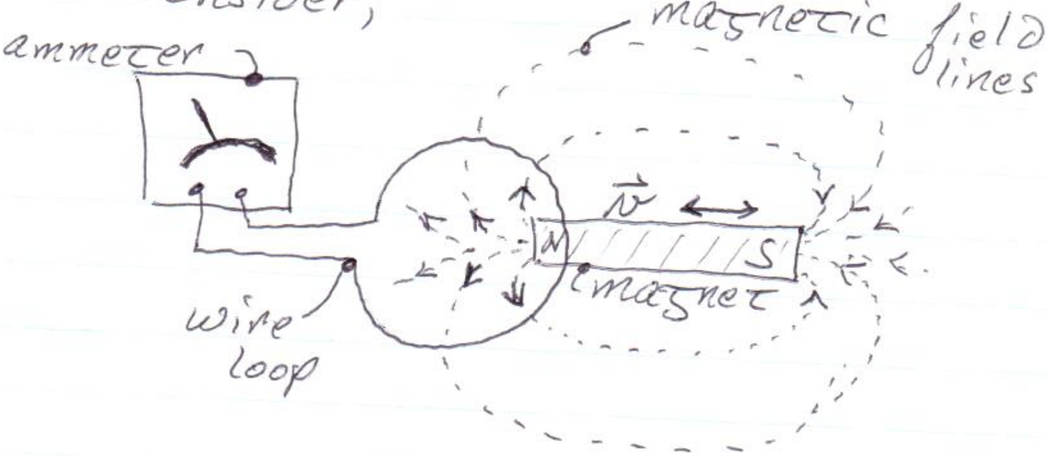
Using Magnet to Induce emf

19.1

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

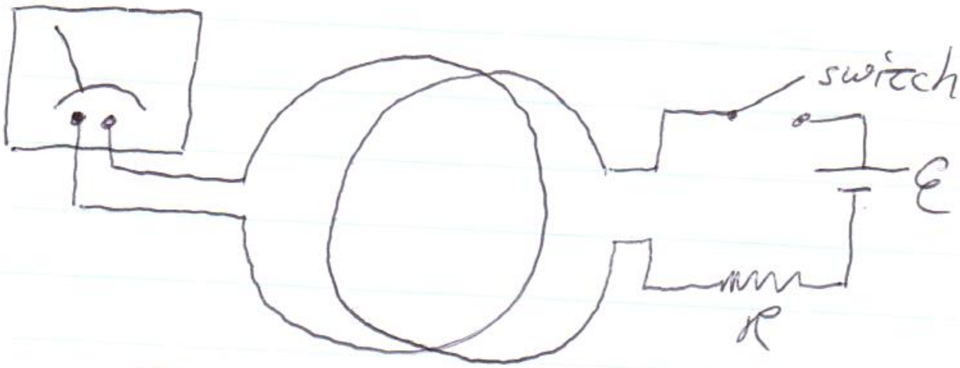
What is this "induced current?"

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 (19.3)

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

(19.4)

We define, as with $\vec{E}$ & ϕ_E:

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

where units are 'Weber' (Wb)

$$1\,Wb = 1\,T\,m^2$$

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

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

- tends to keep original ϕ_B thru circuit from changing

Multiple Loops

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.

$$\phi_B(t=0) = B_0 A = (0T)(0.18m)^2 = \underline{0}$$

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

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

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

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

Example 2

(19.8)

$\vec{B} = 50\,\mu T$

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 $B \cdot A$

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

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

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

Using Faraday's Law, we have

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

$$\boxed{\mathcal{E} = \cancel{2}9.8\,mV}$$