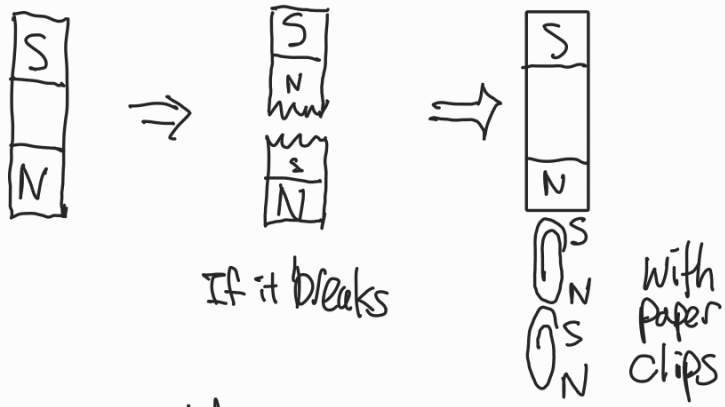
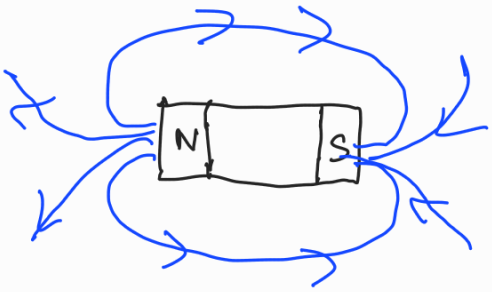
4.4 Electromagnetism

Magnets



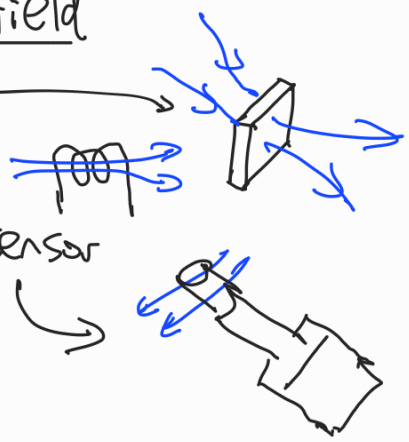
Magnetic Fields

Travels from N → S

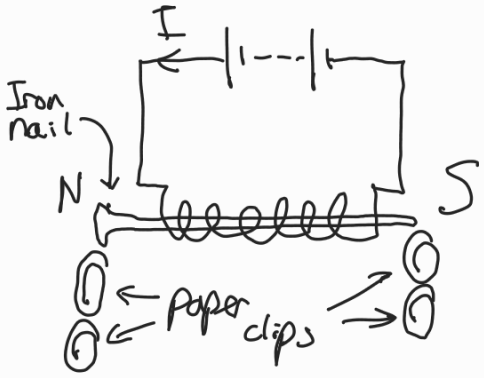


Measure magnetic field

* Hall probe
* Search coil
* Magnete field sensor

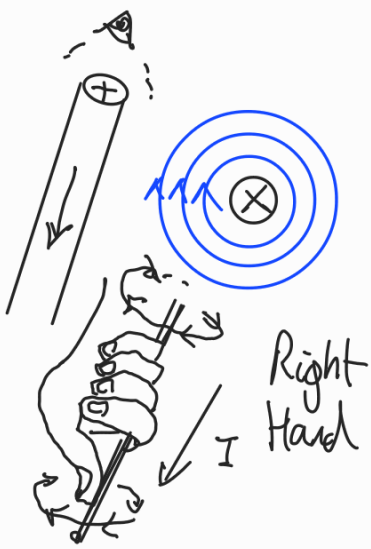


Electromagnets

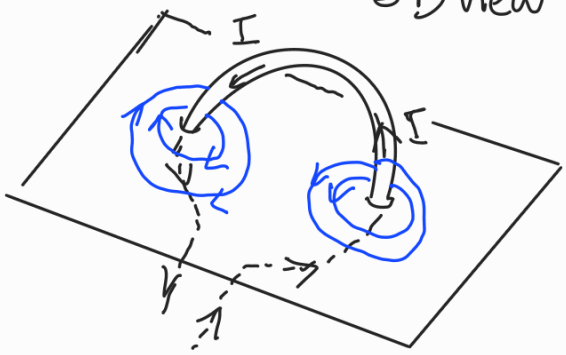


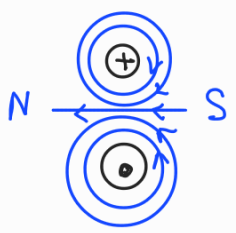
Straight Wire and Magnetic Field

* Thumb is current direction
* Fingers curl in Magnetic Field direction



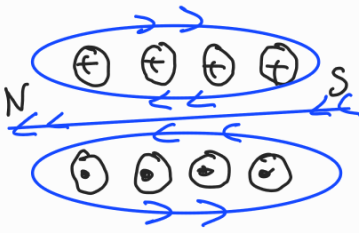
3D view　Top View　(coil 線圈)



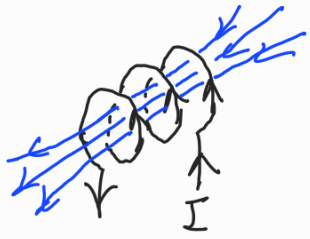


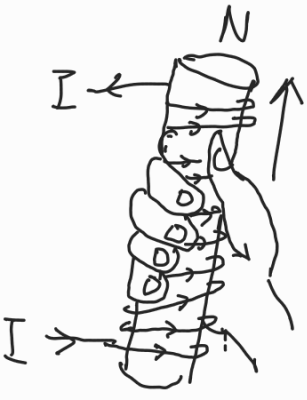
one coil

two coils



multi-coil





* Thumb is magnetic field direction

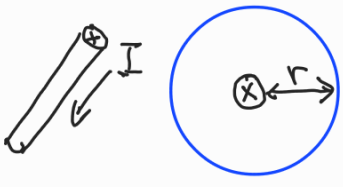
Right Hand

*Fingers are currents direction

Calculations

straight wire

$$B = \frac{\mu_0 I}{2\pi r} \quad \left(B \propto \frac{1}{r}\right)$$



Tesla

B: magnetic field (T)

I: current thrugh wire

r: distance from wire

μ_0: permeability or magnetic constant

μ_0: permeability $(4\pi \times 10^{-7} TmA^{-1})$

air $\times 1\mu_0$

steel $\times 700\mu_0$

iron $\times 4000\mu_0$

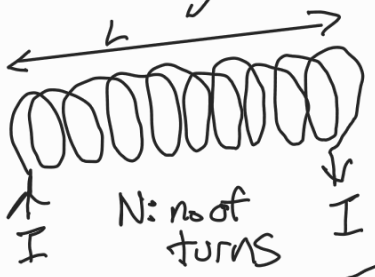
For multi-turn air coil

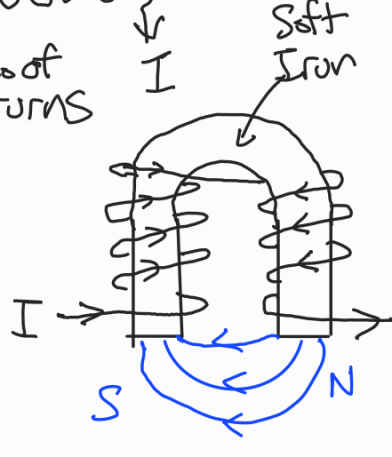
$$B = \mu_0 n I$$

$$n \simeq N/L$$

N: no of turns

L: length of coil



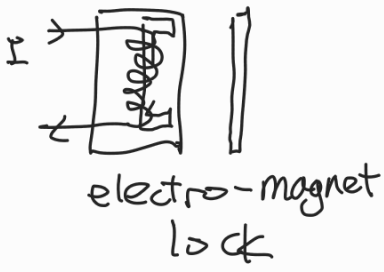


How to increase the strength of electro magnets?

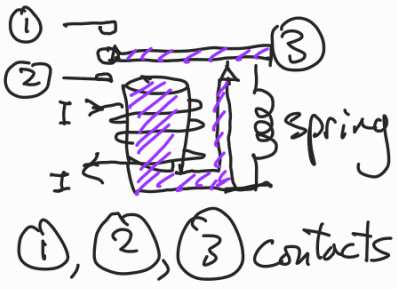
* increase I
* increase n (N/L)
* use soft iron to increase μ_0

Applications

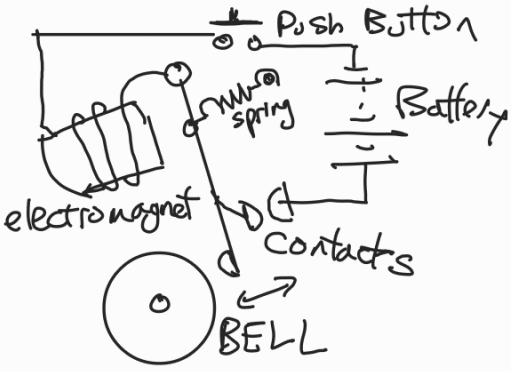
Door Lock



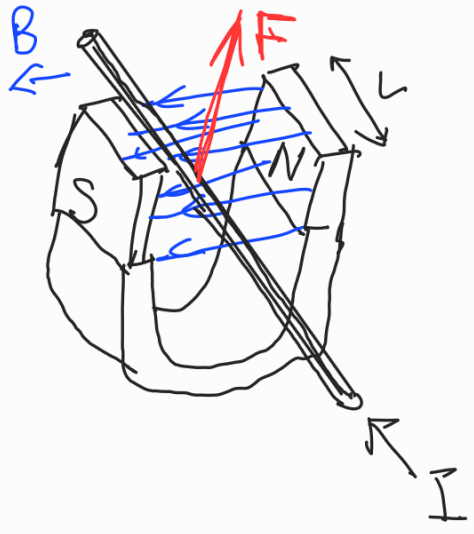
Relay Switch

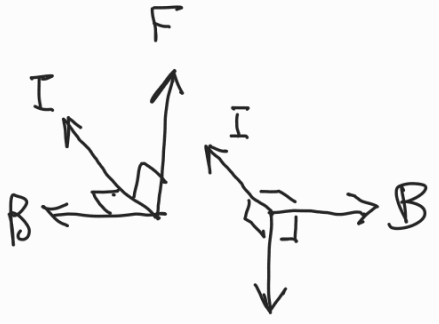


Door Bell



Magnetic Force on a Current (Motor)

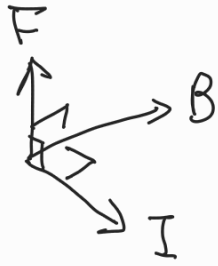




Fleming's left hand rule

$F = L I B_{\perp}$ ← wire ⊥ to field

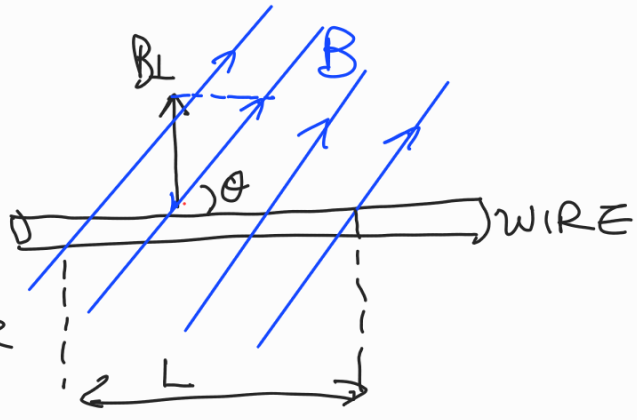
- L: length of wire in the field
- I: current through the wire
- $B_{\perp}$: field



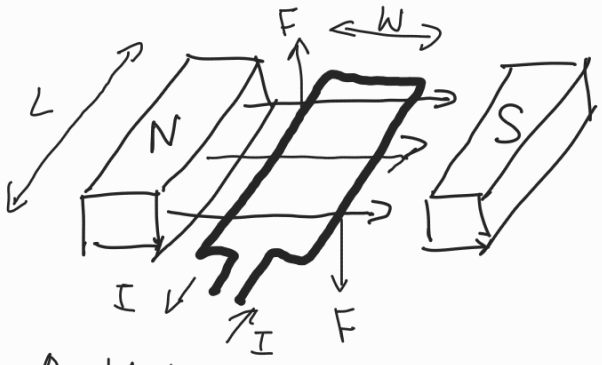
$F = L I B \sin\theta$

$B_{\perp} = B \sin\theta$

If the field is not ⊥ to the wire



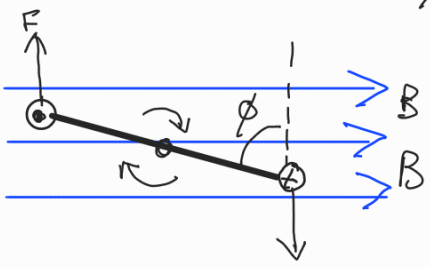
Electric Motor



$A = W \times L$

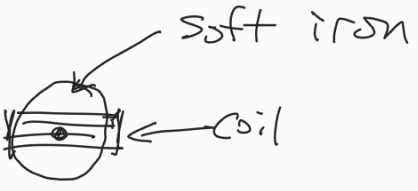
Turning Moment — no of turns of coil — current through coil — magnetic field — area of coil

$\tau = NIBA \sin\theta$ ← angle btw F and B (max 90°)

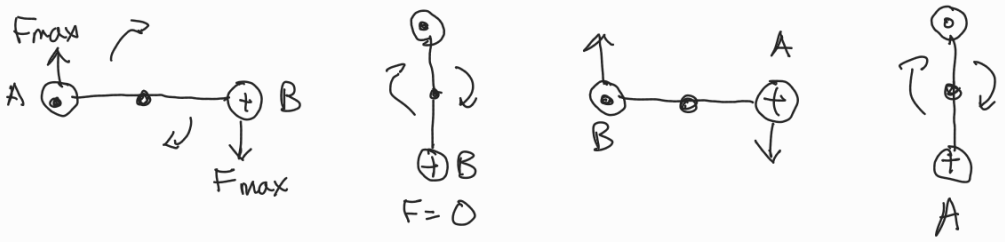


Make Motor more Powerful

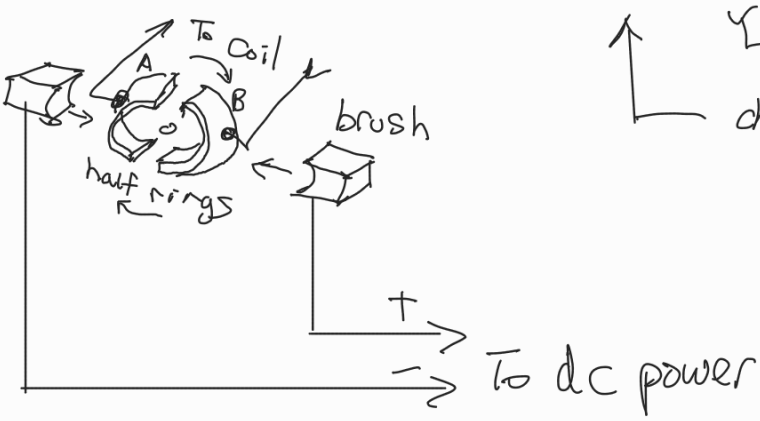
1. Increase N, I, B, or A
2. Wind the coil on a soft-iron core

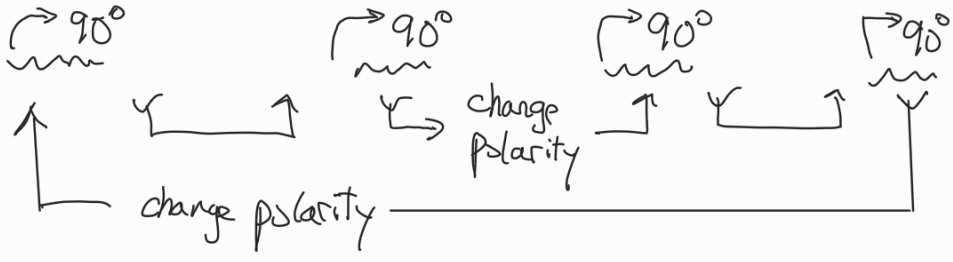


Turning Motor

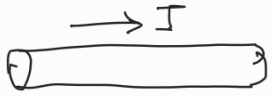


Use a commutator to change polarity

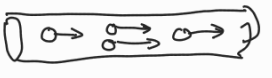




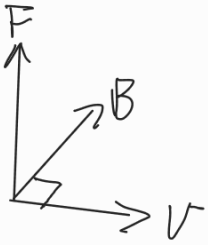
Magnetic Force on Charges



instead of I



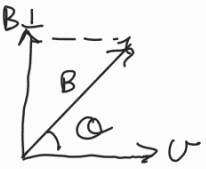
we use particle charge



$F = q v B_{\perp} = q v B \sin\theta$

v: velocity of charge (if $v = 0$, $F = 0$)

max $\theta = 90°$



application: mass spectrometer
vacuum tube display

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