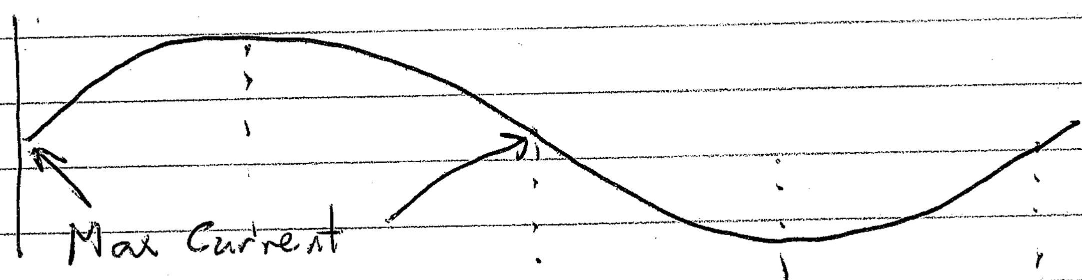
Phys 1402 2017-10-19 Lec ~~15~~ 14

Capacitors in AC

What we know:

- Capacitors store charge $Q = CV$
- They take time to charge $\tau = RC$
  $e^{-t/\tau}$
- Capacitors store energy $E_{nergy} = \frac{1}{2}QV$
  $E_{nergy} = \frac{1}{2}CV^2$

Ac Sinewave applied to capacitor



	$V = \oplus$	$V = \oplus$	$V = \ominus$	$V = \ominus$
	$I = \oplus$	$I = \ominus$	$I = \ominus$	$I = \oplus$
$P = VI$	$P = \oplus$	$P = \ominus$	$P = \oplus$	$P = \ominus$

↑ Max energy ↑ Max Energy

In AC

- Capacitor takes & gives power
- Average power $= 0$

AC Ohm's Law for Capacitor

$$V_{max} = I_{max} \; \underline{X_C}$$

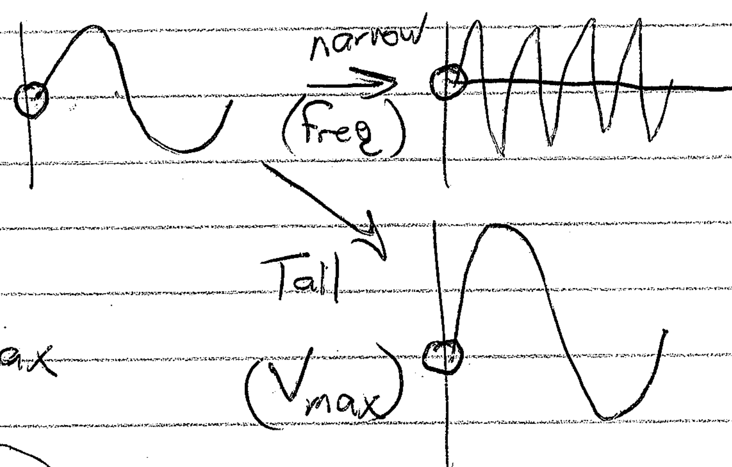
- Reactance (X) is measured in ohms (Ω)

$$V_{Rms} = I_{Rms} \; X_C$$

How is X_C related to C?

$$Q = CV$$

$$I = C \text{ (Rate of change of V)}$$



$$I_{max} \propto C f V_{max}$$

$$I_{max} = 2\pi f C \; V_{max}$$

$$V_{max} = I_{max} \left(\frac{1}{2\pi f C}\right)$$

$$= I_{max} \; (X_C)$$

High freq → Cap never "fills" → Low V for given I

High freqs pass easily

(3)

Ex: $V_{rms} = 120\ V$

$f = 60\ Hz$

Want $I_{rms} = 1\ mA$ max thru cap

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

$$(120\ V) = (0.001\ A) X_C$$

$$\frac{120\ V}{0.001 A} = 120000\ \Omega = X_C$$

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

$m = 10^{-3}$

$\mu = 10^{-6}$

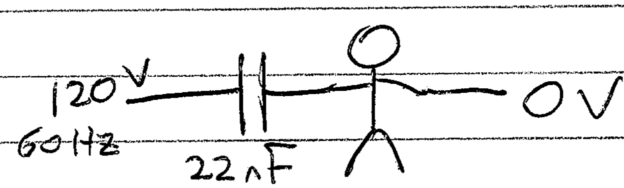
$n = 10^{-9}$

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

$$= \frac{1}{2\pi (60\ Hz)(120000\ \Omega)}$$

$$= 2.2 \times 10^{-8}\ F$$

$$= 22\ nF$$



No more than 1 mV

Less C is safer.

Inductors are magnetic coils

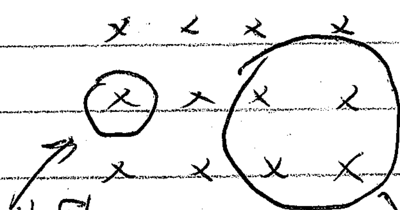
Ex: Solenoid Coil $\quad B = \frac{\mu_0 N I}{l}$

Changing I → Changing B → Voltage

$$\mathcal{E} = \text{Changing } \Phi_B$$

Φ

Magnetic Flux (Φ_B) is $B \cdot A$ and determines induced voltage.



Small flux in small loop

Large flux in large loop

Flux of one loop: $\Phi_1 = B \cdot A$

Flux of whole coil: $\Phi_B = NBA$

For solenoid: $\Phi_B = N(\mu_0 N I / l) A$

$$\Phi_B = \left(\frac{\mu_0 N^2 A}{l}\right) I$$

$$\Phi_B = L \quad I$$

Inductance (L) is in henries (H)

③

Changing current affects inductor.

$$\Phi_B = L\ I$$

Voltage = Changing Φ_B = L (Changing I)

- prop to I_{max}
- prop to freq

$$V_{max} = (2\pi f L)\ I_{max}$$

$$V_{max} = I_{max}\ (X_L)$$

$$V_{rms} = I_{rms}\ X_L$$ Ohm's Law for inductor

- High f → High X_L → Low current for given voltage.

Resistor $V_{rms} = I_{rms}\ R$

Capacitor $V_{rms} = I_{rms}\ X_C$ $\quad X_C = \frac{1}{2\pi f C}$

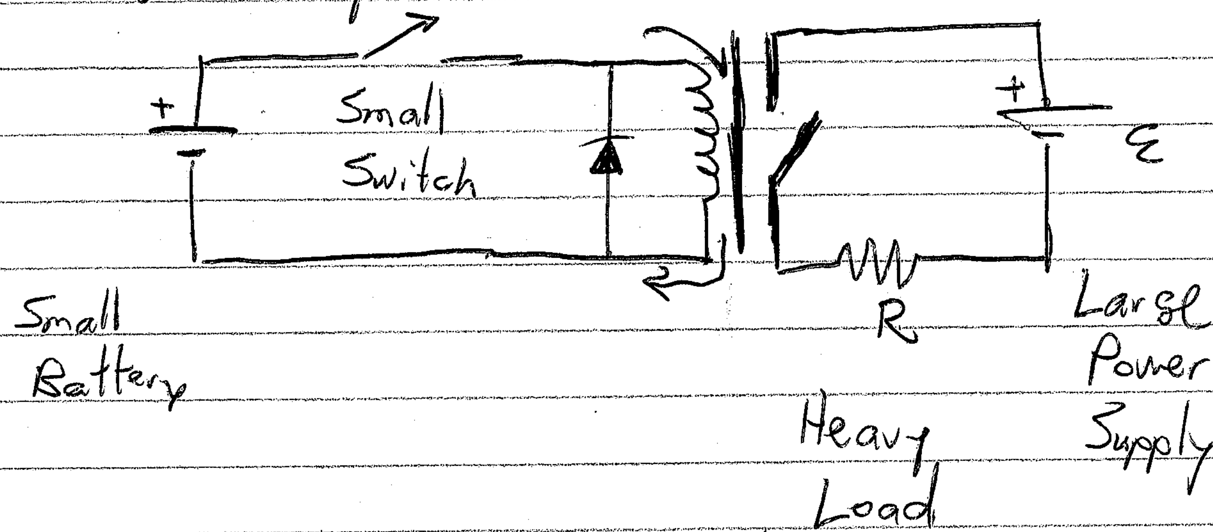
Inductor $V_{rms} = I_{rms}\ X_L$ $\quad X_L = 2\pi f L$

Cap – opp change in V – Energy $= \frac{1}{2} C V^2$

Ind – opp change in I – Energy $= \frac{1}{2} L I^2$

⑥

Solenoid Relay



Turning off the relay generates
a high voltage pulse.
This wrecks the small switch.
Two solutions: 1. Capacitor (Condensor)
2. Diode