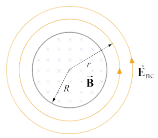
$\vec{B}$ = Magnetic Field L=Height of the Loop V=Velocity

Thermal Energy Rate (Rate of doing work as we pull it from the magnetic field)

$i = \frac{\varepsilon}{R}$ $i = \frac{BLV}{R}$ $F = i\vec{L}\times\vec{B}$ $F = iLB$ $F = \frac{BLV}{R}LB$

$F = \frac{B^2L^2V}{R}$ $P = FV$ $P = \frac{B^2L^2V}{R}V$ $P = \frac{B^2L^2V^2}{R}$ $P = i^2R$

Induced Electric Field



$W = \oint \vec{F} d\vec{s}$

$\varepsilon = \oint \vec{E} d\vec{s}$

$W = \oint (q_0 \vec{E}) d\vec{s}$

$\varepsilon = -\frac{d\Phi_B}{dt}$

$W = \oint (q_0 \vec{E})(2\pi r)$

$\oint \vec{E} d\vec{s} = -\frac{d\Phi_B}{dt}$

r < R – Inside the copper

$\oint \vec{E} d\vec{s} = -\frac{d\Phi_B}{dt}$

$\frac{d\Phi_B}{dt} = -\pi r^2 \frac{dB}{dt}$

$\Phi_B = -BA$

$\oint \vec{E} d\vec{s} = E(2\pi r)$

$\frac{d\Phi_B}{dt} = \frac{d}{dt}(-BA)$

$E(2\pi r = -\frac{d\Phi_B}{dt} \pi r^2$

$\frac{d\Phi_B}{dt} = -A \frac{dB}{dt}$

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

r > R – Outside the copper

$\oint \vec{E} d\vec{s} = -\frac{d\Phi_B}{dt}$

$\frac{d\Phi_B}{dt} = -\pi R^2 \frac{dB}{dt}$

$\Phi_B = -BA$

$\oint \vec{E} d\vec{s} = E(2\pi r)$

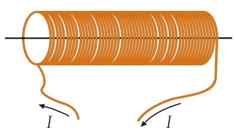
$\frac{d\Phi_B}{dt} = \frac{d}{dt}(-BA)$

$E(2\pi r = -\frac{d\Phi_B}{dt} \pi R^2$

$\frac{d\Phi_B}{dt} = -A \frac{dB}{dt}$

$E = \frac{R^2}{2r} \frac{dB}{dt}$

Inductors and Inductance



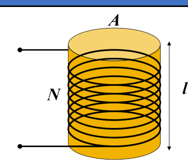
$L = \frac{N\Phi_B}{I} [H] \left[\frac{Tm^2}{A}\right]$

L=Inductance

$\Phi_B =$ Magnetic Flux   I = Current

N = Number of turns

Inductance of a Solenoid



$L = \frac{N\Phi_B}{I} = \mu_o \frac{N^2 A}{l}$ $L = \mu_o n^2 V$

$N = nl$ $V = Al$

Self-Induction

$L = \frac{N\Phi_B}{I} [H] \left[\frac{Tm^2}{A}\right]$

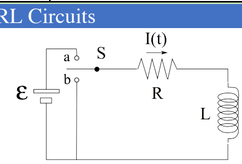
$\varepsilon = -N \frac{d\Phi_B}{dt}$

$L = \frac{N\Phi_B}{I} [H]$

$L = -\frac{d}{dt}(N\Phi_B)[H]$

$\varepsilon = -L \frac{dI}{dt} [Volt]$

RL Circuits



$q = C\varepsilon((1-e^{\frac{t}{T_L}})$

$T = RC$

$\varepsilon - iR - L\frac{dI}{dt} = 0$

$i = \frac{\varepsilon}{R}(1-e^{\frac{t}{T_L}})$

$T_L = \frac{L}{R}$

Energy Stored in Magnetic Field

$i\varepsilon = \left(iR + L\frac{dI}{dt}\right) i$

$i\varepsilon = i^2 R + Li\frac{dI}{dt}$

$\int_0^{U_B} \frac{dU_B}{dt} = \int_0^{i} Li \frac{dI}{dt}$

$U_B = \frac{1}{2} Li^2$

Energy Density of a Magnetic Field

$U_B = \frac{U}{Al} = \frac{B^2}{2\mu_o}$

Energy Stored in RC Circuits

$i = \frac{dq}{dt}$

$U = \frac{1}{2} LV^2 = \frac{1}{2}\frac{q^2}{C}$

Electromagnetic Oscillations and Alternating Current- LC Circuits

$U_B = \frac{1}{2} Li^2$

$U_E = \frac{1}{2}\frac{q^2}{C} = \frac{q^2}{2C}$

$\frac{1}{2}\frac{q^2}{C} = \frac{1}{2} Li^2$

$i_{max} = V\sqrt{\frac{C}{L}}$

Electrical-Mechanical Energy Conversion

Mechanical -Block Spring System

Spring	$PE = \frac{1}{2} kx^2$
Mass	$KE = \frac{1}{2} mV^2$
$V = \frac{dx}{dt}$	$w = \sqrt{\frac{k}{m}}$

Electrical- LC Circuits (LC Oscillator)

Capacitor	$U_E = \frac{1}{2}\frac{q^2}{C}$
Inductor	$U_B = \frac{1}{2}\frac{q^2}{C}$
$i = \frac{dq}{dt}$	$w = \frac{1}{\sqrt{LC}}$

LC Oscillation Equations

Block Spring Oscillator

$X = ACos(\omega t + \phi)$

$\phi =$ Phase Constant , X=Displacement

A=Ampitute, ω= Angular Frequency

Charge Oscillations

$q = QCos(\omega t + \phi)$

$\phi =$ Phase Constant , q=Charge

Q= Ampitute of Charge,

ω= Angular Frequency

Current Oscillations

$i = -\omega QSin(\omega t + \phi)$

$\phi =$ Phase Constant , q=Charge

Q= Ampitute of Charge,

ω= Angular Frequency

Alternating Current

A Resistive Load

$V_R = iR$	Resistive Potential
$i = \frac{V}{R}$	$i = \frac{\varepsilon_0}{R} sin\omega t$

A Capacitive Load

$q = CV = CV_c Sin\omega t$	$X_c = \frac{1}{\omega C}$
$V_c = i_c X_c$	Capacitive Potential

An Inductive Load

$V_L = V_L sin\omega t$	$v_L = L\frac{di}{dt}$ $\frac{di}{dt} = \frac{V_L}{dt} sin\omega t$
$X_L = L\omega$	Inductive Reactance
$V_L = I_L X_L$	Inductor

Series RLC Circuit

$\varepsilon = V_R + V_C + V_L$

$\varepsilon^2 = {V_R}^2 + (V_L - V_C)^2$

$\varepsilon^2 = (iR)^2 + (iX_L - iX_C)^2$

$i = \frac{\varepsilon m}{\sqrt{R^2 + (X_L - X_C)^2}}$

$Z = \sqrt{R^2 + (X_L - X_C)^2}$ Impedance

Power in AC Circuits

$P = i^2 R$

$P = [iSin(\omega t + \phi)\ ]^2 R$

$P = i^2 RSin(\omega t + \phi)\ ^2$

$P_{avg} = \frac{i^2 R}{2}$

$P_{avg} = R\left(\frac{i}{\sqrt{2}}\right)^2$

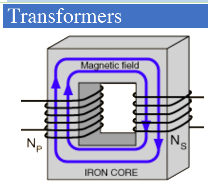
$P_{avg} = {i_{rms}}^2 R$

$i_{rms} = \frac{i}{\sqrt{2}}$

$V_{rms} = \frac{V_{max}}{\sqrt{2}}$

$\varepsilon_{rms} = \frac{\varepsilon_{max}}{\sqrt{2}}$

Transformers



$N_p =$ Number of turns for primary coil $N_s =$ Number of turns for secondary coid

$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_p}{I_s}$

if $N_s > N_p$ then step up transformer

if $N_p > N_s$ then step down transformer