# Lecture 14: Current,Resistance, Ohm's Law

- Current is motion of charges
- Charge carriers in metals are electrons
- Current is created by a potential difference due to an electric field

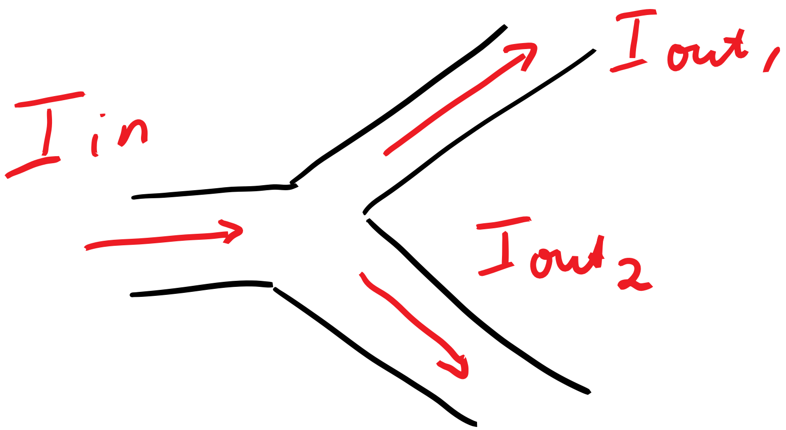
Electric field is zero inside conductor in static equilibrium.

Now: charges move!

# Conservation of current

Current is the same at all points in a current-carrying wire.

Current is not "used up". Charge cannot be created or destroyed.
"What goes in must come out".



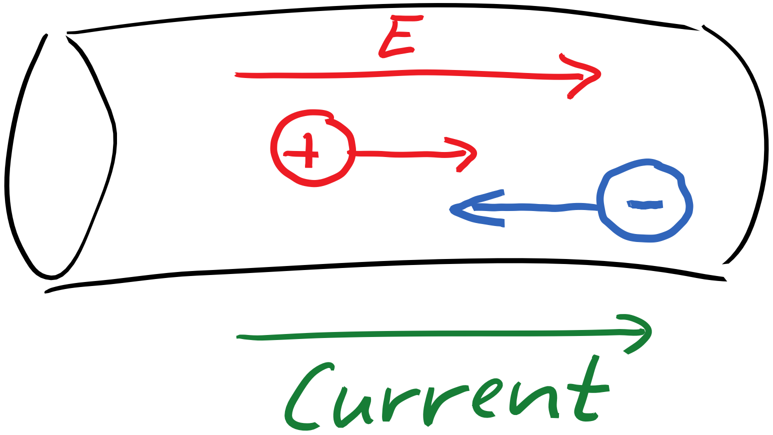

$$\sum I_{in} = \sum I_{out}$$

Kirchhoff's junction rule

# Direction of current

Current is defined as the flow of positive charges. The actual charge carriers in metals are negative electrons. They move in the opposite direction.

$$I = \frac{\Delta q}{\Delta t}$$




Unit: 1C/1s= 1A Ampere

# Batteries

Chemical reactions between electrolyte and electrodes cause separation of positive and negative charges
Work done comes from chemical energy

$\mathcal{E} = W_{chem}/q$ electromotive force

$\Delta V_{bat} = \mathcal{E}$ *

*In reality, slightly less because of internal resistance which we will ignore

Batteries in series: voltages add

# Resistance and resistivity

Current increases proportional to applied voltage

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

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

Resistance

Unit: 1V/1A= 1Ω Ohm

Resistance depends on:

- Material
- Length of wire
- Cross section

Resistance is a device property.

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

ρ resistivity (lower case Greek "rho")
Unit: Ωm
Material property

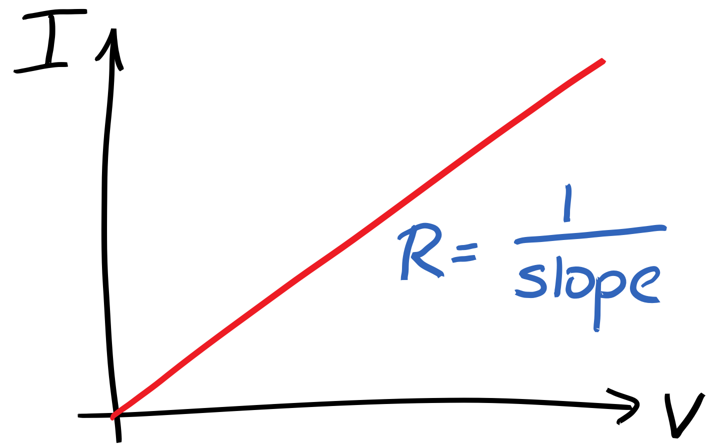
# Example

A Nichrome wire is 15 cm long. If a potential difference of 1.5V is applied, the current through the wire is 2.0A.
What is the diameter of the wire?

# Ohm's Law and Power

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

Ohm's Law

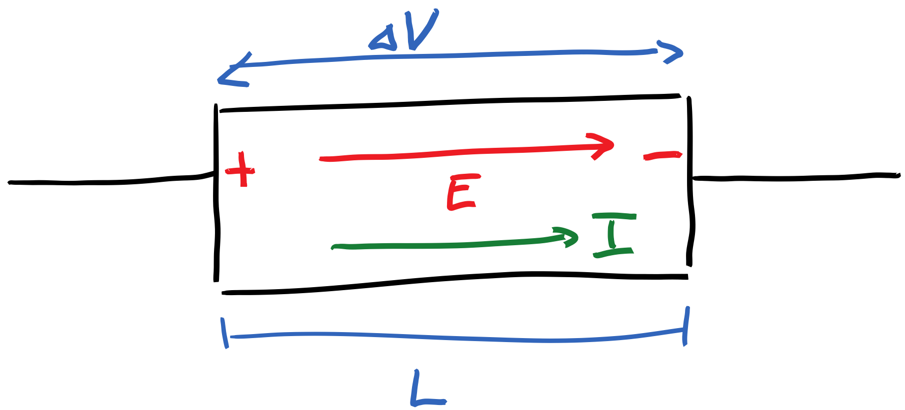



Ohmic materials obey Ohm's Law

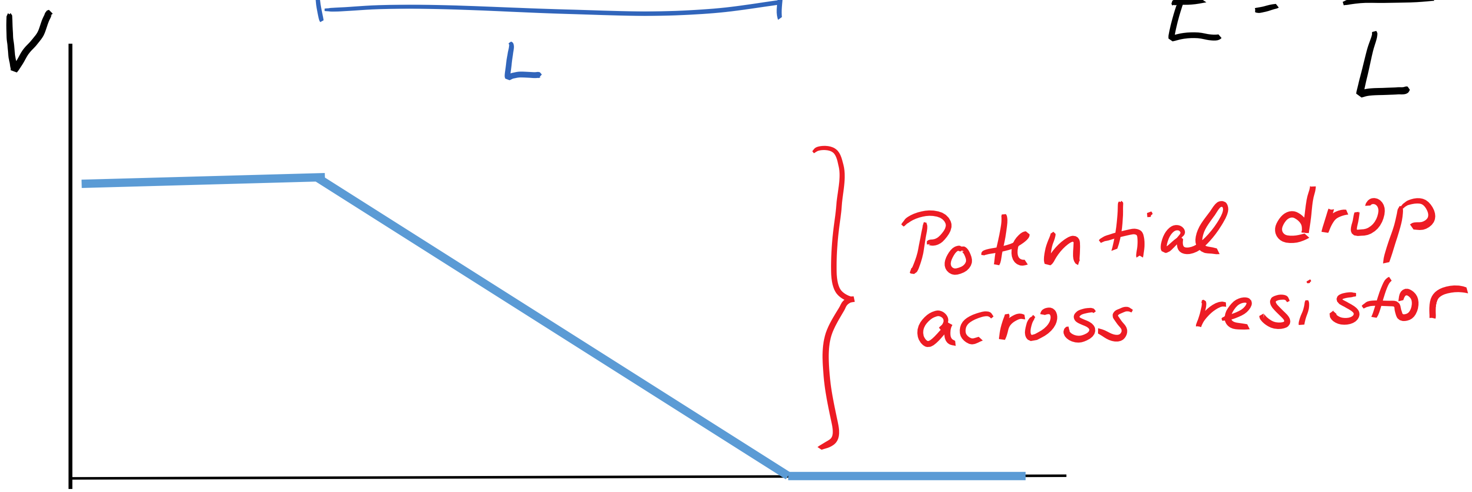
Exceptions: batteries, semiconductors, capacitors, other devices

# Current flow through resistor

Assume “ideal wires” (R=0).
In reality: R wire << R circuit element
Example: flashlight bulb R=3Ω; wire connecting bulb to battery: R=0.01Ω




$$E = \frac{\Delta V}{L}$$



# Energy and Power

Battery supplies $\Delta U = q\mathcal{E}$ to each charge

Per time $\Delta t$, amount of charge $\Delta q$ moves through battery

Power: $P_{battery} = \frac{\Delta q \mathcal{E}}{\Delta t} = I\mathcal{E}$

In resistor: charge loses potential energy (transformed to kinetic energy and then to heat)

$$P_R = I\Delta V_R$$

With Ohm's law:

$$P_R = I\Delta V_R = I^2 R = \frac{(\Delta V_R)^2}{R}$$

Demo

# Example

An electric heater draws 15.0A on a 120V line.
How much power does it use?
How much energy does the heater use per hour?
How much does it cost to run it for 3 hours/day for 30 days,
if electric company charges 9.3ct per kWh?