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# AC Electricity - Why

- Easy to generate
- Works with transformers

## Transformer Primary Coil:

- Apply Voltage - gives energy to transformer
- Current flows
- $I$ causes $B$
- $\Phi = NBA$ is flux in coil (not per turn)
  ($\Phi = BA$ is flux per turn)
- If flux varies EMF is generated
  This is "Back EMF", which reduces current
- $V_{rms} = I_{rms} (\sim)$
  ↳ High proportionality constant

## Secondary

- It "feels" $B$
- $\Phi_B = NBA$
  ↳ different $N$ and $\Phi$
- $\mathcal{E} = NBA\omega$ is proportional to $N$
- Compare: $\frac{\mathcal{E}_s}{\mathcal{E}_p} = \frac{N_s}{N_p}$

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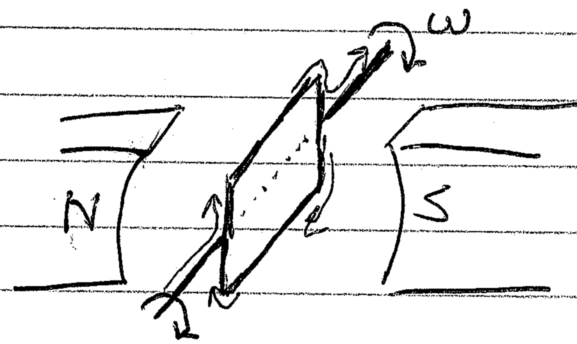
# AC Electricity

Why? Easy to generate.
Works with transformers.



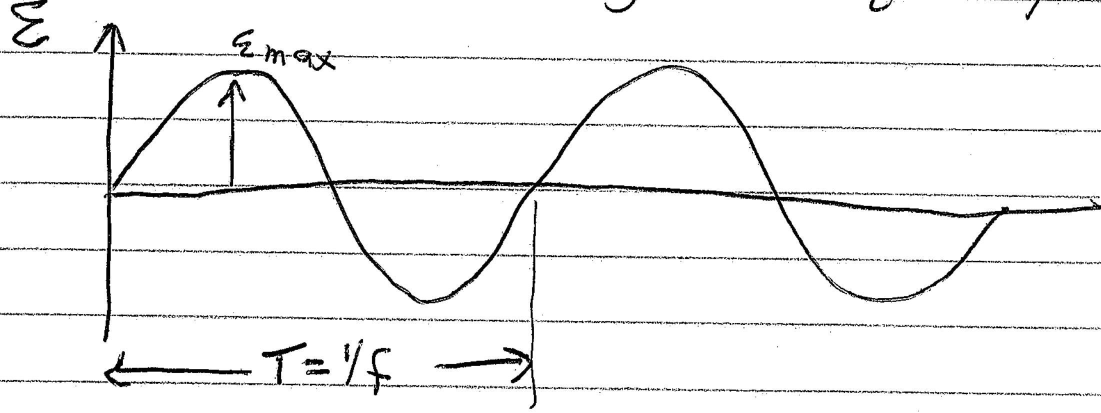

$\Phi_B = NBA\cos(\omega t)$

$\mathcal{E}_{max} = NBA\,\omega$ (Amplitude)

$\mathcal{E} = \mathcal{E}_{max}\sin(2\pi f t)$

↳ sin() or cos()

$\omega = 2\pi f$ = angular frequency



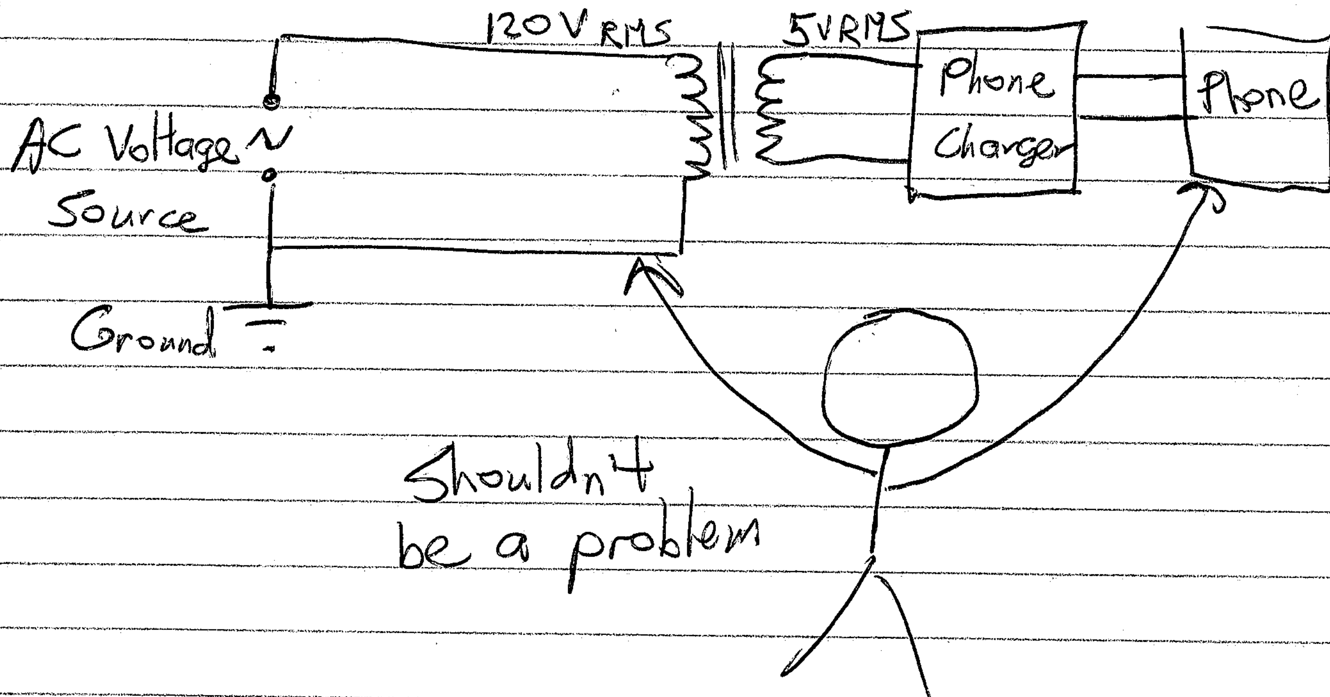
(3)

Ratio of $\mathcal{E}$'s:

$$\frac{\mathcal{E}_s}{\mathcal{E}_p} = \frac{N_s}{N_p}$$

Reminder: If flux isn't changing — no EMF

Side Effect — Isolation




Usually: Phone isolated from ~~charger~~ "Mains"

- Cheap charger?
- Touching plug?
- Damp skin? — makes 120V deadly
- Frayed wires

# AC Components

## Resistor $V = IR$

Let's say $I = I_0 \sin(2\pi f t)$

$$V = I_0 \sin(2\pi f t)\, R$$
$$= (I_0 R)\, \sin(2\pi f t)$$
$$V = V_0 \sin(2\pi f t)$$

Convert both to RMS

$$V_{rms} = I_{rms} R$$
$$P_{avg} = I_{rms}^2 R$$

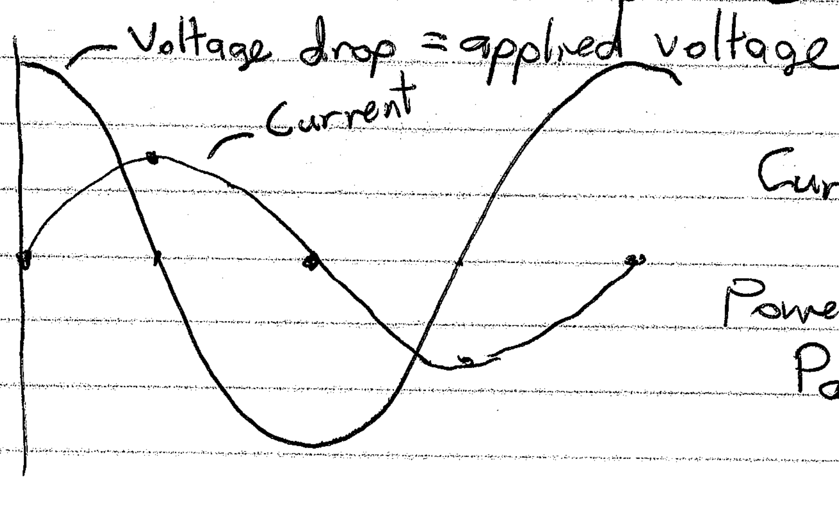
## Inductor $V = L \frac{dI}{dt}$

$$V = L I_0 \cos(2\pi f t)\, 2\pi f$$
$$= I_0\, 2\pi f L \cos(\,)$$
$$= V_0 \cos(\,)$$

$$V_0 = I_0\, 2\pi f L$$

$$V_{rms} = I_{rms}\, 2\pi f L$$
$$V_{rms} = I_{rms}\, X_L$$

$X_L = 2\pi f L$ = inductive reactance




Current "Lags"

Power oscillates
$P_{avg} = 0$

Capacitor

$$V = Q/C$$

$$Q = \int I = \int I_0 \sin(2\pi f t)\, dt$$

$$= \frac{-I_0}{2\pi f} \cos(2\pi f t)$$

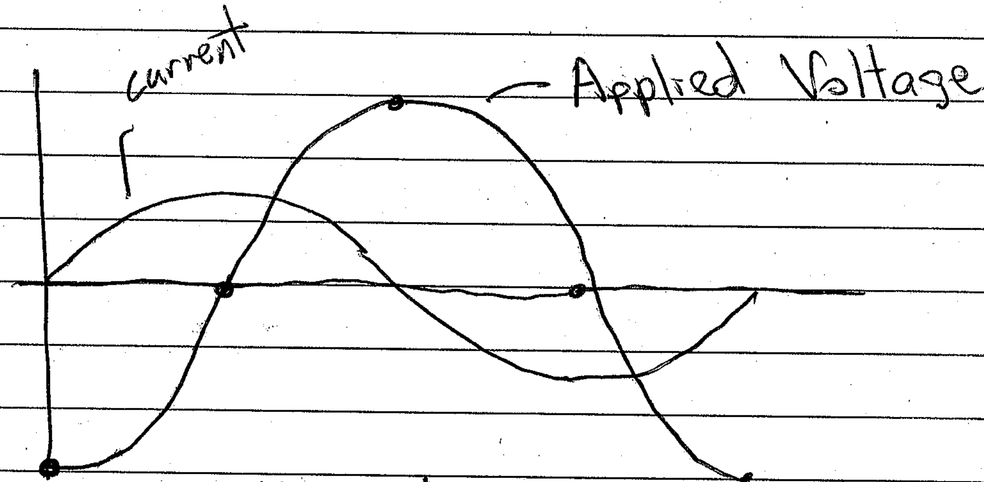
$$V = \frac{-I_0}{2\pi f C} \cos(2\pi f t)$$

$$V = V_0 \left(-\cos(\,)\right)$$

$$V_0 = I_0 \frac{1}{2\pi f C} \qquad V_{rms} = I_{rms} \frac{1}{2\pi f C}$$

$$V_{rms} = I_{rms} X_C$$

$X_C = \frac{1}{2\pi f C}$ = capacitive reactance




Voltage Lags in capacitor.

\+ Current increases Q and V

\- current decreases Q and V

$$P_{avg} = 0$$

# Series AC Circuit

$I_1 = I_2 = \cdots$ still true

$V_{Tot} = V_1 + V_2 + \cdots$ true as function of time

$V_{Tot} = V_{Ro}\sin() + V_{Lo}\cos() - V_{Co}\cos()$

To do this without trig, Add <u>Impedances</u> as vectors.

Resistor: $Z_R = R\,\hat{x}$
Inductor: $Z_L = X_L\,\hat{y}$
Capacitor: $Z_C = X_C(-\hat{y})$

Total $\hat{x}$: $R$
Total $\hat{y}$: $X_L - X_C$

Total magnitude: $Z = \sqrt{R^2 + (X_L - X_C)^2}$

Ex: $R = 1.0\,k\Omega$ $\quad L = 1.0\,H$ $\quad C = 1.0\,\mu F$

In series

Apply $V = 140 \sin(500t)$

Want to use: $V_{rms} = I_{rms} Z$

$$V_{rms} = \frac{140}{\sqrt{2}} = 99\,V$$

$$2\pi f = 500 \qquad f = \frac{500}{2\pi} \approx 160\,Hz$$

$$X_L = 2\pi f L = (500)(1.0) = 500\,\Omega$$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{500 \times 10^{-6}} = 2000\,\Omega$$

$$X_L - X_C = -1500\,\Omega \quad = 1500\,\Omega \text{ capacitive}$$

$$Z = \sqrt{1000^2 + 1500^2} = 1803\,\Omega$$

$$I_{rms} = \frac{99\,V}{1803\,\Omega} = 0.0549\,A$$

Other calculations:

Power Used: $P = I_{rms}^2 R$

$= 3.02\,W$

Not $V_{rms} I_{rms} = (99\,V)(0.0549\,A) = 5.44\,VA$

Capacitor Voltage: $V_{rms} = (0.0549\,A)(2000\,\Omega)$

$= 110\,V$

Bigger than applied voltage!

⑥

# Resonance

$$X_L = X_C$$

At resonance, $Z = R$

- This is the minimum possible $Z$.
- Happens at $f_R = \frac{1}{2\pi\sqrt{LC}}$

- At any other $f$, $Z$ is larger and less current flows.