Capacitors in Circuits : RC circuit

$\tau = \Omega \cdot F$ ($R \times C$) (unit in seconds / s)

- In series circuit, the charge on each capacitor stays the same, the voltage is different depending on its capacitance.
- In parallel circuits, the voltage across each capacitor is the same, the charge depends on its capacitance.

## Magnetism

$Q$ is charge $\vec{B}$ is magntism.

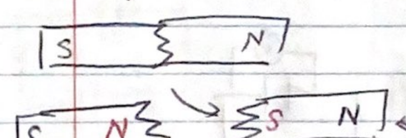
$\vec{B}$ makes moving $Q$s → Moving $Q$s creates $\vec{B}$ → moving $Q$ interacts with $\vec{B}$ → $\vec{B}$ makes moving $Q$s

Magnetism

Induction

Most permanent magnets have iron in them are called ferromagnetic.

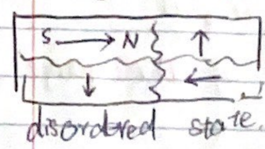
- Each magnet has two poles, North and South.
- Magnets always have North pole to Magnetic North : South to magnetic south.
- There're no magnetic monopoles - one cannot divide a magnet North and a South in isolation.
- Magnetic poles exhibit for interactions : Opposite poles attract and like poles repel.



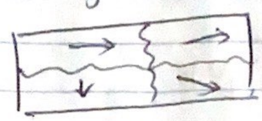

when split, they still to have north and south pole. [N will remain, S is created]

- A property shared by magnetic materials is the presence of small regions called Domains.
- Few elements exhibit magnetic properties in pure state : iron, nickle, cobalt, gadolinium and dysprosium. there are man-made magnetic materials.
- The domain model explains how iron can both be a magnet (with an active magnetic field), and magnetic (attracted to a magnet)

Fe Magnetic pomain. Magnet




disordered state.



ordered state

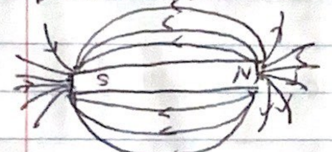
[will decay to become magnetic]

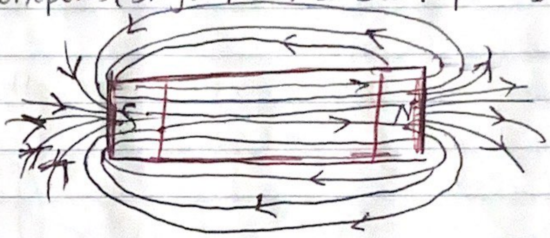
[sweep domain]

- We can turn a magnetic material into a magnet through combing it in one direction
- We can rewind a magent into magnetic through collisions of a metal, or heating it.

## Magnetic Fields:

- Magnetic field lines have no begining and no end - they are continuous loops - this is because there are no monopoles (single North or South poles)
- eg



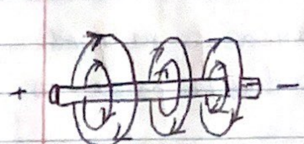

## Geomagnetism

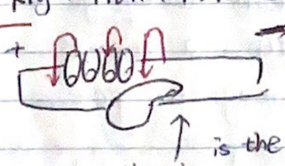
- The Earth's magnetic field appears to come from a giant bar magnet, with its South pole located up near but not exactly at the Earth's Geographic North Pole.
- The true Magnetic North pole is not exactly at North.
- The Geomagnetic north is actually a magnetic South pole.

## $\vec{B}$ around Current carrying wires.

- Moving charges create Magnetism
- At sub-atomic level of permanent magnets, magnetism is created by moving electric charges - electrons orbiting nucleus.

Right Hand Rule 1



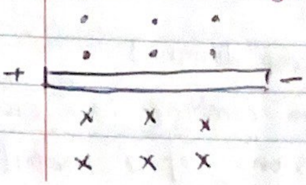



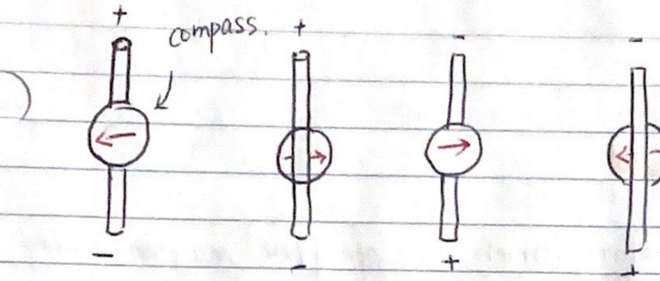

your other fingers tells you the direction when wrapped.

thumb is the to the negative

Arrow Notation.

- when see from behind, we see "X", going into the page
- When we see from front, we see "•", going out of the page.



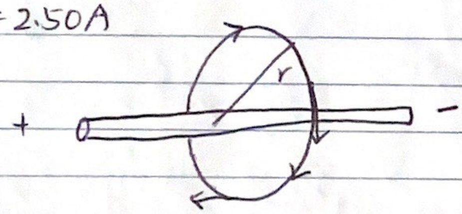



Magnetic Field:

$\boxed{\vec{B} = \frac{\mu_0 I}{2\pi r}}$ $\quad B \propto \frac{I}{r}$ $\quad \mu_0 = 4\pi \times 10^{-7}\ Tm/A$ permeability of free space $\quad \vec{B}$ in Tesla $\frac{N/S}{Cm}$

ex. $r = 0.50m$
$I = 2.50A$

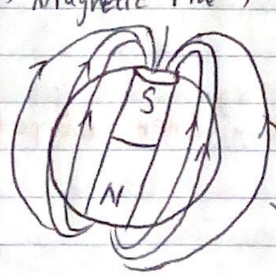
Determine B at P.



$\vec{B} = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 2.50}{2\pi \times 0.50}$

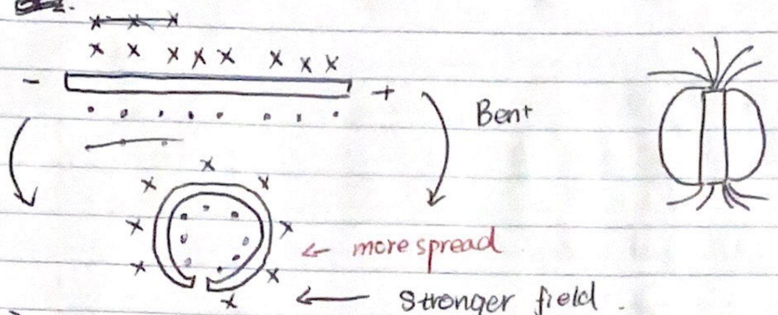
$\vec{B} = 1 \times 10^{-6} T$

Earth's Magnetic Field,



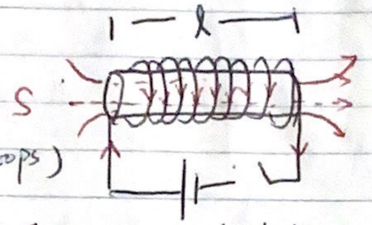
the compass will always go to direction of magnetic field, on earth, a compass will always point to ~~south~~ north magnetic pole.


compass.




✗ $\vec{B}$ inside coil

$\vec{B} \propto \frac{1}{l}$




Inside coil

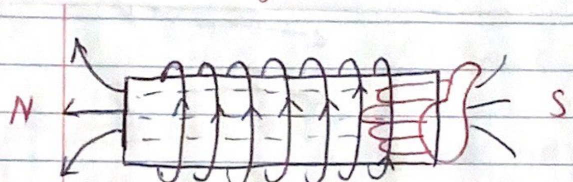
$$\boxed{\vec{B} = \frac{\mu_0 I N}{l}}$$

$\vec{B} \propto N$ (number of loops)

$\vec{B} \propto I$

[magnetic ~~Nn~~ field lines come out of north pole, outside of the south pole]

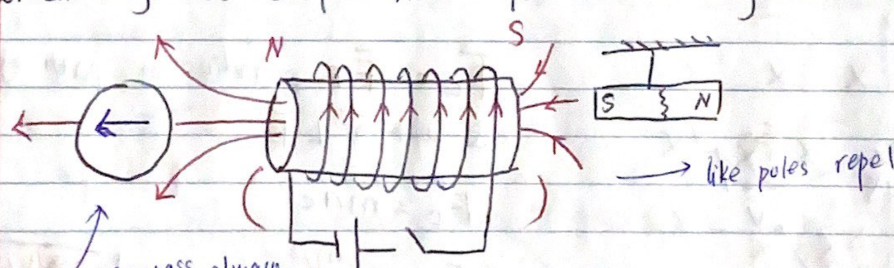
To determine the direction of magnetic field of coil, you ~~follow~~ grab one wire with thumb pointing to direction of one wire, other fingers straight, then the finger is the direction of magnetic field of coil.




✗ Right Hand Rule for coils.

⟵ Direction of magnetic field

ex. Which way does compass needle point. Which way does bar magnet swing.




compass always follow the direction of magnetic field.

A = B  Moving charges make $\vec{B}$

B = C  $\vec{B}$ interacts with other $\vec{B}$

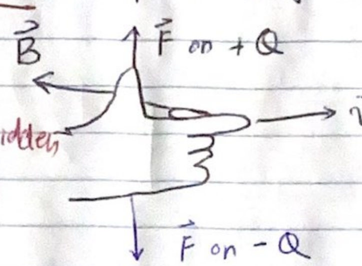
∴ A = C  Moving Qs interact with $\vec{B}$

A moving charge, Q, with $\vec{V} \perp \vec{B}$ will experience a force $\vec{F}$ such that $\vec{F} \perp \vec{V} \perp \vec{B}$;

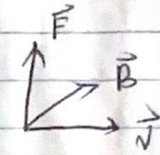
$$\boxed{\vec{F} = Q \cdot \vec{V} \cdot \vec{B}}$$

constant hidden in Tesla

N (Force), C (charge), m/s (velocity), T ← Tesla

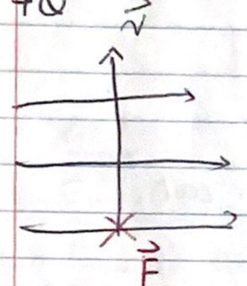



Q+

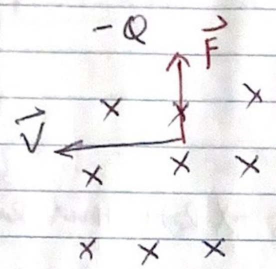



+Q use right hand
−Q use left hand

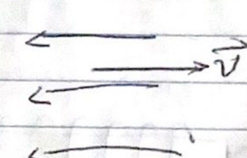
ex. +Q



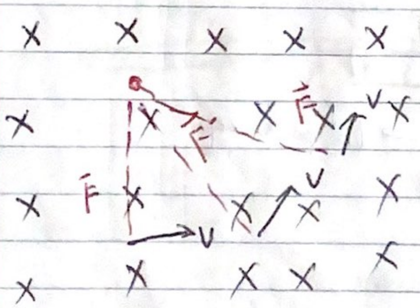

−Q




+Q . none $\vec{F}$




~~X~~ +Q




$\vec{F}_c = \vec{F}_B$  radius of path of Q with $\vec{V} \perp \vec{B}$

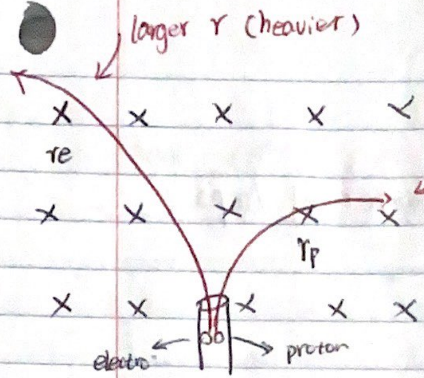
$F_c = ma_c$

$F_B = \frac{mV^2}{r}$

∴ $\vec{Q}\vec{V}\vec{B} = \frac{m\vec{V}^2}{r}$

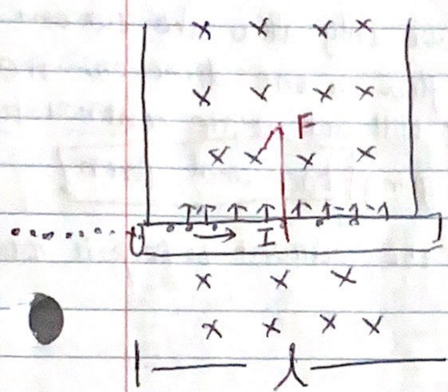
∴ $r = \frac{m\vec{V}}{\vec{Q}\vec{B}}$ → $\frac{\mu_0 I N}{\lambda}$

$V = \sqrt{\frac{-2Q\Delta V}{m}}$




$r_e > r_p$

$m_p > m_e$




the small charges will move the wire in the direction

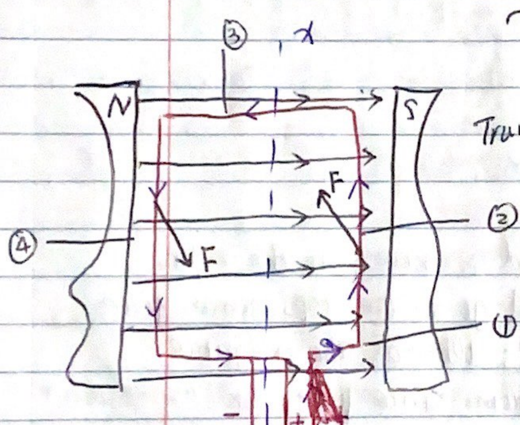
$F = \vec{Q} \cdot \vec{V} \cdot \vec{B}$

but $I = \frac{Q}{t}$

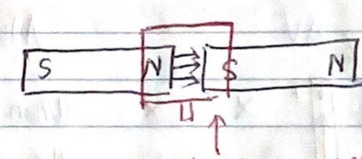
$\vec{V} \cdot t = l$

$\therefore \boxed{\vec{F} = \vec{Q}\vec{V}\vec{B} = I l \cdot \vec{B}}$

$\tau$ on 1 loop




Truncated magnets.




this is a square loop wire

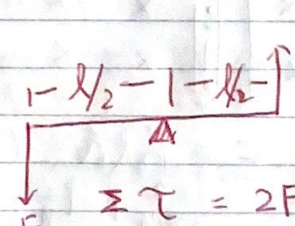
For ① since $\vec{V} \parallel \vec{B}$, thus there are no forces.

For ②, there's a force painting inward

F③, since $\vec{V} \parallel \vec{B}$, no force

For ④, fore painting outward.

Thus, the square loop is going to rotate about x




this is the orientation of torque when wire entirely parallel

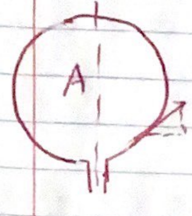
$\Sigma \tau = 2F \cdot \frac{l}{2}$

$\Sigma \tau = F \cdot l$

$\Sigma \tau = I l B l$

$\therefore \boxed{\Sigma \tau = IAB \quad A = l^2}$

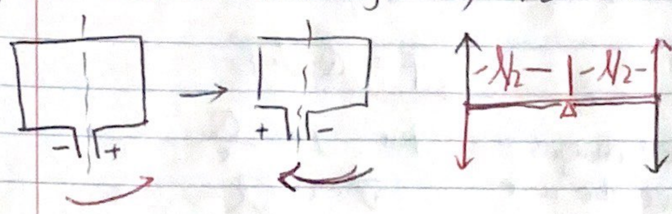
For multiple loops / coil




$$\boxed{\tau = NI\vec{B}A}$$

$N$ = number of loops

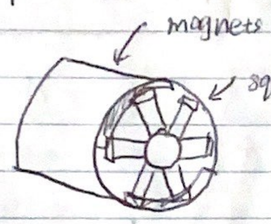
If we rotate the wire by 180°, the $\tau$ direction is going to flip




If we only allow the current to flow in one direction, the loop will not rotate continously but going back and forth

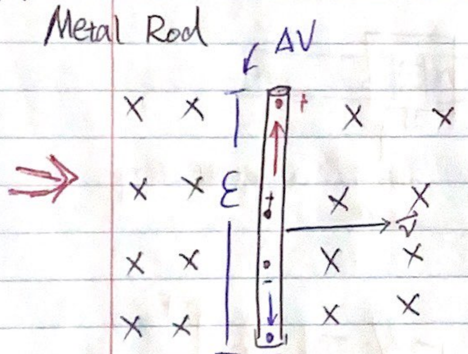
• To solve the problem we need to flip direction of the current to keep it rotate.

Brush Motor.




Methods to make up Electricity :

Metal Rod




Motional Emf.

When the conductive rod is moving to the right, the positive charges will go to the top, since force is upward ~~when~~ for "+"; Whereas the negative charges will go the bottom, since force for "-" is pointing downward.

$$\varepsilon = \vec{B} \ell \vec{v} \quad \text{(volts)}$$

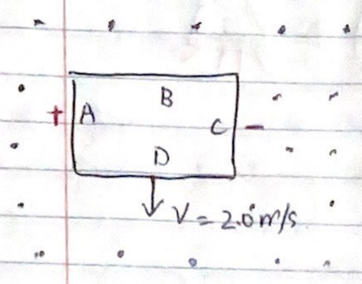
$\vec{B}$: Tesla, $\ell$: m, $\vec{v}$: m/s

$\varepsilon$ is called motional emf.

$\vec{B} \perp \ell \perp \vec{v}$

Cu Sheet (10cm x 30cm)

$\vec{B} = 5.0T$




a) Determine which side is +

b) Determine motional emf across plate.

a) A is positive.

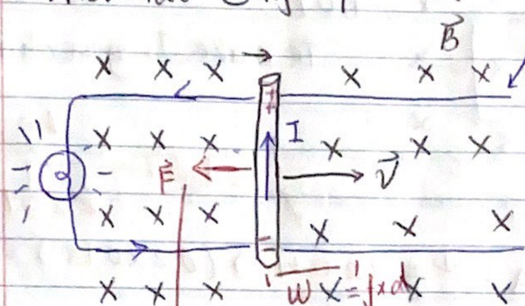
b) $\varepsilon = \vec{B} l \vec{v}$

$= 5.0 \times 0.3 \times 2.0$

$= 3.0V$

→ Motional Emf part 2.

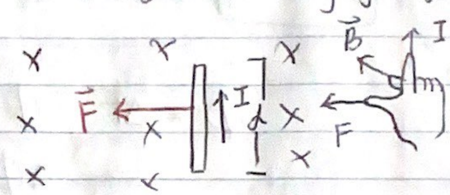
conductive rails




$\varepsilon = \vec{B} l \vec{v}$

you slide the rod to the right, creates potential difference. However, a force opposing it it's created.

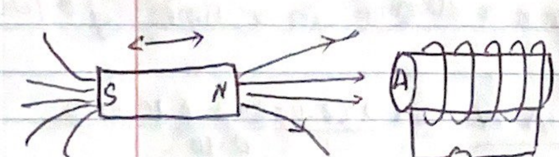
can we get electricity for free




- The rod
- creates a force to the left at rest

→ What must be changed to create electricity?

- Magnetic Flux: number of $\vec{B}$ lines ⊥ to Area of coil.

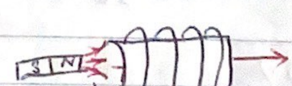



A : $m^2$

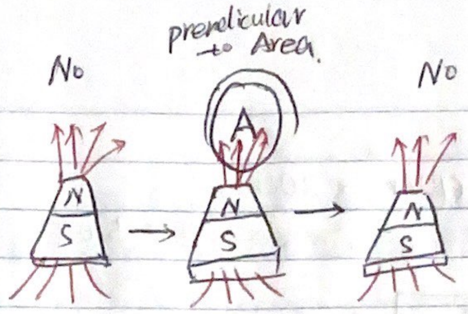
$$\boxed{\begin{array}{c}\phi = \vec{B}_{\perp} A \\ \text{Flux: weber, } Wb = T \cdot m^2\end{array}}$$

3 ways discovered to create electricity

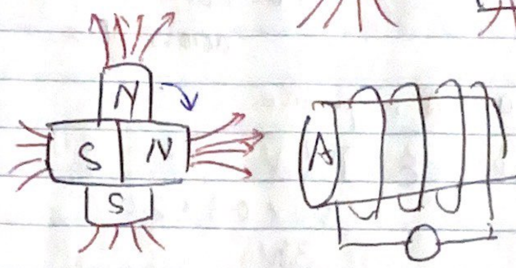
① place magnet going through the coil



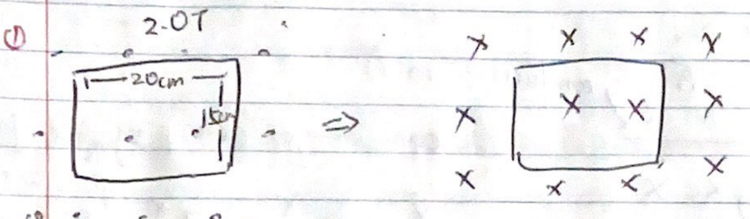
② Sweeping through the coil Area



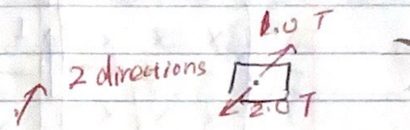

③ Rotation :




① 




To make I, you change $\phi$




~~$\phi = \Delta t$~~ $\quad \phi = \vec{B}_{\perp} A$

$\Delta\phi = \Delta\vec{B} \cdot A$ = $\phi = (2.0+1.0)(0.2 \times 0.15) = 0.090\,wb$

or $\Delta\phi = \vec{B} \cdot \Delta A$

Remember $\vec{B}$ and Area must be prependicular: If not ( $\boxed{\vec{B} \cdot A \cos\angle\alpha}$ )

- Faraday's Law of Induction

$$\boxed{\mathcal{E} = (-)\,N\frac{\Delta\phi}{\Delta t}}$$

← Always come out positive ? the negative sign come out later.

Ex. A coil ($N=100$) has a 2.0T magnet inserted from a distance in a time of 0.10s
If $A = 0.10m^2$, find $\mathcal{E}$.

$$\mathcal{E} = -\frac{N\Delta\phi}{\Delta t} = \frac{(-)\,\Delta\vec{B} \cdot A \cdot N}{\Delta t} = \frac{(-)(\vec{B}_f - \vec{B}_i) \cdot A \cdot N}{\Delta t} = \frac{(-)(2.0-0.0) \cdot 0.10 \times 100}{0.10}$$

$\therefore \mathcal{E} = 200V$

· Lenz's Law

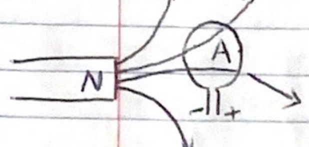
- Nature's mechanism to make you earn or work for induced I.

$$\mathcal{E} = (-) N \frac{\Delta \phi}{\Delta t}$$

what negative sign means

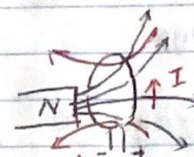
Formal Definition: states that the direction of an induced current is such that its magnetic field opposes the change in flux that produced it.

case 1.



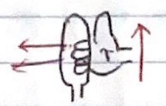

2 field lines
Go through
A

→

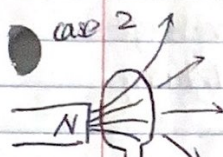



move magnet closer
so now more field
lines go through A.

nature's induced field line try to counteract the increase in flux.

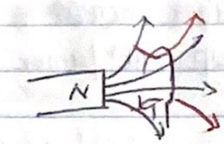


case 2




4 field lines
go through
A initially

→



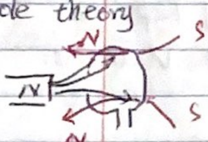

now move N away,
less lines going through A.

Nature wants to go back to original state, so make own induced currente to create field lines

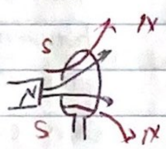
the currents' direction.

Remember current creates induced $\vec{B}$

You can think of it in North pole/ south pole theory

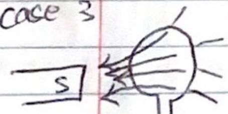



To repel it out

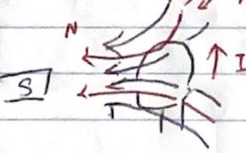



to attract it back

case 3



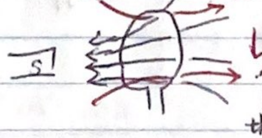

$\xrightarrow{\Delta t}$




nature add more to revert to original state.

case 4.

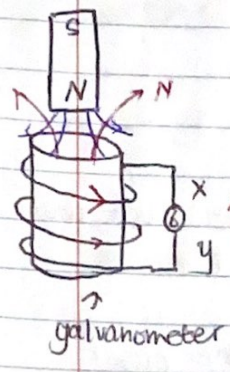

$\xrightarrow{\Delta t}$




nature counteract the increase

the induced current in the ring is downward.

Practice Questions:

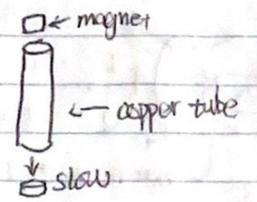



As magnet falls through coil induced current through galvanometer will go x→y then y→x or y→x then x→y.

↑ Initial Answer: y→x then x→y

current in Galvanometer is from y to x initially

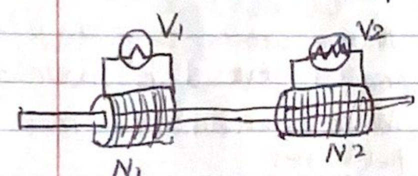
Example of Lenz's Law.




Transformers:

A transformer is a device that either increases or decreases input AC voltage

- A transformer that ↑V step-up transformer and primarily used in lighting
-




$$V = \frac{N\Delta\phi}{\Delta t}$$

There's a relationship exists between the # of loops in each coil and the V across each coil.

$$\frac{V_1}{N_1} = \frac{\Delta\phi}{\Delta t} \qquad \frac{V_2}{N_2} = \frac{\Delta\phi}{\Delta t} \qquad \therefore \frac{V_1}{N_1} = \frac{V_2}{N_2}$$

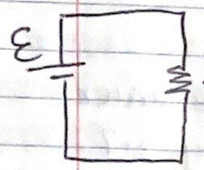
$$\therefore \frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

(s = secondary, p = primary)

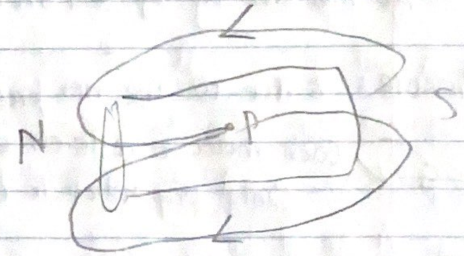
Induction charging

- More waste heat produced
- 60% ~ 80% as efficient as wired charging

- Back Emf of an Electric Motor.
  - Circuit for an electric motor at stall (not turning)




resistance of windings or coil.



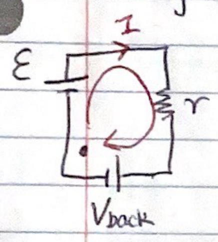

$\varepsilon$ : Driving emf or voltage

$I_s$ : stall current or current at stall

By Ohm's Law : $V = IR$

$$\boxed{\varepsilon = I_s \cdot r}$$

  - Circuit for electric motor while turning




$V_{back}$ : Back emf induced in turning motor

$|V_{back}| < |\varepsilon|$

Magical Ideal motor : $|V_{back}| = |\varepsilon| \Rightarrow I = 0$

Loop Rule to generate an equation relating $\varepsilon$, $V_{back}$, $r$, $I$ (while motor turning)

$\Sigma V_{rise} = \Sigma V_{drop}$

$\varepsilon = Ir + V_{back}$

$\boxed{V_{back} = \varepsilon - Ir}$ @ At

At stall, $\varepsilon = I_s \cdot r$, while turning : $V_{back} = \varepsilon - Ir$ $\boxed{I < I_s}$

That's why we never let electrical motor to stop. since I will burn the system

ex 2) A DC motor connect to a 6V power supply, when turning $I = 1.90A$, $V_{back} = 5.20V$. What is $r$.

a) $V_{back} = \varepsilon - Ir$

$\therefore r = \dfrac{\varepsilon - V_{back}}{I}$ $\quad r = \dfrac{6.0V - 5.20V}{1.90A} = \dfrac{8}{19} = 0.42\ \Omega$

b) $I_s = \dfrac{\varepsilon}{r} = \dfrac{6.0}{0.42}$

$= 14.3A$

# Δ Fluids.

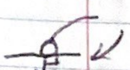
- **Density:**

rho $\rho$ is given as $\boxed{\rho = \frac{m}{V}}$, when dealing with fluids, we express the mass as $\rho V$. [SI unit density = $kg/m^3$ ]

- The density of water is $1 g/cm^3 = 1.0 \times 10^3 \ kg/m^3$

- Specific Gravity: • Density of a substance relative to that of pure water
  - Al has density of $2.7 g/cm^3$, so it has a specific density of 2.7.

- **Pressure:** is due to the net force of molecules in a fluid colliding with the walls.


Each molecule collision exterts a tiny net force on the wall.
Only prependicular component of F remains.

The pressure is defined as the ratio of force to the ~~ea~~ area is exterd

$P = \frac{F}{A}$ (SI unit = Pascal = Pa = $1 N/m^2$ )

Other units:

- $1 atm = 1.013 \times 10^5 \ Pa$
- $kPa = 10^3 \ Pa$
- $1 mmHg = 133 \ Pa$
- $1 psi = 6890 \ Pa$

ex. • Determine the force on the outside surface of a pop can.
- The can is a cylinder of height, h, and r. The surface area ?
  $r = 3.25 cm$ $h = 12.00 cm$

$\because P = \frac{F}{A}$ $\therefore F = P \cdot A$
$= 1.013 \times 10^5 pa (2\pi rh + 2\pi r^2)$
$= 1.013 \times 10^5 \times [2\pi \times 3.25 \times 10^{-2} \times 12 \times 10^{-2} + 2\pi (0.0325)^2]$
$= 3150 \ N$

- **Gauge Pressure:**

$P_G = P - P_{atm}$ (Formula not given.

- **Fluids:**
- fluids take the shape of their container and include both liquids and gases.
- Gas: Pressure and Volume are related by idea gas law

$$PV = nRT$$

At constant temp, if the pressure of a gas is increased, its $V \downarrow$.

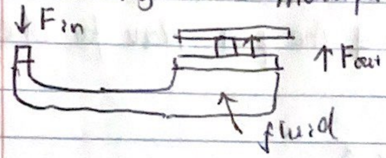
- Liquid: Pressure does not change the volume much since most liquids are incompressible.

- **Pressure & Pascal's Principle:**

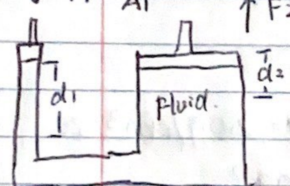
"Pressure applied to any part of an enclosed fluid is transmitted undiminished to every point of the fluid and to the walls of the container."

— Each face feels same force.

- Application: Hydraulic multiplication




$\downarrow P_1 = \frac{F_1}{A_1}$ $\uparrow F_2 = \frac{A_2}{A_1} F_1$




$P_2 = \frac{F_2}{A_2}$

Pressure At X = Pressure At Y

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_1 d_1 = F_2 d_2$$

$$d_1 = \frac{F_2}{F_1} d_2 = \frac{A_2}{A_1} d_2$$

— Pressure At Depth: $P = P_0 + \rho g h$

- Ex: Determine pressure at the bottom of a 5m water tank.

Solution: $P = P_0 + \rho g h$

$P = 1.013 \times 10^5 + 1000 kg/m^3 \times 9.80 \times 5.0$

$P = 1.5 \times 10^5$ Pa

# Archimedes' Principle

※ The bouyant force on an object and the weight of the fluid ~~p~~ displaced by the object are the same.

$$F_B = \rho V g \quad (\rho = \text{density},\ V = \text{volume},\ g = \text{gravity})$$

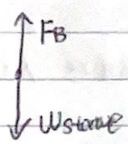
(Bouyant force)

ex1. A ball of mass $M$ and volume $V$ floates on a swimming pool. The density of wood is $\rho_{wood} < \rho_{H_2O}$. The buoyant force acting on the ball is

ⓐ Since the wood is not sinking, then bouyant force = all weight of ball

$\therefore F_B = M_{Ball}\, g$

ex2. A small swimming pool has an area of 10 square meters. A wooden 4000-kg status of density 500 kg/m³ is then floated on top of the pool. How far does water rise?


$F_B = W_{statue}$

$\rho V g = mg$

$V = \dfrac{m}{\rho}$

$V = A \cdot x$

$\therefore x = \dfrac{V}{A}$

$\therefore x = 40\text{ cm}$

ex3. A sphere with a radius of $r = 10.0\text{cm}$ and density $\rho = 2.0\text{g/cm}^3$ is suspended in water. What is the tension in the string?

$\Sigma F_y = 0$

$F_T = W - F_B$

$F_T = \rho V g - \rho_{H_2O} V g$

$F_T = Vg(\rho_{steel} - \rho_{H_2O})$

$\therefore F_T = \frac{4\pi}{3} r^3 g(\rho_{steel} - \rho_{H_2O})$

$F_T = 41N$