Class 36: Inductance and LC Circuits


HEY PHYSICS MAJORS!
Interested in research? Maybe even theory?
Come to SPS Open Lab Day
This Saturday Nov 22 8:30-2:00 starting in CP 177
For Fun, Food, and Physics!
We will be showcasing labs from all types of physics research going on at UK. We will also have speakers from theory and astronomy and even a tour of the observatory!
Breakfast and Lunch will be provided!
See you there!
If you have any questions, please email
lesm226@g.uky.edu
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Cosmic Lunch

There will be a Cosmic Lunch

Friday, Nov 21 at 12:00 in CP 103

Dr. Sumit Das will be discussing Holograms and Black Holes and how they are related to string theory.

Lunch will be provided

Hope to see you all there!

Summary of Maxwell's Equations so far

Maxwell's 1st equation: (Gauss's Law foe electric field)

$$\varepsilon_0 \oiint \vec{E} \cdot d\vec{A} = q_{in}$$

Maxwell's 2nd equation: (Gauss's Law for magnetic field)

$$\oiint \vec{B} \cdot d\vec{A} = 0$$

Maxwell's 3rd equation: (Ampere's Law - incomplete)

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{in}$$

Maxwell's 4rd equation: (Faraday's Law)

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d}{dt}\int \vec{B} \cdot d\vec{A}$$

Maxwell's equations describe only the fields, it does not include the effect of the field on charges or currents:

$$\vec{F}_E = q\vec{E}$$

$$\vec{F}_B = q\vec{v} \times \vec{B} \quad (\text{or } d\vec{F}_B = I d\vec{s} \times \vec{B})$$

— Not included in Maxwell's equations

Self Inductance

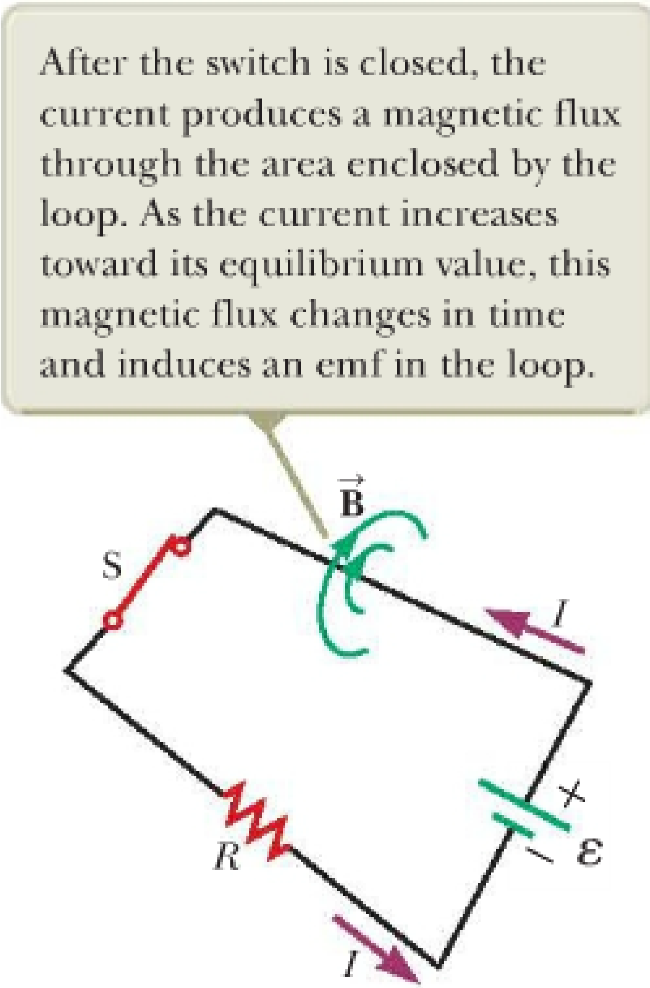


Figure 32.1 Self-induction in a simple circuit.

$$\text{Back emf} = \varepsilon_L = -\frac{d}{dt}\Phi_B$$

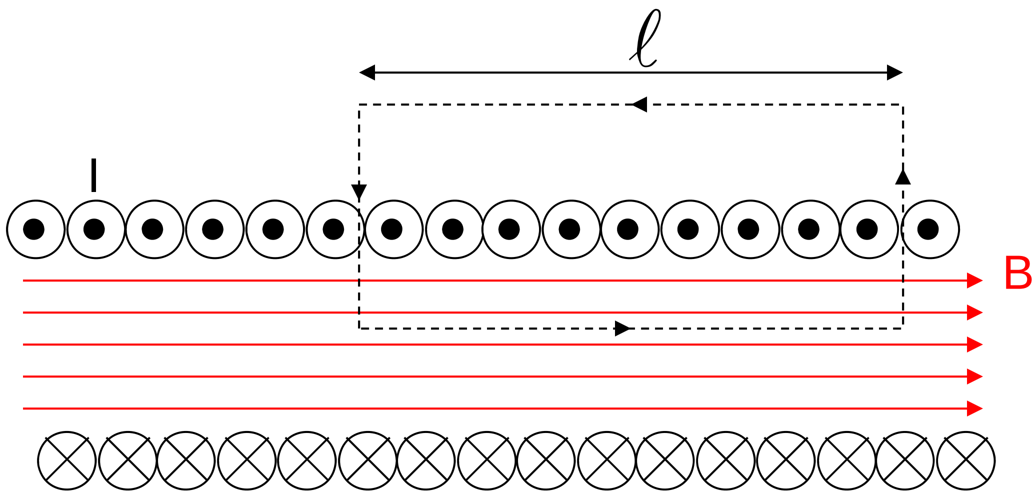
$$\Phi_B \propto B \propto I$$

$$\varepsilon_L \propto -\frac{d}{dt}I \quad \Rightarrow \quad \boxed{\varepsilon_L = -L\frac{dI}{dt}}$$

L is called the inductance.

SI unit of L : Henry (H)

Inductor



$$B = \mu_0 n\, I$$

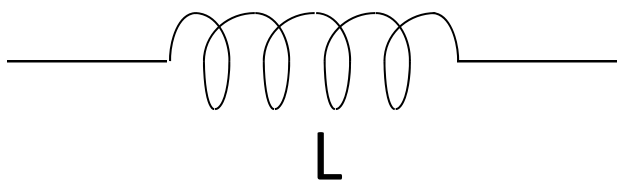
$$\Phi_B = NBA = N(\mu_0 n\, I)A = \mu_0 nNAI$$

$$\text{Back emf} = \varepsilon_L = -\frac{d}{dt}\mu_0 nNAI$$

$$= -\mu_0 nNA\frac{d}{dt}I$$

$$\therefore L = \mu_0 nNA \quad \text{or} \quad \mu_0 \frac{N^2}{\ell}A$$

Inductor symbol:



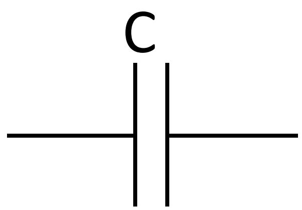
Capacitor and Inductor

Capacitor C	Inductor L
Charge Q	Current I
E field	B field
$V = \frac{Q}{C}$	$\varepsilon = -L\frac{dI}{dt}$
Parallel plate capacitor (uniform E field) $C = \frac{\varepsilon_0 A}{d}$ and $E = \frac{V}{d}$	Solenoid (uniform B field) $L = \mu_0 nNA$ and $B = \mu_0 nI$

From Class 15

(Slide 6)

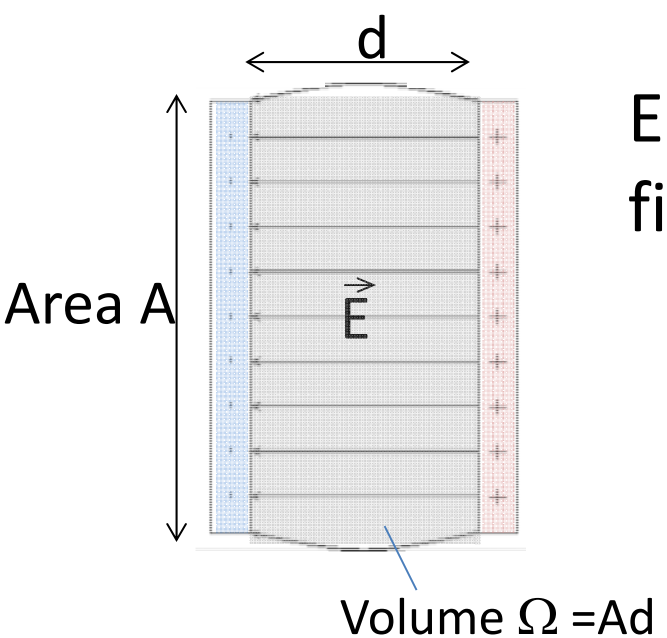
Energy Stored in a Capacitor



Energy stored in a charged capacitor:

$$U = \frac{1}{2} C V^2$$

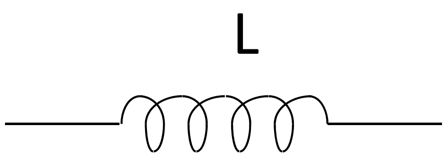
(Do not forget $C = \frac{Q}{V}$.)



Energy density stored in an electric field:

$$u_E = \frac{U}{\Omega} = \frac{1}{2} \varepsilon_0 E^2$$

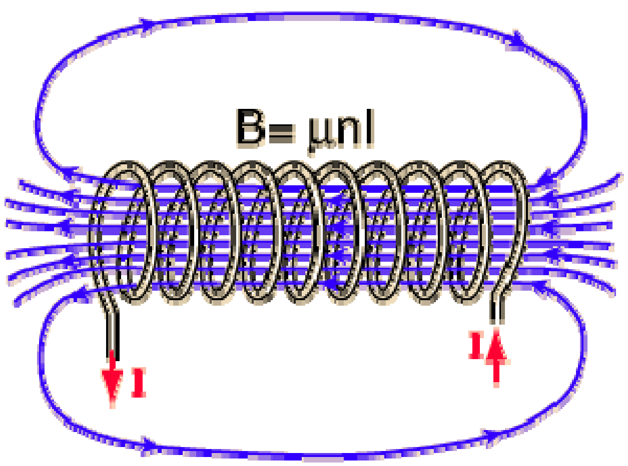
Energy Stored in an Inductor



Energy stored in an inductor:

$$U = \frac{1}{2} L I^2$$

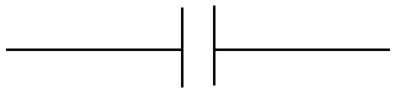
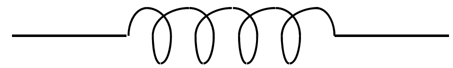
(Do not forget $\varepsilon = -L\frac{dI}{dt}$.)



Energy density stored in a magnetic field:

$$u_B = \frac{U_B}{\Omega} = \frac{1}{2\mu_0} B^2$$

Capacitor and Inductor

Capacitor C	Inductor L
	
Charge Q	Current I
E field	B field
$V = \frac{Q}{C}$	$\varepsilon = -L\frac{dI}{dt}$
Parallel plate capacitor (uniform E field) $C = \frac{\varepsilon_0 A}{d}$ and $E = \frac{V}{d}$	Solenoid (uniform B field) $L = \mu_0 nNA$ and $B = \mu_0 nI$
$U_E = \frac{1}{2}CV^2$ and $u_E = \frac{1}{2}\varepsilon_0 E^2$	$U_B = \frac{1}{2}LI^2$ and $u_B = \frac{1}{2\mu_0}B^2$