Electric Generator (Alternator)

Without movement $\Phi_B = NBA \cos \Theta = \text{const.}$

$\dot{\Theta} = 0$

Spin the loop on the axis $\Theta = \omega t$

$\Phi_B = NBA \cos (\omega t)$

$\dot{\Phi_B} = -NBA \sin (\omega t) \omega$

$\varepsilon = NBA \omega \sin (\omega t)$

$\varepsilon = NBA \omega$  $\Theta = 2\pi / \omega$

$\dot{\varepsilon} = \frac{1}{\omega} \frac{d\omega}{dt}$

$f = \frac{1}{T} = \frac{2\pi}{\omega}$

$\omega = 2\pi f$

$\varepsilon_{max} = NBA \omega$

US Household: $\varepsilon_{max} = 170V$, $f = 60$ Hz
What happens when AC voltage is applied to a load?

\[ E_{\text{max}} = 170 \text{ V} \]

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>170 V</td>
<td>Bright</td>
</tr>
<tr>
<td>0</td>
<td>Off</td>
</tr>
<tr>
<td>-170 V</td>
<td>Bright</td>
</tr>
</tbody>
</table>

Average meaningless

The avg brightness is the same as if the bulb was hooked to \( V_{\text{DC}} = 120 \text{ V} \).

If we take an RMS average of the AC signal, it is 120 V.

\[ V_{\text{RMS}} = \sqrt{\frac{1}{T} \int (V(t))^2 \, dt} \]

\[ V_{\text{RMS}} = \frac{1}{\sqrt{2}} V_{\text{max}} = 0.707 V_{\text{max}} \]

AC Ohm's Law

\[ V_{\text{RMS}} = I_{\text{RMS}} R \]

\[ P_{\text{avg}} = V_{\text{RMS}} I_{\text{RMS}} \]

\[ I_{\text{RMS}} = \frac{1}{\sqrt{2}} I_{\text{max}} \]

\[ P_{\text{avg}} = \frac{1}{2} P_{\text{max}} \]
Ex: Cell Phone Charger

\[ V_{\text{rms}} = 120 \text{ V} \quad (10 \text{ W}) = (120 \text{ V})(I_{\text{rms}}) \]
\[ I_{\text{rms}} = 0.083 \text{ A} \]

\[ V_{\text{out}} = 5.0 \text{ V} \quad \Rightarrow \quad P_{\text{out}} = VI = 10 \text{ W} \]
\[ I_{\text{out}} = 2.0 \text{ A} \]

Transformers - Interlocking Coils

Current in primary causes \( B \) in core.
Since \( I \) oscillates, so does \( B \).
Each coil feels flux \( \Phi = NBA \cos \theta \)
They have the same \( B \), \( A \).
Primary: \( E_1 \propto N_1 \Rightarrow E_1 \propto N_1 \)
This \( E_1 \) limits the current \( I_1 \).

Secondary: \( E_2 \propto N_2 \Rightarrow E_2 \propto N_2 \)
This \( E_2 \) pushes \( I_2 \) thru \( R \).
Transformer equations:

\[
\frac{N_2}{N_1} = \frac{V_2}{V_1} \quad \text{"turns ratio"}
\]

\[V_1 I_1 = V_2 I_2 = \text{power transmitted}\]

\[
\text{with efficiency } \varepsilon
\]

\[
P_{\text{out}} = \varepsilon P_{\text{in}}
\]

\[
P_{\text{in}} = P_{\text{out}} + P_{\text{waste}}
\]

Cell Charger Transformer

\[
V_1 = 120 \text{ V} \quad N_1 = 2400
\]

\[
V_2 = 5 \text{ V} \quad N_2 = ? = 100
\]
Resistor: \( R \)  \[ V=IR \]  \[ P=IV \]

- **Input:** Voltage that pushes current
- **Output:** Heat, Light, etc.

Battery: \( E \)

- **Input:** Chemical Energy
- **Output:** Specific voltage \( = E \), any current

Motor:  \[ I = NBAI \sin \theta \]

- **Input:** Voltage that pushes current
- **Output:** Torque that spins a shaft
- **Side-effect:** \( E \) limits \( I \) more \( I \) when slow

Generator:  \[ E = NBA \omega \sin \theta \]

- **Input:** Spinning shaft
- **Output:** Voltage that pushes current
- **Side-effect:** Torque increases with \( I \)
- **Harder to spin when lights are on**