Physics II: 1702
Gravity, Electricity, & Magnetism

Professor Jasper Halekas
Van Allen 70 [Clicker Channel #18]
MWF 11:30-12:30 Lecture, Th 12:30-1:30 Discussion

Inductance

What does inductance tell us?

$$L = \frac{\Phi_B}{i}$$

$$\Phi_B = Li$$

$$\frac{d\Phi_B}{dt} = L\frac{di}{dt}$$

L is independent of time.
Depends only on geometry of inductor (like capacitance).

Inductor Effect in Circuit

$$\frac{d\Phi_B}{dt} = L\frac{di}{dt}$$

Recall Faraday's Law

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

$$-\varepsilon = L\frac{di}{dt}$$

$$\varepsilon = -L\frac{di}{dt}$$

Changing the current in an inductor creates an EMF which opposes the change in the current. Sometimes called "back EMF"

Inductor in a Circuit

$$\varepsilon = -L\frac{di}{dt}$$

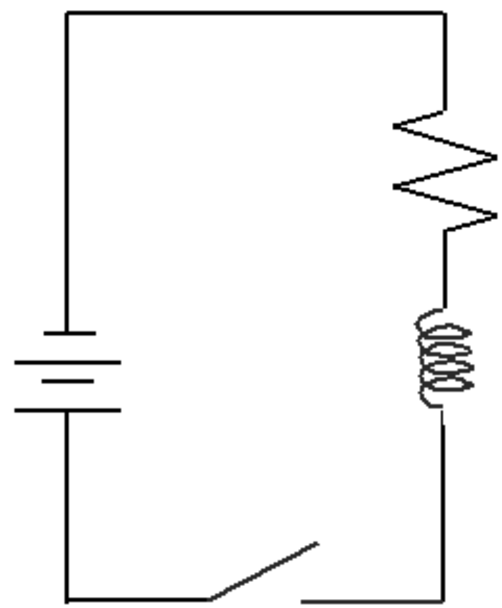
It is difficult (requires big external Voltage) to change quickly the current in an inductor.

The current in an inductor **cannot** change instantly.

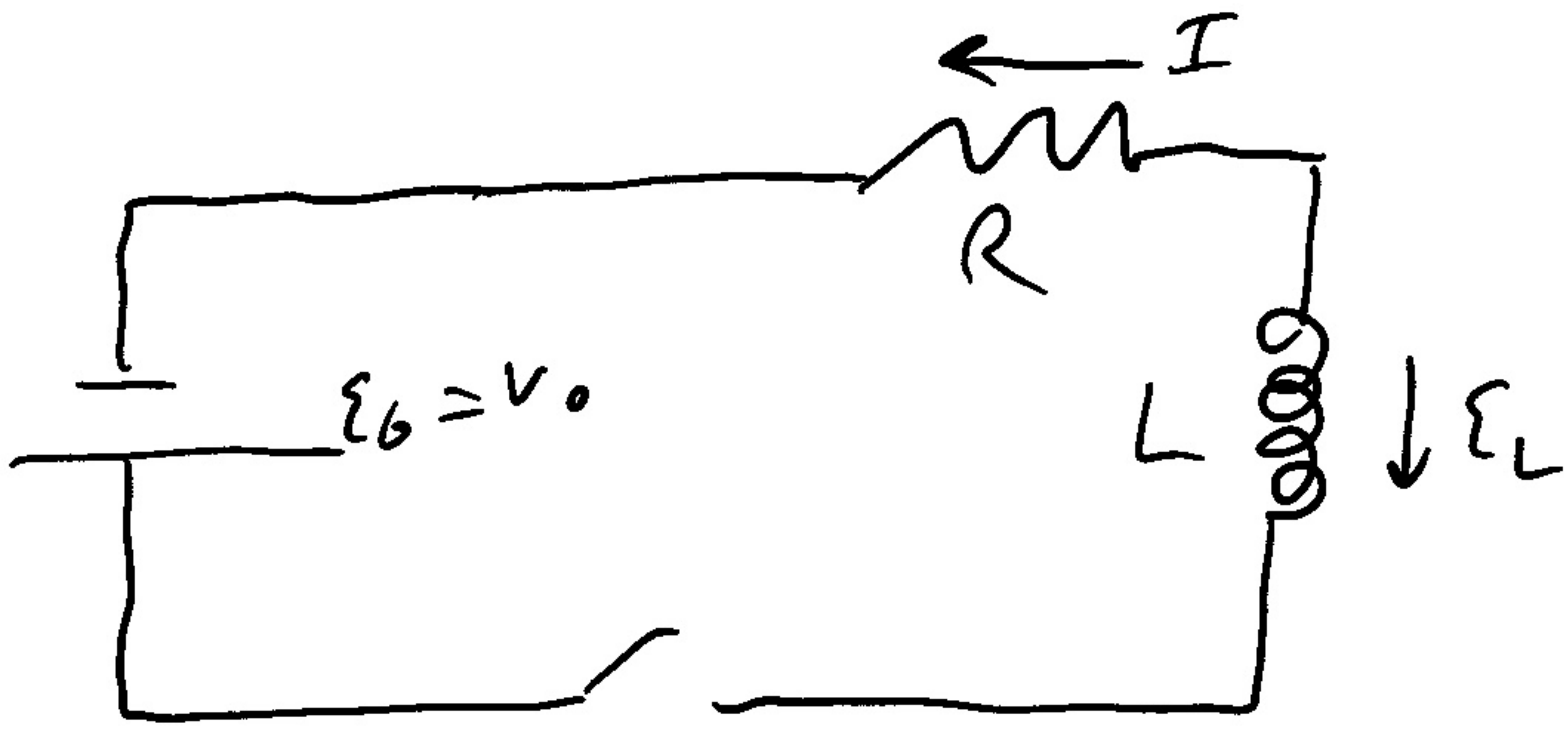
If it did (or tried to), there would be an infinite back EMF. This infinite back EMF would be fighting the change!

Concept Check

In the LR circuit shown, what happens when the switch is closed?



1) Current flows CW and increases.
2) Current flows CCW and increases.
3) Current flows CW and decreases.
4) Current flows CCW and decreases.



- switch closes
- current tries to flow
- Inductor opposes change and tries to drive opposing current

- Loop Rule (still valid since dB/dt only in core)

$$V_0 - L\, dI/dt - IR = 0$$

$$\Rightarrow dI/dt = I' = (V_0 - IR)/L = V_0/L - IR/L$$

- looks like equation for discharging RC circuit but w/ I instead of q and R/L instead of RC

$$I' + R/L\, I - V_0/L = 0$$

guess solution

$$I(t) = A + B e^{-t/\tau_L}$$

$$B \cdot \left(-1/\tau_L\, e^{-t/\tau_L}\right) + R/L\,(A + Be^{-t/\tau}) - V_0/L = 0$$

$$\Rightarrow RA/L - V_0/L = 0$$

or $A = V_0/R$

$$B/\tau_L + RB/L = 0$$

$$\Rightarrow \tau_L = L/R$$

$$I(t) = V_0/R + B e^{-t/\tau_L}$$

$$I(0) = 0$$

$$\Rightarrow \boxed{I(t) = V_0/R\left[1 - e^{-t/\tau_L}\right]}$$

$$I(t \gg \tau_L) = V_0/R$$

(no EMF in inductor after a long time, all voltage across resistor)

$$\mathcal{E}_L = -L\, dI/dt = -\frac{V_0 L}{R} \cdot 1/\tau_L\, e^{-t/\tau_L}$$

$$= -V_0 e^{-t/\tau_L}$$

starts @ $-V_0$ and decays to zero

- What about turning off battery after equilibrium reached?

$$I' + R/L\, I = 0$$

$$\Rightarrow \quad I(t) = I_0 e^{-t/\tau_L}$$
$$= V_0/R \; e^{-t/\tau_L}$$

- current keeps flowing after battery removed!

$$\tau_L = L/R$$

combare to $\tau_C = RC$

Big R $\longrightarrow$ small I ($= V/R$)
- means RC w/ big R discharges slowly

- but RL circuit w/ big R settles quickly since current and thus back EMF smaller