Study Guide

In a series $LR$ circuit, the current turns on or off with an exponential time dependence, with a characteristic time

$$\tau = \frac{L}{R}.$$  

In a series $LC$ circuit, the current oscillates back and forth with angular frequency

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

The energy stored in an inductor is

$$\text{energy} = \frac{1}{2} Li^2.$$  

If we think of this energy as being stored in the magnetic field, then the energy per unit volume is

$$\text{energy per unit volume} = \frac{|\vec{B}|^2}{2\mu_0}.$$  

This formula is valid for any other magnetic field as well.

You should be able to predict the qualitative behavior of simple alternating-current circuits containing resistors, capacitors, and inductors. A capacitor acts like a large resistor at low frequency but a small resistor at high frequency. An inductor has the opposite effect: it acts like a large resistor at high frequency but a small resistor at low frequency.

In an ideal transformer, the “voltages” (really emf’s) on the primary and secondary coils are proportional to the number of turns:

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

Since the power is the same on both sides, this implies that the currents are inversely proportional to the number of turns, or inversely proportional to the voltages.

Under non-steady-state conditions, Ampere’s law must be modified by adding the “displacement current” term:

$$(\text{circulation of } \vec{B}) = \mu_0 i + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt},$$

where $\Phi_E$ is the flux of the electric field through the same surface used for determining $i$. The four complete equations for the flux and circulation of $\vec{E}$ and $\vec{B}$ are called Maxwell’s equations; these equations can be solved to find $\vec{E}$ and $\vec{B}$ for any source of charges and currents whatsoever.

The most important implication of Maxwell’s equations is that accelerating charged particles create electromagnetic waves, traveling at speed

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = 3.00 \times 10^8 \text{ m/s}.$$  

Within such a wave, the electric and magnetic fields are perpendicular to each other and to the direction the wave is traveling. Electromagnetic waves are created by any accelerating charged particle. The waves are strongest in the direction perpendicular to the acceleration, and carry no energy in the direction of the acceleration.