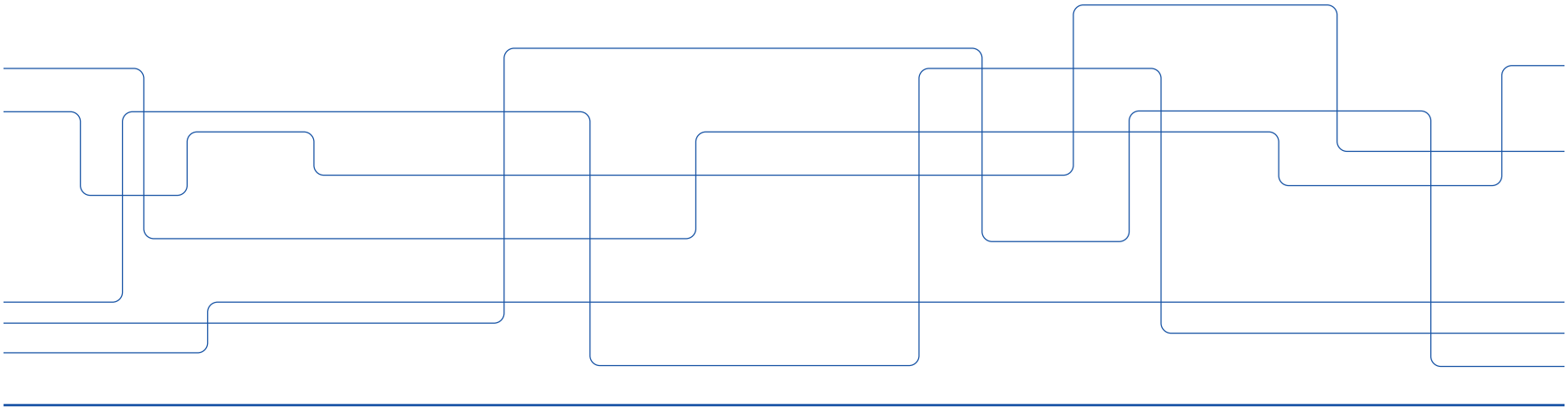
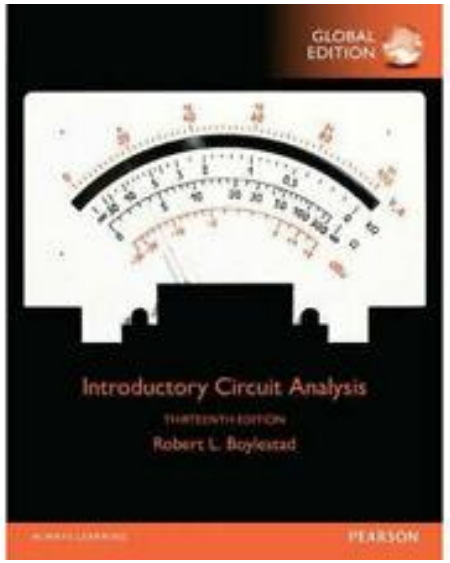
HE1027 Electrical Principals

Lecture 1: Basic concepts



Course Structure

- 10 lectures (digital)
- 7 exercises (physical)
- 6 online quizzes (optional)
- 5 labs (physical)
  - book times in the calendar
- 2 partial exams (optional, physical)
  - April 11
  - May 16
- written exam (physical)
  - June 3



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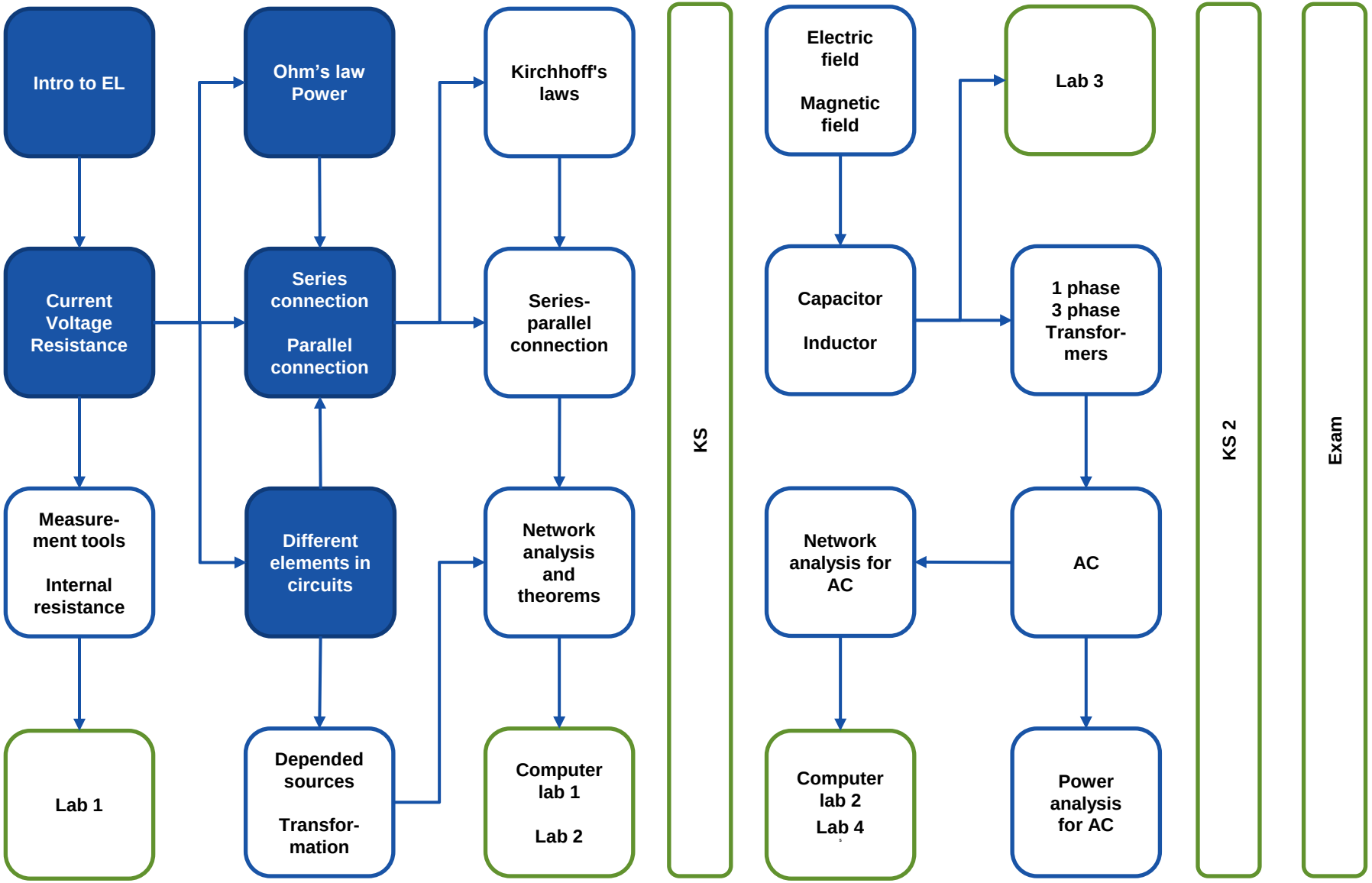


Already covered

Is covered today

Will be covered

What is ELECTRICITY?

Electricity is a form of energy that can be changed into other forms

Two Types of Electricity

Static electricity produced when some materials are rubbed together

Current electricity is caused by electrons that move through metal

Where does Electricity come from?

Power Stations

Supply a lot of energy

Power generators

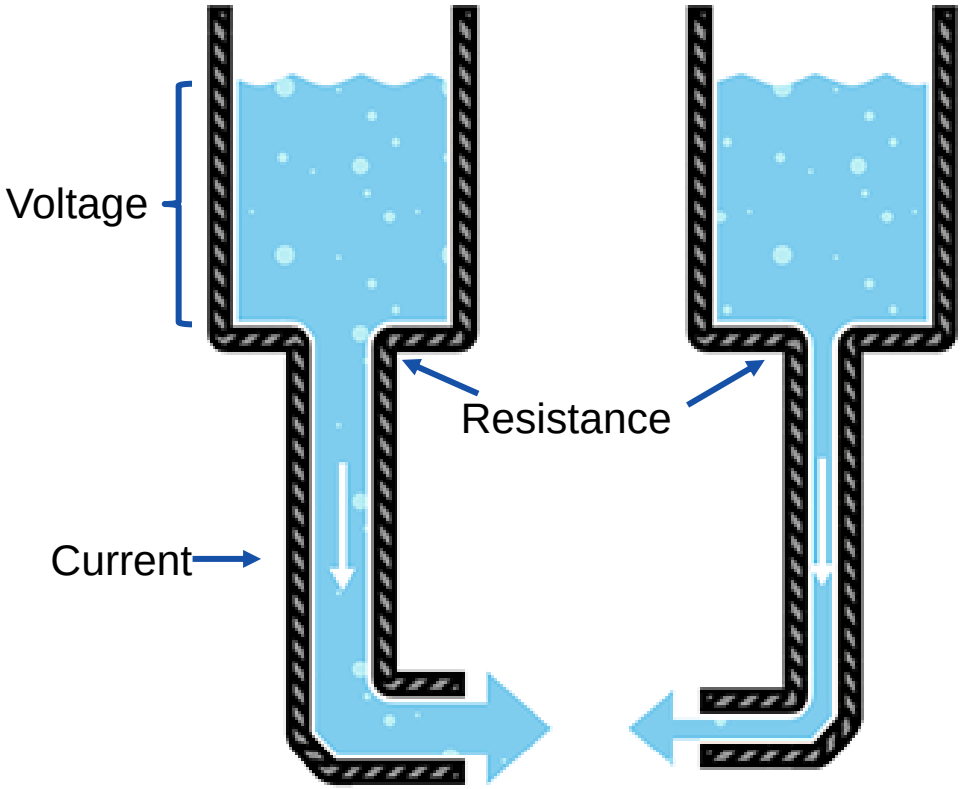
Similar to power stations

Electric batteries

Supply a little electricity
Portable
Safe

Electrical Units

- Basic units of measurement
  - Current (amperes A)
  - Voltage (volts V)
  - Resistance (ohms Ω)



Current

- To make an electrical appliance work, electricity must flow through it

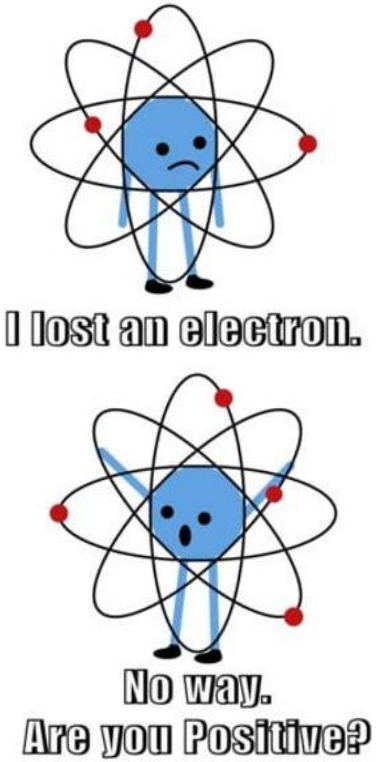
- The flow of electricity is called an ***electric current***
  – An electric current is the rate of flow of ***electric charges*** in a circuit

- The path along which the electric current moves is called the ***electric circuit***

Electric Charge and Current

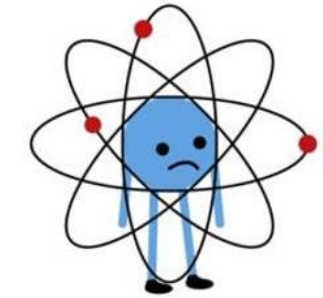
- Atoms have positive protons and negative electrons, where $Nr_{protons}=Nr_{electrons}$

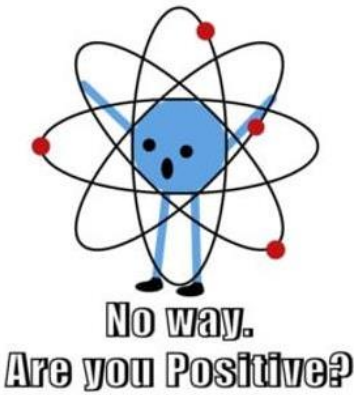
- Some electrons can leave their atoms and flow without any specific direction



Electric Charge and Current

- Atoms have positive protons and negative electrons, where $Nr_{protons}=Nr_{electrons}$
- Some electrons can leave their atoms and flow without any specific direction
- Charge (Q) is measured in ***coulombs (C)***
  1 coulomb = 6 242 000 000 000 000 000 electrons
- When wire is connected to an electric source, electrons in the wire start to move from negative terminal to positive. This flow is ***electric current***





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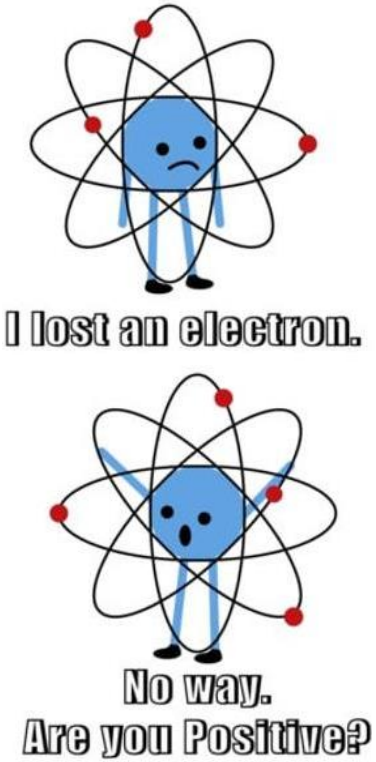
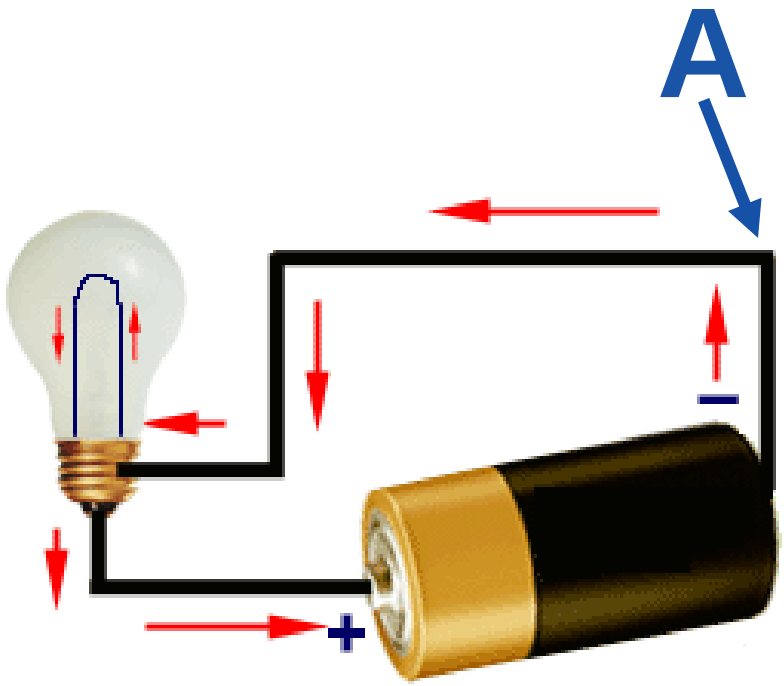
- When wire is connected to an electric source, electrons in the wire start to move from negative terminal to positive. This flow is ***electric current***
- Electric current (I) is measured in ***amperes (A)***
  1 ampere =1 coulomb / 1 second



Example 1

– The charge in point A is 0.16 C
– The charge flows every 64 ms.

– *What is a current in that point?*



$$I = \frac{Q}{t} = \frac{0{,}16}{0{,}064} = 2{,}5A$$

Example 2

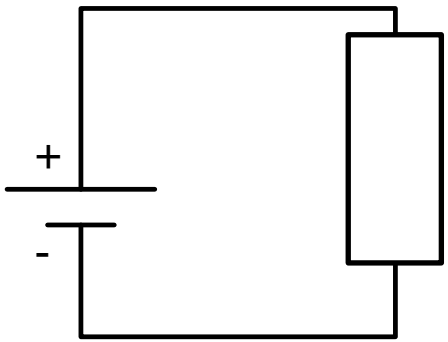
– The current is 5mA

– *How long it will take for $4*10^{16}$ electrons to pass?*

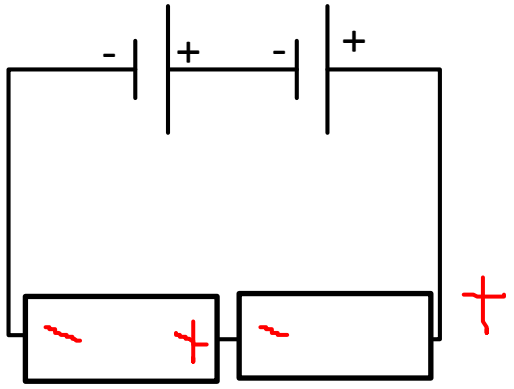
$$Q = \frac{4 \cdot 10^{16}}{6.242 \cdot 10^{18}} = 6.41 \cdot 10^{-3} C$$

$$t = \frac{Q}{I} = \frac{6.41 \cdot 10^{-3}}{5 \cdot 10^{-3}} = 1{,}28 s$$

Current Flow



- Electron flow goes from negative to positive
- However, in analysis is used **convention flow**
- Convention flow goes from highest to lowest (from positive to negative)
- Similar high and low we can determine for all elements by determine by looking how element changes potential



Voltage

- An electric cell gives energy to the electrons and pushes them round a circuit. Voltage is a measure of how much energy the electrons receive

- Voltage (V) = $\frac{\text{energy (W)}}{\text{charge (Q)}}$

- Different voltages are supplied by different cells and batteries

Resistance: Conductors and Insulators

- When an electric current flows through a circuit, there will be some resistance that opposes it

Low resistance	**High resistance**
Good conductors	Poor conductors
Superconductor $\rho=0$	Superinsulators $\rho=\infty$
Silver $\rho= 1.59 \times 10^{-8}$	Teflon $\rho=10^{24}$
Copper $\rho=1.68 \times 10^{-8}$	Dry wood $\rho=10^{15}$
Gold $\rho=2.44 \times 10^{-8}$	Air $\rho=10^{12}$
Aluminium $\rho=2.65 \times 10^{-8}$	Rubber $\rho=10^{13}$
Iron $\rho=9.7 \times 10^{-8}$	Diamond $\rho=10^{12}$

$$\text{Resistance}(R) = \frac{\text{resistivity}(\rho) * \text{length}(L)}{\text{cross sectional area } (A)}$$

Resistors

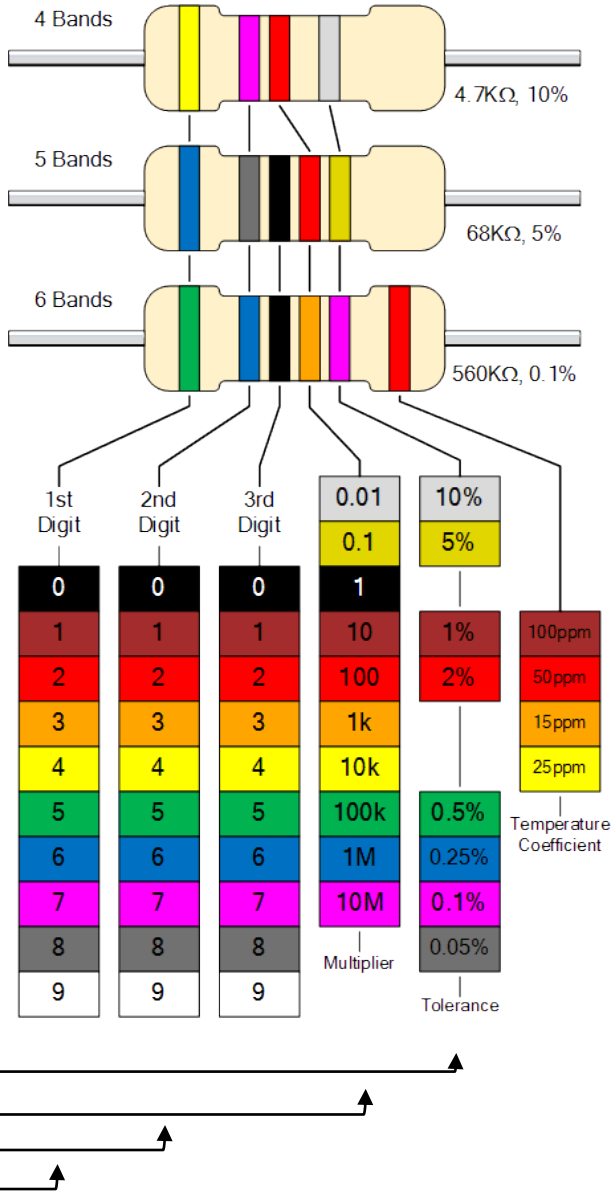
- Resistors are electrical components that are specially made to have a certain resistance
- Resistors are connected in a circuit to resist the current flow
- Resistors can be:
  - fixed resistors (only one resistance value)
  - variable resistors (resistors can be adjusted to change the resistance)

Resistor Color-coding

- Thin-film resistors use colour coding based on 4, 5 or 6 bands
- If 4 bands: 1st digit, 2nd digit, multiplier, tolerance
- If 5 bands: 1st digit, 2nd digit, 3rd digit, multiplier, tolerance
- If 6 bands: 1st digit, 2nd digit, 3rd digit, multiplier, tolerance, temp coof

$100\Omega \pm 5\%$

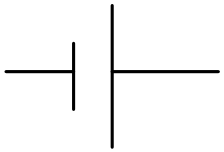
1 0 x 10 ± 5%



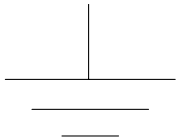
Drawing Circuits

wire

inductor

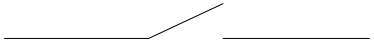


Voltage source

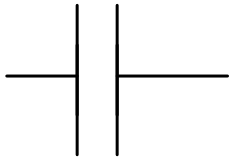


earth

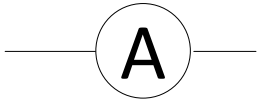
power supply



switch

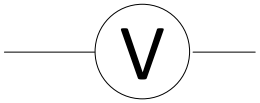


capacitor



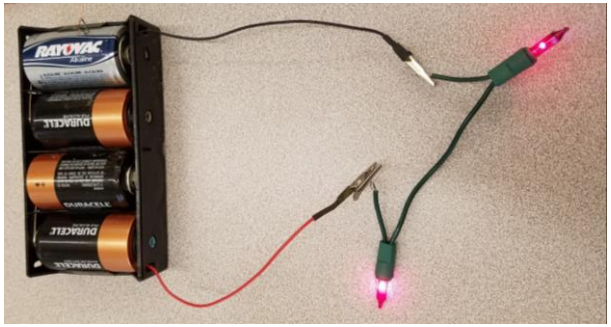
ammeter

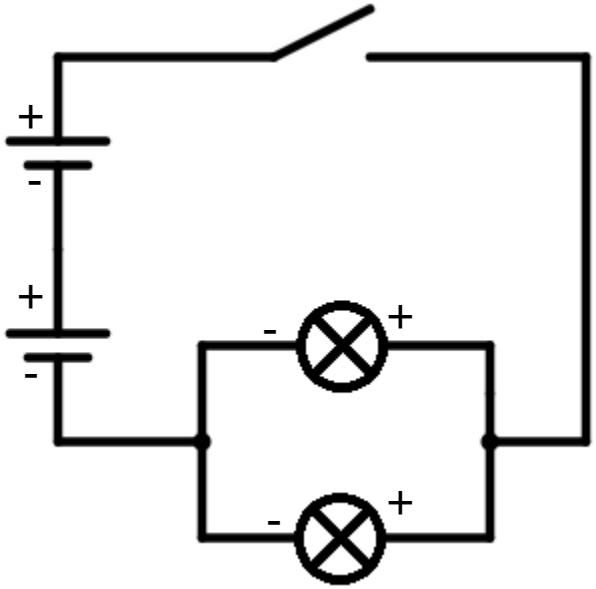
resistor

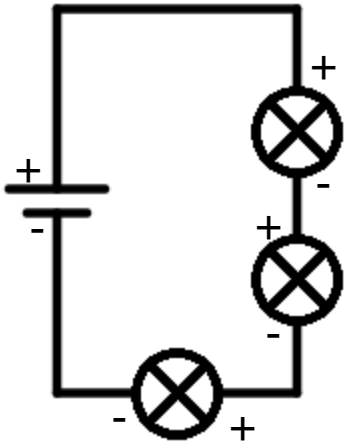


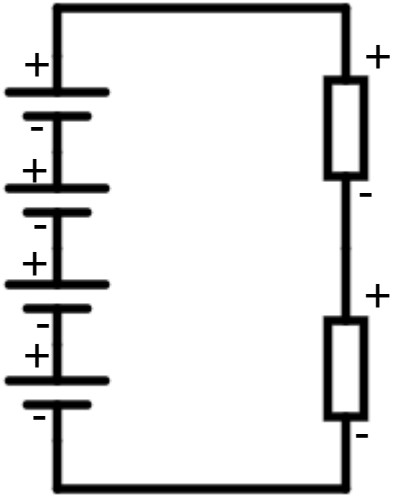
voltmeter

Examples







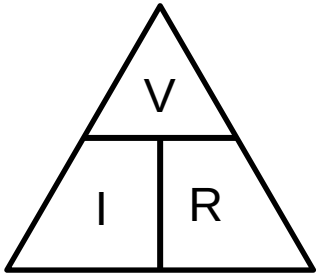


Ohms Law

- Current through a conductor between two points is directly proportional to the voltage across the two points

- Current (I) = $\frac{\text{Voltage (V)}}{\text{Resistance (R)}}$

- $I = \frac{V}{R}$ $\qquad V = I * R$ $\qquad R = \frac{V}{I}$



- V is applied to voltage drops
- E is applied to voltage sources

$V=E$

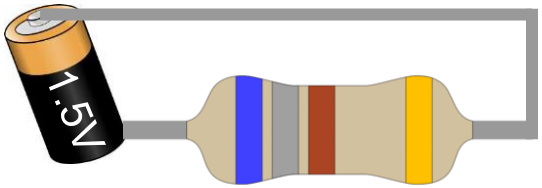
Example 1

What is a resistance of a light bulb if current is 500 mA and voltage is 220V?

$$I = \frac{V}{R} \rightarrow R = \frac{V}{I} = \frac{220}{0{,}5} = 440\Omega$$

Example 2

- What is a current?

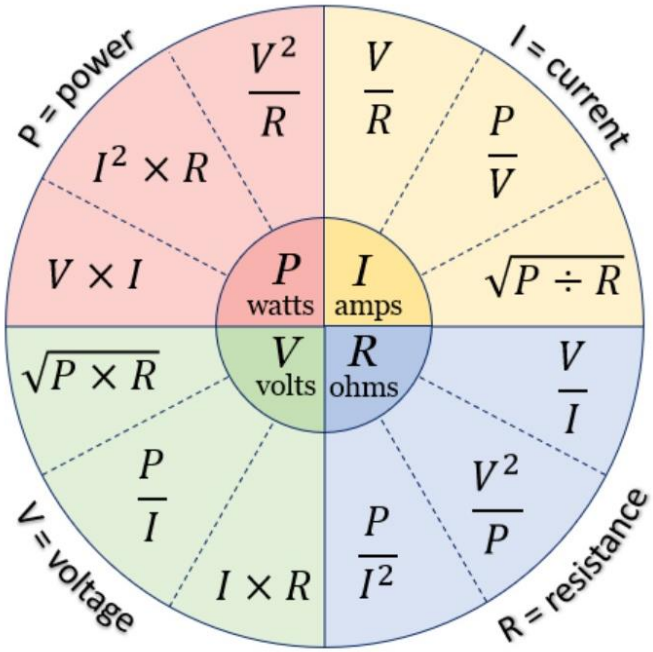


$$I = \frac{V}{R} = \frac{1{,}5}{68 \cdot 10} = \frac{1{,}5}{680} = 2{,}2mA$$

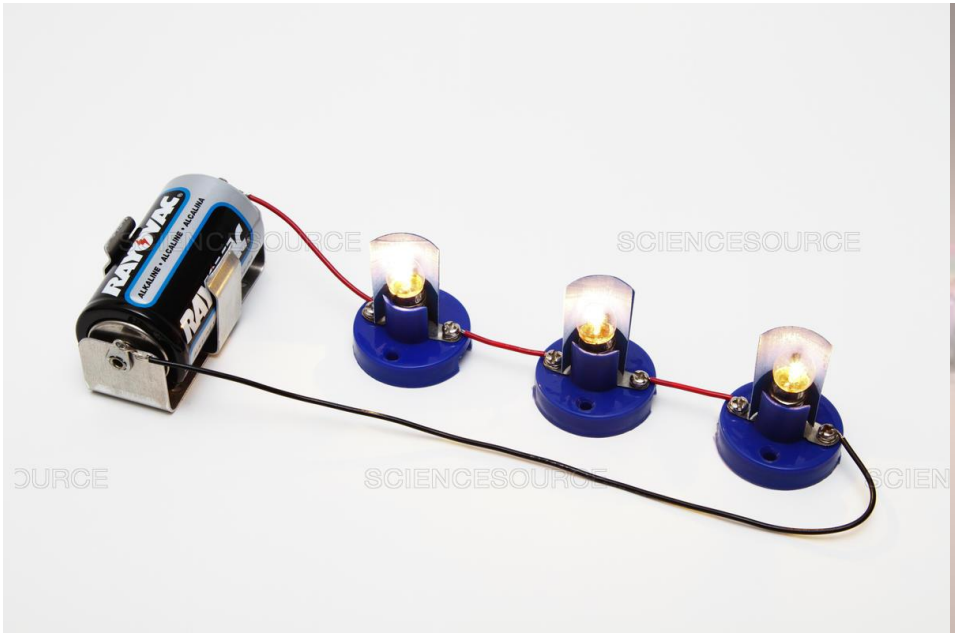
Power

- Power shows how much work (energy conversion) can be done in a specific amount of time

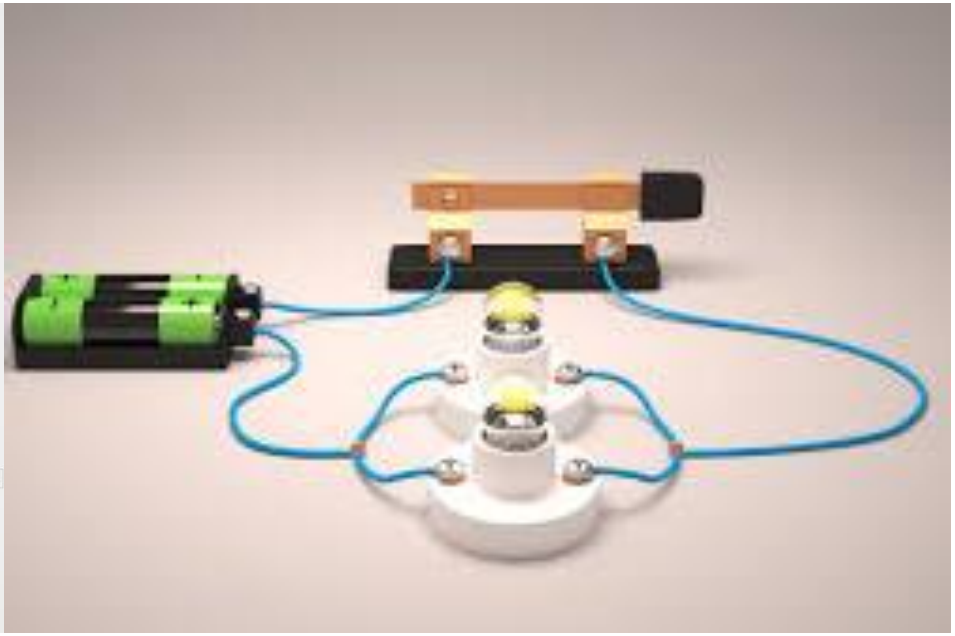
- Power (P)= $\frac{\text{energy (W)}}{\text{time (t)}}$



Different Types of Connection

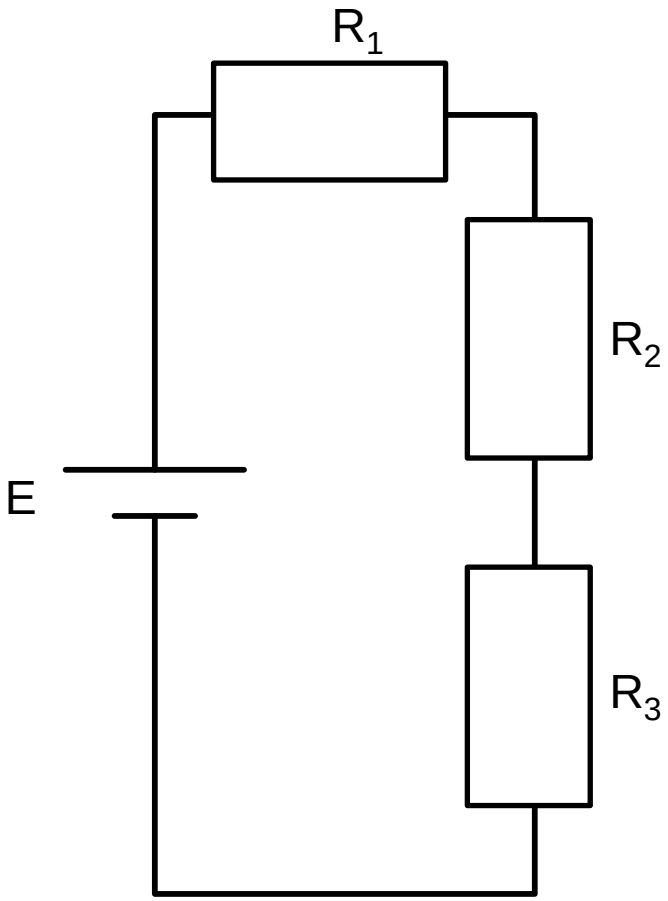


Series Connection



Parallel Connection

Series Circuits



- The total resistance of a series configuration is a sum of the resistance levels

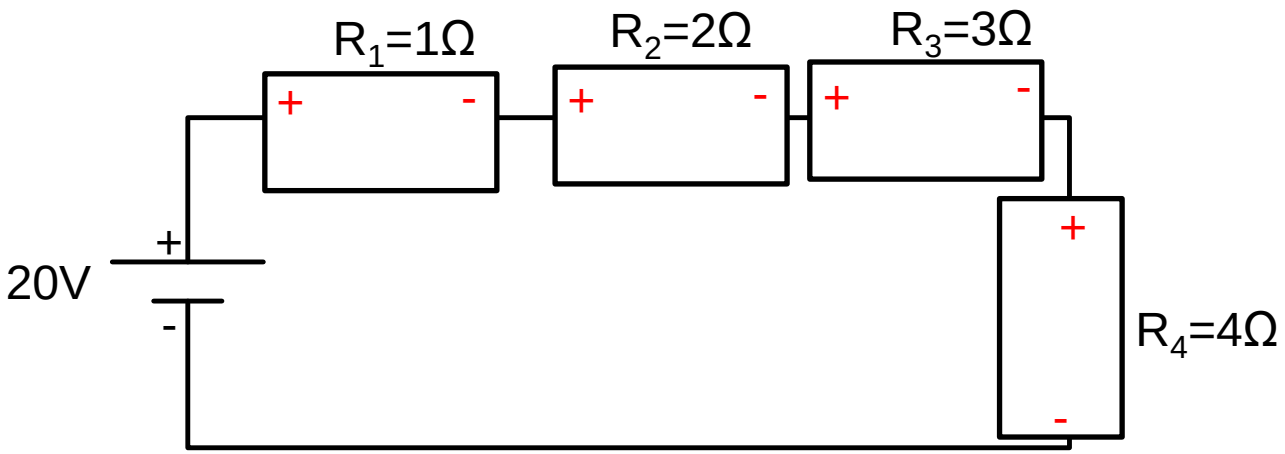
$$R_T=R_1+R_2+R_3$$

- The current is the same at every point in a series circuit

$$I_T=I_1=I_2=I_3 \qquad I_T=\frac{E}{R_T}$$

- Voltage is calculated for each element

Example



Determine the voltage across each resister and indicate their polarity

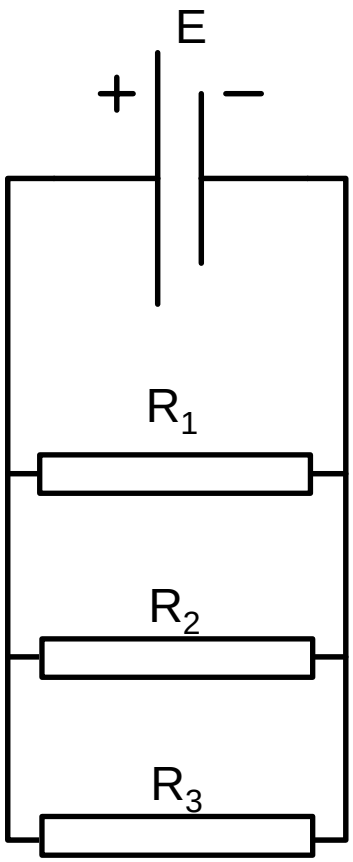
$$R_{Total} = 1\Omega+2\Omega+3\Omega+4\Omega=10\Omega$$

$$I_{Total} = I_1 = I_2 = I_3 = I_4 = \frac{E}{R_{Total}} = \frac{20}{10} = 2A$$

$$V_1 = R_1 \cdot I_1 = 2V \qquad V_3 = R_3 \cdot I_3 = 6V$$

$$V_2 = R_2 \cdot I_2 = 4V \qquad V_4 = R_4 \cdot I_4 = 8V$$

Parallel Circuits



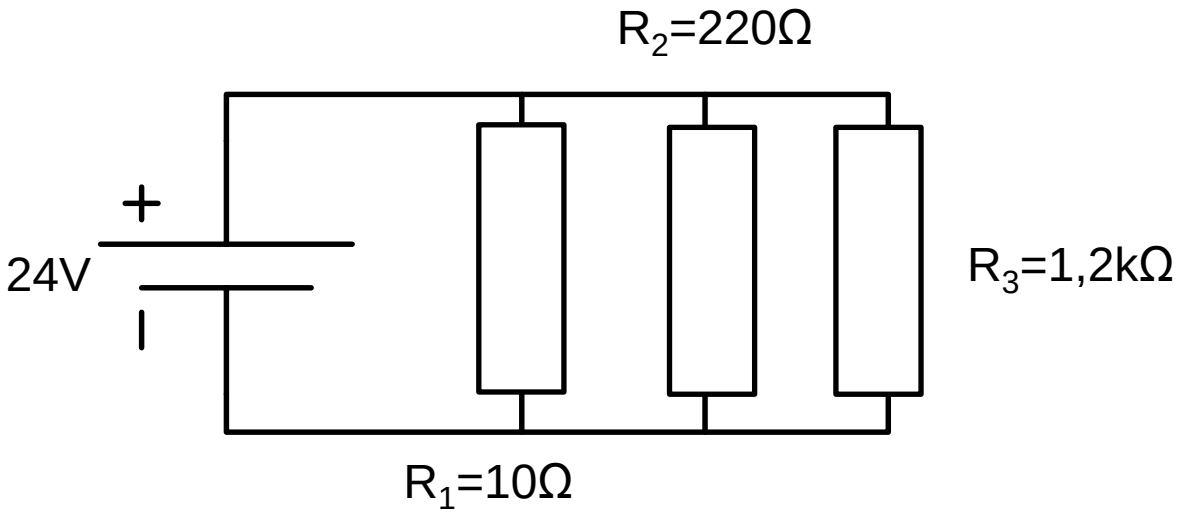
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Voltage is the same for all branches

Current is calculated for each element

For two parallel resistors: $R_T = \frac{R_1 \cdot R_2}{R_1 + R_2}$

Example



Determine the voltage through each branch

Since it is parallel connection, $V_1 = V_2 = V_3 = V_{Total} = 24\text{v}$

Find the total resistance

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{10} + \frac{1}{220} + \frac{1}{1200} = 0{,}10538 \qquad R_T = \frac{1}{0{,}10538} = 9{,}49\Omega$$

Calculate the source current

$$I = \frac{V}{R_T} = \frac{24}{9{,}49} = 2{,}53A$$

Determine the current through each branch

$$I_1 = \frac{V}{R_1} = \frac{24}{10} = 2{,}4A \qquad I_2 = \frac{V}{R_2} = \frac{24}{220} = 0{,}11A \qquad I_3 = \frac{V}{R_3} = \frac{24}{1200} = 0{,}02A$$

Suggested reading

Introductory Circuit Analysis

- Kap 1: 1.6 – 1.8
- Kap 2: 2.2 - 2.12, **2.2 - 2.8**
- Kap 3: 3.4, **3.5 - 3.8**, 3.9
- Kap 4: **4.2 - 4.5**
- Kap 5: **5.1 - 5.5**
- Kap 6: **6.2 - 6.4**

*suggestions in bold are more important

Suggested exercises

- Kap 1: 30-33
- Kap 2: 8-11, 14-17
- Kap 3: 34-35, 44
- Kap 4: 1-12, 24-28
- Kap 5: 3, 7, 10
- Kap 6: 7, 13, 15, 17