Phys 1402 2017-10-24 Lec 15

Today
- Inductor & Capacitor together
- Transformers

AC Ohm's Law $V_{rms} = I_{rms} Z$

Impedance (Z) is like resistance for AC.

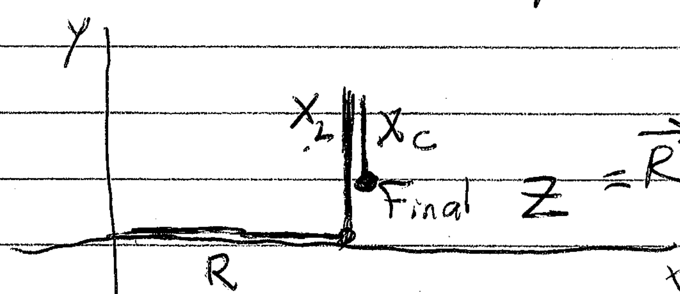
Resistor: $Z = R$

Inductor $Z = X_L = 2\pi f L$

Capacitor $Z = X_C = \frac{1}{2\pi f C}$

What happens when R, L, C are combined?
In general: Need different math.
In series: Can use vector math.

Resistors: $+x$ direction
Inductors: $+y$ direction } These can
Capacitors: $-y$ direction } cancel!



$\text{Final } Z = \vec{R} + \vec{X_L} + \vec{X_C}$

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

②

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

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

$V_{max} = (140\,V)$ $\quad 2\pi f = 500$

$f = 500/(2\pi) = 79.6\,Hz$

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

To find I_{rms}, use AC Ohm's Law

$V_{rms} = I_{rms} Z$ $\quad R = 1000\,\Omega$

$(99V) = I_{rms}(1803\,\Omega)$ $\quad X_L = 2\pi f L = 500\,\Omega$

$\boxed{I_{rms} = 0.0549\,A}$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{(500)(1\times10^{-6})}$$

$$= \frac{1}{0.0005} = 2000\,\Omega$$

Total Reactance

$$X = X_L - X_C = -1500\,\Omega$$

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

Power in AC: Only the resistor!

$$P = V_R I_R = IR\,I = I^2 R = (0.0549A)^2(1000\Omega)$$

$$= 3.02\,W$$

Compare to $(99V)(0.0549A) = 5.4\,VA$

VA Rating ↗

③

Since $X = X_L - X_C$, $X = 0$ is possible.

Cause: $X_L = X_C$

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

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

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

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

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

For 1.0 H, 1 μF

$$f = \frac{1}{2\pi\sqrt{(1.0)(1\times10^{-6})}} = 159 \text{ Hz}$$

If we changed to the resonant freq with the same voltage ... ($R = 1000\Omega$)

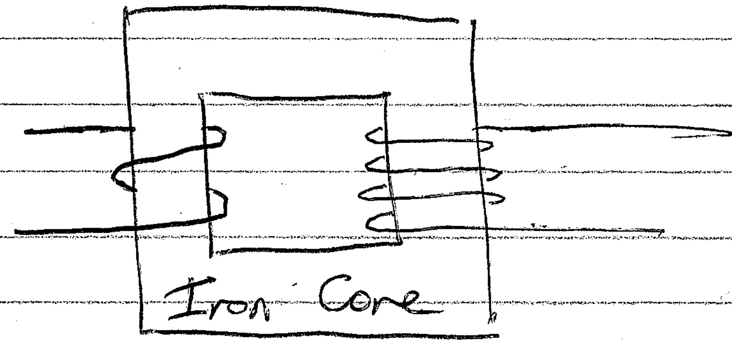
Effect: $X = X_L - X_C = 0$

$$Z = \sqrt{R^2 + X^2} = \sqrt{R^2} = R$$

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{99V}{1000\Omega} = 0.099 A$$

More Current!

<u>Transformers</u> - two coils with interconnected magnetic fields.



Apply voltage to one coil. This is the <u>primary</u>.
Current flows in the primary.
~~If the current is AC~~
The current causes B in the iron core.
Both coils "feel" the magnetic flux.

Flux per loop: $\Phi_1 = BA$

Primary Flux $\Phi_p = N_p BA$
Secondary Flux $\Phi_s = N_s BA$

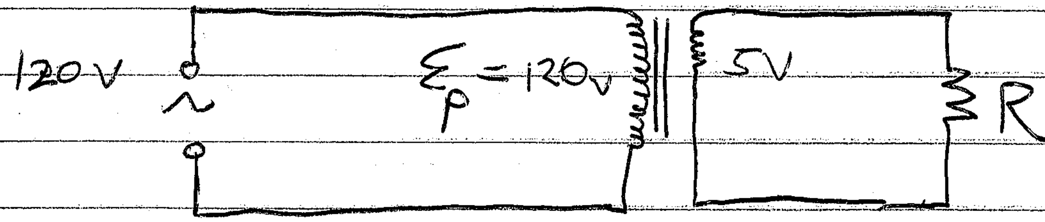
If the current is AC, the flux is AC and it generates EMF.
EMF depends on flux proportionally.

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

Current? $\mathcal{E}_p I_p = \mathcal{E}_s I_s$ (Ideally)

(5)

Ex: Transformer in a cell phone charger



If $N_s = 100$, What is N_p?

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

$$\frac{120v}{5v} = \frac{100}{N_p}$$

$$120 N_p = (100)(5)$$

$$N_p = \frac{(100)(5)}{120} = 4.17$$

$$\frac{5v}{120v} = \frac{N_s}{N_p}$$

$$5 N_p = (120)(100)$$

$$N_p = \frac{(120)(100)}{5} = 2400$$

More voltage in primary $\Rightarrow$ more loops in primary

If $I_R = 1.5\ A$, what is I_p?

$$\mathcal{E}_p I_p = \mathcal{E}_s I_s$$

$$(120 v) I_p = (5v)(1.5 A)$$

$$I_p = \frac{5}{120}(1.5A) = 0.0625 A$$