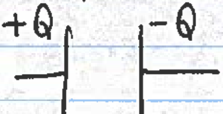
From electricity to electronics

Electricity (static)	Electronics
Electric field $\vec{E}$	Electric current
(stationary charges)	(moving charges)
Electric potential $V \Rightarrow \vec{E} = -\nabla V$	Potential difference - voltage

We know one element of the electronic circuit

Capacitor



potential diff

$\Delta V_+ - \Delta V_- = \frac{Q}{C}$

voltage

$V = Q/C$

Relations b/w voltage & charge

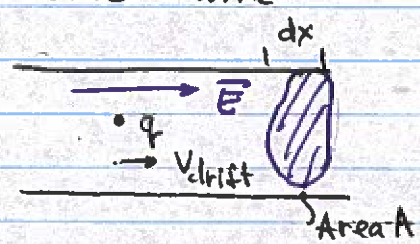
$V = Q/C$

Energy stored in a capacitor

$U_C = \frac{Q^2}{2C} = \frac{QV}{2} = \frac{CV^2}{2}$

How to make charges move? We need a force

Electric wire → neutral conductor



For historic reasons we consider current carrier positive charges

To make it move, we need a force

How much charge flow through A per unit time?

$I = \frac{dQ}{dt} = \frac{q \cdot A \cdot n_q \cdot dx}{dt} =$

$V_{drift} \propto E$

(not obvious, discuss later)

$= q \cdot n_q \cdot A \cdot V_{drift} \propto q \cdot n_q \cdot A \cdot E$

($q \cdot n_q$ — depends on material)

In general $I = A \cdot \sigma \cdot E = A \cdot \frac{1}{\rho} \cdot E$

σ – conductivity
$\rho = \frac{1}{\sigma}$ – resistivity
} material property

$\vec{E}$ is constant inside the wire $E = \frac{V}{\ell}$

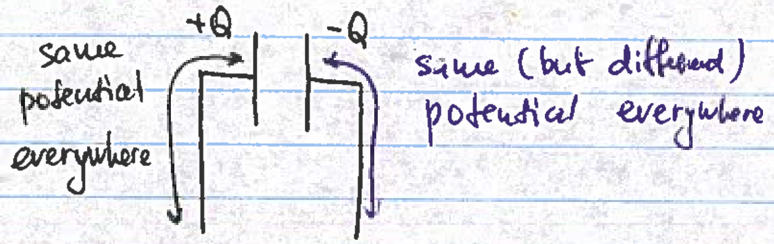
$I = A \cdot \sigma \cdot \frac{V}{\ell} \Rightarrow V = I \cdot \frac{\ell}{\sigma A} = I \frac{\rho \ell}{A}$ — R resistance

Ohm's law $V = I \cdot R$

① We need voltage to create current

② If $R = 0$ (ideal wires w/o resistance), $V = 0$

Unless explicitely stated, we consider wires to have no resistance, so they connect points with same potential

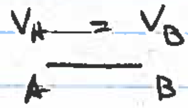


To charge a capacitor we need to provide a source of electric force moving the charges

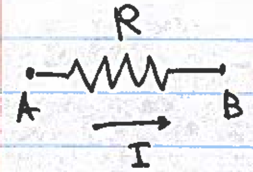
Electromotive force, or emf (ideal battery)

$\mathcal{E}$ is the max constant voltage the battery provides

Common notation

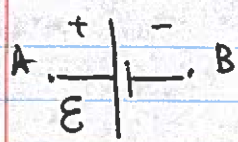


– connecting wire. Normally no resistance, connects points with same potential



– resistor; voltage drop across a resistor

$V_A - V_B = IR$



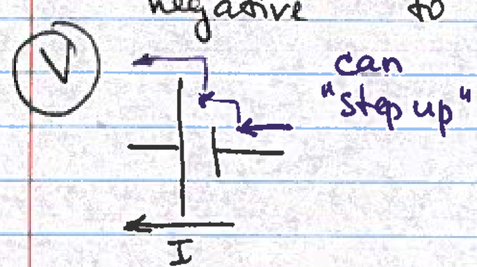
– battery (emf)

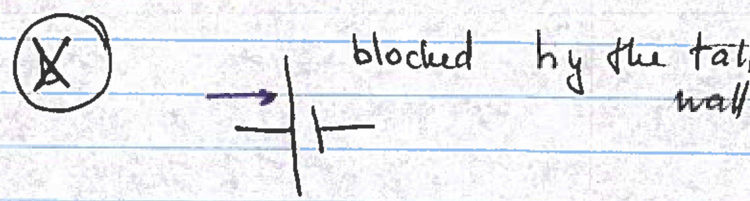
$V_A - V_B = \mathcal{E}$

Some memory tricks I use!

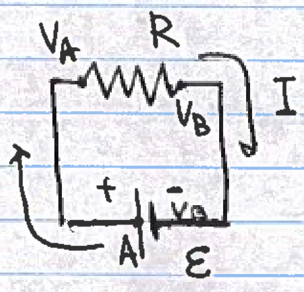
1. "long" terminal of the battery is +, since one can break a longer stick in two pieces to make +

2. The battery will try to push current from negative to positive terminal



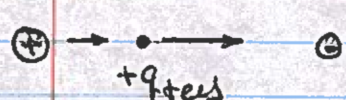


A simplest circuit



Since we (historically) assume positive current carriers, the current flows naturally from positive to negative terminal

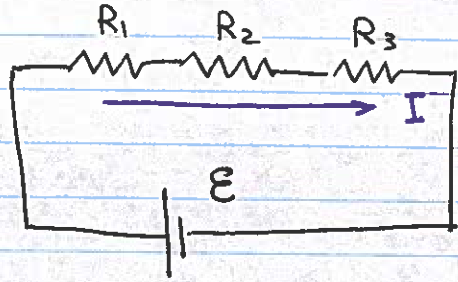
$V_B = V_A - IR$



$V_A = V_B + \mathcal{E} = V_A - IR + \mathcal{E} \Rightarrow IR = \mathcal{E}$

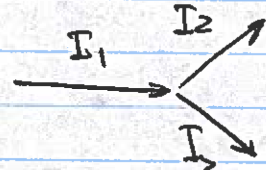
$I = \mathcal{E}/R$

If we have different resistors <u>in series</u> the current through all of them is the same (because there is no other way for charges to go



$$\mathcal{E} = \underbrace{IR_1 + IR_2 + IR_3}_{\text{voltage drop of each resistor}} = I(R_1+R_2+R_3$$

<u>junction</u>

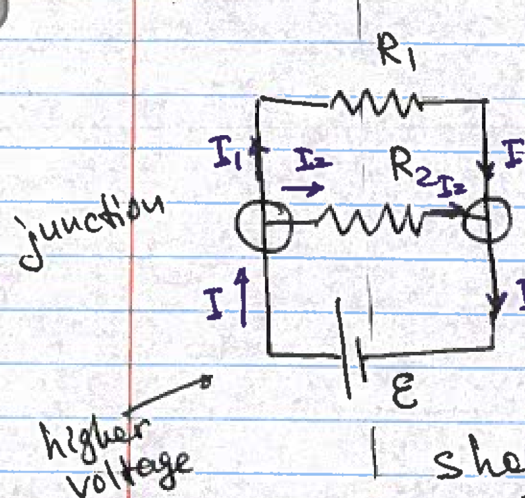


$I_1 = I_2 + I_3$

If a wire splits, currents add up

$I_{incoming} = I_{outgoing}$

Parallel connection of resistors



Here there is 3 different currents

On both junctions

$I = I_1 + I_2$

Plus, voltage change across each element (here) should be the same

$$I_1R_1 = I_2R_2 = \mathcal{E}$$

$$I_1 = \frac{\mathcal{E}}{R_1} \qquad I_2 = \frac{\mathcal{E}}{R_2}$$

$$I_{tot} = I_1 + I_2 = \frac{\mathcal{E}}{R_1} + \frac{\mathcal{E}}{R_2} = \mathcal{E}\frac{R_1R_2}{R_1+R_2}$$