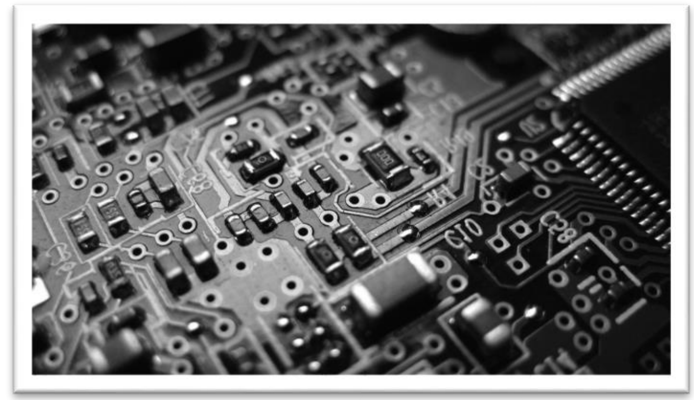
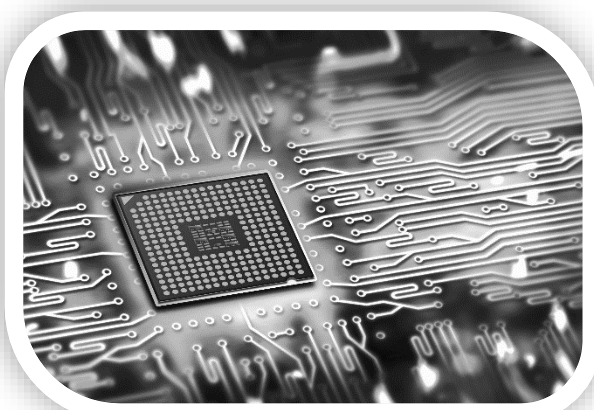
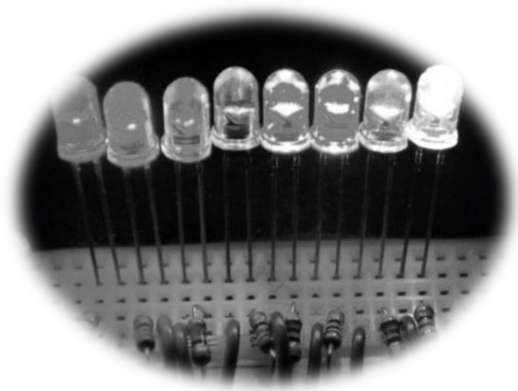
Introduction to Electronics
EHB222E







Grading

Grading: Two midterm exams (each 30%) and one final exam (40%).

Midterm exams: 4th of April and 16th of May

Before the final exam the sum of your midterm exam grades **should be larger than 50 (MT1+MT2} ≥ 50).**

Introduction to Electronics

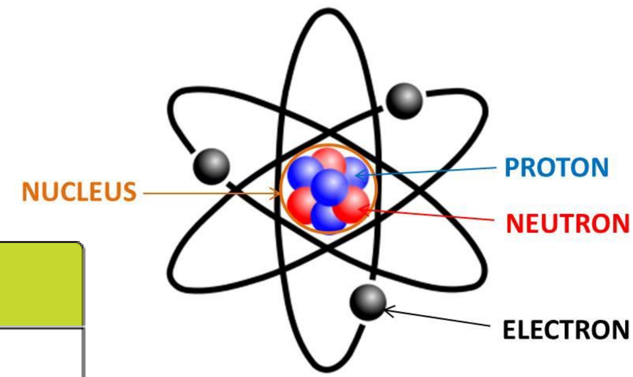
- Introduction
- Semiconductors & Doping, Basics of pn junction
- Diodes
- BJT Transistors
- MOSFET Transistors
- Operational Amplifiers

What is Electricity?

Atoms contain

1. Protons (+)
2. Neutrons (0)
3. Electrons (-)

Electricity is generated from the motion of tiny charged atomic particles called electrons and protons!



The unit of charge is Coulomb (C)

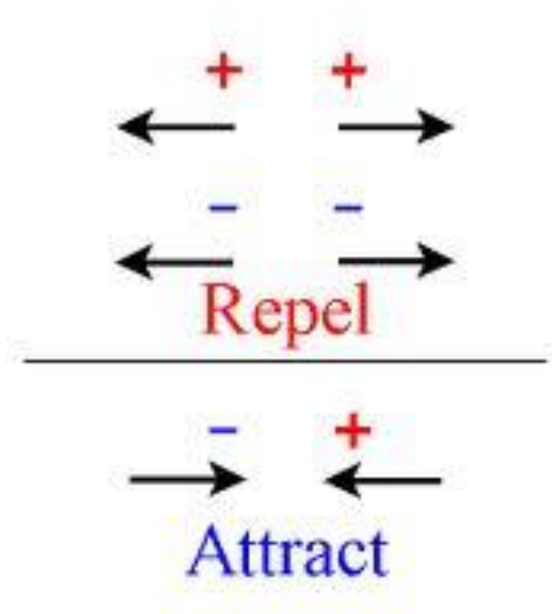
The Sub-atomic Particles			
Relative size	Name	Mass (Kg)	Charge (C)
	Proton	1.67×10^{-27}	$+1.602 \times 10^{-19}$
	Neutron	1.67×10^{-27}	0
size exaggerated	Electron	9.11×10^{-31}	-1.602×10^{-19}

Protons are positively charged and electrons are negatively charged.

Law of Electric Charges

The law of electric charges states that like charges repel, and opposite charges attract.

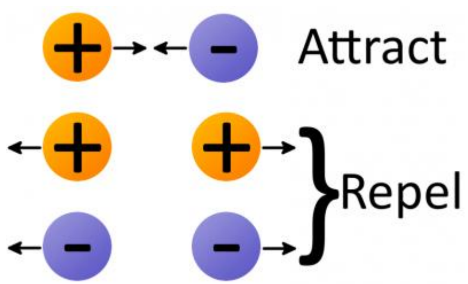
Protons are positively charged and electrons are negatively charged, so they are attracted to each other.

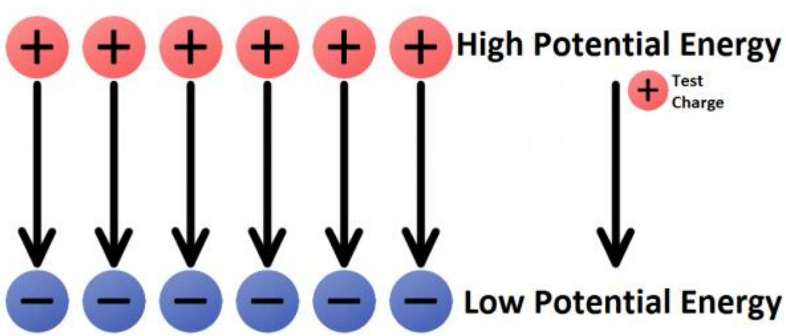


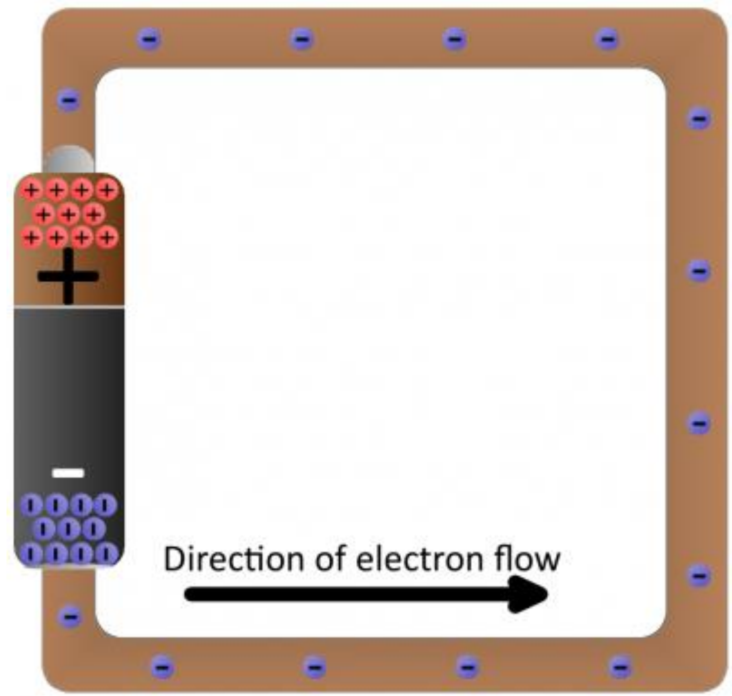
What is Voltage? - measured in *volts*.

Voltage is the difference in energy level from one end of the battery (or any other energy source) to the other.

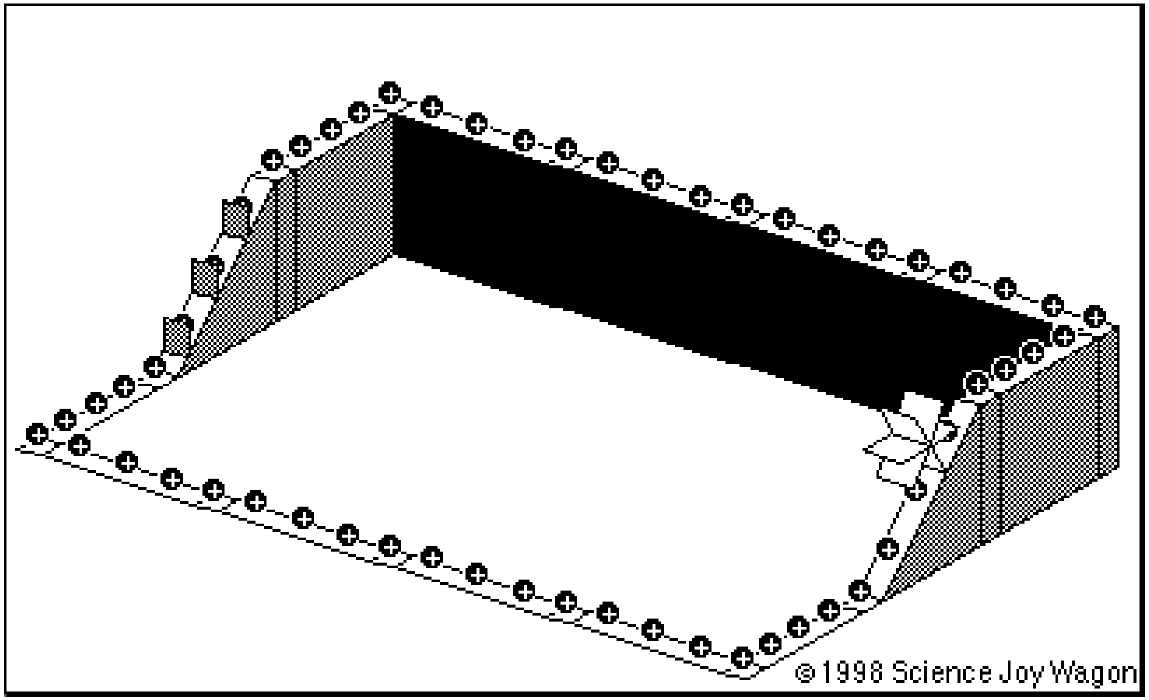
The **energy difference** causes **the negative charges to move from a lover voltage level to higher** voltage in a closed circuit.







A battery in an electrical circuit plays the same role as a pump in a water system.



A battery establishes a difference of potential that can pump electrons.

A battery pushes the electrons through the conductor.

Current

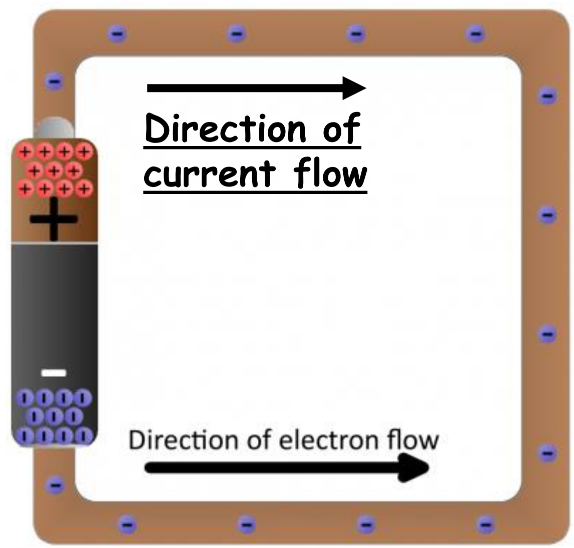
- Current is the **amount of electric charge** (coulombs) flowing through a cross section of a conductor in one second.

1 Ampere = 1 Coulomb/second

- Electron flow is from a lower potential (voltage) to a higher potential (voltage).
- Current flow is from a higher potential (voltage) to a lower potential (voltage).

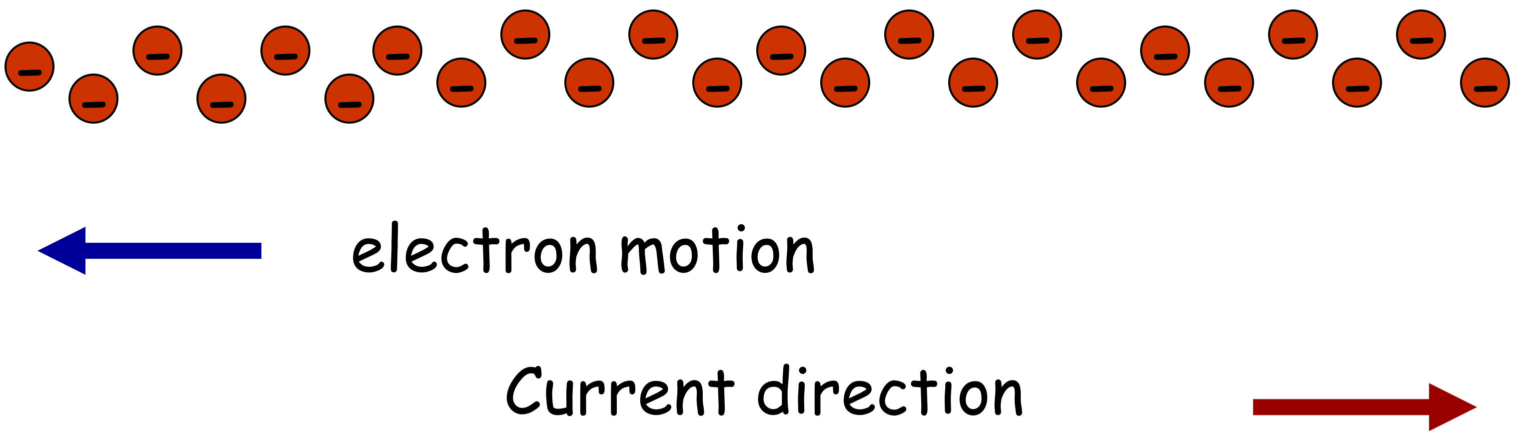
higher potential

lower potential



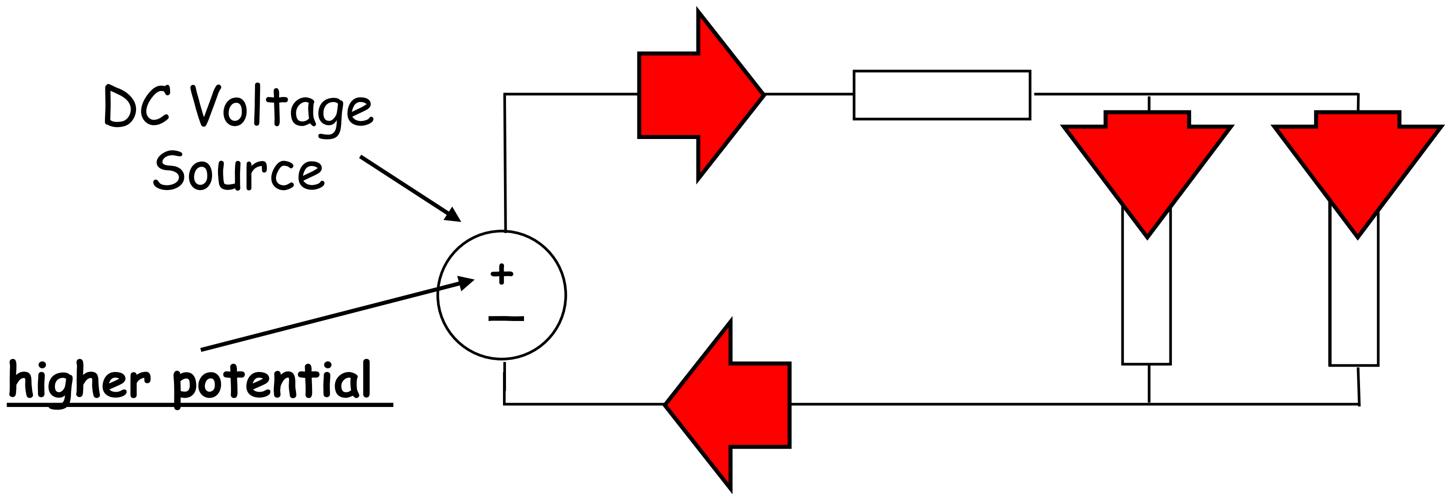
Sign Convention for Current Flow

- Electrons carry negative charge
- Current flow is in opposite direction



Current Flow

- The direction of current flow is indicated by an arrow.



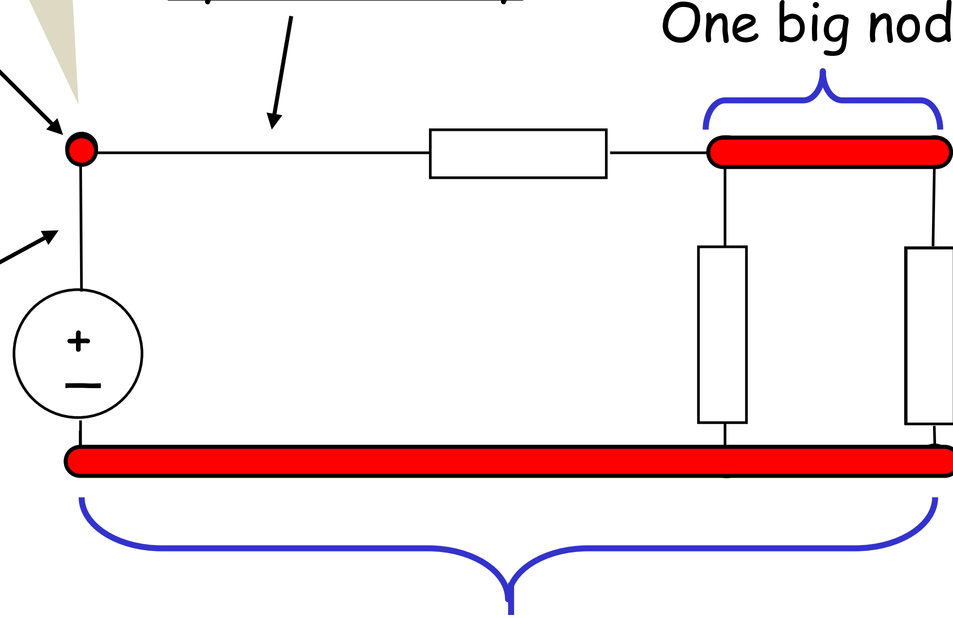
Current flow is from a higher potential (voltage) to a lower potential (voltage).

Note: The **voltage sources** in the circuit flow current through nodes and wires.

Electric Circuit

Intersection point of wires is call as a node

If two or more nodes are connected just by wires, intersection point can be considered as one single node.



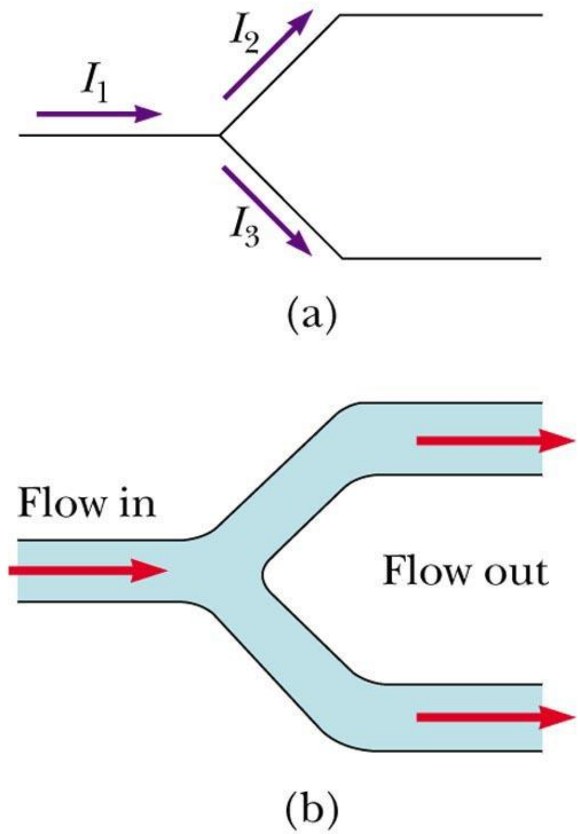
From Conservation of Charge

Current is the **amount of electric charge** (coulombs) flowing through a cross section of a conductor in one second.

The sum of charges flowing **into** a node must be equal to the sum of the charges flowing out of the node.

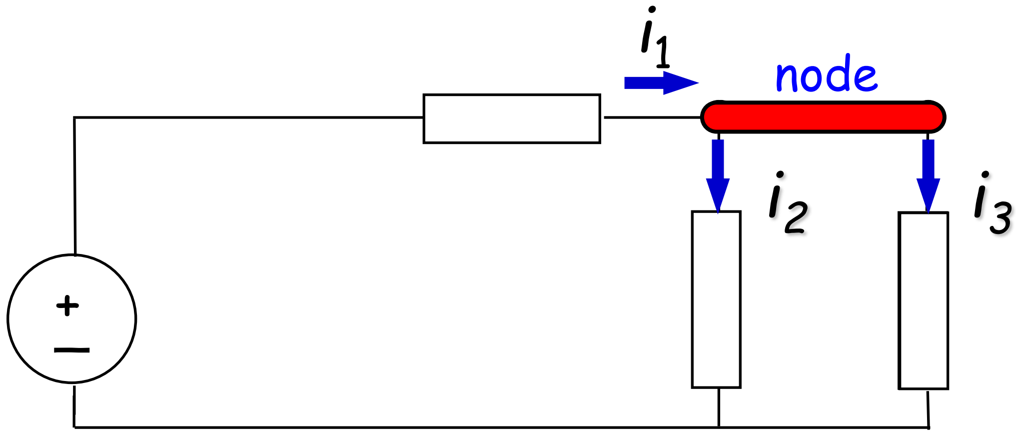
$I_1 = I_2 + I_3$

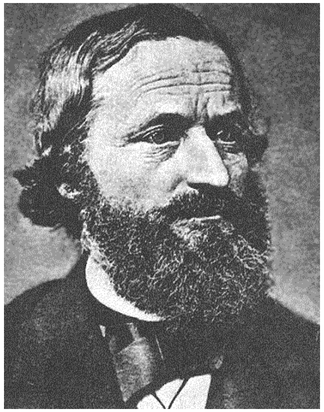
Diagram "b" shows a mechanical analogy



Kirchhoff's Current Law

- The sum of currents flowing **into** a node must be balanced by the sum of currents flowing **out** of the node.





Gustav Kirchoff
was an 18th century German mathematician

i_1 flows **into** the node

i_2 flows **out** of the node

i_3 flows **out** of the node

$$\boxed{i_1 = i_2 + i_3}$$

Sometimes Kirchhoff's Current Law is abbreviated just by

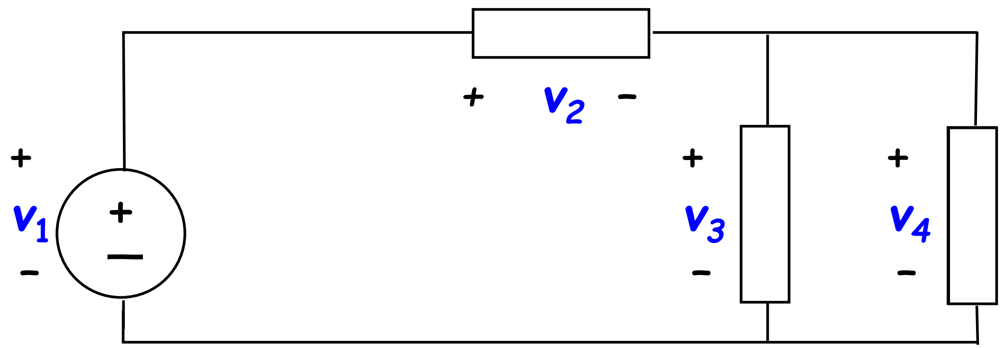
KCL

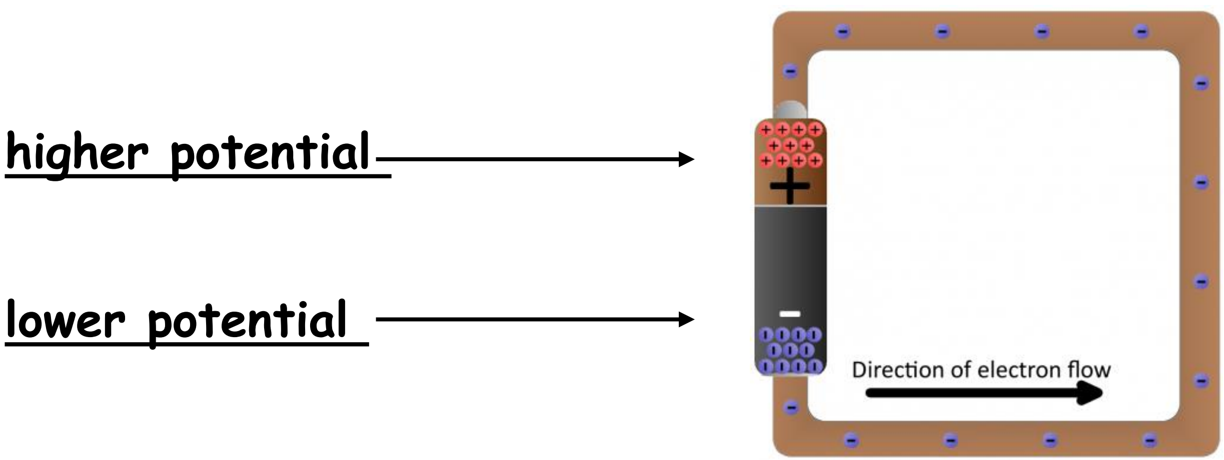
Review: Different ways to state KCL:

- ✓ The sum of *all* currents **entering** a node must be zero.
- ✓ The net current entering a node must be zero.
- ✓ Whatever flows into a node must come out.

Voltage (Difference in energy level)

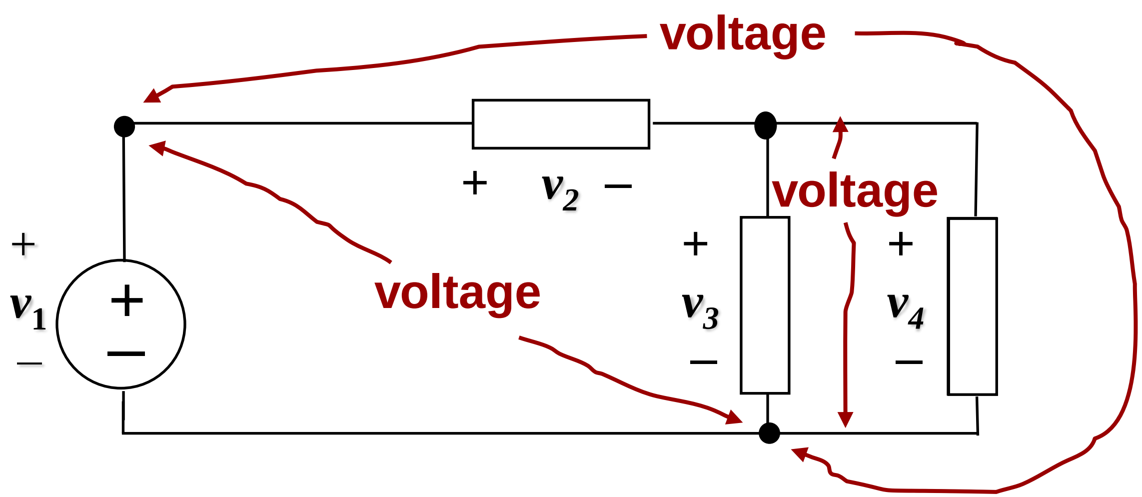
- **Voltages** are measured *across* the ***nodes*** of a circuit.
- The **direction** of a voltage is indicated by + and – signs.





Kirchhoff's Voltage Law

The voltage measured between any two nodes does not depend of the path taken.



Example of KVL: $v_1 = v_2 + v_3$

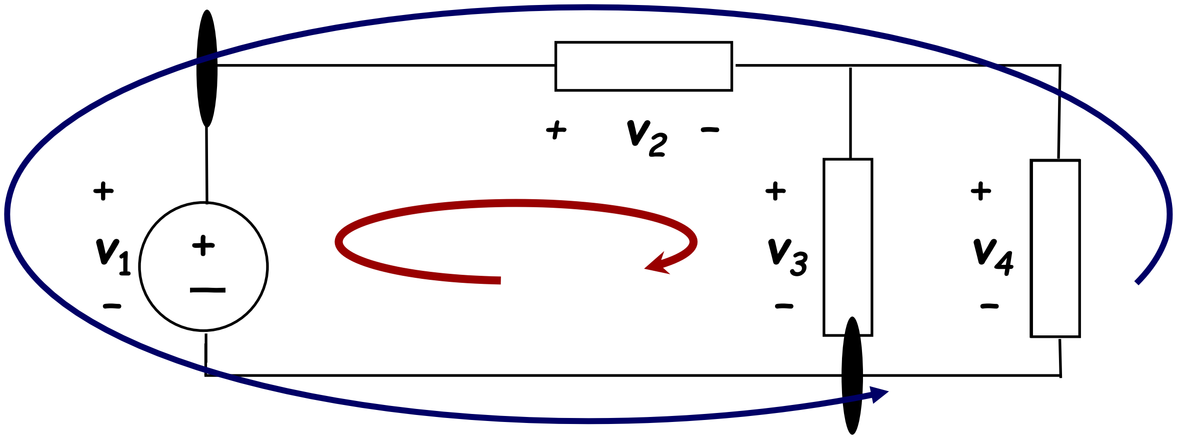
Similarly: $v_1 = v_2 + v_4$

and: $v_3 = v_4$

Using the Formal Definition of KVL

"The sum of voltages around a closed loop is zero."

- Define an arrow direction around a closed loop.
- Sum the voltages that are encountered around the loop.
- If the arrow first encounters a **plus** sign, enter that voltage with a (+) into the KVL equation.
- If the arrow first encounters a **minus** sign, enter that voltage with a (–) into the KVL equation.



For the inner loop : $-v_1 + v_2 + v_3 = 0$

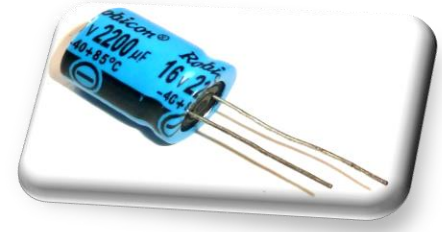
For the outer loop: $-v_4 - v_2 + v_1 = 0$

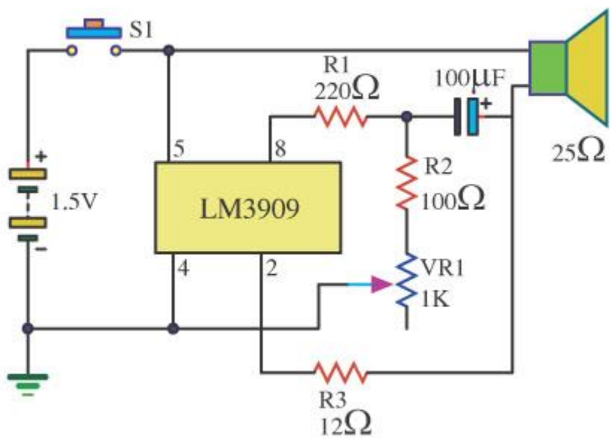
Electronic Circuits

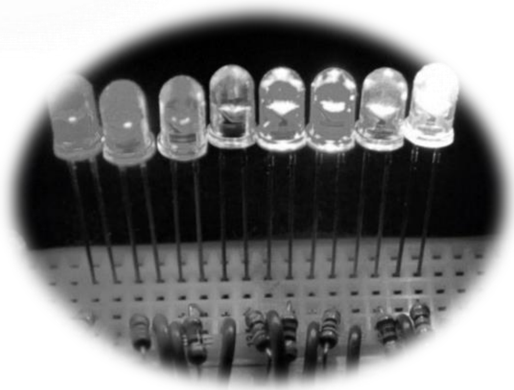
Circuits are obtained by connecting electronic elements

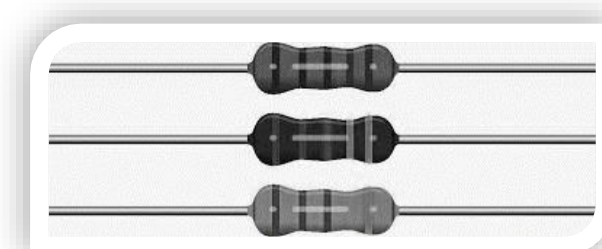
Typical electronic elements are

- diodes
- resistors,
- capacitors,
- inductors



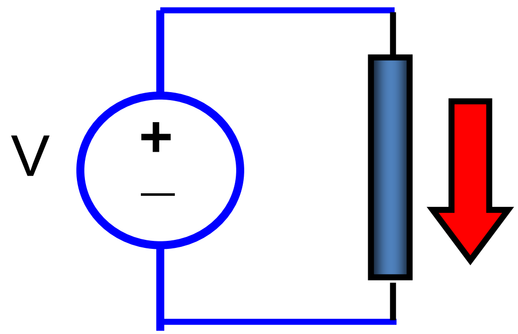






Ohm's Law & Resistors

Let us remind the Ohm's Law



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

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

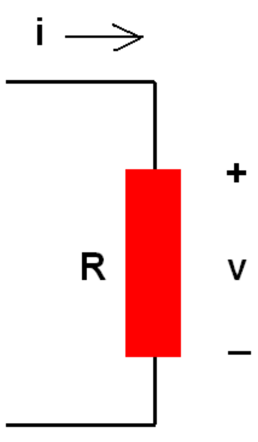
Georg Ohm

- Assume that the wires are "perfect conductors"
- The unknown circuit element limits the flow of current.
- The resistive element has ***resistance*** *R*

Ohm's Law

Voltage drop across a resistor is proportional to the current flowing through the resistor

$$v = iR$$



If the resistor is a perfect conductor (or a short circuit)

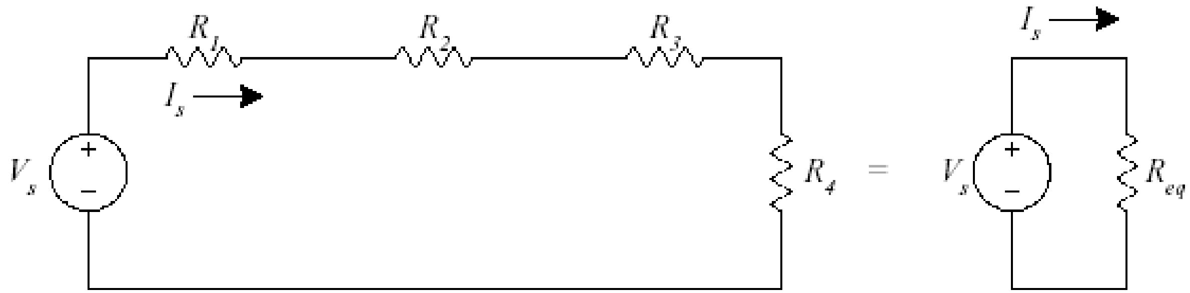
$R = 0\Omega$, then

$v = iR = 0$ V

no matter how much current is flowing through the resistor

Resistors in Series

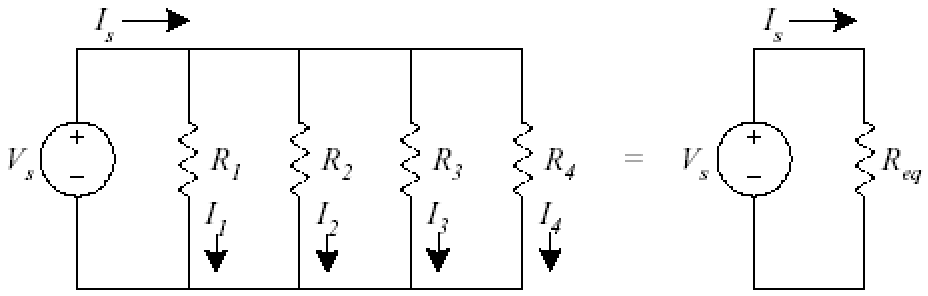
$v = iR$



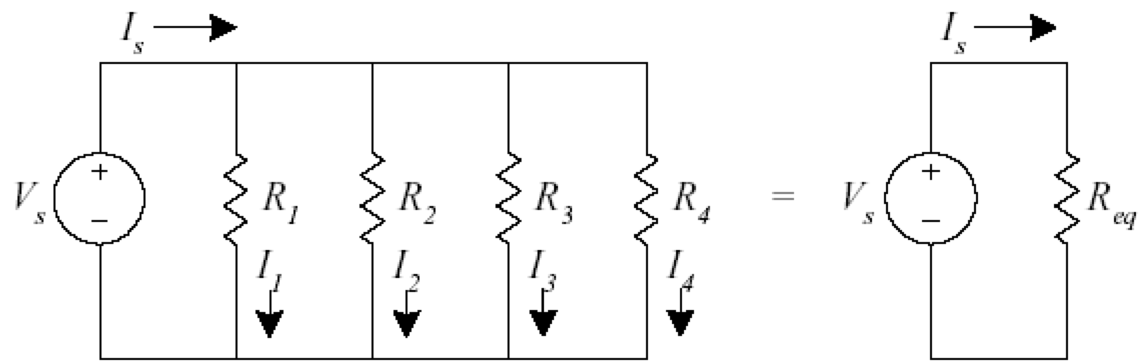
By KVL

Resistors in Parallel

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



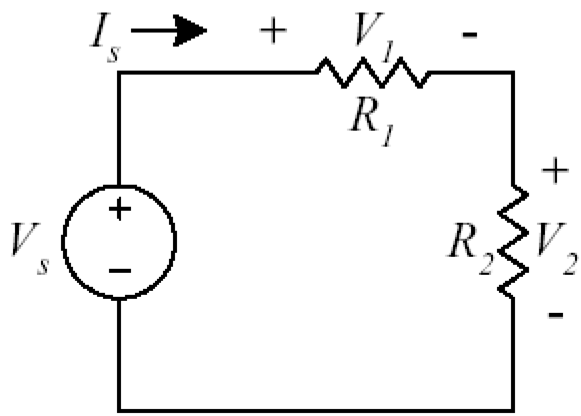
Resistors in Parallel



$$
\begin{aligned}
\frac{1}{R_{eq}} &= \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} \\
G_{eq} &= G_1 + G_2 + G_3 + G_4
\end{aligned}
$$

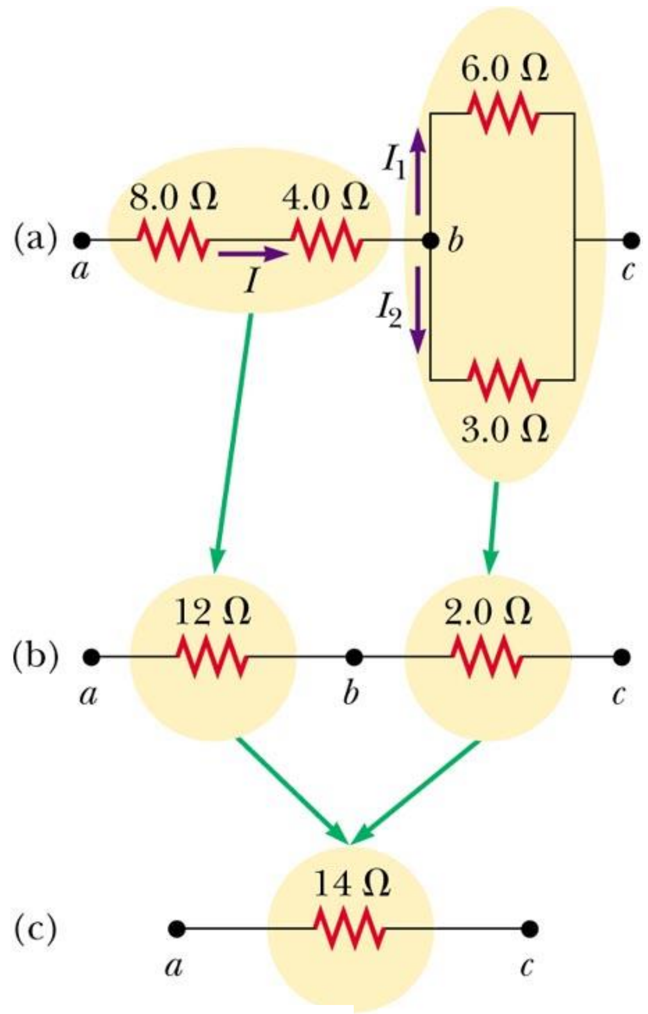
- Resistors in parallel have a more complicated relationship
- Easier to express in terms of conductance
- For two resistors: $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$

Voltage Divider

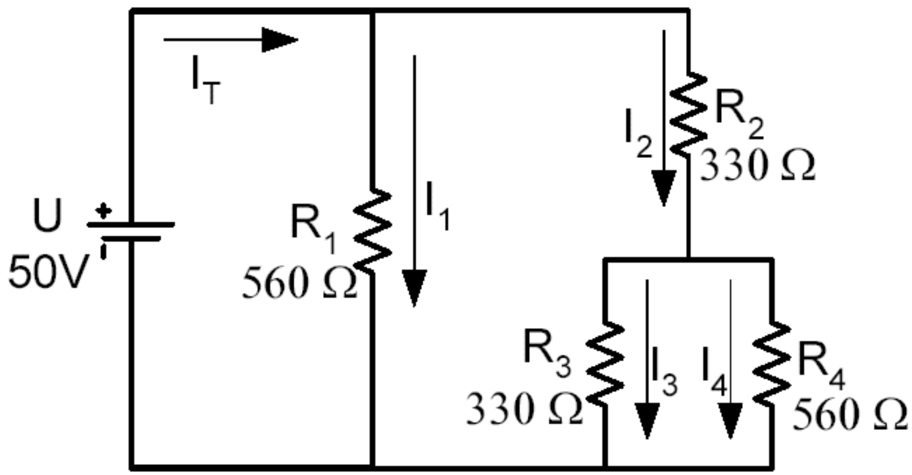


$$
\begin{aligned}
R_{eq} &= R_1 + R_2 \\
I_s &= \frac{V_s}{R_{eq}} \\
&= \frac{V_s}{R_1 + R_2} \\
V_2 &= I_s R_2 \\
&= V_s \frac{R_2}{R_1 + R_2} \\
V_1 &= I_s R_1 \\
&= V_s \frac{R_1}{R_1 + R_2}
\end{aligned}
$$

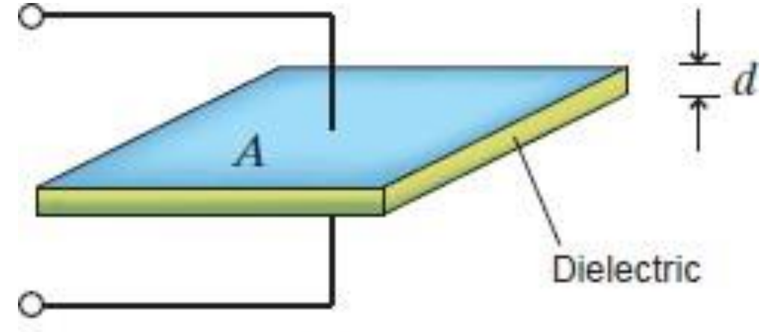
Equivalent Resistance – Complex Circuit



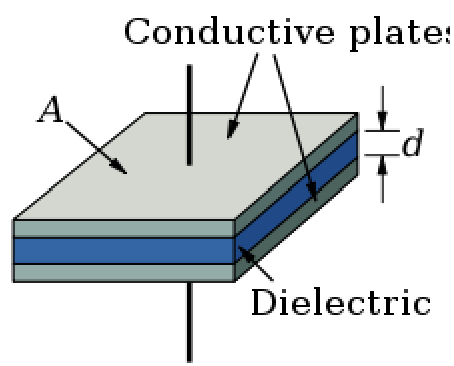
Example: Calculate the current which is flowing through R4.

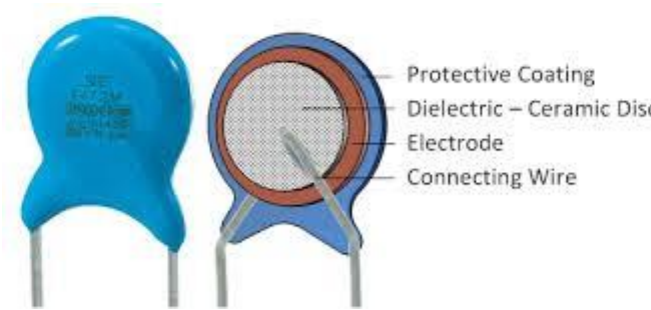


CAPACITOR
Energy Storage Device



(a)

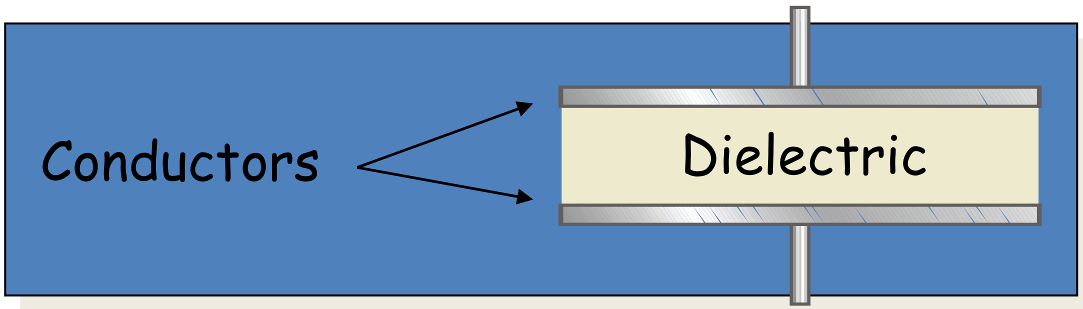




The Capacitor

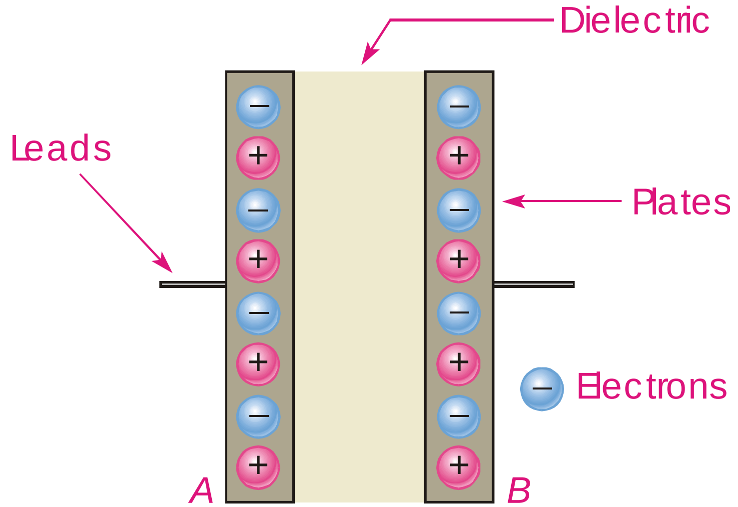
Capacitors are one of the fundamental passive components. In its most basic form, it is composed of two conducting plates separated by a dielectric material.

The ability to store charge is the definition of **capacitance**.

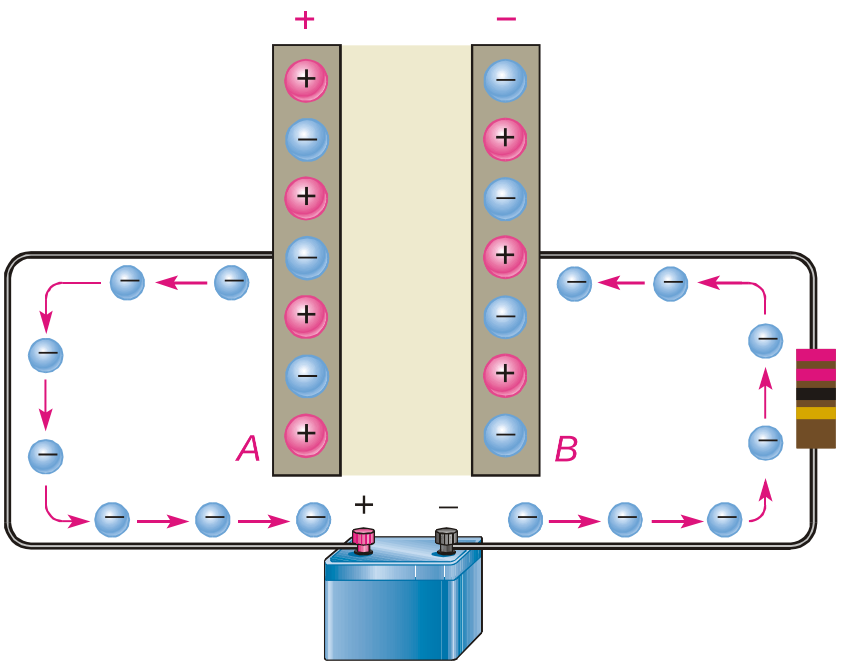


$$C = \frac{Q}{V}; \quad Unit: \; Farad = \; Coulombs \; per \; volt$$

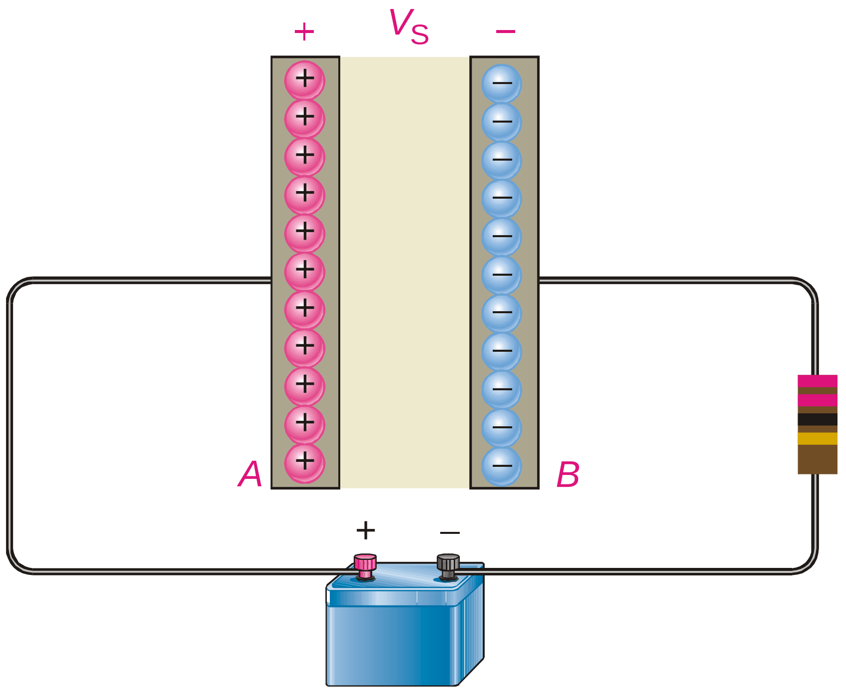
Initially uncharged capacitor



Charging

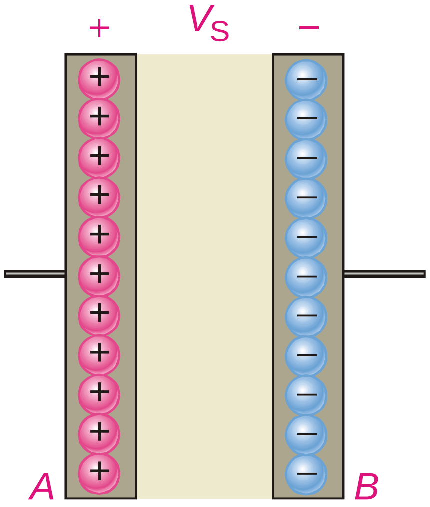


Fully charged



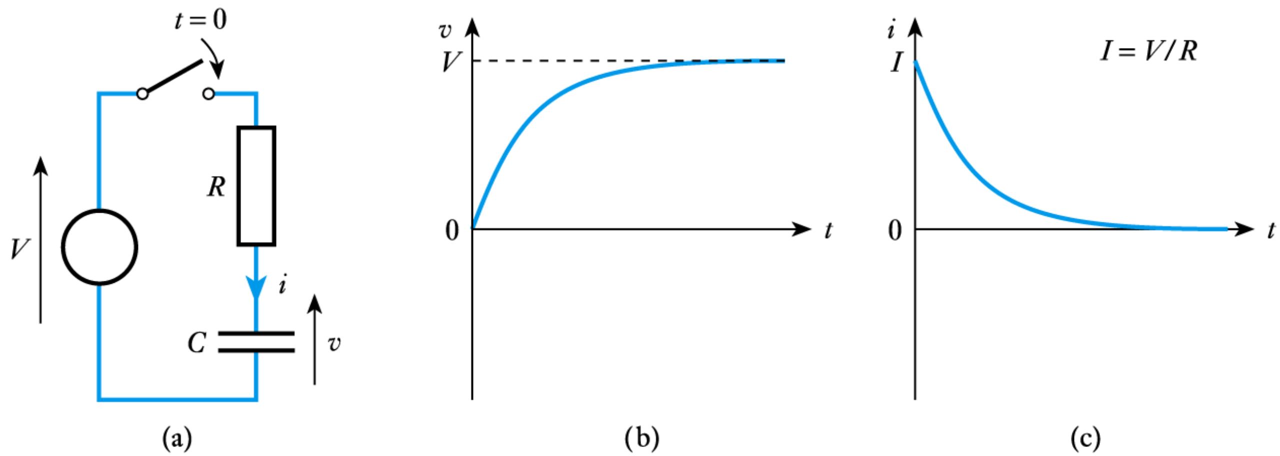
After fully charged, a capacitor behaves as an open circuit and does not allow current flow.

Source removed



A capacitor with stored charge can act as a temporary battery.

Both the voltage and current have an exponential forms



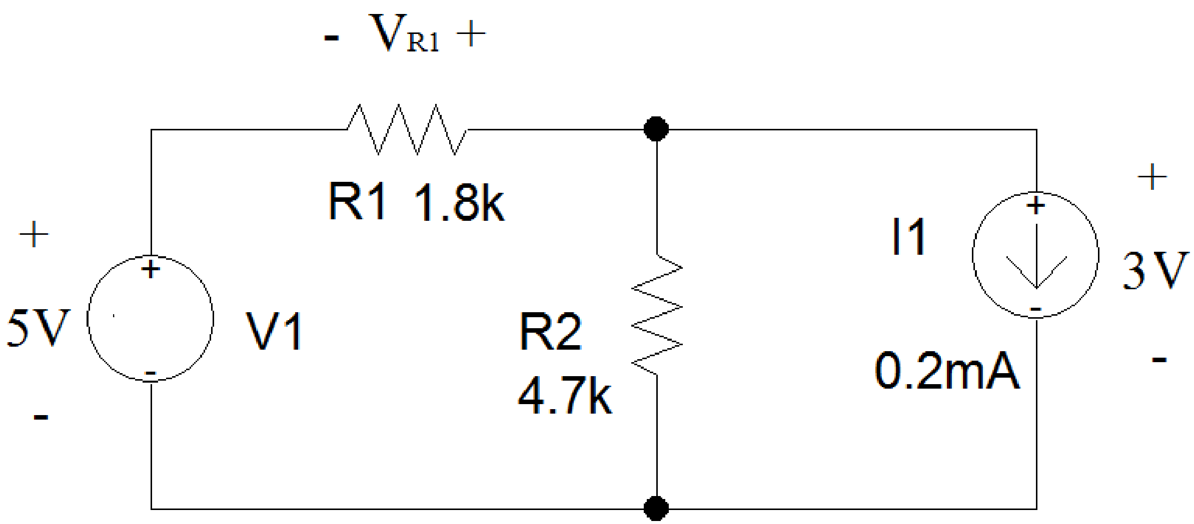
- C, capacitance, has the unit of Farad (F)

1 F = 1 A.sn/V

Example

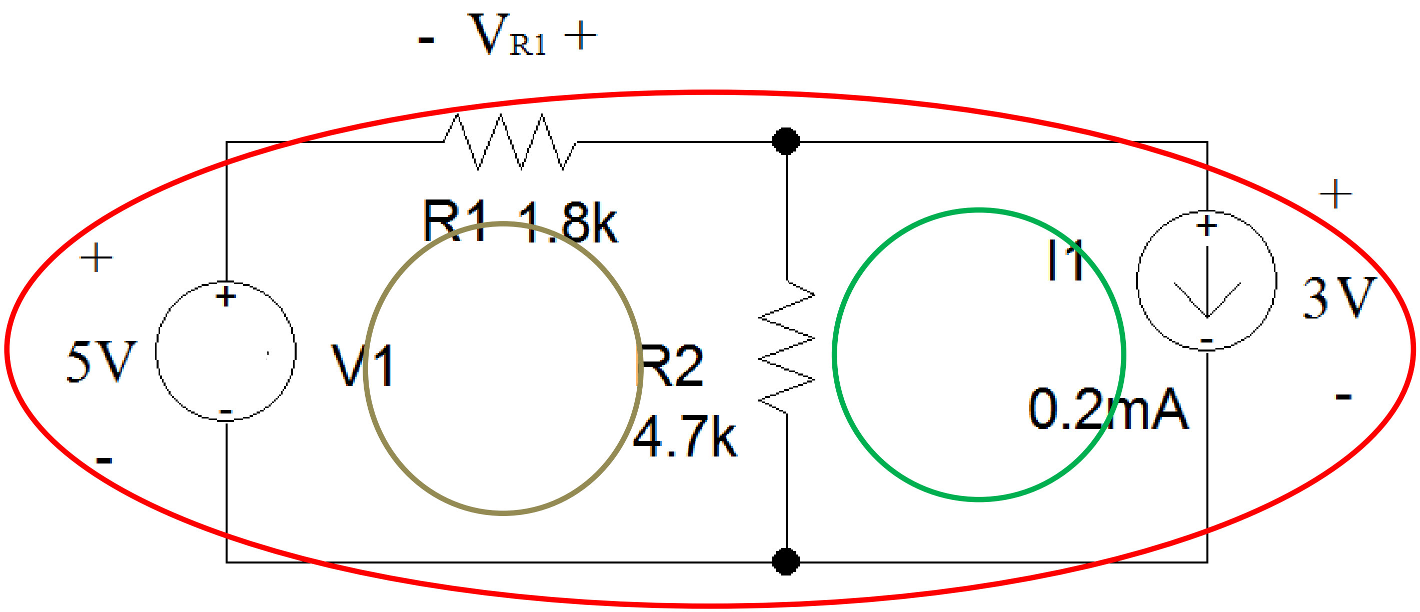
Find the voltage across R1. Note that the polarity of the voltage has been assigned in the circuit schematic.

First, define a loop that include R1.



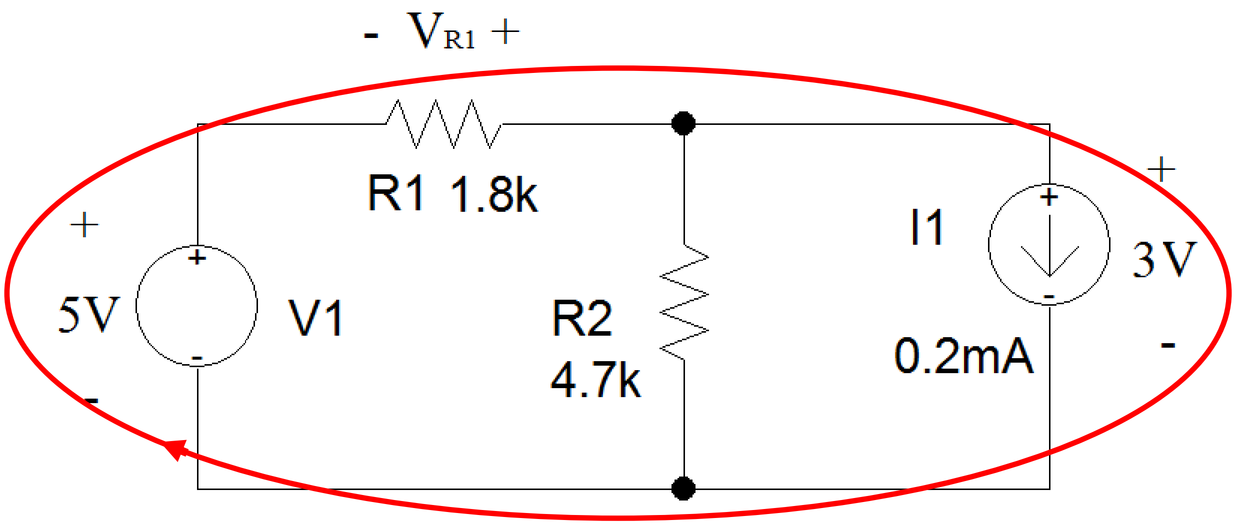
Example (con't)

There are three possible loops in this circuit. Only two of them include R_1. Either loop may be used to determine V_{R1}.



Example (con't)

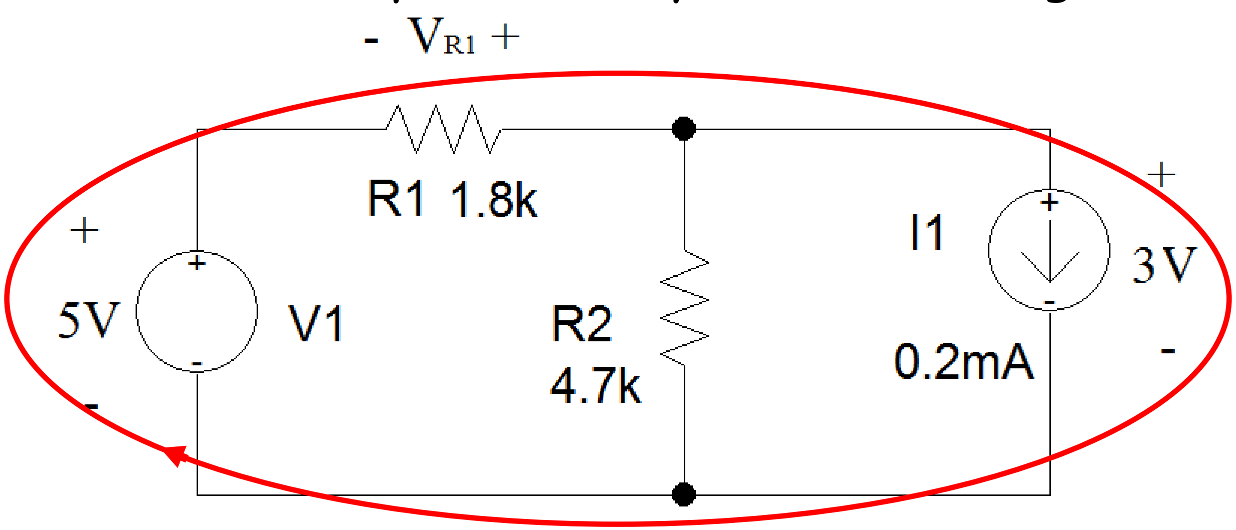
If the outer loop is used, follow the loop clockwise.



Example (con't)

Follow the loop in a clockwise direction.

- The 5V drop across V1 is a voltage rise.
- V_{R1} should be treated as a voltage rise.
- The loop enters on the positive side of the CURRENT source and exits out the negative side. This is a voltage drop as the voltage becomes less positive as you move through the component.



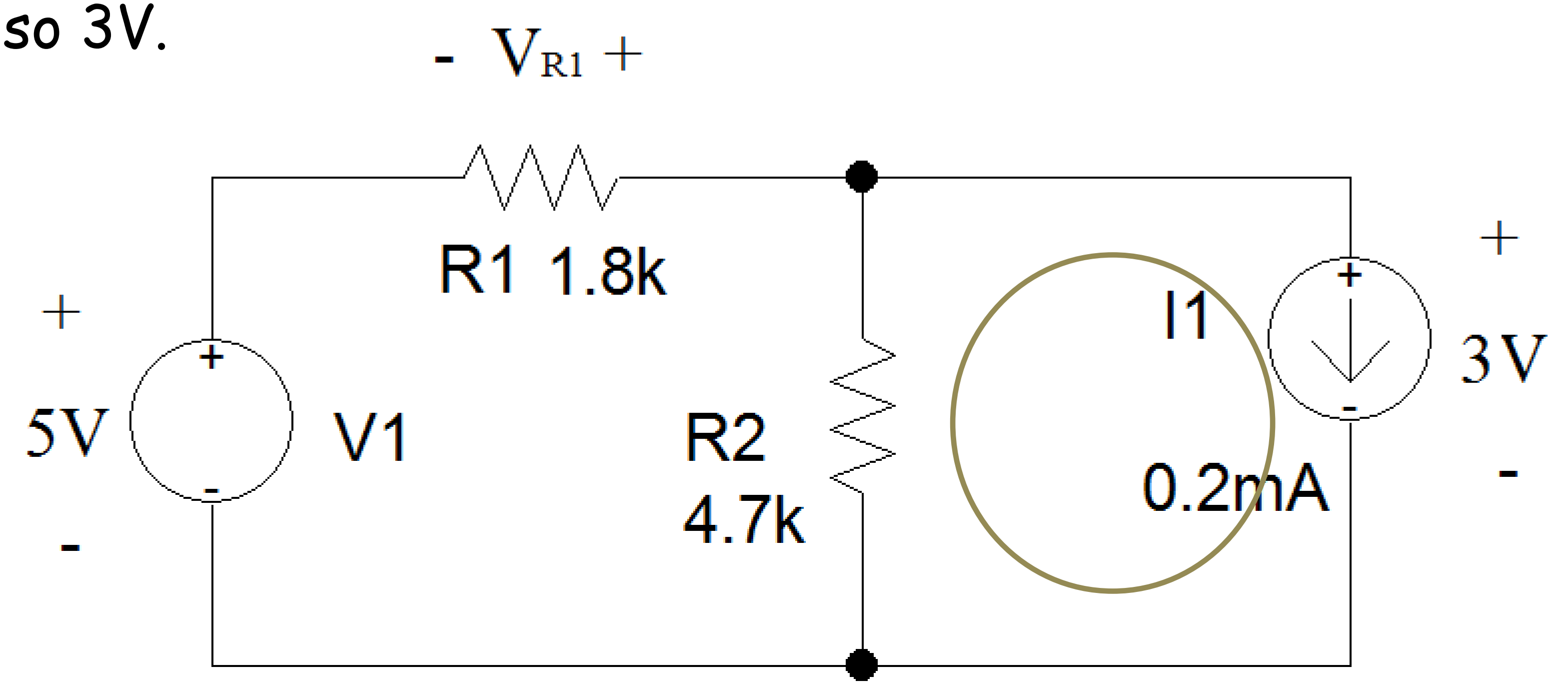
$$-5V - V_{R1} + 3V = 0$$

$$V_{R1} = -2V$$

Example (con't)

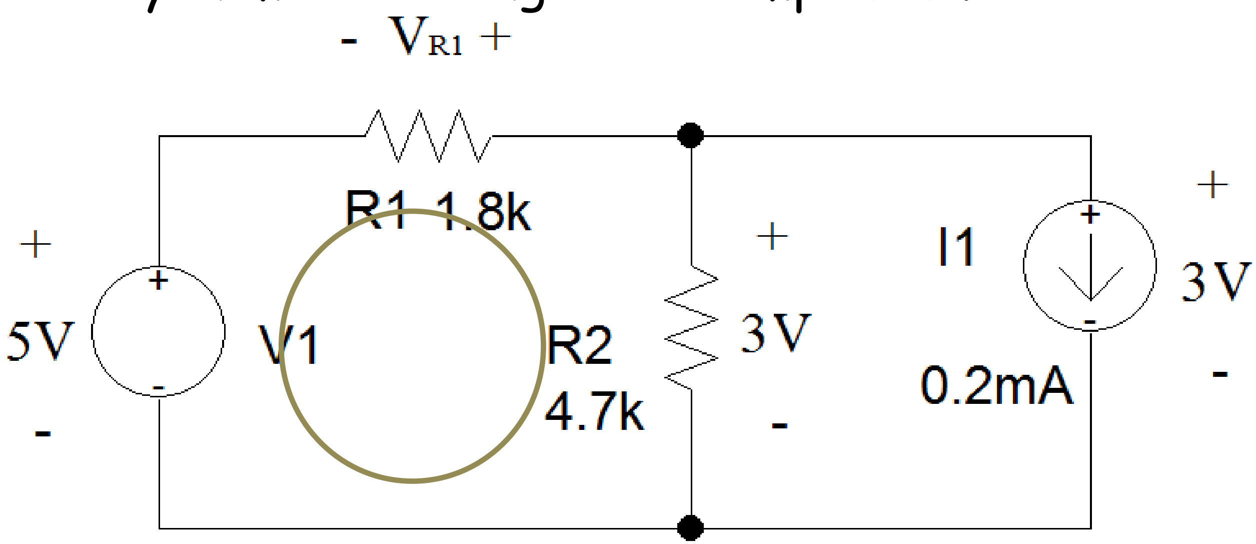
Suppose you choose the green loop instead.

Since R_2 is in parallel with I_1, the voltage drop across R_2 is also 3V.



Example (con't) *Follow the loop in a clockwise direction.*

- The 5V drop across V1 is a voltage rise.
- V_{R1} should be treated as a voltage rise.
- The loop enters R_2 on the positive side and exits out the negative side. This is a voltage drop as the voltage becomes less positive as you move through the component.



$$-5V - V_{R1} + 3V = 0$$

$$V_{R1} = -2V$$