Physics 142 - November 1, 2007

Exams 2 one week from today
- in Hoyt
- reg. class time
- welcome to bring formula sheet as last time
- will try to set up a Q&A session

To be covered:

Topics
- Potential
- Capacitance
- Energy in E
- E in materials
dielectrics
Kirchhoff's Rules
DC circuits with R, RC
Special Relativity
Lorentz Force Law
Biot-Savart
Ampere's Law

Lectures
- Sept 27 - Oct 30

Problem Sets
- 4-7

Workshops
- 4-8

Chapters
- 25-30, 36
Induction

\[ \nabla \times \mathbf{B} = \text{constant} \]

Magnetostatics

Kirkhoff

\[ \oint \mathbf{E} \cdot d\mathbf{l} = 0 \]

Closed loop

Statement of Kirkhoff's law in free space

Changing Magnetic Field

\[ \varepsilon = \oint \mathbf{E} \cdot d\mathbf{l} = -\frac{d\Phi_m}{dt} \]

Induced EMF

Faraday's law

\[ \Phi_m = \int \mathbf{B} \cdot d\mathbf{A} \]

True in free space

Materials

Wire
Lenz's Law - An induced current in a closed conducting loop will appear in such a way as to oppose the change that created it.

\[
i \text{ increasing with time}
\]

\[
\text{induce a counter-clockwise current in II}
\]
\[ E = - \frac{d \Phi_m}{dt} = - \frac{d(BxI)}{dt} = -B \frac{dx}{dt} = -Blv \]

Loop has resistance \( R \) \( iI = \frac{Blv}{R} \)

\[ v = iR \]
\[ E = iR \]

Be sure to check out the "Induction" Java Applet on the class Website!
Solenoid - each turn has area $A$

$\mathbf{B} = \mu_0 n_i A$

$\Phi_m = B A = \mu_0 n_i A$

$\Phi_m \times i$

$\Phi_m = \mu_0 n_i A \times i$

length $l$ of solenoid

$N L$ turns

$\Phi_m = \mu_0 n_i A \times i$

$\Phi_m \times i$

length $l$
\[ \Phi_m = L_i \]

**Constant of Self-inductance**

change \( i \) \( \rightarrow \) change \( \Phi_m \) \( \rightarrow \) \( \frac{d\Phi_m}{dt} \) \( \rightarrow \) \( \mathcal{E} \)

\[ \mathcal{E} = -\frac{d\Phi_m}{dt} = -L \frac{di}{dt} \]
\( \Delta i \) in \( \text{I} \)
\( \Delta B \) in \( \text{II} \)

\( \Phi_m \text{ in } \text{II} \propto i \)

\( \Phi_m \text{ in } \text{II} = LIi \)

Constant of Mutual Inductance
Energy + Magnetic Field

new circuit element → inductor

\[ \sum \mathcal{E} = 0 \]

\[ \mathcal{E} - iR - L \frac{di}{dt} = 0 \]

\[ \mathcal{E} = iR + L \frac{di}{dt} \]

LR circuit

mult by \( i \)

\[ \mathcal{E}i = i^2R + Li \frac{di}{dt} \]

Power

Energy going in or out of B field
\[ \frac{dU_B}{dt} = L \frac{di}{dt} \]

\[ dU_B = L \, di \]

\[ U_B = \int_0^I L \, di = \frac{1}{2} L I^2 \]

Analogous: \( U \) in capacitor = \( \frac{1}{2} C V^2 \)

Solenoid with \( i \), \( n \) turns/\( \text{cm}^2 \), consider length \( l \)

\[ \Rightarrow \text{find energy density of magnetic field} \]
\[ B_{\text{solenoide}} = \mu_0 n i \quad \text{(inside)} \]
\[ = 0 \quad \text{(outside)} \]

\[ U_B = \text{Energy density in } B = \frac{U_B}{A l} \]

\[ U_B = \frac{1}{2} Li^2 \]
\[ \Phi_m = Li \quad L = \frac{Q_m}{i} = \frac{(BA)(nl)}{i} \quad \text{(geometry)} \]

\[ L = \mu_0 n A \quad \text{nl} = \mu_0 n^2 A l \]

\[ U_B = \frac{1}{2} \frac{\mu_0 n^2 A l i^2}{A l} = \frac{1}{2} \mu_0 i^2 n^2 = \frac{B^2}{2 \mu_0} \]
\[ U_B = \frac{B^2}{2 \mu_0} \]

Energy density in magnetic field

Analogous to

\[ U_E = \frac{\varepsilon_0 E^2}{2} \]