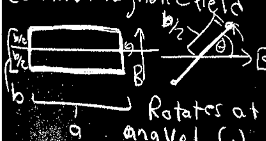
Lenz's Law

Opposes change

A/C Generator

Coil in a magnetic field



Rotates at ang Vel. ω

Velocity of sides of Loop $V = \omega\left(\frac{b}{2}\right)$

Motional EMF

$\mathcal{E} = VB\sin\theta\, a =$

$= \frac{1}{2}\omega Bab\sin\theta$

for each side of Coil of length A

Sum together:

$\mathcal{E} = \omega Bab\sin\theta$

A: area $= ab \Rightarrow \mathcal{E} = \omega BA\sin\theta$

Loop lies in xy plane at $t=0$, $\Rightarrow \theta_0 = \theta(t_0) = 0$

$\theta = \theta_0 + \omega t = \omega t$

$\mathcal{E} = \omega AB\sin\omega t$

Varies sinusoidally with max value when $\sin\omega t = 1$

$\mathcal{E}_M = \omega AB$, $\Rightarrow \mathcal{E} = \mathcal{E}_M \sin\omega t$

Changing Mag fields, but no clear current path

Eddy Currents

Conducting sheet + region of mag field

out of board

Currents I in $\vec{B}$

resulting force

$\vec{F} = I\vec{l} \times \vec{B}$ ⟹

Slows Conductor

1873 Maxwell's Equations

① $\oint \vec{E}\cdot d\vec{A} = q_n/\epsilon_0$ = Gauss' Law

② $\oint \vec{B}\cdot d\vec{A} = 0$ Gauss' Law for magnetism

③ $\oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$ Faraday's Law of induction

④ $\oint \vec{B}\cdot d\vec{s} = \mu_0 \epsilon_0 \frac{d\Phi_E}{dt} + \mu_0 I$

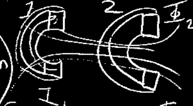
Ampere-Maxwell Law

Lorentz Force law

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

Mutual Inductance

2 Coils



Current in Coil 1, I_1, produce flux Φ_2 in Coil 2

Mag field in Coil 2, Φ_2 is proportional to current in Coil 1, I_1 $\Rightarrow$ If I_1 changes $\Rightarrow$ Φ_2 changes $\Rightarrow$ EMF in Coil 2:

$$\mathcal{E}_2 = -N_2 \frac{\Delta \Phi_2}{\Delta t}$$

N ~ # Turns in Coil 2

$\Phi_2 \propto I_1 \Rightarrow N_2 \Phi_2 \propto I$

Define prop. constant M.

$N_2 \Phi_2 = M I_1 \Rightarrow$

$$N_2 \frac{d\Phi_2}{dt} = M \frac{dI_1}{dt}$$

$$\mathcal{E}_2 = -M \frac{dI_1}{dt}$$

M depends only on geometry of 2 Coils $\Rightarrow$

$M \equiv$ Mutual Inductance

$M = N\Phi_2 / I_1$, for Coil 2 acting on Coil 1: $M' = N\Phi_1 / I_2$

$\Rightarrow$ for 2 Coils: $M' = M$

only 1 Mutual Inductance

Unit of Inductance: $\frac{\text{Flux}}{\text{Current}}$

$= \frac{\text{Webers}}{\text{Ampere}} = \frac{1 \text{ Volt-sec}}{\text{Ampere}}$

$= 1 \text{ Henry} = 1 \text{Wb} A^{-1} = 1 \text{VS} A^{-1}$

Typical Inductances are microhenries: $\mu h = 10^{-6}$ henries

One Solenoid by itself With a varying Current $\Rightarrow$ causes a varying B-field in Solenoid $\rightarrow$ induces EMF

$\Rightarrow$ Self Induction $\Rightarrow$

$\mathcal{E}$ = Self-Induced EMF

Faraday: $\mathcal{E} = -N \, d\Phi_B / dt$

N = # turns, Φ_B = flux thru each turn

Total Flux is proportional to Current

Constant of prop. $\equiv L$

$N\Phi_B = LI \Rightarrow L = \frac{N\Phi_B}{I}$

L = Self Inductance

Faraday: $\mathcal{E} = -N\frac{d\Phi_B}{dt} = -L\frac{dI}{dt}$

$$L = \frac{-\mathcal{E}}{dI/dt}$$

(analogy $C = q/V$)

If no material involved, then only depends on geometry

Symbol for inductor:

(analogy Capacitor )

Find direction of induced EMF from Lenz's Law

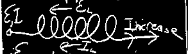
Steady Current I exists in Coil

Decrease EMF that produces I

I decreases, Lenz opposes $\Rightarrow$ puts current in same direction as original

⇒ Induced EMF in same direction as original EMF

Increase original ℰ ⇒ increase current.
Lenz opposes



$\mathcal{E} = -L\frac{dI}{dt}$

For a Capacitor, calculate capacitance for cases like Parallel Plate Capacitor

For Self-Inductance, calculate inductance for case of Solenoid (∞-ly long)

$L = \frac{N\Phi_B}{I}$, look at piece of length l.

n turns per unit length ⇒ $nl = N$

$N\Phi_B = nl(BA)$, A = Cross section area of Solenoid

$B(\text{Solenoid}) = \mu_0 n I$ (known)

$N\Phi_B = (nl)(\mu_0 n I A)$
$= \mu_0 n^2 l I A$

$L = \frac{N\Phi_B}{I} = \boxed{\mu_0 n^2 l A}$

proportional to Volume (lA)