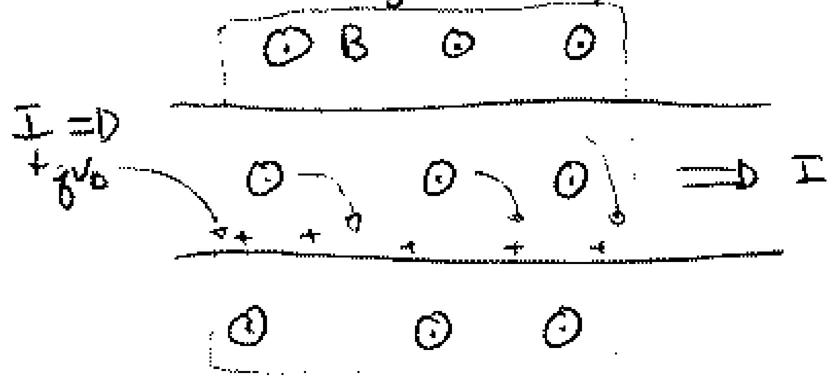
Last time I promised to tell you how to find out which charges are moving in a conductor carrying current

- Consider what happens in a magnetic field when we hold a wire in place

IF charges were positive:

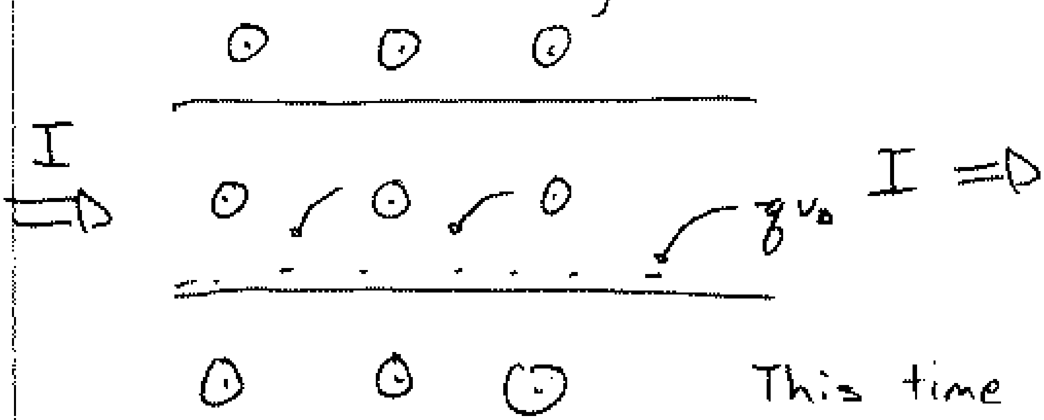


- some of that positive charge would flow to the bottom of the wire
- does so until the E field set up by that displaced charge offsets the B field

⇒ You get a potential difference between the bottom & top of the wire

$qE = qv_0 B$

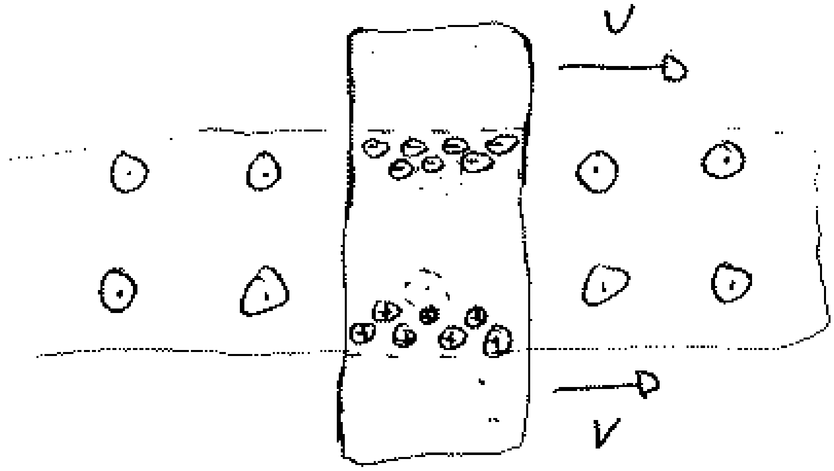
Consider the negative case:



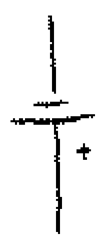
This time - charges build up on the bottom of the wire

Hall Effect ⇒ Potential difference in opposite direction measured & discovered by a Student last Century now, we could just as easily create a current by moving the charges ourselves.

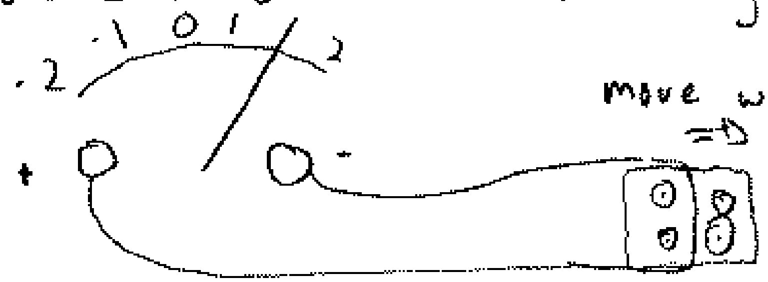
ex move a conductor in a magnetic field



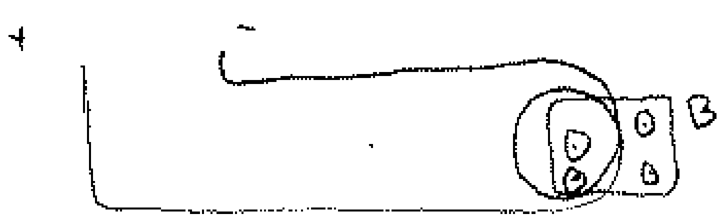
this looks like a battery



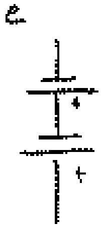
So, if we move a wire through a Bfield, we should be able to generate this Emf.



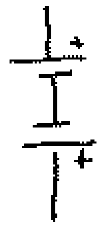
2 wires, twice as much



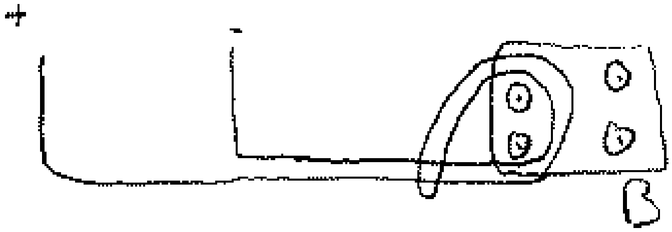
like



2 wires the opposite way should be like



and we expect 0 Emf at the ends of the wires



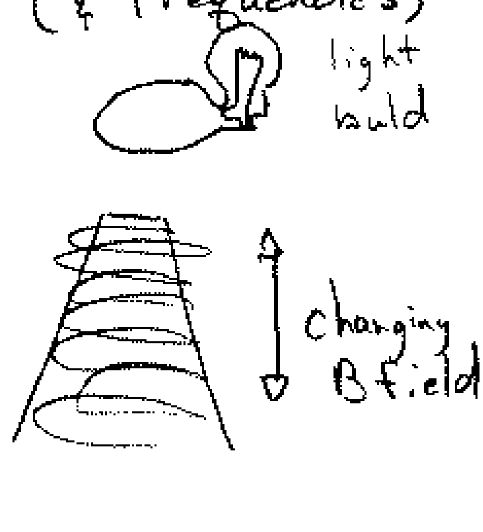
Notice :

The Emf I generate

$$\mathcal{E} \propto \begin{pmatrix} \text{\# of loops oriented} \\ \text{in a particular} \\ \text{way} \end{pmatrix} \begin{pmatrix} \text{how fast I} \\ \text{move the loops} \\ \text{through the field} \end{pmatrix}$$

Heres anoter example:

In a Tesla coil, changing B fields and transformers are used to generate high voltages (& frequencies)



notice that the intensity of the light depends on the Orientation of the B field to the loop or

$$\mathcal{E} \propto \text{Rate of change of B field \& orientation of loop}$$

So we have

Emf $\leftrightarrow$ an area, a B field and how fast either one changes

Mathematically, this is called Faradays Law of Induction

$$\mathcal{E}_{mf} = -\frac{d}{dt}(\vec{B}\cdot\vec{A}) \quad \text{or} \quad -\frac{d}{dt}\phi$$

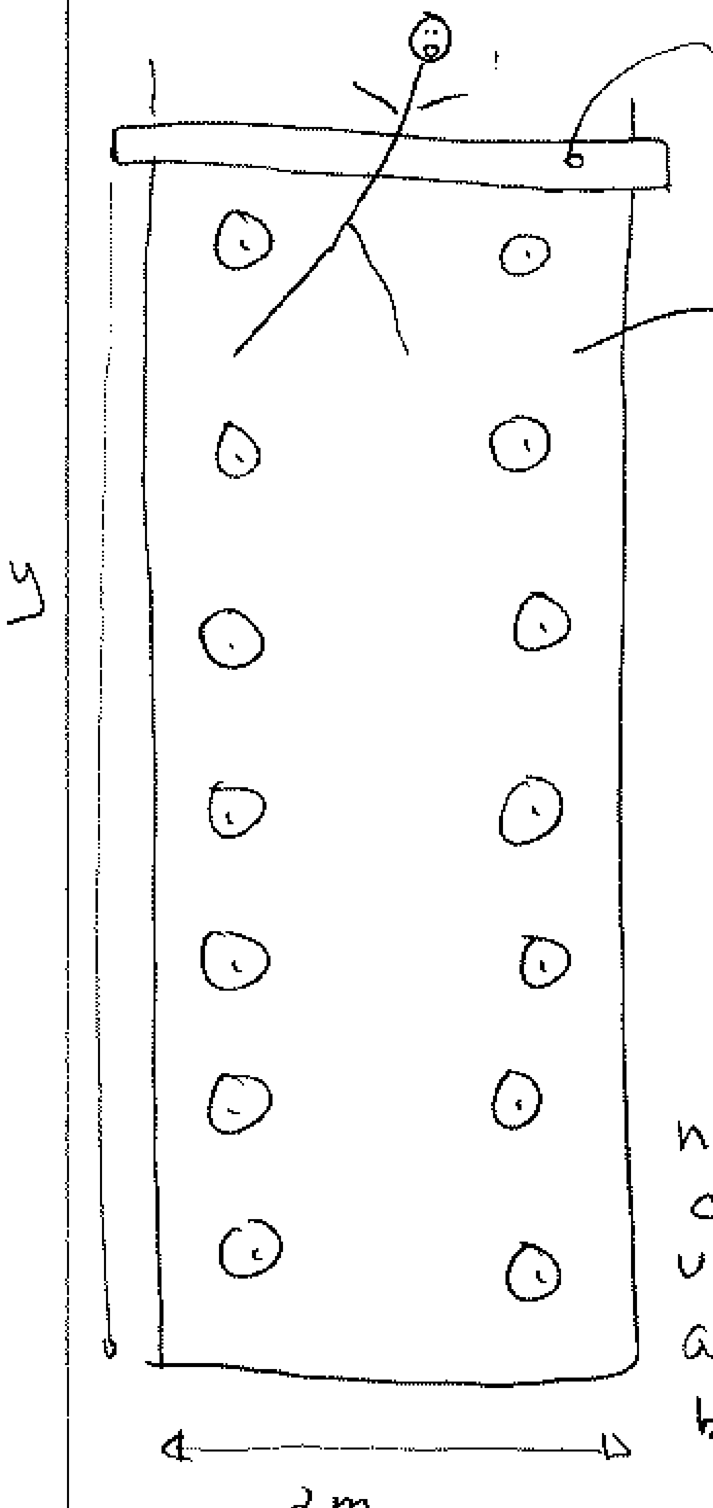
$$\Phi = \int \vec{B}\cdot d\vec{A}$$ is magnetic flux

Is this useful?

1) we can generate energy!

2) we can make an amusement ride

I want to turn the Batman Building in to a fun ride using faradays law



B field inside is 0.5 T

flux inside $= BA$

$= B(2m)y$

$$\frac{d\phi}{dt} = \frac{d}{dt}(B(2m))y$$

$$= B(2m)\frac{dy}{dt}$$

$$= B(2m)\,V_y$$

now, I'm sure at a certain point my velocity will be constant

at that point the bar will dissipate $\frac{\varepsilon^2}{R} = P$

and this energy will be supplied by the earths gravity

$P = mgv$ $\quad m = 100kg$!

$$P_{gravity} = P_{dissipated}$$

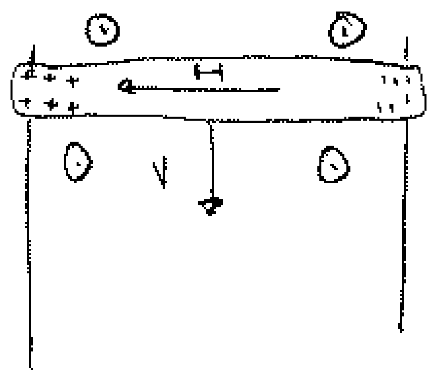
$$mgv_y = \frac{(B(2m)\,v_y)^2}{10\Omega}$$

$$\frac{(10\Omega)\,mg}{(B\,(2m))^2}\cancel{v_y} = v_y^{\cancel{2}}$$

$$\frac{10\Omega\,(100kg)(9.8\frac{m}{s})}{\left(0.5\frac{N}{\cancel{m}A}\;2\cancel{m}\right)^2} = 9800\ m/s$$

hmm, guess I should rethink this business plan.

Notice a couple things though



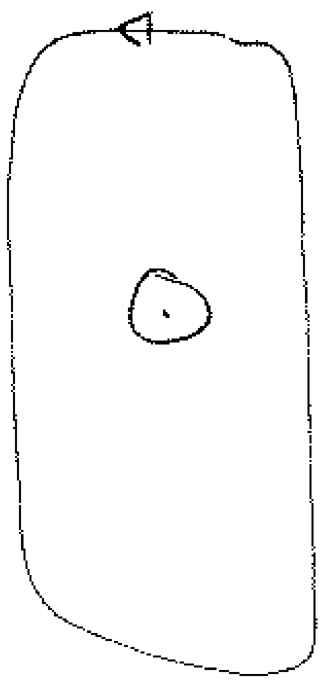
In the falling bar a current will flow since there are wires hooked up to the ends

This current flow moves to oppose the changing flux.

In other words you can think of the problem this way.

The rail system would like to maintain the same amount of Φ_B inside, so it will produce a current to do so

notice



current flow in rail set up produces a B out of the page to try and maintain the same flux

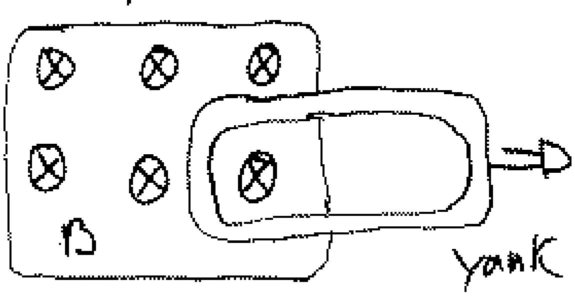
Emf is produced to make that happen

So, 2 ways to remember

can think about how charge moves

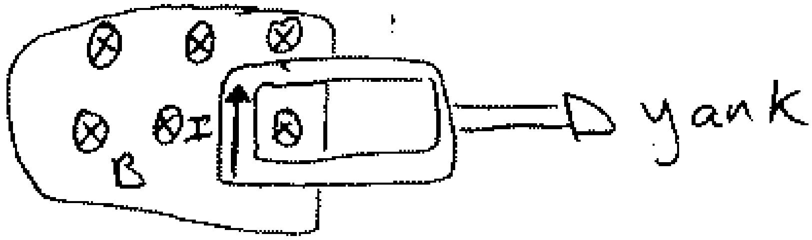
can think about how flux changes

example

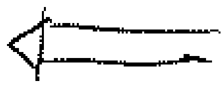


suppose I want to yank a loop of wire out of this B field, which direction would current flow (Emf be induced?)

Correct Emf would be induced so as to oppose the change



$I l \times B$ points



This actually works for a solid piece of metal too, as long as a part of it is outside the magnetic field, Emf is induced to oppose the change in flux, and hence, oppose the movement of the metal.

$$\mathcal{E} = -\frac{d\Phi}{dt}$$

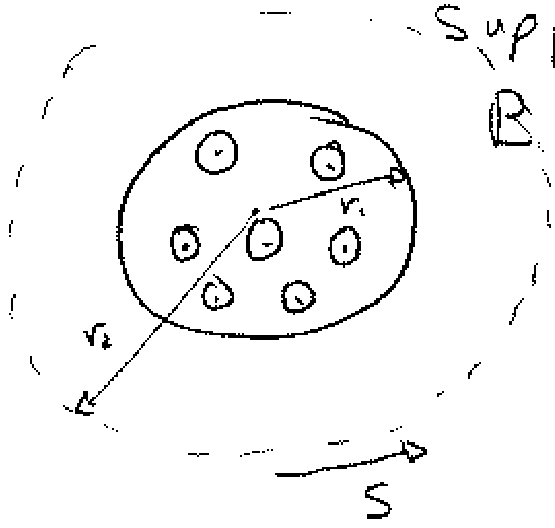
Finally, you can generalize this Emf (a potential difference)

$$\mathcal{E} = \oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi}{dt}$$

closed loop

really only works well when you have a great symmetry

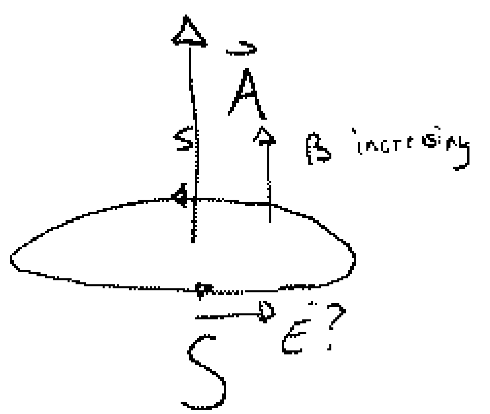
Suppose you have a B arranged lik this



$$B(t) = 10\frac{T}{s}\,t$$

$r_1 = 1cm$
$r_2 = 10cm$

choose a symmetric S around the B



$$E\,2\pi(0.1m) = -\frac{d\Phi}{dt}$$

$$\Phi = \vec{B}\cdot\vec{A}$$

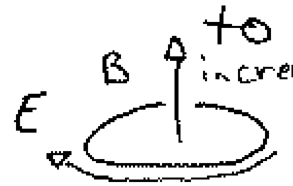
$$E(2\pi)(0.1m) = -\frac{d}{dt}\left(10\frac{T}{s}t\right)\left(\pi(.01m)^2\right)$$

$$= -\frac{10T}{s}(\pi)(.01m)^2$$

$$E = -\frac{10T}{s}\,\frac{\cancel{\pi}(.01m)^2}{2\cancel{\pi}(0.1m)}$$

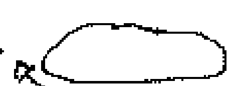
$$= -1.0\times10^{-2}\,\frac{N}{C}$$

so E points opposite to S



recall, E will be created to maintain the original flux

Since B is increasing ↑ we need E for creating some B that points down ↓

so E goes 

(same direction I would need to flow to make B down