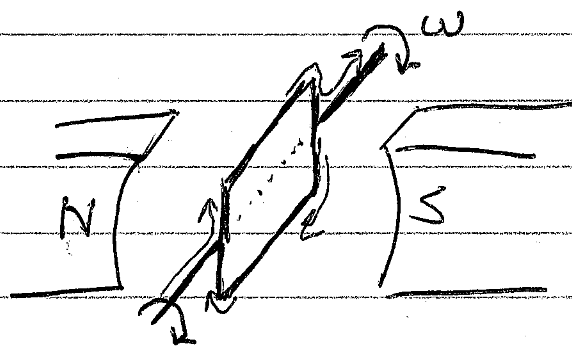
① Phys 1402 2017-07-25 Lec 13

AC Electricity

Why? Easy to generate.
Works with transformers.



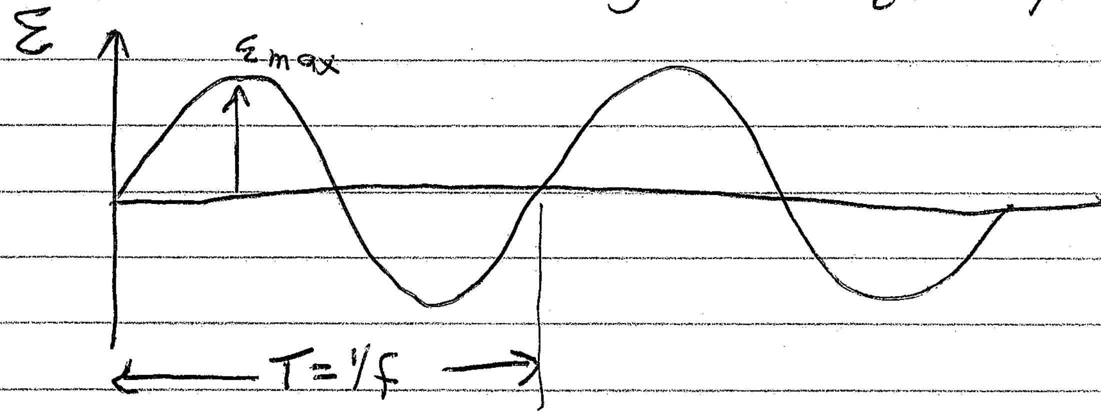
$\Phi_B = NBA\cos(\omega t)$

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

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

↳ sin() or cos()

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



Transformers

Primary – Apply voltage here.
Energy goes in.
Current flows because of applied voltage.
Low R, so current could be huge.
I causes B.
$\Phi = NBA$ is magnetic flux (total)

If input voltage is DC ⇒ Bad!
(Only a little R to limit current.)

If input voltage is AC:
I varies
B varies
Φ varies
Changing Φ makes "Back EMF".
This reduces the effective voltage.
which Limits the current.

Secondary
B from primary is "felt"
$\Phi = NBA$ is flux.
↑ ↑ specific values for secondary.
$\mathcal{E}$ is proportional to N.

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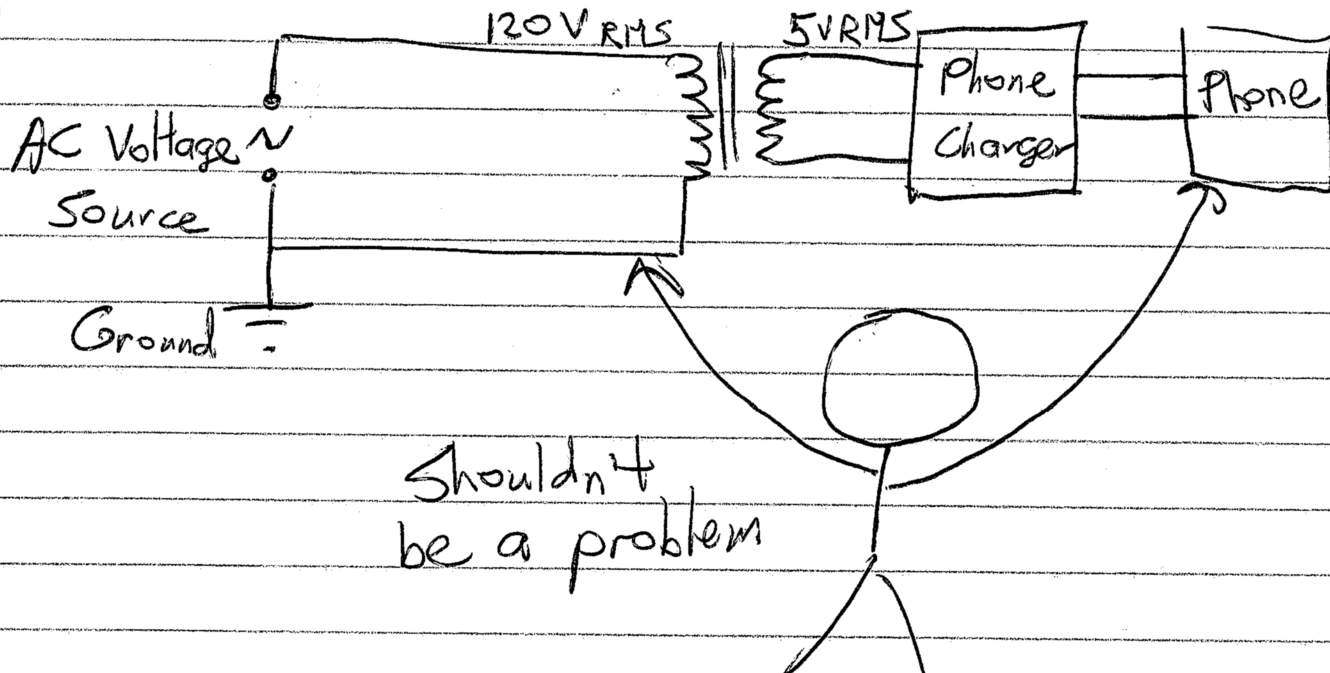
Ratio of $\mathcal{E}$'s:

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

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

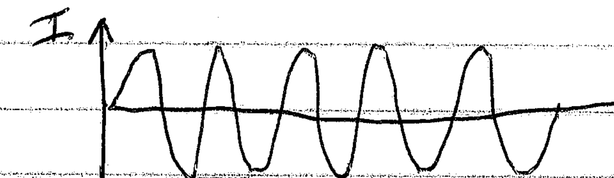
Circuits in AC

Resistors - Same as DC $V_{rms} = I_{rms} R$

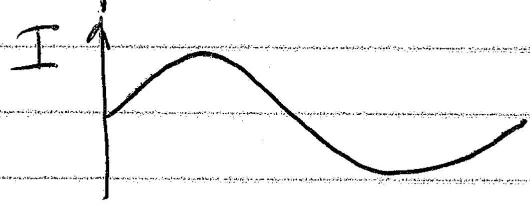
Power is also similar: $P_{avg} = V_{rms} I_{rms}$

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

Inductors - oppose changing current



Fast change
Needs more voltage



Slow change
Needs less voltage.

frequency describes rapidness of change.

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

Inductive Reactance
(X_L)

Capacitors - charging takes time.
Without allowing time current flows back and forth.

Quickly varying AC flows with low voltage.

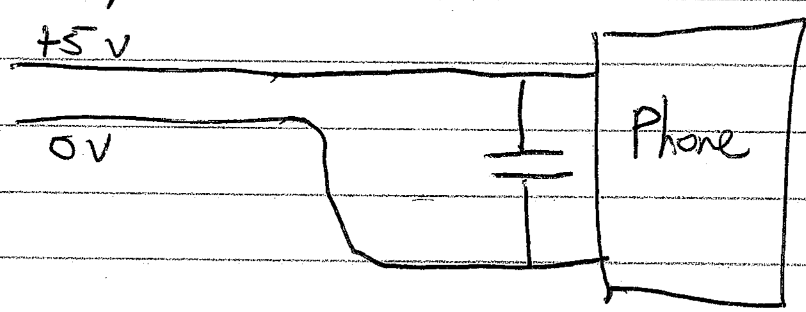
$$V_{rms} = I_{rms} \underbrace{\left(\frac{1}{2\pi f C} \right)}_{\text{Capacitive Reactance } (X_c)} \qquad V_{rms} = I_{rms} X_c$$

Review:

$$\left.\begin{array}{l} V_{rms} = I_{rms} R \\ V_{rms} = I_{rms} X_L \\ V_{rms} = I_{rms} X_c \end{array}\right\} V_{rms} = I_{rms} Z$$

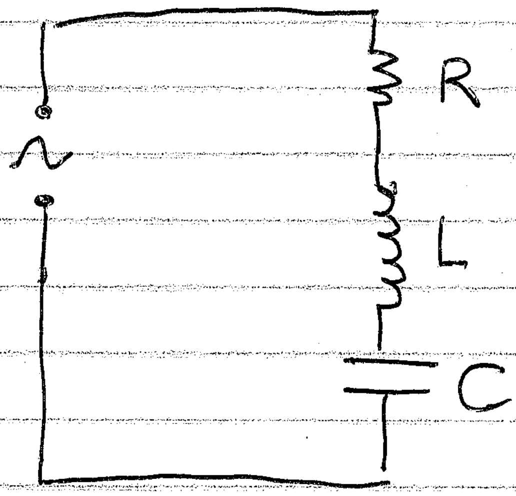
Z = Impedance = Like resistance for AC

Example of capacitor:



- Any stray AC goes thru capacitor
- The DC power goes into the phone.

Series AC Circuit



DC: Add resistances.

AC: Add impedances as vectors.

Resistor: $\hat{x}$ direction
Inductor: $+\hat{y}$ direction
Capacitor: $-\hat{y}$ direction

	x	y
Resistor	R	
Inductor		$X_L = 2\pi f L$
Capacitor		$-X_C = \frac{-1}{2\pi f C}$
Total	R	$X_L - X_C$

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

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Ex: $1\,k\Omega$, $1.0\,H$, $1\,\mu F$ in series

$V = 140 \sin(500\,t)$ $\quad I_{rms} = ?$

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

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

$2\pi f = 500 \qquad f = \frac{500}{2\pi} = ?$

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

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

$$(X_L - X_C) = -1500\ \Omega$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(1000)^2 + (1500)^2}$$

$$= 1803\ \Omega$$

$$V_{rms} = I_{rms} Z$$

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

Power: Only resistor!

$$P = I^2 R = (0.0549\ A)^2 (1000\ \Omega) = 3.02\ W$$

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Since the inductor is $+\hat{y}$ and the capacitor is $-\hat{y}$, they can ~~cancel~~. cancel.

If $X_L = X_C$, resonance.

$$2\pi f L = \frac{1}{2\pi f C}$$

$$(2\pi f)^2 = \frac{1}{LC}$$

$$2\pi f = \frac{1}{\sqrt{LC}}$$

$$f_R = \frac{1}{2\pi\sqrt{LC}}$$

At this frequency, Z is minimized.

Ex: $f = \frac{1}{2\pi\sqrt{(1.0\,H)(10^{-6}\,F)}} = 159\ Hz$

We were at $f = \frac{500}{2\pi} = 80\ Hz$
= below resonance.

At $f_R \rightarrow Z = R$