University Physics 2

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Magnetic Induction

Lenz's Law states that if there is a change in magnetic flux through a conductor, there will be an induced magnetic field to oppose that change. This is done by the creation of an induced current through the conductor. The direction is given by the right hand rule.

Faraday's Law

Recall the formula for magnetic flux:

$$\Phi_B = \oint \vec{B} \cdot \, \mathrm{d}\vec{A} = 0$$

Magnetic flux through a closed loop is zero because there are no magnetic monopoles. Faraday's Law is the following:

$$\epsilon = -\frac{\mathrm{d}\Phi_B}{\mathrm{d}t}$$

We also know the following about EMF:

$$\epsilon = \oint \vec{E} \cdot \, \mathrm{d}\vec{L}$$

Therefore:

$$\oint \vec{E} \cdot \, \mathrm{d}L = -\frac{\mathrm{d}\Phi_B}{\mathrm{d}t}$$

Note that this implies a changing magnetic fields creates an electric field. If we substitute the formulas for magnetic flux:

$$\epsilon = -\frac{\mathrm{d}}{\mathrm{d}t}\left(\oint \vec{B} \cdot \, \mathrm{d}\vec{A}\right)$$

We can get EMF three ways:

$$\epsilon = -\frac{\mathrm{d}}{\mathrm{d}t}\left(BA\cos\theta\right)$$

If we have N wires:

$$\begin{aligned}\epsilon &= -N\frac{\mathrm{d}\Phi_B}{\mathrm{d}t}\\ &= -N\frac{\mathrm{d}}{\mathrm{d}t}(BA\cos\theta)\end{aligned}$$

Transformers

Transformers use Faraday's Law with coils of wire wrapped around a magnetic core to step up or step down voltage. The voltage in and out of a transformer can be described by:

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

If $N_2 < N_1$, the transformer is a step down transformer. If $N_2 > N_1$, then the transformer is a step up transformer. By conservation of energy:

$$\begin{aligned}P_1 &= P_2\\ I_1V_1 &= I_2V_2\end{aligned}$$

As you step up the voltage using a transformer, your current proportionally goes down.

Inductance

Consider two concentric solenoids:

$$\begin{aligned}\epsilon_2 &= -N_2\frac{\mathrm{d}\phi_B}{\mathrm{d}t}\\ B_1 &= n\mu_\circ I\\ \phi_B &= B_1 \cdot A_1\\ &= n\mu_\circ IA\\ &= M_{12}i_1(t)\end{aligned}$$

where M_{12} is the mutual inductance between solenoids 1 and 2 and $i_1(t)$ is a current that varies over time.

$$\begin{aligned} N_2 \frac{\mathrm{d}\phi_B}{\mathrm{d}t} &= M_{21} \frac{\mathrm{d}i}{\mathrm{d}t} \\ \epsilon_2 &= -M_{21} \frac{\mathrm{d}i}{\mathrm{d}t} \\ M_{21} &= \frac{N_2 \phi_B}{i_1} \end{aligned}$$

Self-Inductance

An inductor is a circuit element that opposes change in current because of Faraday's Law.

$$\begin{aligned} L &= \frac{N\phi_B}{i} \\ \epsilon &= -L \frac{\mathrm{d}i}{\mathrm{d}t} \end{aligned}$$

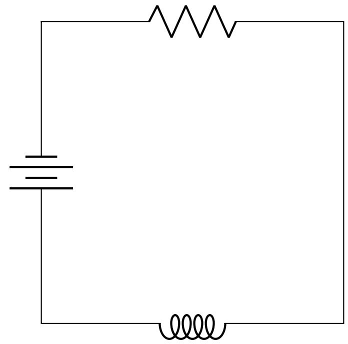
The unit of L is a Henry, and the voltage drop across an inductor is measured as:

$$\begin{aligned} \Delta V_L &= L \frac{\mathrm{d}i}{\mathrm{d}t} \\ P = IV &= iL \frac{\mathrm{d}i}{\mathrm{d}t} \end{aligned}$$

Power is energy per time:

$$\begin{aligned} P &= \frac{\mathrm{d}U}{\mathrm{d}t} \\ \mathrm{d}U &= P \ \mathrm{d}t \\ U_L &= \frac{1}{2} L i^2 \end{aligned}$$

RL Circuits



We can use Kirchoff's Loop Rule to solve this circuit.

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\begin{aligned}
\epsilon - \Delta V_R - \Delta V_L &= 0 \\
\epsilon - iR - L\frac{\mathrm{d}i}{\mathrm{d}t} &= 0 \\
\frac{\mathrm{d}i}{\mathrm{d}t} &= \frac{\epsilon}{L} - \frac{R}{L}i \\
i &= \frac{\epsilon}{R}(1 - \mathrm{e}^{-\frac{R}{L}t}) \\
&= \frac{\epsilon}{R}(1 - \mathrm{e}^{-\frac{t}{\tau}}) \\
\tau &= \frac{L}{R}
\end{aligned}
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You can find all my notes at `http://omgimanerd.tech/notes`. If you have any questions, comments, or concerns, please contact me at alvin@omgimanerd.tech