Physics 142 - November 6, 2007

- Exam 2 on Thursday
  - Q+A Session B+L106
    - Wednesday 3:30 - 5:00
  - Checking about running it from 4-5:30 instead

- Presentation groups
  - Elect Spokesperson
  - Each group to meet briefly w/me before Thanksgiving break.
Induction

Faraday's Law

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.

Gives direction of induced effect

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

\[ \Phi_m = \oint_{\text{loop}} \mathbf{B} \cdot d\mathbf{A} \]
\[ \phi_m = L \cdot i \]

\( L \) = Constant of Self-inductance

\[ \varepsilon = -\frac{d\phi_m}{dt} = -L \frac{di}{dt} \]

\[ \varepsilon \text{ by 0} = -M \frac{di_1}{dt} \]

\[ \varepsilon \text{ by 0} = -M \frac{di_2}{dt} \]

\( M \) = Constant of Mutual inductance

SAME "M" Cross-talk dictated by Geometry

unless problem is specifically about Mutual inductance ... usually treat inductance in a circuit as self-inductance
Energy density in the fields:

\[ U_E = \frac{E_0 E^2}{2} \quad \text{and} \quad U_B = \frac{B^2}{2\mu_0} \]

General — Say nothing about circuits or sources or boundary conditions!

Energy in Inductor

\[ U = \frac{1}{2} LI^2 \]

Similar to \( U_{\text{capacitor}} = \frac{1}{2} CV^2 \)
$LR$ Circuit

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

\[ i = \frac{\varepsilon}{R} (1 - e^{-\frac{t}{\tau_L}}) = \frac{\varepsilon}{R} (1 - e^{-\frac{t}{\tau_L}}) \]

\[ V = iR \quad \text{for} \quad V \text{ across } R \]

\[ V = \varepsilon (1 - e^{-\frac{t}{\tau_L}}) = \varepsilon (1 - e^{-\frac{t}{\tau_L}}) \]

Inductive Time Constant

\[ \frac{L}{R} = \tau_L \]
Remove EMF, Short L across R

\[ 0 = iR + L \frac{di}{dt} \]

After\ it reaches value of \( E/R \)

\[ i = \frac{E}{R} e^{-t/\tau_L} = i_0 e^{-t/\tau_L} \]
\[ U = U_B + U_E = \frac{1}{2} L \frac{d^2i}{dt^2} + \frac{B^2}{2C} \]

\[ R \text{ in circuit } \rightarrow 0 \]

\[ \frac{dU}{dt} = 0 = \frac{1}{2} L \frac{d^2i}{dt^2} + \frac{2q}{2C} \frac{dg}{dt} \]

\[ 0 = L \frac{d^2i}{dt^2} + \frac{9}{C} \]

\[ 0 = L \frac{d^2g}{dt^2} + \frac{8}{C} \]

\[ \text{SHM} \]

\[ m \frac{d^2x}{dt^2} = -kx \]
\( q(t) = Q \cos(\omega t + \phi) \)
\( \omega = \frac{1}{\sqrt{LC}} \)

Energy Flow
\( U_E = \frac{q^2}{2C} = \frac{Q^2 \cos^2(\omega t + \phi)}{2C} \)

\( i(t) = \frac{dq(t)}{dt} = -Q \omega \sin(\omega t + \phi) \)

\( U_B = \frac{1}{2} L i^2 = \frac{L Q^2 \omega^2 \sin^2(\omega t + \phi)}{2} \)

Harmonic
LC Oscillations

\[ \frac{Q^2}{2c} \]

\[ U(t) \]

\[ U_E(t) \]

\[ U_B(t) \]

\[ T = \frac{2\pi}{\omega} = 2\pi \sqrt{LC} \]
LC oscillations
AC Circuits

\[ E = E_{\text{max}} \sin \omega t \]

Kirchhoff's

\[ E - IR = 0 \]

\[ I = \frac{E}{R} = \frac{E_{\text{max}} \sin \omega t}{R} \]

I is in phase with E

Power (instantaneous)

\[ P = IV = I \cdot E = \frac{E_{\text{max}}^2 \sin^2 \omega t}{R} \]

Average Power

\[ \overline{P} = \frac{E_{\text{max}}^2}{2R} \]

\[ \langle \sin^2 \rangle \sim \frac{1}{2} \]