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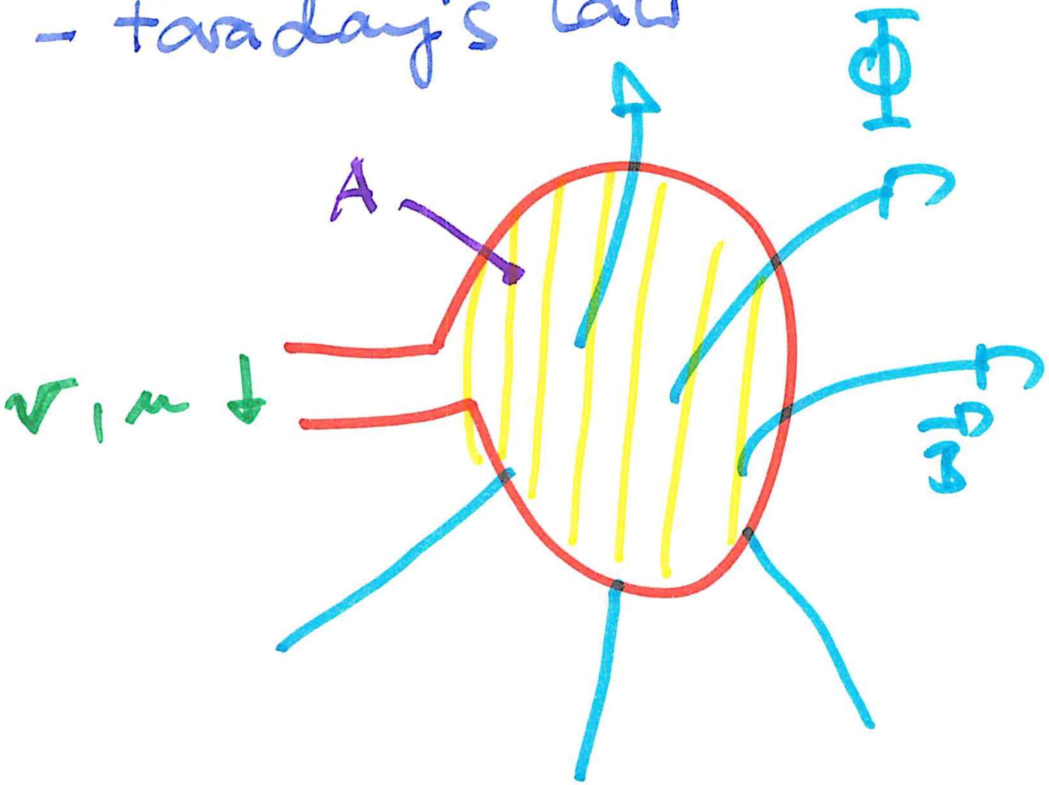
EC - Lecture, 1.4.18

- Inductance and capacitors
  - Faraday's law



$\Phi = \Phi(t)$ = magnetic flux in unit Vs
↳ second
↳ voltage

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$$\Phi = \Phi(t) = \int \vec{B} \, d\vec{A}$$

$\vec{B}$ ↓ flux density

$\vec{A}$ ↓ Area

$\vec{B} = B(t)$: vector field in unit $\frac{Vs}{m^2}$

Faraday said:

$$u = N \frac{d\Phi}{dt}$$

$\{ U = R \cdot I$

N: Number of windings of the coil

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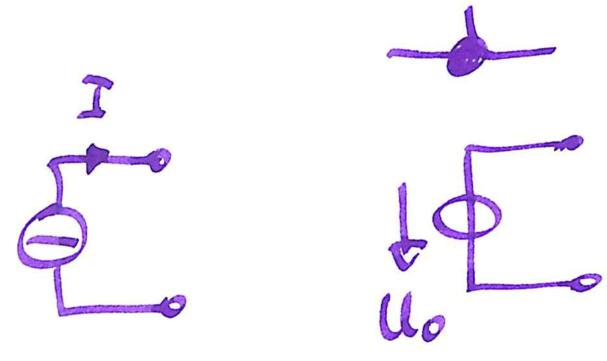
- New device of an electric circuit: <u>Inductance</u>

old devices:



or

L → coil

<u>Pre analysis:</u>

each current is linked with a magnetic field?

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- We know no current without a magnetic field.
- So we can measure ~~the~~/a current, if we measure the magnetic field.
- Magnetic field $\vec{H}$ (vector)

$\vec{H}$ in $\frac{A}{m}$

- Magnetic field is linked with the magnetic flux density

$$\vec{B} = \mu \vec{H} = \mu_0 \cdot \mu_r \vec{H}$$

μ → permeability; μ_0 → absolut permeab.; μ_r → relative permeab.

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$\vec{B}$ in $\frac{Vs}{m^2}$ magn. flux density

Φ in Vs magn. flux

$\mu_0 = 4\pi \cdot 10^{-7}$ in $\frac{Vs}{Am}$

$\mu_r = 1$ → air, copper, wood, PVC, ...
..

$\mu_r = 100 .. 200 .. 500$ → ferro magnetic materials as Iron, steel, ..

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→ $I \rightarrow \vec{H} \rightarrow \vec{B} \rightarrow \Phi$

⋮

$I \sim \Phi$ } equation

$I = a \cdot \Phi$; a : constant

$\Phi = L\,I$

$L = \frac{\Phi}{I}$ in $\frac{Vs}{A} = H$: → Henry

Inductance

in general:

$L = \frac{N\Phi}{I}$ N: Number of windings

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→ Faradays law: $u = N\frac{d\Phi}{dt}$

→ Def. inductance: $L = N \frac{\Phi}{I}$

$\Phi = LI$

$u = N\frac{d}{dt}(LI) = NL\frac{dI}{dt}$

$L_{new} = L$

$u \neq 0$ → if $I \neq$ const

⇒ $I = I(t)$ → time dependent current

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if time dependent:

$I(t) = i$

$U(t) = u$

$P(t) = p$

small letters

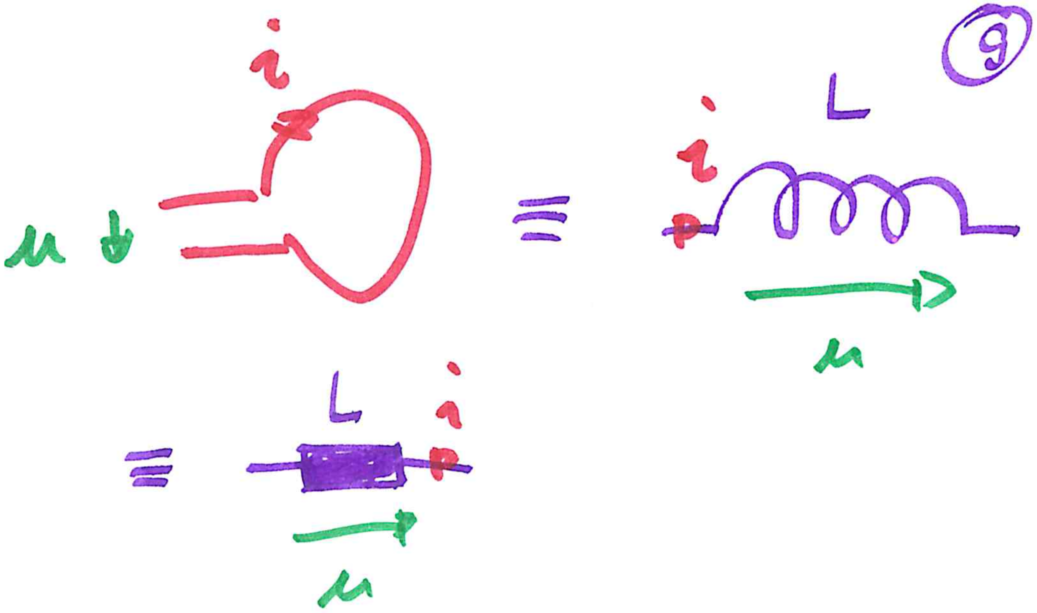
if not time dependent

I, U, P → big letters

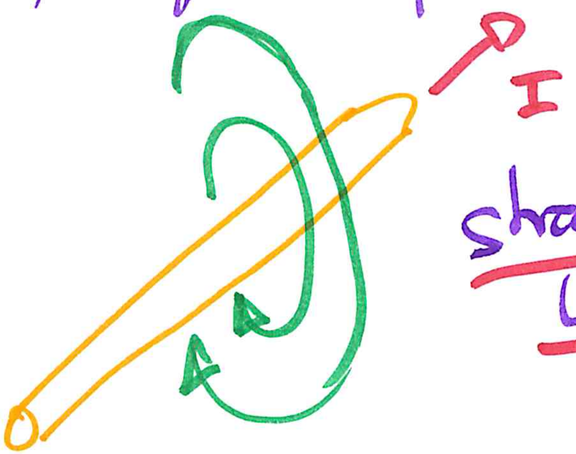
$$u = L\frac{di}{dt}$$

$= u$

the current is simpler to handle as the flux. Modification of Faraday's Law:

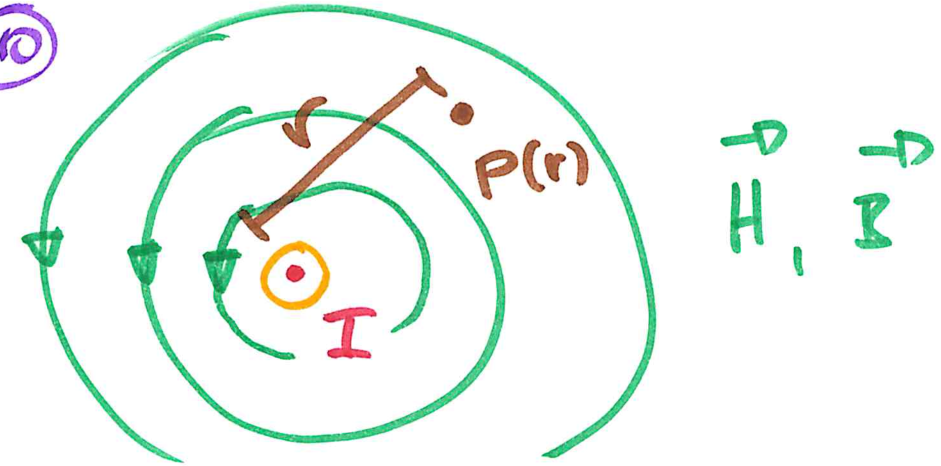


• Same thing to current and magnetic field

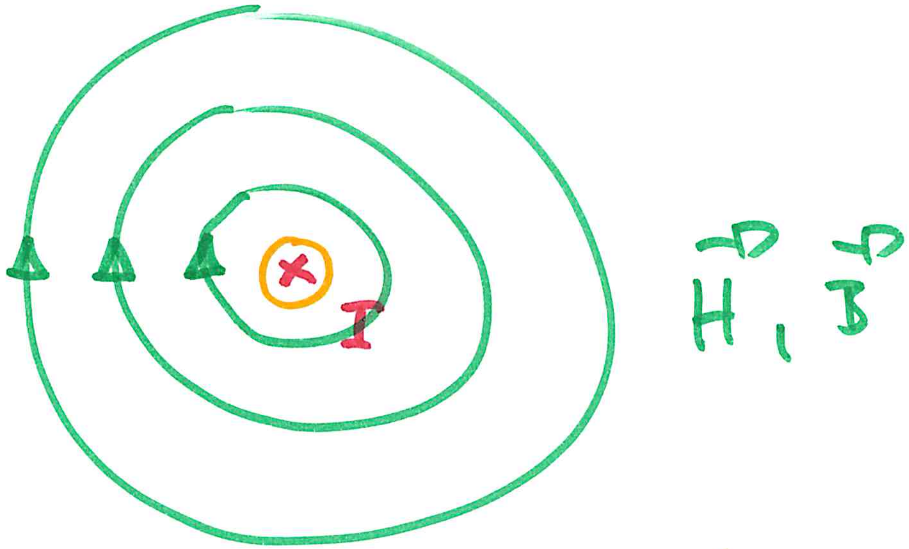


straight wire !

$\vec{H}$: magnetic field strength



current flows to me



current goes into the paper

{ EMA ? EMF)

$$H(P) = \frac{I}{2\pi r}$$

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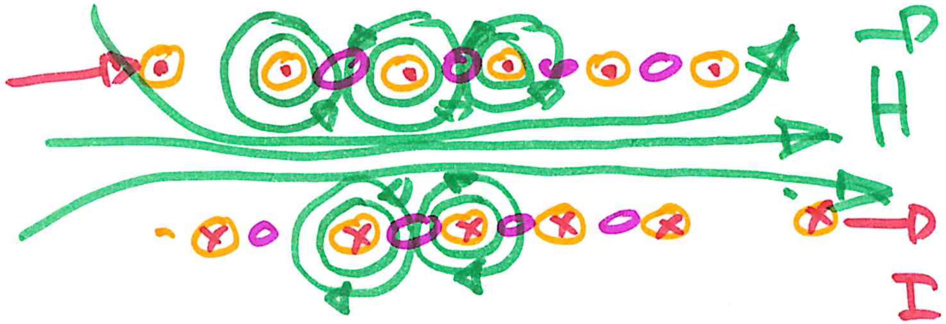
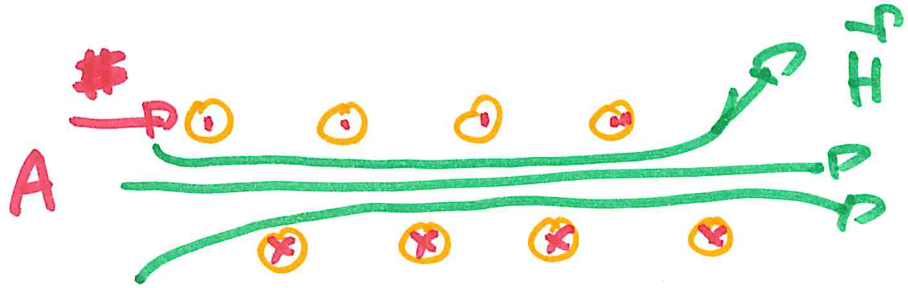
• magnetic field of a coil (not a straight wire !!)



zoom



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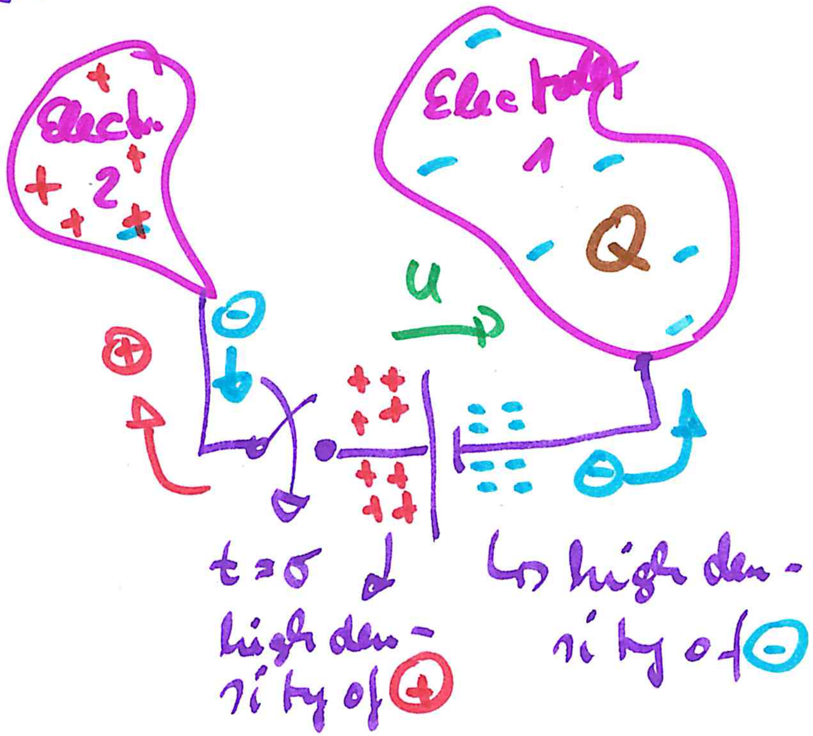
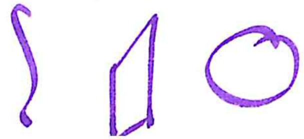
– Other new device of an electric circuit : Capacitor

experiment, virtual :
$t \leq 0$: 2 electrodes are neutral



() : metal



$U \downarrow \rightarrow Q \downarrow$

$U \uparrow \rightarrow Q \uparrow$

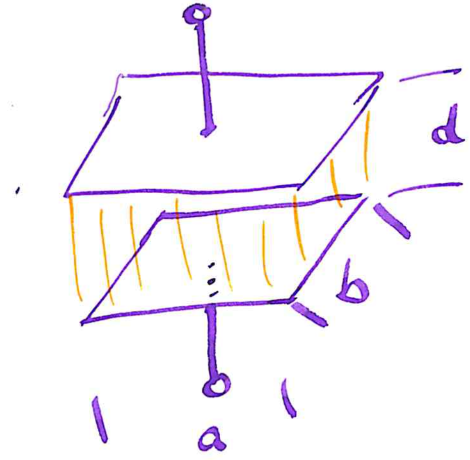
$U \sim Q$ ✗

$U = a \cdot Q$ ✓

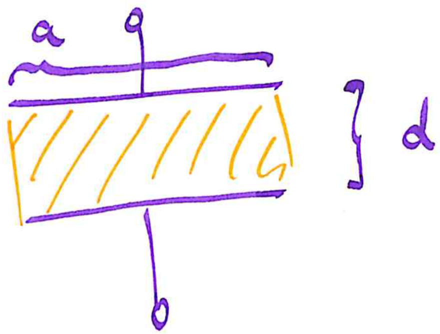
$$\frac{Q}{U} = C \quad \text{in} \quad \frac{As}{V} = F$$

Definition of capacitance — Farad

example:

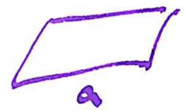


another sight:



/// permittivity

ε



b; $A = b \cdot a$

$$C = \varepsilon \frac{A}{d} = \varepsilon_0 \varepsilon_r \frac{A}{d}$$

C of a plate capacitor

ε: permittivity; ε_0: permittivity of vacuum $= 8.8 \cdot 10^{-12} \frac{As}{Vm}$

ε_r: relative perm.;

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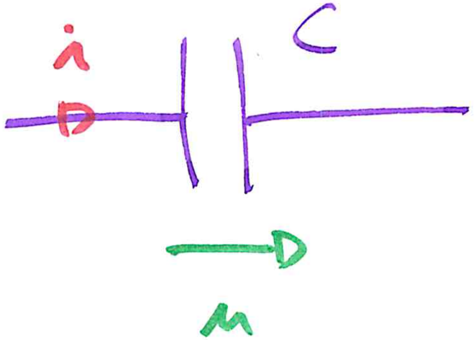
$$\mu_0 = 4\pi \cdot 10^{-7} \frac{Vs}{Am}$$ math. const

$$\varepsilon_0 = 8.8 \cdot 10^{-12} \frac{As}{Vm}$$ physical const

→ you can measure

- C at voltage and current



Def. of current:

$$I = \frac{dQ}{dt} = i$$

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$$Q = C \cdot u$$

$$i = \frac{d}{dt}(Cu) =$$

$$i = C\frac{du}{dt}$$

$$u = L\frac{di}{dt}$$

$$u = R\,i$$