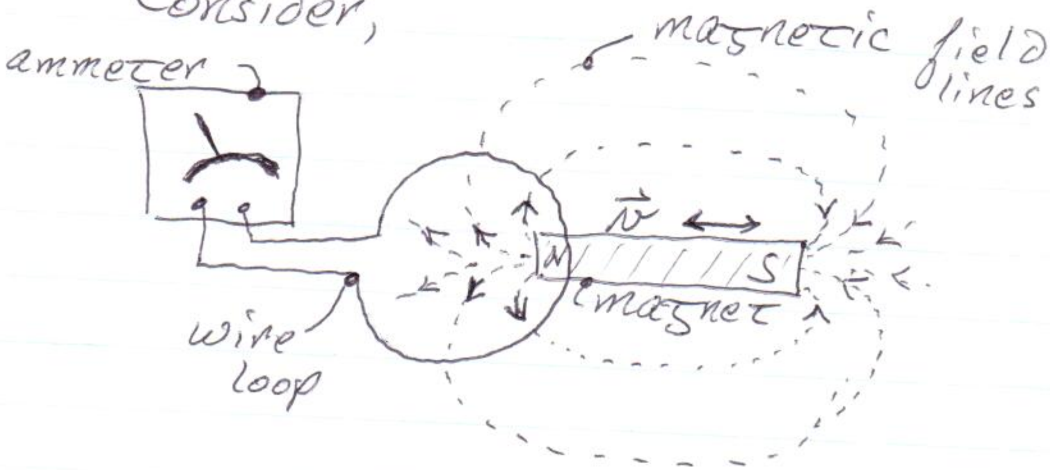
Using Magnet to Induce emf

When see moving charge
→ B field
What about a moving magnet?

Consider,



- There is No battery or electrical power source.
- no net motion of charges

So should be no current on wire, right?

turns out when loop in motion

→ <u>We see a current!</u>

If stop motion → $\underline{I=0}$

If move in opposite direction:

$$I = -I_{original}$$

If we reverse magnet?

- changes sign on I again

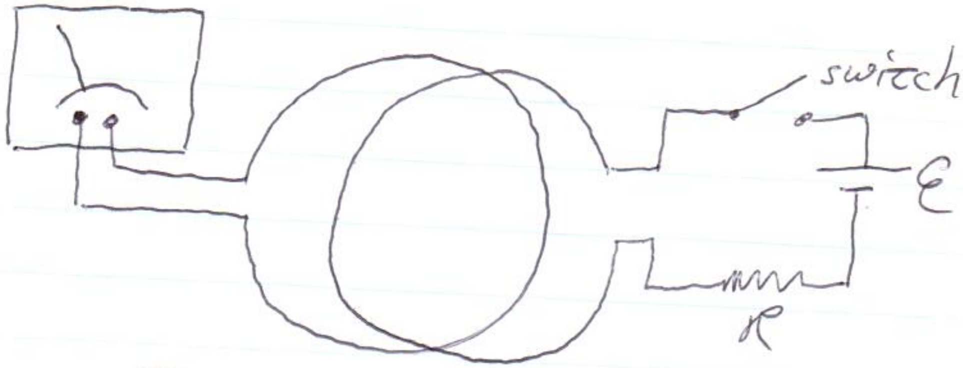
What is this "induced current?"

It's the magnetic field lines thru the surface bounded by the left loop that matters.

- Move magnet closer: more field lines thru surface
- Increase I: more field lines also

Two Conducting Loops

Okay, let's try another way to change B field: change current in a circuit.



Two wire loops very close to each other

When close switch, see a momentary current in left loop

- corresponds to time when I increases initially to equilibrium value

Magnetic Flux

We define, as with $\vec{E}$ + ϕ_E:

$$\phi_B \equiv \oint \vec{B}\cdot d\vec{A}$$

where units are 'Weber' (Wb)

$$\underline{1\,Wb = 1\,Tm^2}$$

Note, by analogy, integral over a closed surface

$$\phi_B = \oint \vec{B}\cdot d\vec{A} = \mu_0 M$$

"magnetic charge" inside surface
= 0 since no magnetic monopoles

Gauss's Law for Magnetism $\boxed{\phi_B = \oint \vec{B}\cdot dA = 0}$

Faraday's Law of Induction (19.5)

$$\boxed{\mathcal{E} = - \frac{d\phi_B}{dt}}$$

("Lenz's Law")

$\mathcal{E}$ is 'induced' emf

- equal to negative of rate at which magnetic flux thru the circuit (loop) is changing

<u>Lenz's Law</u>: induced emf sets up current producing a $\Delta\phi_B$ <u>opposing</u> the <u>inducing</u> $\Delta\phi_B$

- tends to keep original ϕ_B thru circuit from changing

<u>Multiple Loops</u> 19.6

Consider a solenoid with N turns. Multiply effect

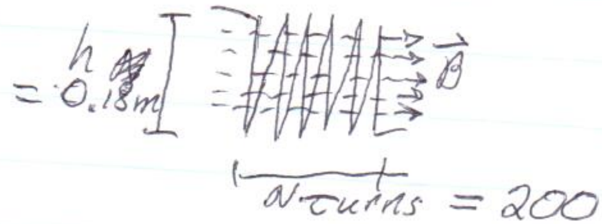
$$\boxed{\mathcal{E} = -N \frac{d\phi_B}{dt}}$$

- each turn occupies essentially same space
  - therefore has same ϕ_B

Example

19.7

Square coil



What is the emf induced on the coil if a magnetic field coaxial with it from 0T to 0.5T over 0.8s.

$$\Phi_B(t=0s) = B_0 A = (0T)(0.18m)^2 = 0$$

$$\Phi_B(t=0.8s) = B_{0.8} A = (0.5T)(0.18m)^2 = \underline{1.6 \times 10^{-2}\,Tm^2}$$

$$|\mathcal{E}| = N\frac{d\Phi_B}{dt} = N\frac{\Delta\Phi_B}{\Delta t}$$

$$= (200)\frac{(1.6\times10^{-2}\,Tm^2 - 0)}{0.8s}$$

$$= 4.1\,Tm^2/s = \boxed{4.1V}$$

Example 2

19.8

Place a coil w/ diameter 1m and co-axial with Earth's B-field.

We flip the coil in 0.2s.

Assume linear change in $B \cdot A$

$$\Phi_B^{t=0s} = BA = (50\mu T)(\pi r^2)$$

$$= 3.9\times10^{-5}\,Tm^2 \qquad \underline{r = \tfrac{1}{2}\,m}$$

$$\Phi_B^{t=0.2s} = -\Phi_B^{0} = -3.9\times10^{-5}\,Tm^2$$

Using Faraday's Law, we have

$$\mathcal{E} = -N\frac{\Delta\Phi_B}{\Delta t} = -(25)\left(\frac{7.8\times10^{-5}\,Tm^2}{0.2s}\right)$$

$$\boxed{\mathcal{E} = 9.8\,mV}$$