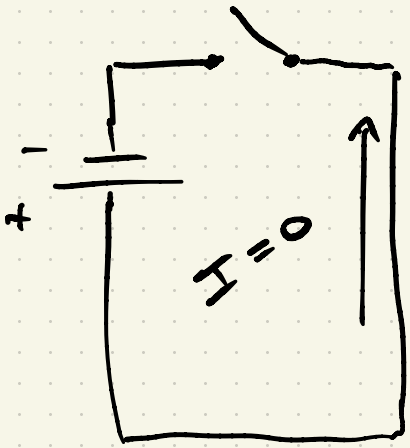
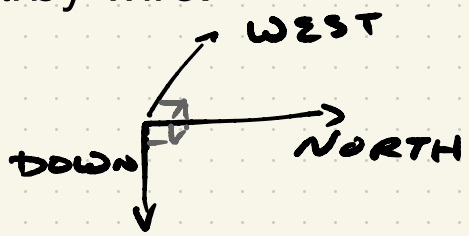
LECTURE 19

CURRENT-GENERATED MAGNETIC FIELDS

History:

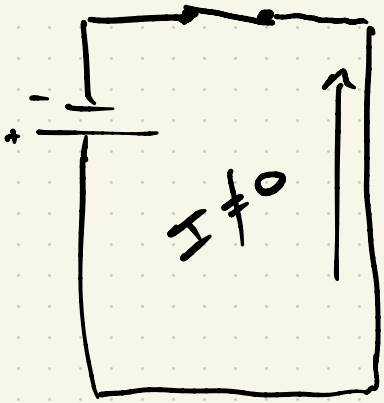
In 1818 Danish scientist Oersted observes that compass needle is deflected when current conducts in nearby wire:



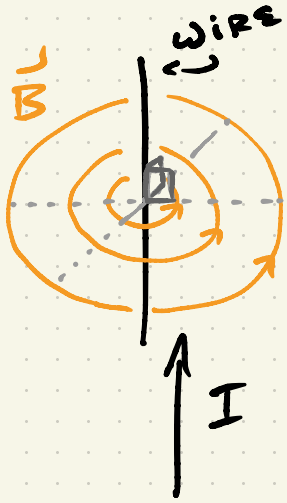


NO CURRENT: COMPASS POINTS NORTH W/ EARTH'S $\vec{B}$ FIELD.

CURRENT ON: COMPASS DEFLECTED IN WEST-WARD DIRECTION!

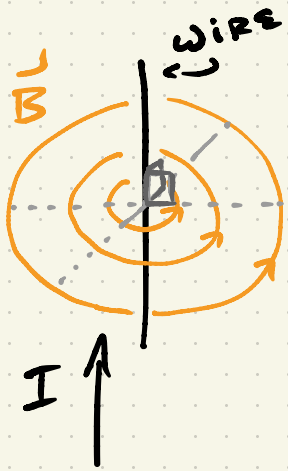


- ELECTRIC CURRENTS GENERATE MAGNETIC FIELDS!



- FOR LONG, STRAIGHT WIRE*:
  - $\vec{B}$ FIELD LINES FORM CIRCLES CENTERED ON & PERPENDICULAR TO WIRE (SEE DIAGRAM ↑).

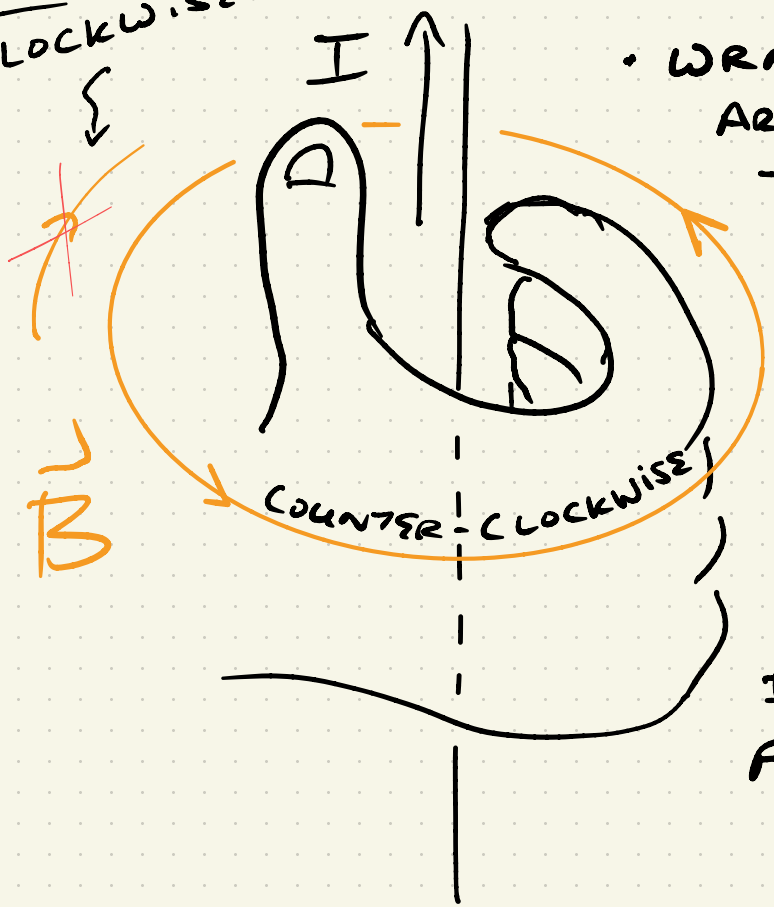
* SEE 4.7. VIDEO W/ COMPASSES AROUND WIRE



- $\vec{B}$ FIELD AROUND WIRE IS "RIGHT-HANDED":

- RIGHT-HAND RULE #2:

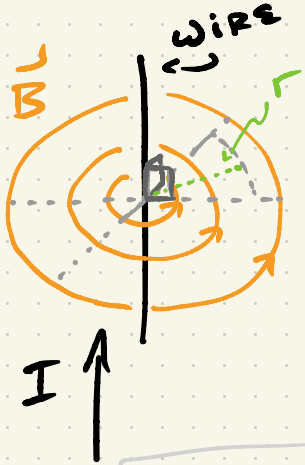
NOT CLOCKWISE!



- WRAP R.H. AROUND WIRE, THUMB POINTING IN DIR. OF CURRENT.

- $\vec{B}$ FIELD POINTS IN DIR. OF FINGERS.

- STRENGTH OF $\vec{B}$ FIELD FOR LONG, STRAIGHT WIRE:



- $\propto I$
- $\propto \frac{1}{r}$

[r : DISTANCE FROM WIRE]

MORE CURRENT, B ↑

$$B = \frac{\mu_0}{2\pi} \times \frac{I}{r}$$

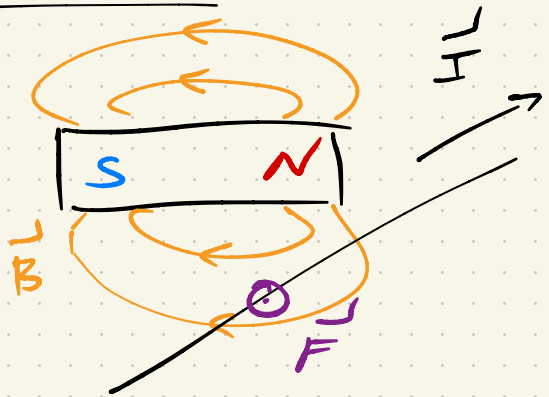
CONSTANT

GETS WEAKER AS YOU MOVE AWAY FROM WIRE.

μ_0 : "VACUUM PERMEABILITY" $\simeq 1.257 \frac{T}{m \cdot A}$

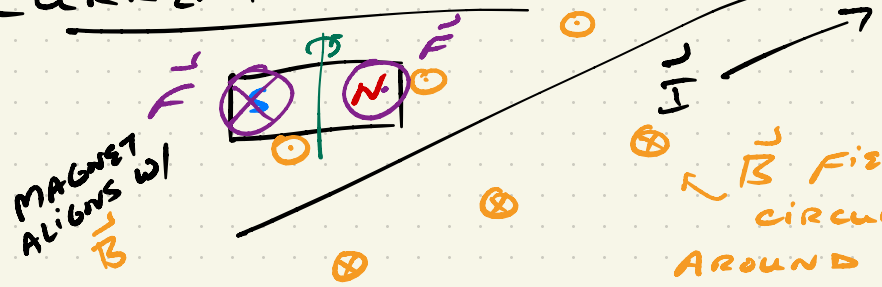
- PAUSE HERE & NOTE PARALLEL W/ PREVIOUS LECTURE (18):

PREV. LECTURE



MAGNET → GENERATES → $\vec{B}$ FIELD → EXERTS $\vec{F}$ ON → WIRE W/ CURRENT $\vec{I}$

CURRENT LECTURE:



WIRE → GENERATES → $\vec{B}$ FIELD → GENERATES TORQUE ON → MAGNET

NO PUN INTENDED

EXAMPLE:

* SEE Y.T. VIDEO!

ATTRACTION / REPULSION BETWEEN TWO WIRES*

CURRENTS PARALLEL:

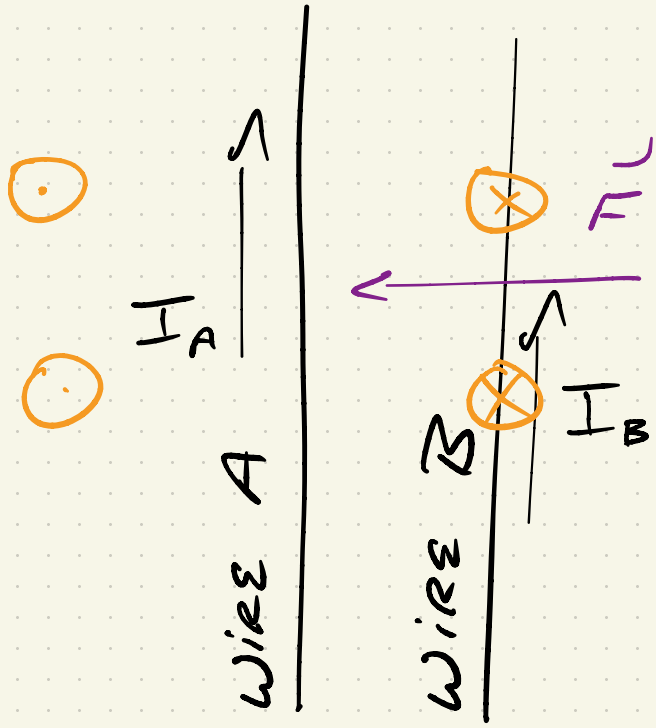
LEGEND

⊙, ⊗

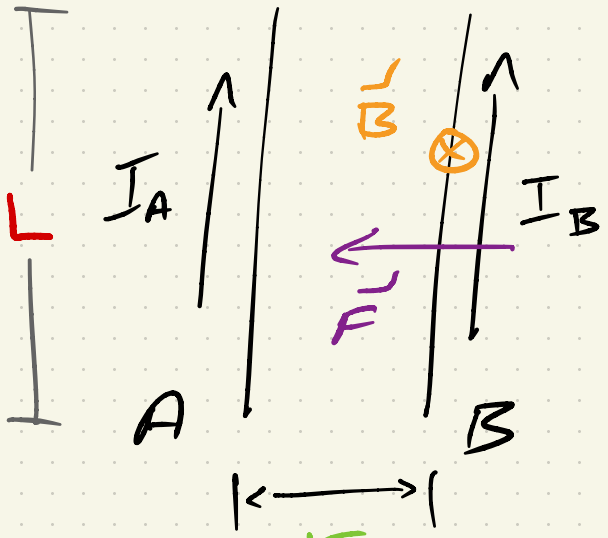
$\vec{B}$ - FIELD DUE TO WIRE A

← $\vec{F}$ ON B DUE TO $\vec{B}$ FROM A

FORCE ATTRACTIVE!



STRENGTH OF FORCE:



↳ FROM PREV. LECTURE

$$F = I B L \sin\theta$$

- $I \longrightarrow I_B$
- $B = \frac{\mu_0}{2\pi} \times \frac{I_A}{r}$
- $\sin\theta = 1$

$$\left[\vec{I}_B \perp \vec{B}, \longrightarrow \theta = 90^\circ \right]$$

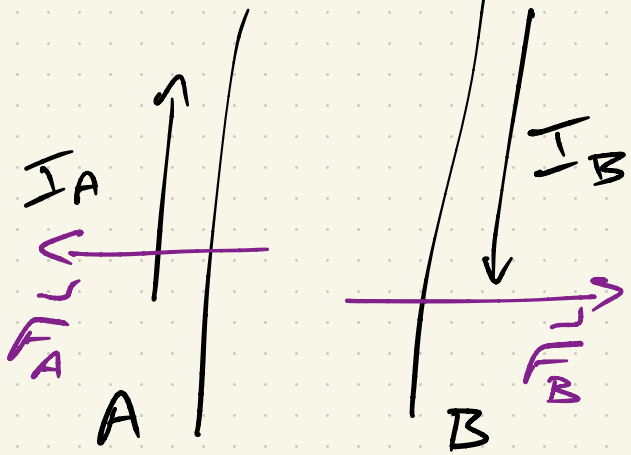
$$\longrightarrow F = \frac{\mu_0}{2\pi r} I_A I_B L$$

EXERCISE FOR YOU:

- CHECK THAT NEWTON'S 3RD LAW HOLDS, i.e. THAT FORCE ON WIRE A DUE TO $\vec{B}$ FROM WIRE B is EQUAL + OPPOSITE + SO ALSO ATTRACTIVE.

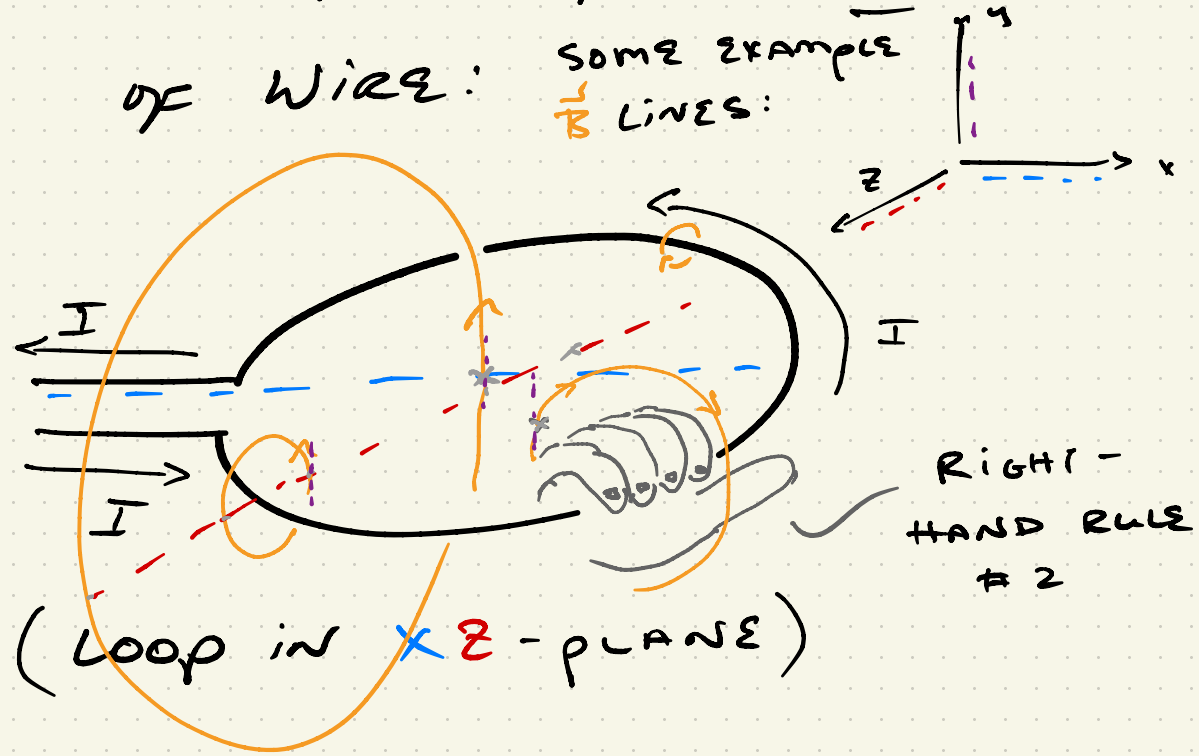
By SAME REASONING:

CURRENTS ANTI-PARALLEL: WIRES REPEL!



- $\vec{B}$ FIELD FROM LOOP OF WIRE:

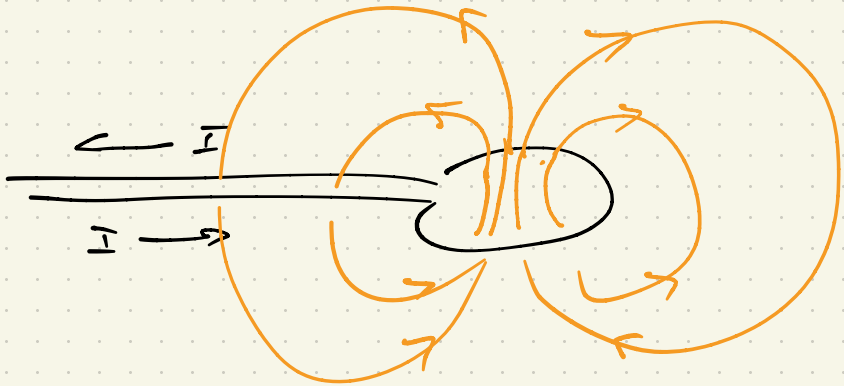
SOME EXAMPLE $\vec{B}$ LINES:



RIGHT-HAND RULE #2

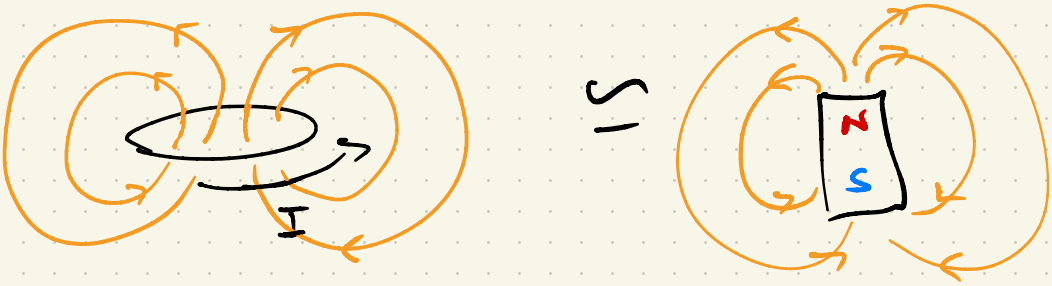
(LOOP IN XZ-PLANE)

ZOOMED OUT:



- LOOP(S) OF WIRE W/ CURRENT:

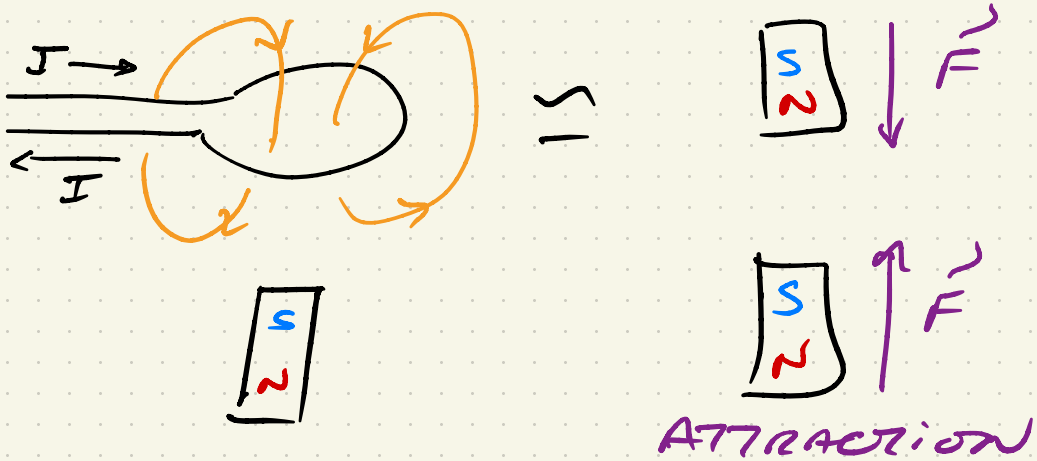
"ELECTRO-MAGNET"



- CURRENT LOOP IS MAGNETIC DIPOLE!

- EXAMPLE:

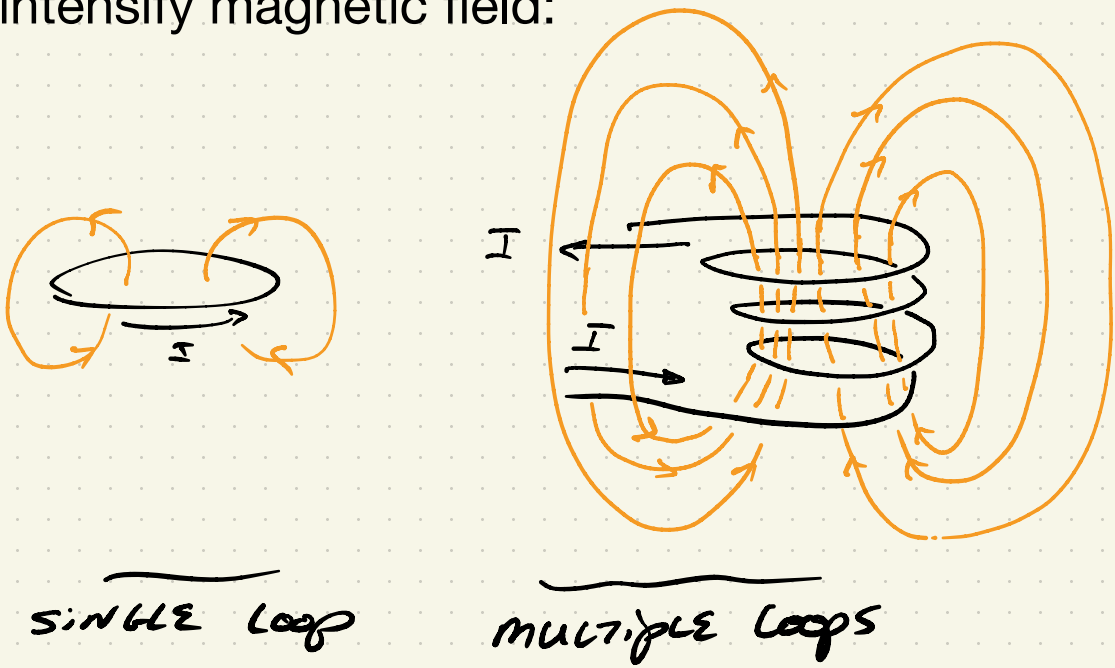
- ELECTROMAGNET CAN ATTRACT PERMANENT MAGNET:



QUESTION FOR YOU:

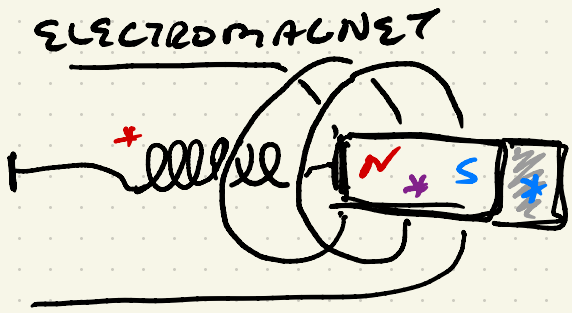
- WHAT IF WE REVERSE THE DIRECTION OF CURRENT?

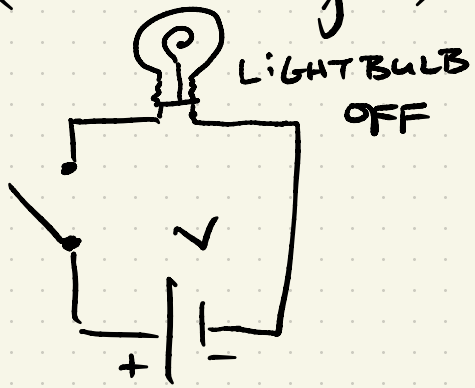
Superposition principle: magnetic fields from multiple loops add together to intensify magnetic field:



APPLICATION:

ELECTROMAGNETIC SWITCH ("RELAY")





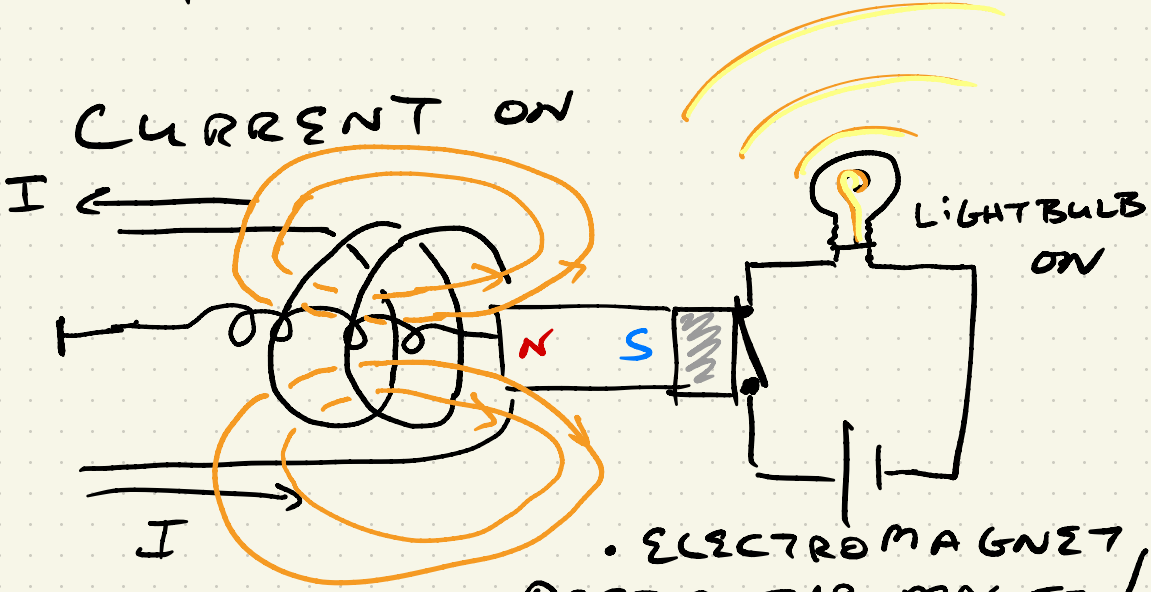
CURRENT OFF

* SPRING KEEPS MAGNET PULLED BACK.

* INSULATOR

* BAR MAGNET

CURRENT ON



. ELECTROMAGNET REPELS BAR MAGNET!