Physics 142 - November 4, 2014

- Exam 2 B+L 109 0800 Thursday
- Yes, chapter 36 (relativity) is fair game
- Q+A session Today 3pm. B+L 407

  Will try to answer questions Wed. if you have them

- Post Exam 2 but pre Thanksgiving

  Groups meet + discuss

  Choose a spokesperson/contact for me

  Set up MTing w/ me to chat about topic + plan

Changing B Field

$$\mathcal{E} = \int_{loop} \vec{E} \cdot \vec{dl} = -\frac{d\phi_M}{dt}$$

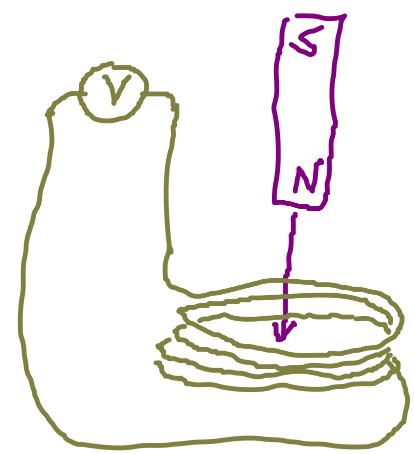
"Induced" EMF

$$\text{Magnetic Flux} \equiv \phi_M = \int \vec{B} \cdot \vec{dA}$$

True in Material (wire)

and

Free space



Induction

$$\varepsilon = \int_{loop} \vec{E} \cdot d\vec{l} = -\frac{d\Phi_M}{dt}$$

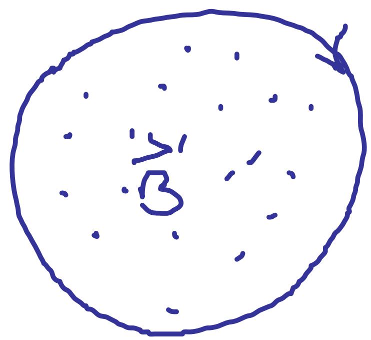
↑ induced EMF

$$\Phi_M = \int_{loop} \vec{B} \cdot d\vec{A}$$

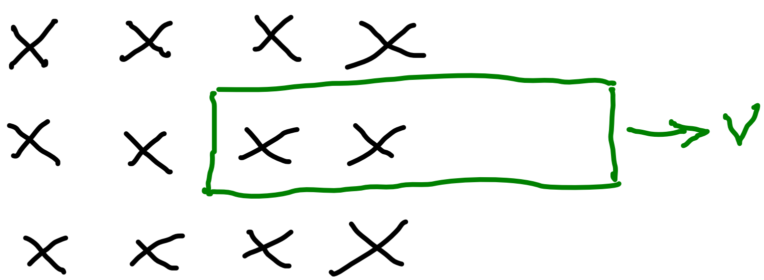
All very Important

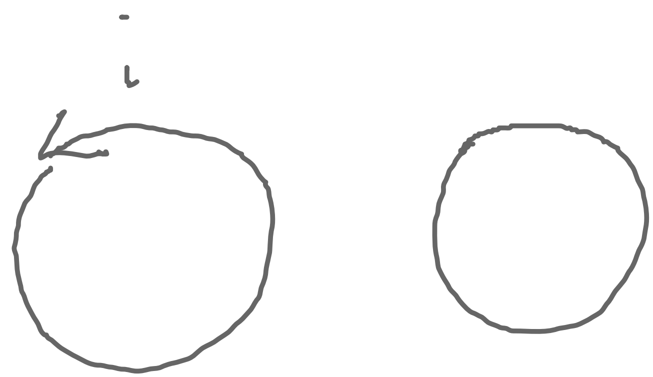
Lenz's Law - An induced current in a closed conducting loop will appear in such a way as to oppose the change that created it

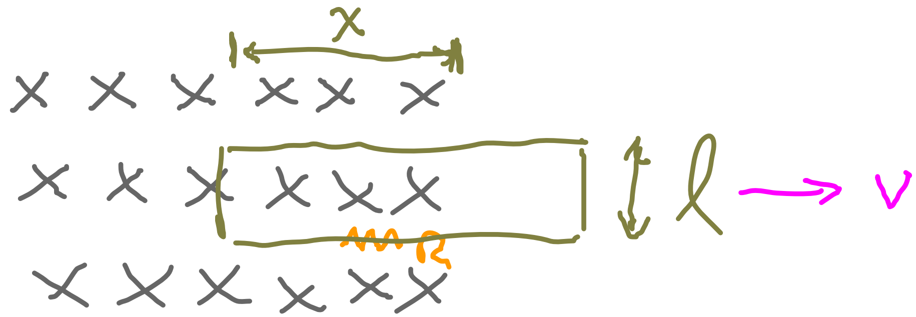
Gives the direction of induced effect



i induced clockwise
if
B increasing







$$\mathcal{E} = -\frac{d\Phi_m}{dt} = -\frac{d}{dt}(Blx) = -Bl\underbrace{\frac{dx}{dt}}_{v}$$

$$\mathcal{E} = -Blv$$

$$|i| = \frac{\mathcal{E}}{R} = \frac{Blv}{R}$$

n turns / length

Each turn has area A

$$\phi_m = BA = \mu_0 n i A$$ Single turn

($\mu_0 n i$: calc'ed earlier)

For length l

$$\phi_m = \mu_0 n i A l n = \mu_0 i A l n^2$$

$$\phi_m \propto i \rightsquigarrow \phi_m = L i$$

L: Self inductance (for a geometry)

[constant of proportionality

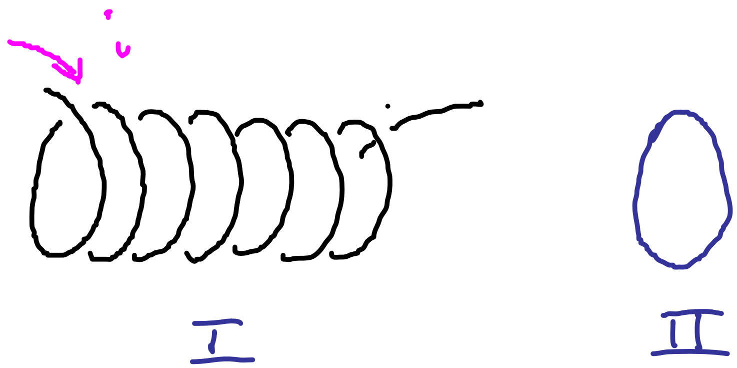
$$\mathcal{E} = -\frac{d\Phi_m}{dt} = -L\frac{di}{dt}$$

$$\mathcal{E} = -L\frac{di}{dt}$$

geometry

self-inductance

units ⟶ Henrys (MKS)

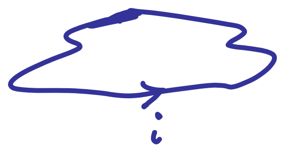


change i in I $\rightarrow$ changing Φ_M in II $\rightarrow$ $\mathcal{E}$ in II

$$\Phi_{M \text{ in II}} \propto i_{\text{in I}}$$

$$\Phi_M = M\, i \qquad \mathcal{E}_{\text{in II}} = -M \frac{di_{I}}{dt}$$

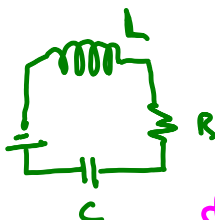
M ← constant of mutual inductance

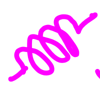


$\phi_m = L\,i$

L ≡ constant of self-inductance

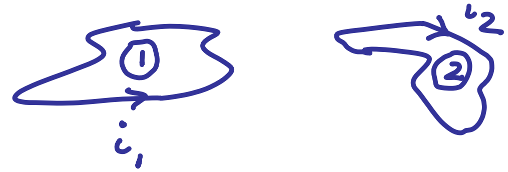
$\mathcal{E} = -\frac{d\phi_m}{dt} = -L\frac{di}{dt}$



 ≡ L units Henrys

$$\boxed{\mathcal{E} = -L\frac{di}{dt}}$$

unless problem is specifically about mutual inductance ... usually treat inductance in a circuit as self-inductance



$\phi_{m_2} = M\,i_1$

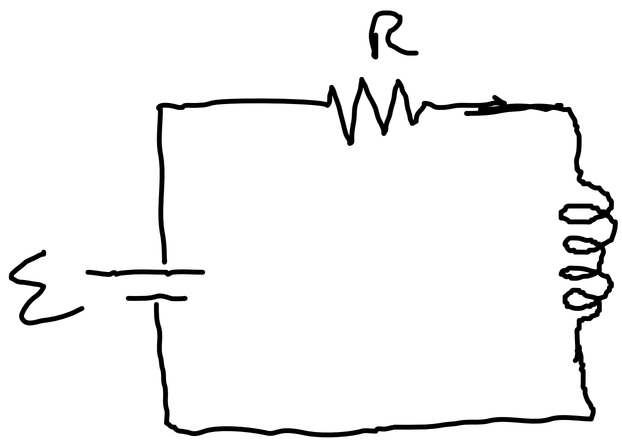
$\phi_{m_1} = M\,i_2$

same "M" cross-talk dictated by geometry

M ≡ constant of mutual inductance

$\mathcal{E}_{2 \text{ by } 1} = -M\frac{di_1}{dt}$

$\mathcal{E}_{1 \text{ by } 2} = -M\frac{di_2}{dt}$



$$\Sigma V = 0$$

$$\varepsilon - iR - L\frac{di}{dt} = 0$$

multiply by i

$$\varepsilon i = i^2 R + L i \frac{di}{dt}$$

Power output of ε

Power dissipated in Resistor

Must be a power as well

Rate of change of Energy in B field

$$\frac{dU_B}{dt} = L\,i\,\frac{di}{dt}$$

$U_B \equiv$ Energy stored in Magnetic field

$$dU_B = L\,i\,di$$

Let i go from 0 to I

$$U_B = \int_0^I L\,i\,di = L\frac{I^2}{2} = \frac{1}{2}LI^2$$

Solenoid $$B = \begin{cases} \mu_0 n i & \text{inside} \\ 0 & \text{outside} \end{cases}$$

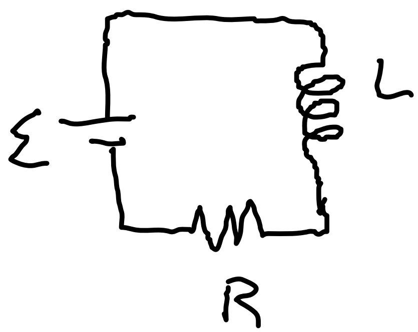
i, n turns/length, l

$u_B \equiv$ Energy density in B field

$$u_B = \frac{U_B}{Al} = \frac{\frac{1}{2} L i^2}{Al} = \frac{1}{2} \frac{(\mu_0 A l n^2)\, i^2}{Al}$$

$$u_B = \frac{1}{2} \mu_0 i^2 n^2 = \frac{|B|^2}{2\mu_0} \qquad u_E = \frac{\varepsilon_0}{2} E^2$$

LR circuit



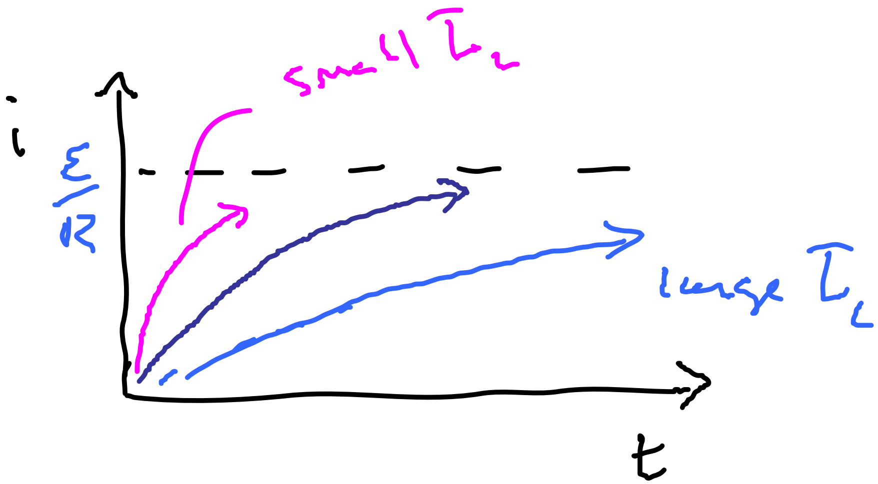
$$\sum V = 0$$

$$\mathcal{E} - L\frac{di}{dt} - iR = 0$$

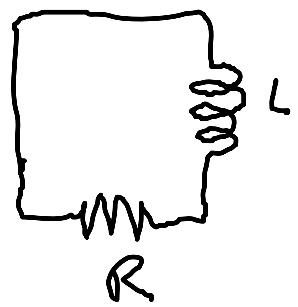
$$i = \frac{\mathcal{E}}{R}\left(1 - e^{-tR/L}\right) = \frac{\mathcal{E}}{R}\left(1 - e^{-t/\tau_L}\right)$$

$\frac{L}{R} \equiv \tau_L \equiv$ inductive time constant

↑ time constant



at some large time t later, short L across R



$$0 = iR + L\frac{di}{dt}$$

$$i = \frac{\mathcal{E}}{R} e^{-t/\tau_L}$$