① Phys 1402 2016-10-20 Lec 17

Components of AC Circuits

Voltage Source

Resistors

$$V_R = I R \qquad P = V I$$

$$V_{rms} = I_{rms} R \qquad P_{avg} = V_{rms} I_{rms}$$

Inductors - basically coils

$$V_L = L \frac{\Delta I}{\Delta t} \qquad (\text{Energy})_L = \frac{1}{2} L I^2$$

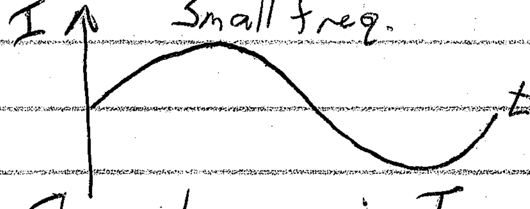
- Voltage makes the current increase
- Constant current requires no voltage.
- Inductor doesn't use energy

$$V_{rms} = I_{rms} \underline{X_L} \qquad P_{avg} = 0$$

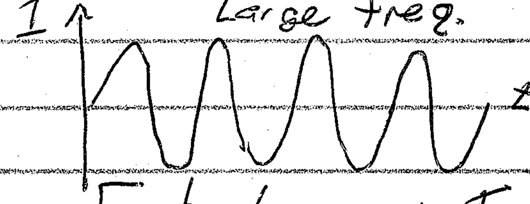
X_L = inductive reactance $= 2\pi f L$

- Passes Low f
- Blocks High f

Compare:



Slow changes in I.
Small $\Delta I / \Delta t$



Fast changes in I.
Large $\Delta I / \Delta t$

Capacitors - Breaks in the circuit w/ lots of surface area.

$V_c = Q/C$ $\qquad$ $(\text{Energy})_C = \frac{1}{2}CV^2$

$Q = CV_c$

- Current changes Q, which changes V_c. (opposite of inductor)
- Constant Voltage → const Q → no current
- Cap doesn't use power.

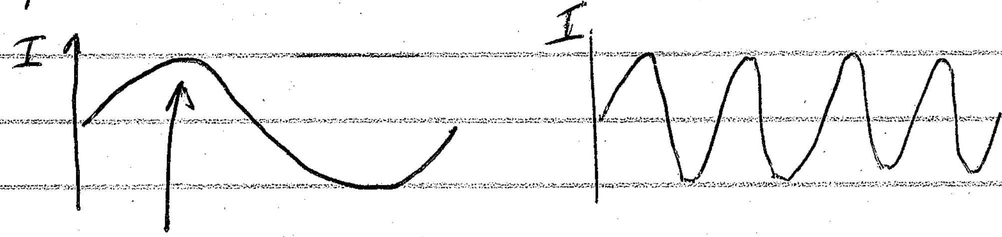
$V_{rms} = I_{rms} X_C$ $\qquad$ $P_{avg} = 0$

X_c = capacitive reactance

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

- Blocks Low-f
- Passes High-f

Compare:



- Lots of time to charge capacitor
- Q gets large
- V_c gets large
- Low f → High X_C
- Low C → High X_C

(3)

Ex: $V_{rms} = 120 \text{ V}$
$f = 60 \text{ Hz}$

Attach a $0.1\ \mu F$ capacitor

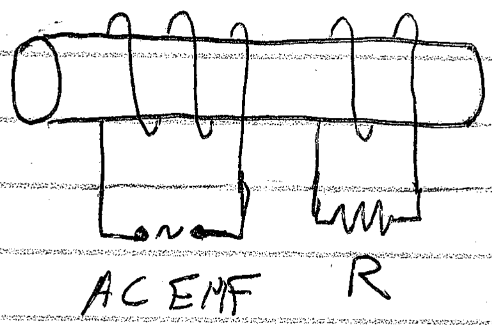
$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(60)(0.1\times10^{-6})} = 26500\ \Omega$$

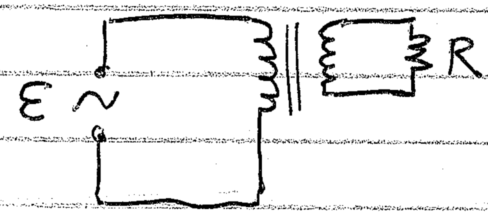
$$V_{rms} = I_{rms} X_C$$

$$I_{rms} = \frac{120\text{ V}}{26500\ \Omega} = 0.0045\text{ A} = 4.5\text{ mA}$$

This capacitor mostly blocks 60 Hz AC.

Transformer – Two coils with overlapping magnetic fields.





In a transformer:

- EMF applied to primary, must be AC!
  - AC current flows
  - B oscillates
- Secondary coil "feels" B.
  - Φ_B oscillates
  - Generates EMF in secondary
- Load (R) attached to secondary
  - ε_2 pushes current in load.

The EMF's are related

$$\text{Voltage Ratio} = \frac{\varepsilon_2}{\varepsilon_1} = \frac{N_2}{N_1} = \text{Turns Ratio}$$

Ex: $\varepsilon_1 = 120\,\text{v}$

$N_2 = 50$

$\varepsilon_2 = 5\,\text{V}$

$$\frac{5}{120} = \frac{50}{N_1}$$

$$N_1 = 1200$$

(5)

Transformers pass energy fairly efficiently.

$$P_{in} = P_{out}$$

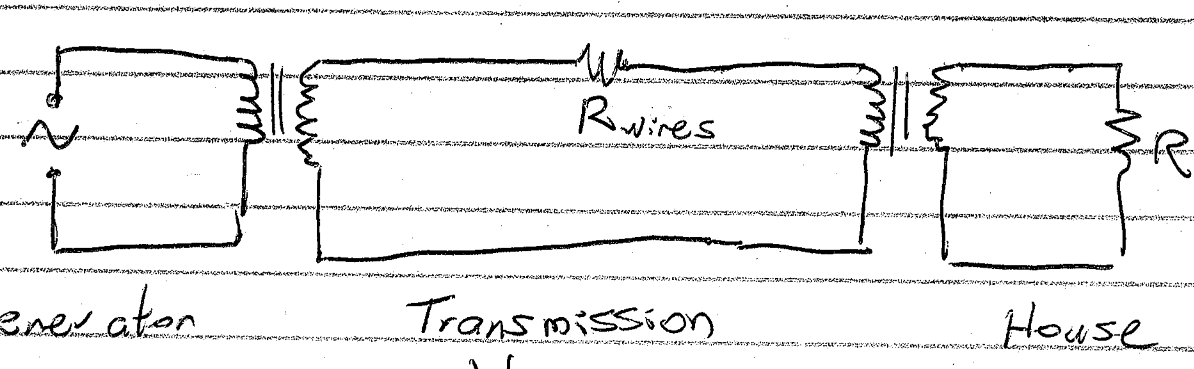
$$\mathcal{E}_1 I_1 = \mathcal{E}_2 I_2$$

If our 5V is at 2.0 A

$$120 \cdot I_1 = 5 \cdot 2$$

$$I_1 = \frac{10}{120} = 0.08 A$$

This transformer increases the current!
The voltage is decreased → step-down



R_{wires} wastes energy $P = I^2 R$
High voltage → Low current