ELECTRIC FIELDS

- Electric Charge
- Coulomb's Law
- Concept of Electric Field
- Electric Field of a Point Charge
- Uniform Electric Field
- Electric Potential

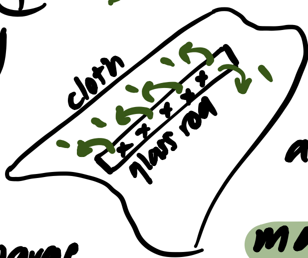
Positive Charge (+)
- protons
- +ve ions

Negative Charge (−)
- electrons
- −ve ions

Unlike Charges: (+) → ← (−) — attractive force

Like Charges: ← (+) (+) → — repulsive force

same magnitude, opposite direction



neutral materials are rubbed, electrons (experience friction!) are rubbed off

mass of electron < proton (move easily!)

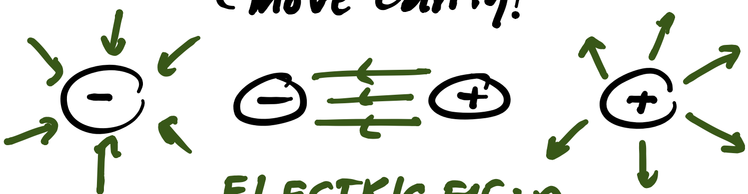
(+) (−) (−) (+) (+) (−): equal amounts of +ve & −ve charge = electrically neutral

PRINCIPLE OF CONSERVATION OF CHARGE

in a closed / isolated system,

total charge before interaction = total charge after interaction

transfer! ✗ created ✗ destroyed



ELECTRIC FIELD

a region where charged particles experience force

force → ELECTROSTATIC FORCE

COULOMB'S LAW

(+) Q_1 ←— r —→ (−) Q_2

$F \propto Q_1 Q_2$

$F \propto \frac{1}{r^2}$

$F \propto \frac{Q_1 Q_2}{r^2}$

Newton's Third Law: equal magnitude, opposite direction

① $F = k\frac{Q_1 Q_2}{r^2}$

k depends on medium

② $k = \frac{1}{4\pi\varepsilon_0}$ / permittivity of free space (vacuum)

ε_0 ↳ $8.85 \times 10^{-12}\ C^2/Nm^2$ minimum!

other medium: relative $\varepsilon_r > 1$

$\frac{1}{4\pi\boxed{\varepsilon_0\varepsilon_r}}$ (larger than ε_0)

①, ②:

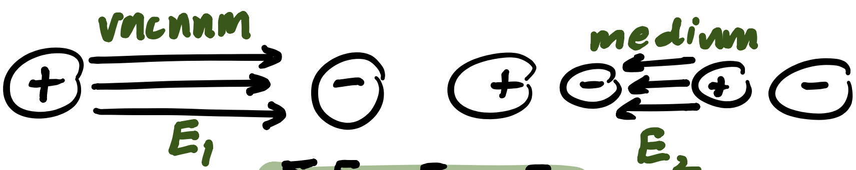
$$\boxed{F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}}$$

$(9 \times 10^9)\frac{Q_1 Q_2}{r^2}$

Relative permittivity

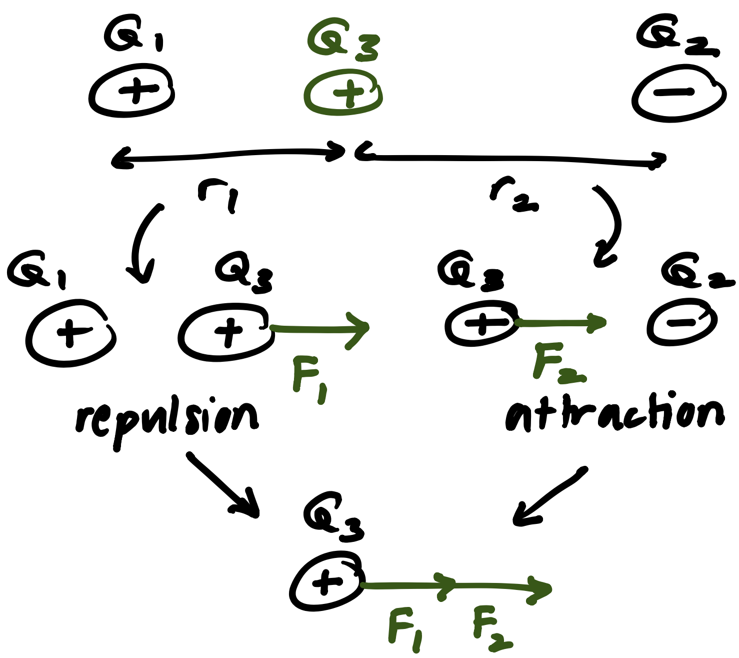
$\varepsilon_r = \frac{\varepsilon \leftarrow \text{medium}}{\varepsilon_0 \leftarrow \text{vacuum}}$ (ratio)

- the factor by which the Coulomb force decreased relative to in a vacuum



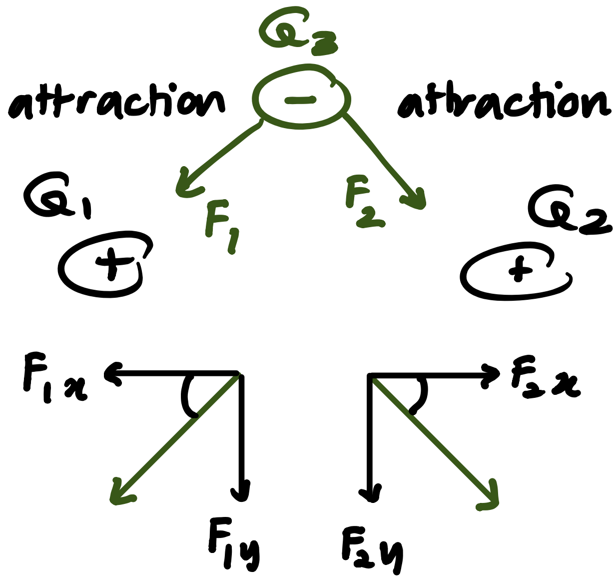
$\Sigma F = E_1 - E_2$

Forces in Vector



$\Sigma F = F_1 + F_2$

in regards to direction not charge! (vector)

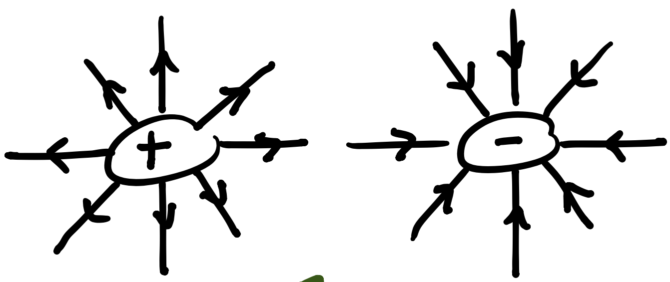


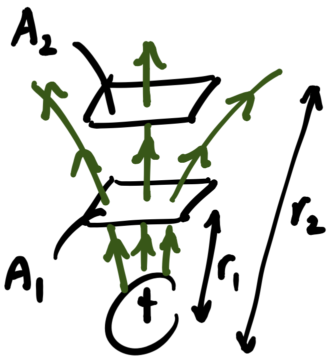
$\Sigma F_x = -F_{1x} + F_{2x}$

$\Sigma F_y = -F_{1y} - F_{2y}$

$\Sigma F = \sqrt{\Sigma F_x^2 + \Sigma F_y^2}$

ELECTRIC FIELD



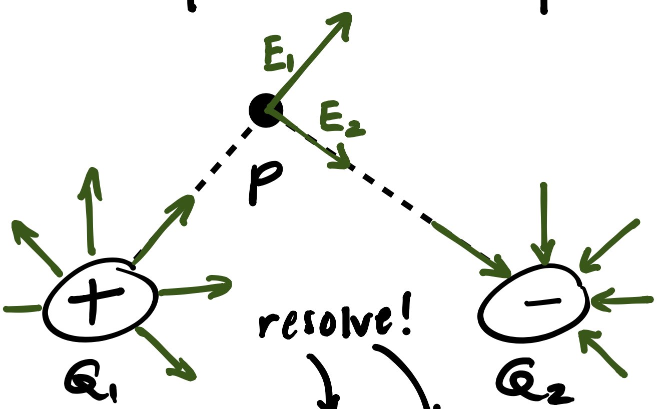


$A_1 = A_2$

$r_2 > r_1$

stronger electric field at A_1 than A_2

$E \propto \frac{1}{r^2}$



$\Sigma E = E_1 + E_2$

vector! $E = \frac{F}{Q_2}$

towards negative

positive test charge

force experienced by Q_2

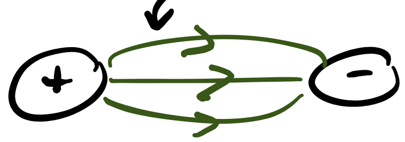
Q_1 is source of electric field

$E = k\frac{Q_1 \cancel{Q_2}}{r^2 \cancel{Q_2}} = k\frac{Q_1}{r^2}$

strength of electric field generated by Q_1 at distance r

Uniform! Electric Field

non-uniform



$W_{EPE} = QV$

Electric Potential Energy

↓↑

Kinetic Energy

$W_{EXT} = Fd$

$W_{EXT} = W_{EPE}$

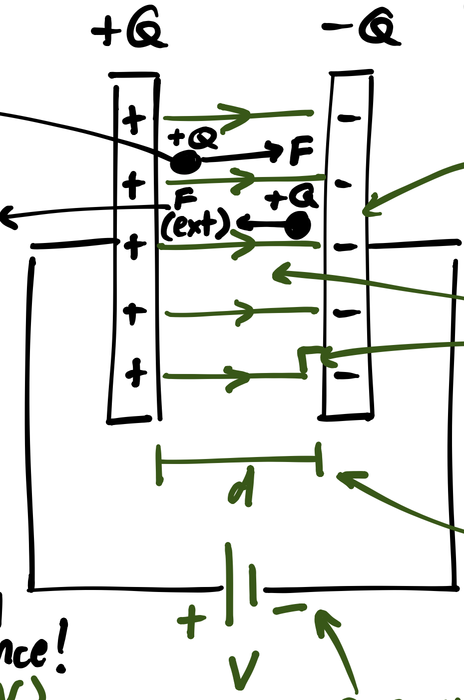
$Fd = QV$

$\frac{F}{Q} = \frac{V}{d}$

$E = \frac{V}{d}$

potential difference! $+V-(-V)$

distance between plates



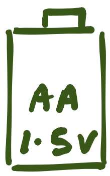
metal plates
· surface filled w electrons

equally spaced & perpendicular to plates

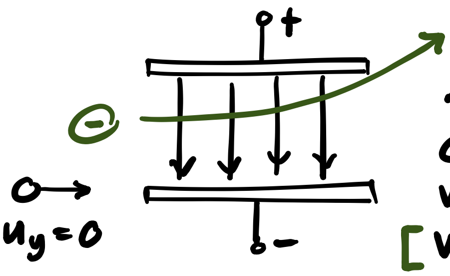
└ strength of Electric Field is uniform throughout

very close

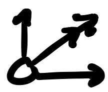
D.C. voltage supply



1.5 J of energy supplied to 1C of charge



$u_y = 0$



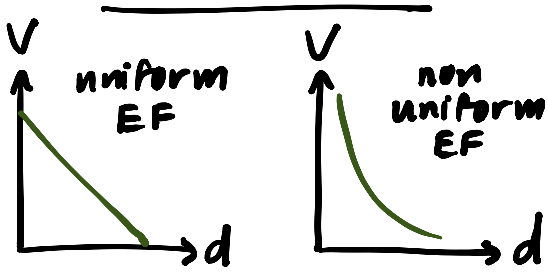
$v_x = u_x$

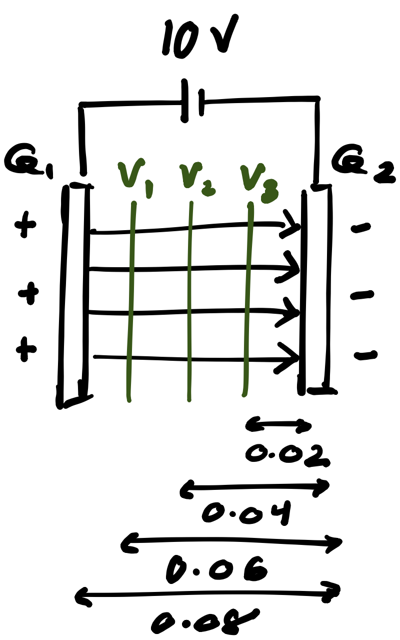
$[v_y > u_y]$

$F = ma$

Scalar!

Electric Potential





$E = \frac{V}{d}$

$= \frac{10V}{0.08m}$

$E = 125 NC^{-1}$

$V_1 = (125)(0.06) = 7.5V$

$V_2 = (125)(0.04) = 5.0V$

$V_3 = (125)(0.02) = 2.5V$

$V_1 > V_2 > V_3$

$m = E = -\frac{V}{r}$

$E = k\frac{Q}{r^2}$

by the test charge, Q_2

set up by Q_1

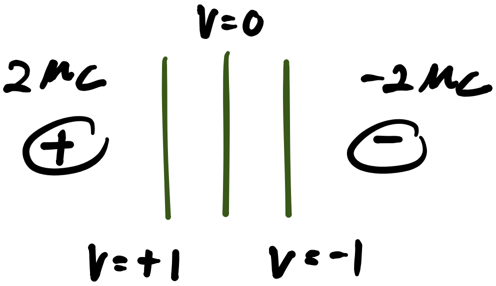
$QV = W$

$V = \frac{W}{Q}$

E gained by Q_2

$V = k\frac{Q}{r}$

consider +ve & -ve Q!



Circuit Symbols

Symbol	Component Name	Symbol	Component Name	Symbol	Component Name
	Connecting lead		Alternating signal (a.c.)		Inductor (solenoid)
	Cell	V	Voltmeter		Diode
	Battery of cells	A	Ammeter		Light-emitting diode (LED)
	Power supply / accumulator	G	Galvanometer		Filament lamp
	Switch		Fixed resistor		Fuse
	Switch (alt.)		Variable resistor		Loudspeaker
	Junction of conductors (node)		Light-dependent resistor (LDR)		Microphone
	Crossing conductors (no connection)		Thermistor (thermal-resistor)		Earth (ground)
	Crossing conductors (no connection)(alt.)		Capacitor		Current source

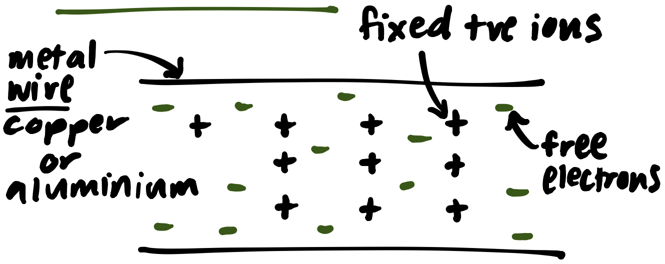
- Circuit Symbols
- Charge Carriers
- Electric Current
- Potential Difference
- Resistance
- Electric Power

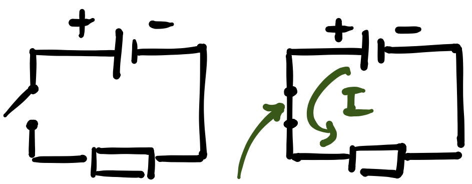
has to be free moving to conduct electricity!

Charge Carriers (charged particles)

- in metals → negatively charged free electrons
- in gas / non-metallic liquid → positive & negative ions
  ↳ electrolyte

Electric Current





potential difference is established

$\bar{e}$ move towards +ve terminal

produces current!

current

1 Coulomb is 1 ampere in 1 second

$Q = It$

elementary charge (smallest!)

$1.602 \times 10^{-19} C$

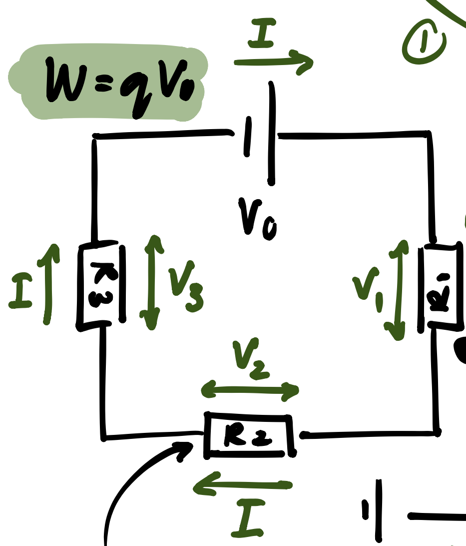
- electron, + proton

$\boxed{Q = Ne}$

total charge, no of particles, individual charge

① ② $W = qV$

$W = qV_0$



electric potential of $\bar{e}$ drops ⇒ potential drop

kinetic!

electron loses energy

resistor gains energy

$W = qV_1$

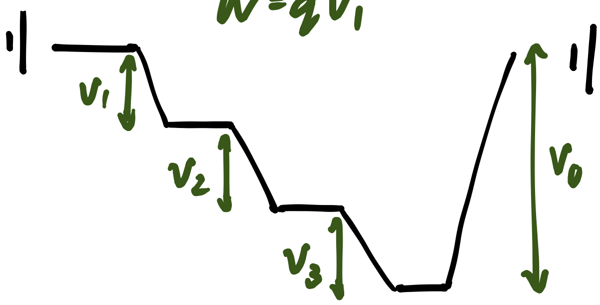
resistor! resist movement of electrons

Charge Carriers	electron in wires	potential diff is established
Energy	battery provide potential E	

E_{EPE} converts to E_{KE}

↳ Charge Carriers move = current!

$$\boxed{I = \frac{dQ}{dt} = \frac{Q}{t}}$$



Principle of Conservation of Energy

$V_0 = V_1 + V_2 + V_3$

Factors of Conduction

① Charge Carrier Density, n

diff metal/element = diff no of free electrons

$$\boxed{n = \frac{N}{V}}$$

N ← amount of charge carriers

V ← volume

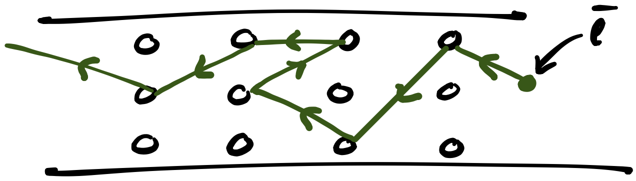
$$\boxed{V_d = \frac{I}{nqA}}$$

② Drift Velocity, V_d

electrons collide with atoms

⇓

electrons move in zigzag

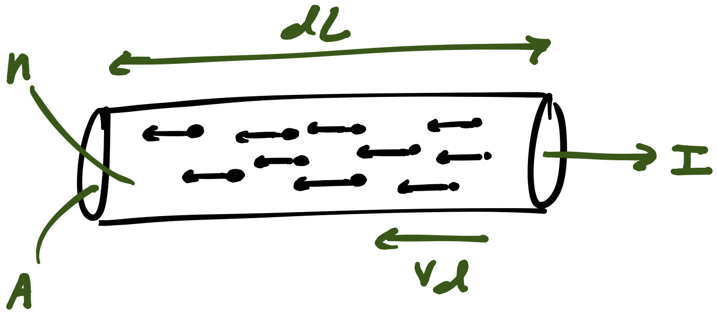


V_d in semiconductor is higher (higher mobility)

③ Cross Sectional Area of Conductor, A

$$\boxed{I \propto A} \qquad J = \frac{I}{A}$$

J ← current density



Number of Charge Carriers

$$nA \cdot dL = N$$

$n = \frac{N}{V}$, $A \cdot dL = V$

Charge

$dQ = Nq$

$$\boxed{dQ = (nA \cdot dL)q} \longrightarrow ①$$

Time taken for charge to pass through

$$dt = \frac{dL}{V_d} \longrightarrow ②$$

$$\boxed{\begin{array}{l} \uparrow V_d \quad \uparrow I \\ \uparrow A \\ \downarrow n \quad \uparrow V_d \end{array}}$$

$$I = \frac{dQ}{dt}$$

Sub ① and ②:

$$I = (nA \cdot dL)q \cdot \left(\frac{V_d}{dL}\right)$$

$$\boxed{I = nAqV_d} \leftarrow \text{General case!}$$

Alloy

Metal A + Metal B

$x\%, n_A$ $\quad$ $y\%, n_B$

$I = I_A + I_B$ ← parallel current

$$\boxed{I = \begin{array}{c} n_A q v_d \cdot (x\% A) \\ + \\ n_B q v_d \cdot (y\% A) \end{array}}$$

Composite

Conductor + Insulator

$x\%, n_A$ $\quad$ $y\%$, no charge carrier

$I = I_A$

$$\boxed{I = n_A q V_d \cdot (x\% A)}$$

Gas

Molecule A + Molecule B

$I = I_A + I_B$

$$\boxed{I = (n_A + n_B) A q v_d}$$

* volume of gas is negligible

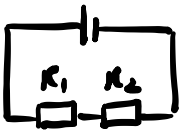
Potential Difference

Electrical energy (W) transferred by 1 Coulomb

charge

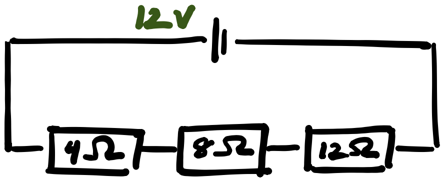
$$\boxed{V = \frac{W}{Q}}$$

V_0 ← voltage



V_1 V_2 ← voltage drop

$V_0 = V_1 + V_2$



2 V 4 V 6 V } ratio

Resistance

Ratio of potential diff to current

$$\boxed{R = \frac{V}{I}}$$

⇓

Ohm's Law

$$\boxed{V = IR}$$

Metal !

$V\uparrow \rightarrow I\uparrow \rightarrow e\uparrow$

Q/t

$R\uparrow$ ← collision ↑

E in atom ↑ → T ↑
(lattice)

vibration ↑
amp.

repeated

until!

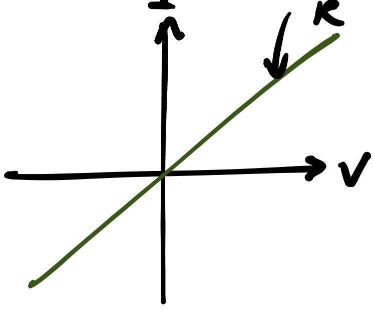
vibration amplitude MAX

resistance is max

current saturated (constant)

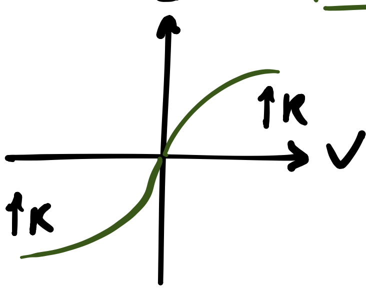
I-V Characteristic

$m = \frac{1}{R}$



Ohmic Conductor

① pure metal / fixed resistor at constant temperature



↑ heat
↑ collision
↑ resistance

Non-ohmic Conductor

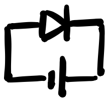
② filament lamp (tungsten)

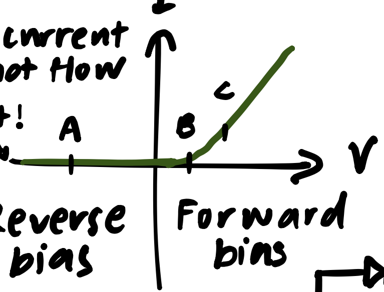
③ Semiconductor (Diode)

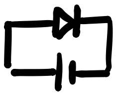
A very high R (~ infinite)

B barrier voltage

C diode is activated (very little resistance)



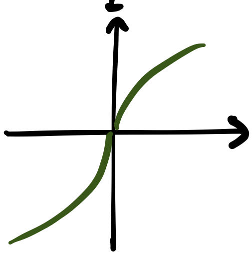




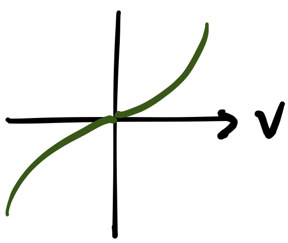
Non-Ohmic Conductor

④ Thermistor ← sensitive to temp (R not constant)

PTC



NTC



Non-ohmic conductor

$T\uparrow, R\uparrow$ → PTC : +ve temp coefficient

$T\uparrow, R\downarrow$ → NTC : -ve temp coefficient

Semiconductor !

$T\uparrow \rightarrow R\downarrow \rightarrow$ vibration amp. ↑ → free e^- ↑

no free electrons ! (covalent bonding)

∵ e^- gain energy

Electrical Power

energy

$$\boxed{P = \frac{W}{t} = \frac{QV}{t}}$$

rate at which resistance converts electrical E to other forms of E

$$P = VI = \underbrace{I^2R}_{\text{mostly series}} = \underbrace{\frac{V^2}{R}}_{\text{mostly parallel}}$$

Efficiency

$$= \frac{\text{Useful output}}{\text{Input}} \times 100\%$$

- Resistivity
- Resistors in Series
- Resistors in Parallel
- Ammeters and Voltmeters
- Voltage Divider Rule
- Current Divider Rule

Resistivity

$R \propto L$

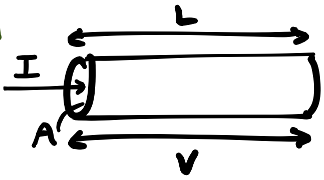
$R \propto \frac{1}{A}$

$$R = \rho \frac{L}{A}$$

$$\boxed{\rho = R\frac{A}{L}}$$

ρ depends on temperature

Unit: $\Omega\, m$



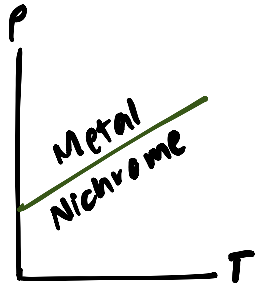
Metal 10^{-8}

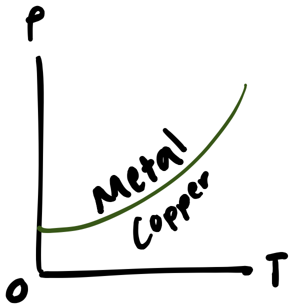
Semicon $10^{-5} \sim 10^{1}$

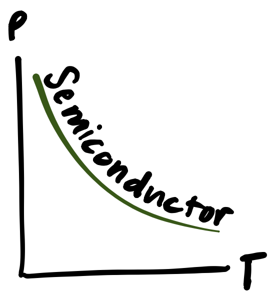
Insulator $>10^{10}$

Conductivity

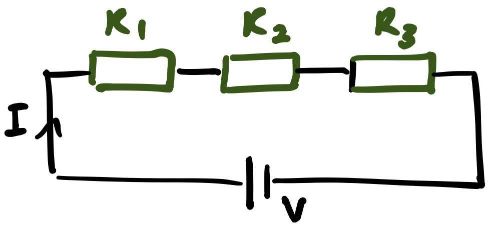
$\sigma = \frac{1}{\rho}$ Unit: $\Omega^{-1} m^{-1}$







[Series]



$V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$

$V = I(R_1 + R_2 + R_3) = IR_{eq}$

$$R_{eq} = R_1 + R_2 + R_3$$

Ammeter

in series

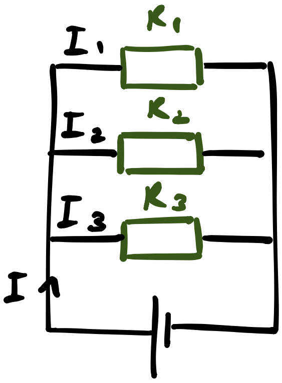
- low internal resistance
- low V

Voltmeter

in parallel

- high internal resistance
- low I

[Parallel]



$I = I_1 + I_2 + I_3$

$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

$I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

in parallel

If $R_1 = R_2 = \ldots = R_n$, $R_{eq} = \frac{R}{n}$

Voltage Divider Rule

in series!

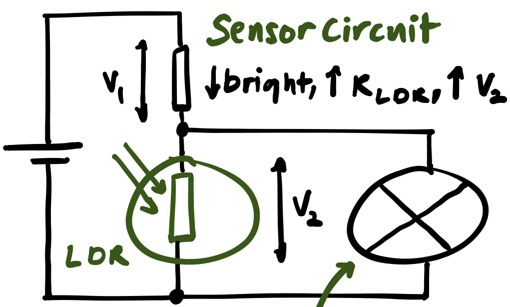
$$V \propto R$$

$$\frac{R_{target}}{R_{total}} = \frac{V_{target}}{V_{total}}$$

$$\boxed{V_x = \frac{R_x}{R_{eq}} V_0}$$

$$V_{tar} = \frac{R_{tar}}{R_{tot}} \times V_{tot}$$

Sensor Circuit



↓bright, ↑R_{LDR}, ↑V_2

load w high R

∴ V_{out} reduced less

$$\boxed{R_{load} > 10R_2}$$

When $V_2 > \min V_{load}$

⇒ Load is activated

Current Divider Rule

in parallel!

$$I \propto \frac{1}{R}$$

$$\boxed{I_x = \frac{R_{eq}}{R_x} I}$$

positive $\xrightarrow{}$ -ve & negative ions (+ve $\leftarrow$) } relative motion

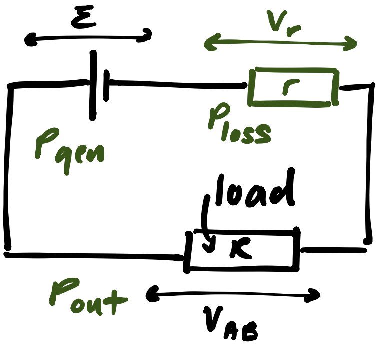
Chemical cells have Internal Resistance

Energy transfer
① From cell to charge
② From charge to component

* Electromotive Force
* Internal Resistance
* Determination of the E.m.f. and Internal Resistance

Electromotive Force

$$\boxed{\mathcal{E} = \frac{W}{Q}}$$ in V or JC^{-1}



Ideal case!

$P_{gen} = P_{out}$

$I\mathcal{E} = IV_{AB}$

$\mathcal{E} = V_{AB}$

Actual case!

$V_{AB} < \mathcal{E}$

$P_{gen} = P_{out}^{*} + P_{loss}$

$I\mathcal{E} = IV_{AB} + IV_r$

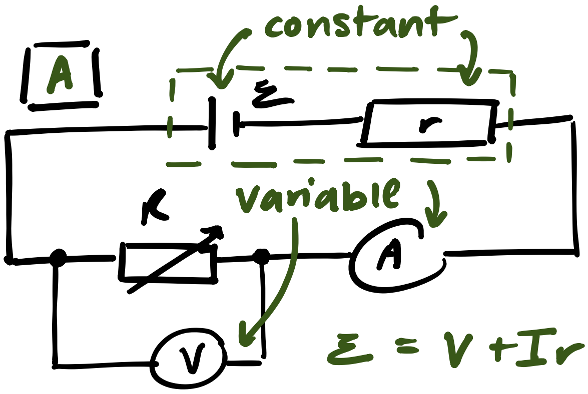
$\mathcal{E} = V_{AB} + V_r$

$\mathcal{E} = IR + Ir$

$$\boxed{I = \frac{\mathcal{E}}{R+r}}$$

$V_{AB} = \frac{R}{R+r}\mathcal{E}$ } VDR

*terminal voltage!



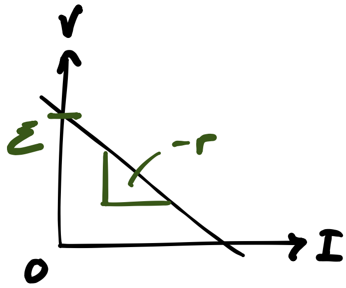
$\mathcal{E} = V + Ir$

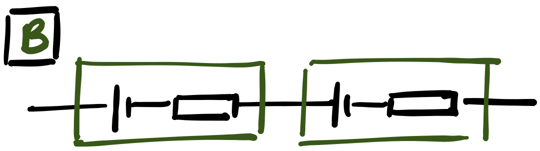
$V = -r(I) + \mathcal{E}$

$y = m\ x + c$

y-intercept = $\mathcal{E}$

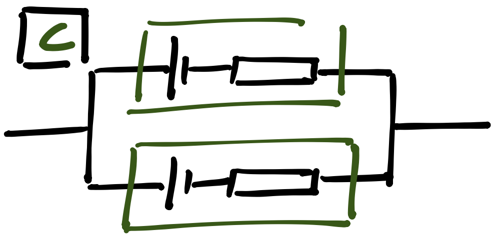
|gradient| = r





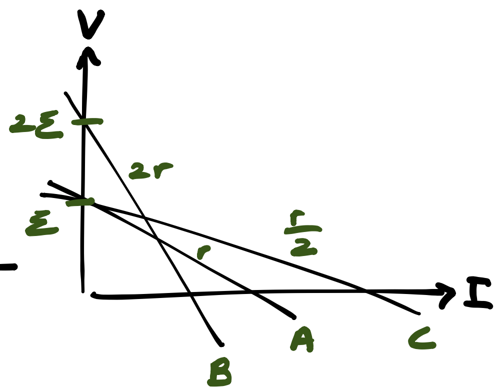
$\Sigma\mathcal{E} = 2\mathcal{E}$

$\Sigma r = 2r$



$\Sigma\mathcal{E} = \mathcal{E}$

$\Sigma r = \left(\frac{2}{r}\right)^{-1}$



- Kirchoff's Law
- Kirchoff's Voltage Law
- Kirchoff's Current Law
- Applying Kirchoff's Law
- Methods of Analysis

Kirchoff's Law

Current Law

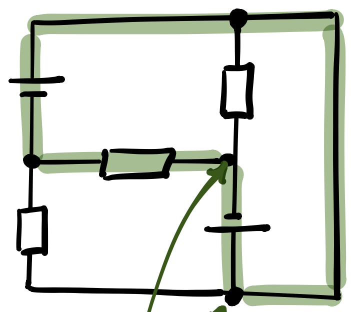
$\Sigma I_{in} = \Sigma I_{out}$

[junction]

Voltage Law

$V_1 + V_2 - V_3 = 0$

[loop]

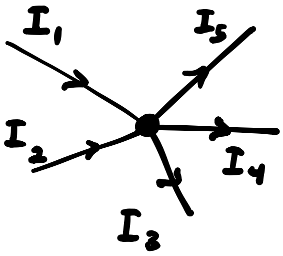


loop

no specific shape!

junction

CURRENT LAW



current entering a junction

$I_1 + I_2$

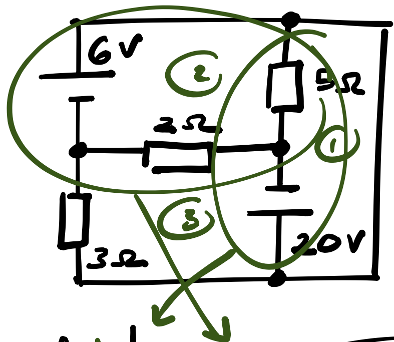
$= I_3 + I_4 + I_5$

current leaving the same junction

Principle of Conservation of Charge

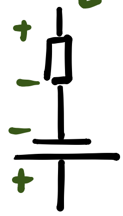
$Q_1 + Q_2 = Q_3 + Q_4 + Q_5$

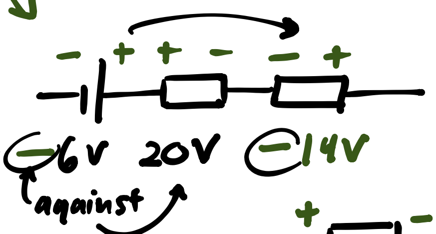
VOLTAGE LAW

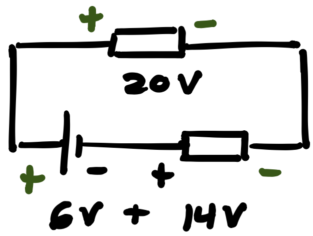


1. $V_{5\Omega} = 20V$
2. $V_{5\Omega} = 6V + V_{2\Omega}$
   $V_{2\Omega} = 14V$
3. $20V = V_{2\Omega} + V_{3\Omega}$
   $V_{3\Omega} = 6V$

polarity against each other

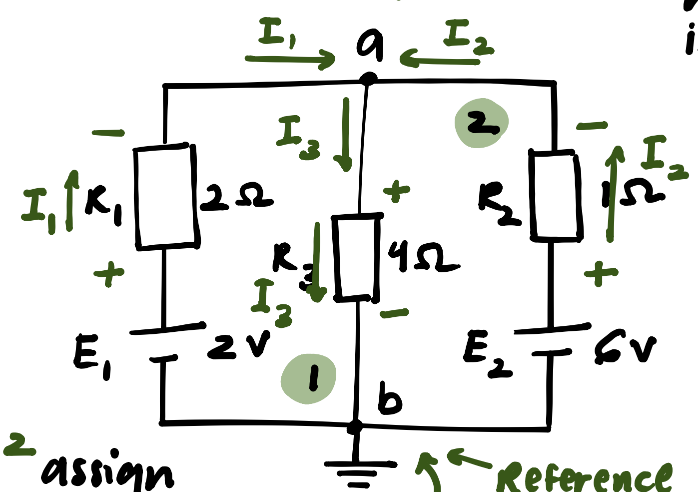






Principle of Conservation of Energy

Branch-Current Analysis



2 assign polarities

Reference Ground point

1 assume current in junction

$I_1 + I_2 - I_3 = 0 \longrightarrow (1)$

3 use KVL in each loop

1

$E_1 - V_1 - V_3 = 0$

$E_1 - I_1R_1 - I_3R_3 = 0$

$2 - 2I_1 - 4I_3 = 0$

$I_1 + 2I_3 = 1 \longrightarrow (2)$

2

$E_2 - V_2 - V_3 = 0$

$E_2 - I_2R_2 - I_3R_3 = 0$

$E_2 - I_2 - 4I_3 = 0$

$I_2 + 4I_3 = 6 \longrightarrow (3)$

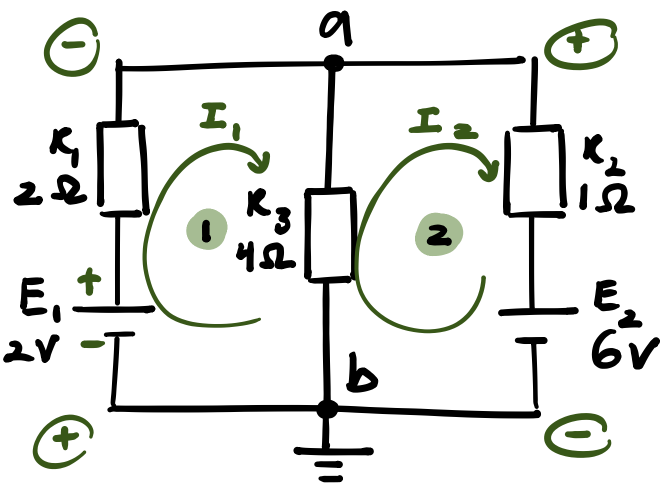
$I_1 = -1A\ (\leftarrow)$

$I_2 = 2A\ (\leftarrow)$

$I_3 = 1A\ (\downarrow)$

4 find values, reassign direction

Mesh-Current Analysis



Loop I_1:

$(R_1+R_3)I_1 - R_3 I_2 - E_1 = 0$

$(2+4)I_1 - 4I_2 - 2 = 0$

$6I_1 - 4I_2 = 2 \longrightarrow (1)$

Loop I_2:

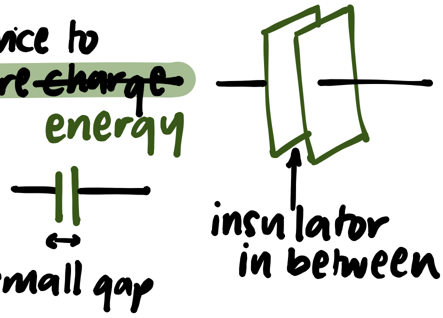
$(4+1)I_2 - 4I_1 + 6 = 0$

$-4I_1 + 5I_2 = -6 \longrightarrow (2)$

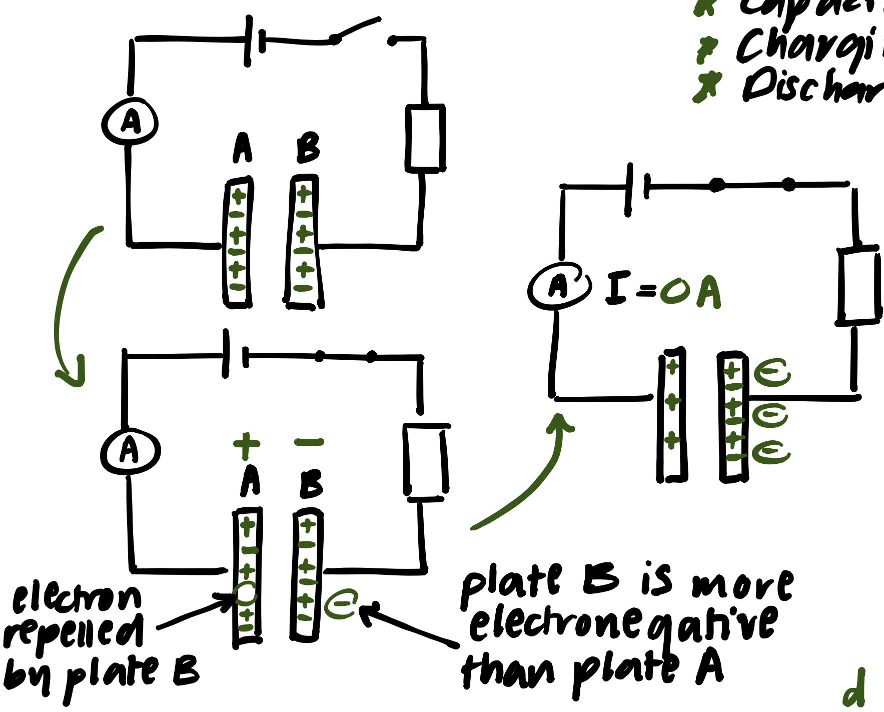
$I_1 = -1A, I_2 = -2A$

CAPACITORS

(device to ~~store charge~~ store energy



* Capacitors
* Capacitance
* Capacitors in Series
* Capacitors in Parallel
* Energy stored in a Capacitor
* Charge Redistribution in Capacitors
* Capacitance of Isolated Bodies
* Charging Process of a Capacitor
* Discharging Process of a Capacitor



Capacitance

↑ capacitance ≠ more charge stored

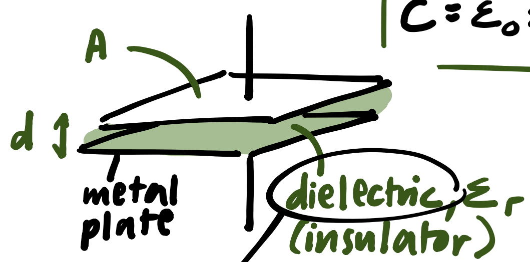
L measure of ability to store charge

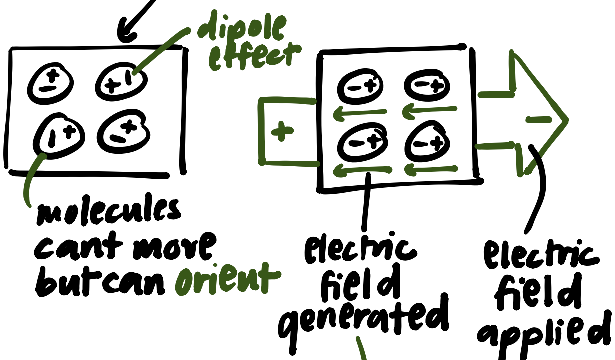
$\boxed{Q = CV}$ in Farads (F)

amount of charge

voltage

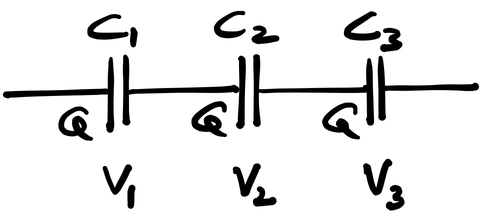
$$\boxed{C = \varepsilon_0 \varepsilon_r \frac{A}{d}}$$





dielectric polarization

Capacitors in Series



$Q = C_1V_1 = C_2V_2 = C_3V_3$

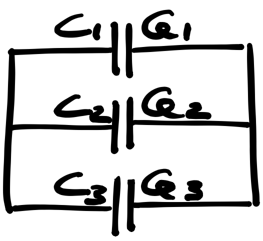
$V_0 = V_1 + V_2 + V_3$

$V_0 = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$

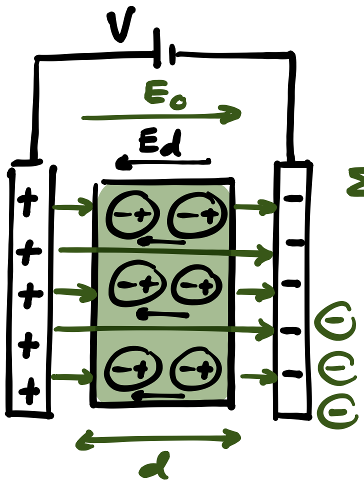
$\frac{V_0}{Q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

$$\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

Capacitors in Parallel



$$\boxed{C_{eq} = C_1 + C_2 + C_3}$$



$\Sigma E = E_0 - E_d$

$E_0 = \frac{V}{d}$ ← both remain constant

more charge is attracted

$\Rightarrow \Sigma E = E_0$

(overcome E_d)

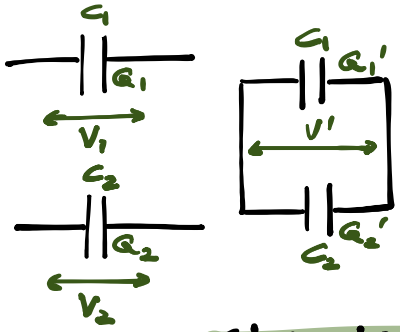
Energy in Capacitor

$$W = \frac{1}{2} C V^2$$

$$W = \frac{1}{2} \frac{Q^2}{C}$$

$$W = \frac{1}{2} Q V$$

Charge Redistribution in Capacitors



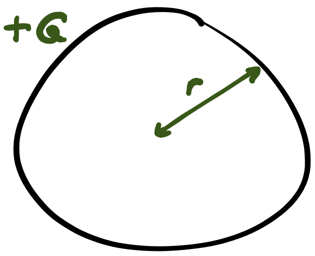
Principle of Conservation of Charge

$$Q_1 + Q_2 = Q_1' + Q_2'$$

before parallel — after parallel

$$C_1 V_1 + C_2 V_2 = (C_1 + C_2) V'$$

Isolated Bodies

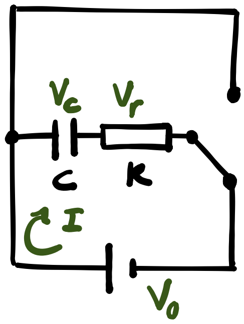


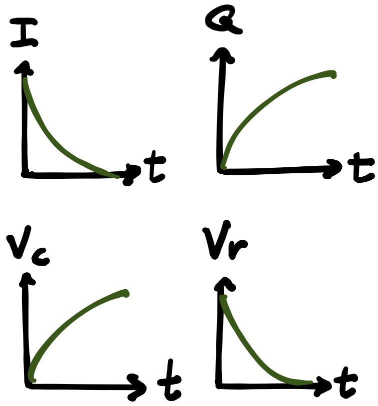
$$V = \frac{1}{4\pi\varepsilon_0} \frac{Q}{r}$$

$$C = \frac{Q}{V}$$

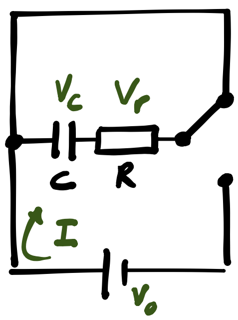
$$\boxed{C = 4\pi\varepsilon_0 r}$$

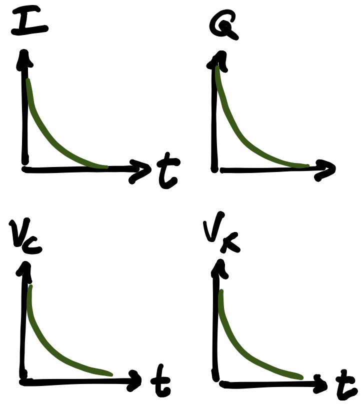
Charging





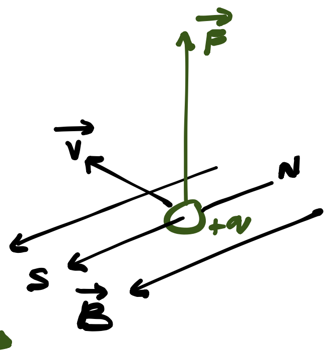
Discharging





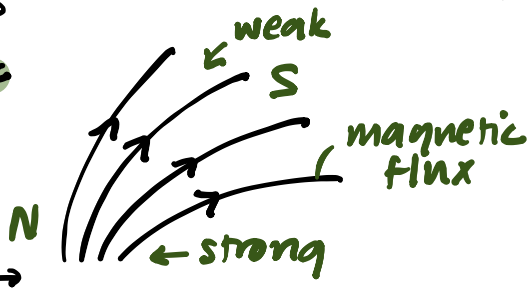
MAGNETIC FIELDS AND ELECTROMAGNETISM

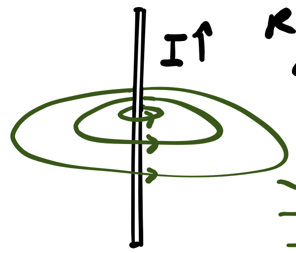
Interaction between magnetic field and velocity produces a force



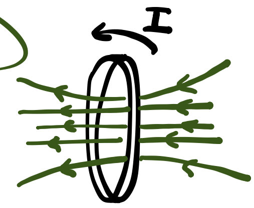
- Magnetic Fields
- Magnetic Field Lines
- Force on Moving Charged Particles
- Circulating Charges
- Velocity Selector
- Force on a Current-Carrying Wire
- Measuring Magnetic Flux Density

Moving charged particle —create→ **Magnetic field** —affect→ Moving charged particle





Right hand grip rule

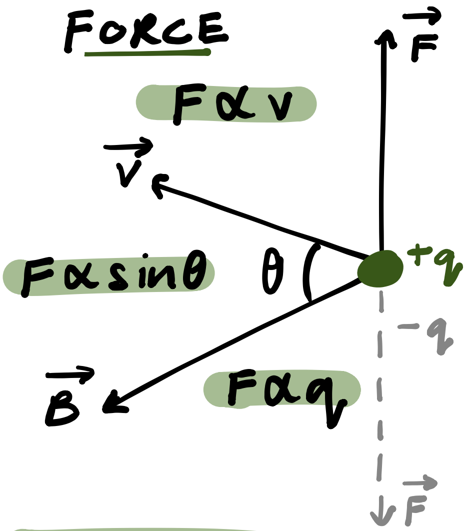


FORCE

$F \propto v$

$F \propto \sin\theta$

$F \propto q$



$$\boxed{\vec{F} = q(\vec{v} \times \vec{B})}$$

$F = qvB\sin\theta$

Unit: tesla (T)

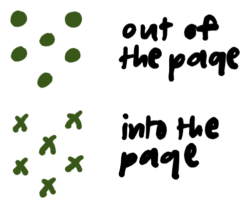
$$q\left(\frac{\vec{L}}{t} \times \vec{B}\right)$$

$$\frac{q}{t}(\vec{L} \times \vec{B})$$

For current-carrying wire

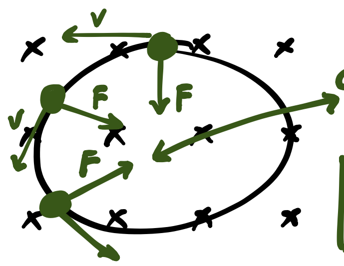
$$\boxed{F = I(\vec{L} \times \vec{B})}$$

$F = ILB\sin\theta$



Magnetic Flux Density (strength

CIRCULATING CHARGE



centripetal force = circular motion

$$\boxed{F = \frac{mv^2}{r}} = qvB\sin\theta$$

90°

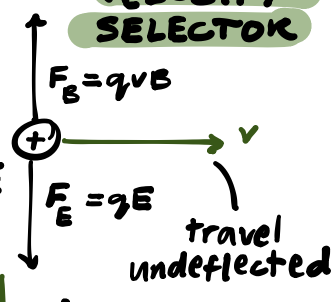
VELOCITY SELECTOR

$$F_B = F_E$$

$$qvB = qE$$

$$vB = E$$

$$\boxed{v = \frac{E}{B}}$$



↑ v, deflect up

↓ v, deflect down

Period

$$T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$$

Frequency

$$f = \frac{1}{T} = \frac{qB}{2\pi m}$$

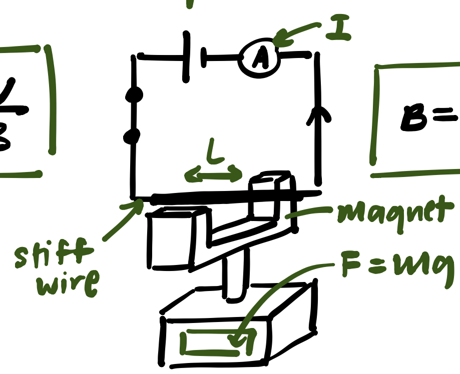
Angular velocity

$$\omega = 2\pi f = \frac{qB}{m}$$

$$qvB = \frac{mv^2}{r}$$

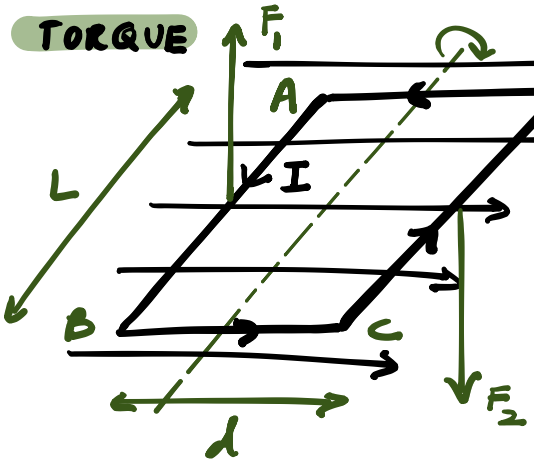
$$\boxed{r = \frac{mv}{qB}}$$

Magnetic Flux Density



$$\boxed{B = \frac{F}{IL}}$$

TORQUE



$F = ILB\sin\theta$

$\tau = rF$

$= F_1(\frac{d}{2}) + F_2(\frac{d}{2})$

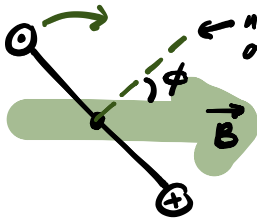
$= ILBd$

$\tau = IAB$

$$\boxed{\tau = NIAB\sin\phi}$$

number of coils

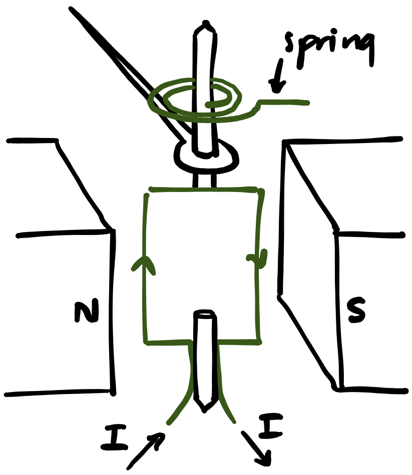
- Torque on a Current-Carrying Loop
- Galvanometer
- Loudspeakers
- Cyclotrons
- The Hall Effects



$\phi = 90°$, Max τ

$\phi = 0°$, Min τ

GALVANOMETER



$$\boxed{\tau_{loop} = NIAB\sin\phi}$$

$\tau_{spring} = k\theta$

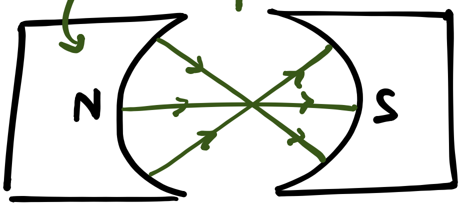
$\tau_{loop} = \tau_{spring}$

$NIAB\sin\phi = k\theta$

$$\boxed{\theta = \frac{NIAB\sin\phi}{k}}$$

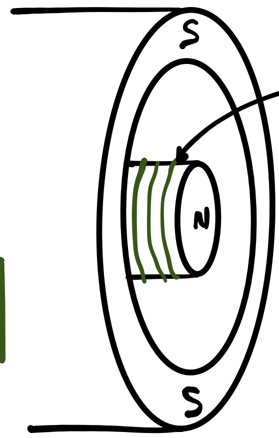
$\theta \propto I$

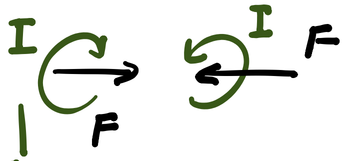
curved pole magnet



$\theta = \frac{NIAB}{k}$

LOUDSPEAKER

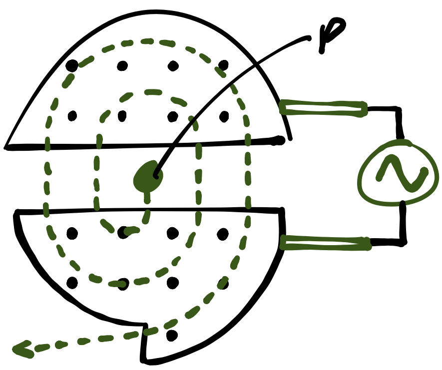




$$\boxed{F = ILB}$$

number of turns × circumference

CYCLOTRONS



Cyclotron Frequency

$w = \frac{qB}{m}$ (rad s^{-1})

Oscillator Frequency

$f = \frac{1}{T} = \frac{w}{2\pi}$

$= \frac{qB}{2\pi m}$

Kinetic Energy

$K = \frac{1}{2}mv^2 = \frac{r^2q^2B^2}{2m}$

HALL EFFECT

Hall Field

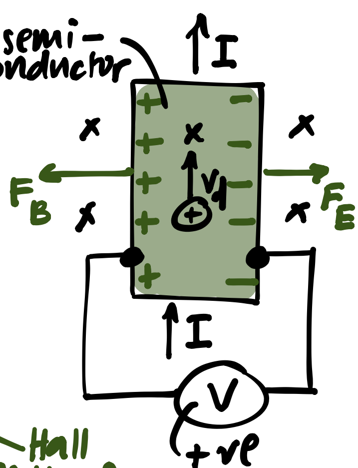
$F_B = F_E$

$qv_dB = qE_H$

$v_dB = \frac{V_H}{d}$

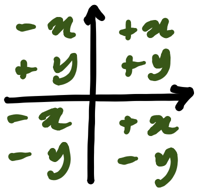
$v_d = \frac{V_H}{Bd}$

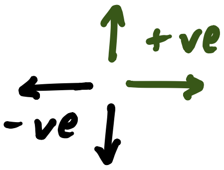
Hall voltage



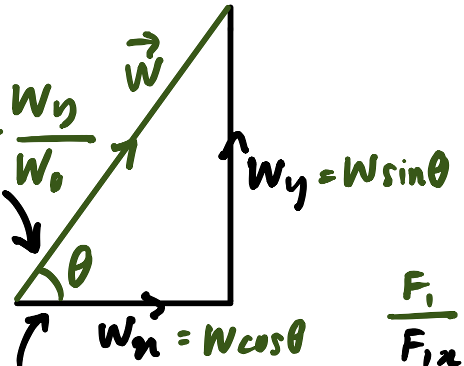
from $v_d = \frac{I}{nAq}$, $n = \frac{IB}{V_H t q}$

VECTORS QUICK GUIDE



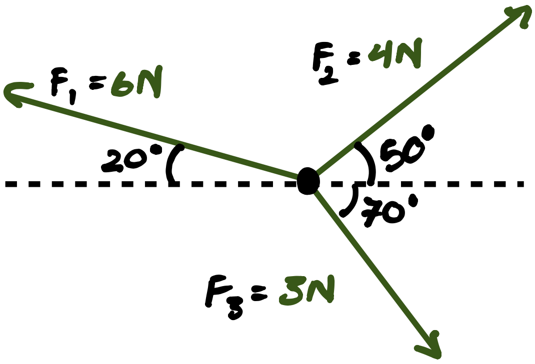


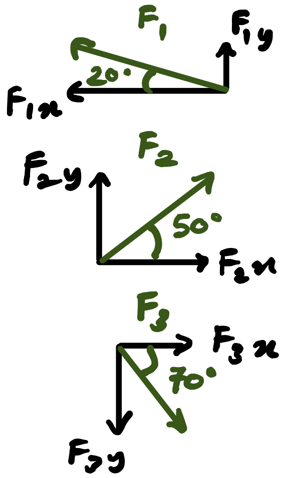
- Resolving vectors
- Resultant of vectors



$$\sin\theta = \frac{W_y}{W_0}$$

$$\cos\theta = \frac{W_x}{W}$$





F_1

$F_{1x} = -F_1 \cos 20°$

$F_{1y} = F_1 \sin 20°$

F_2

$F_{2x} = F_2 \cos 50°$

$F_{2y} = F_2 \sin 50°$

F_3

$F_{3x} = F_3 \cos 70°$

$F_{3y} = -F_3 \sin 70°$

$$\Sigma F = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2}$$

$$= 3.07N$$

$$\theta = \tan^{-1}\frac{\Sigma F_y}{\Sigma F_x}$$

$= 48.4°$ (in 2nd quadrant)

$\Sigma F_x = F_{1x} + F_{2x} + F_{3x}$

$= -6\cos 20° + 4\cos 50° + 3\cos 70°$

$= -2.04N$

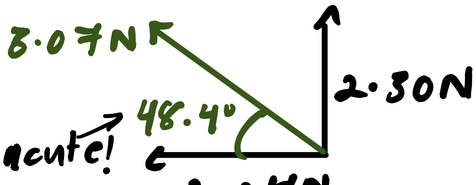
left!

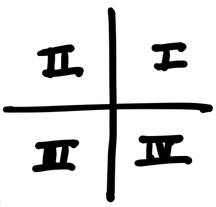
$\Sigma F_y = F_{1y} + F_{2y} + F_{3y}$

$= +6\sin 20° + 4\sin 50° - 3\sin 70°$

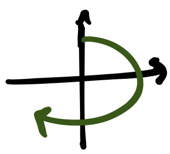
$= +2.30N$

upwards!





Bearing



angle is always with respect to the horizontal axis!