Electrical Circuits and Electronics

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Outlines

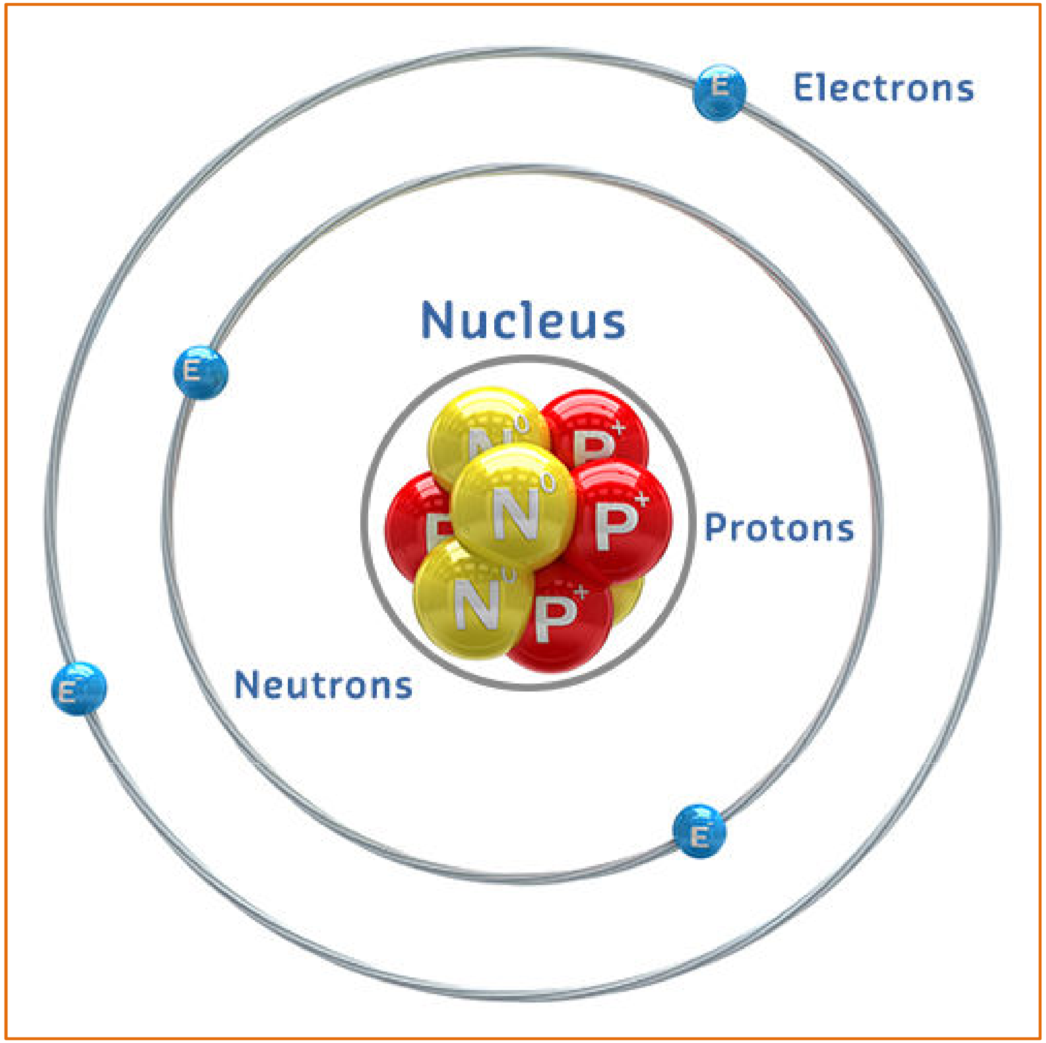
- What is electricity?
- Atoms and electrons
- Current, voltage, resistance
- Electric circuits and schematic diagrams
- Ohm's law
- Resistors, capacitors and inductors
- Binary
- Floating point numbers

What is Electricity

- **Electricity** is a form of energy. **Energy** is the generic name we give to everything that can produce work.
- Electricity is at the heart of many modern technologies, being used for: **electric power** and **electronics**.

Atoms and Electrons

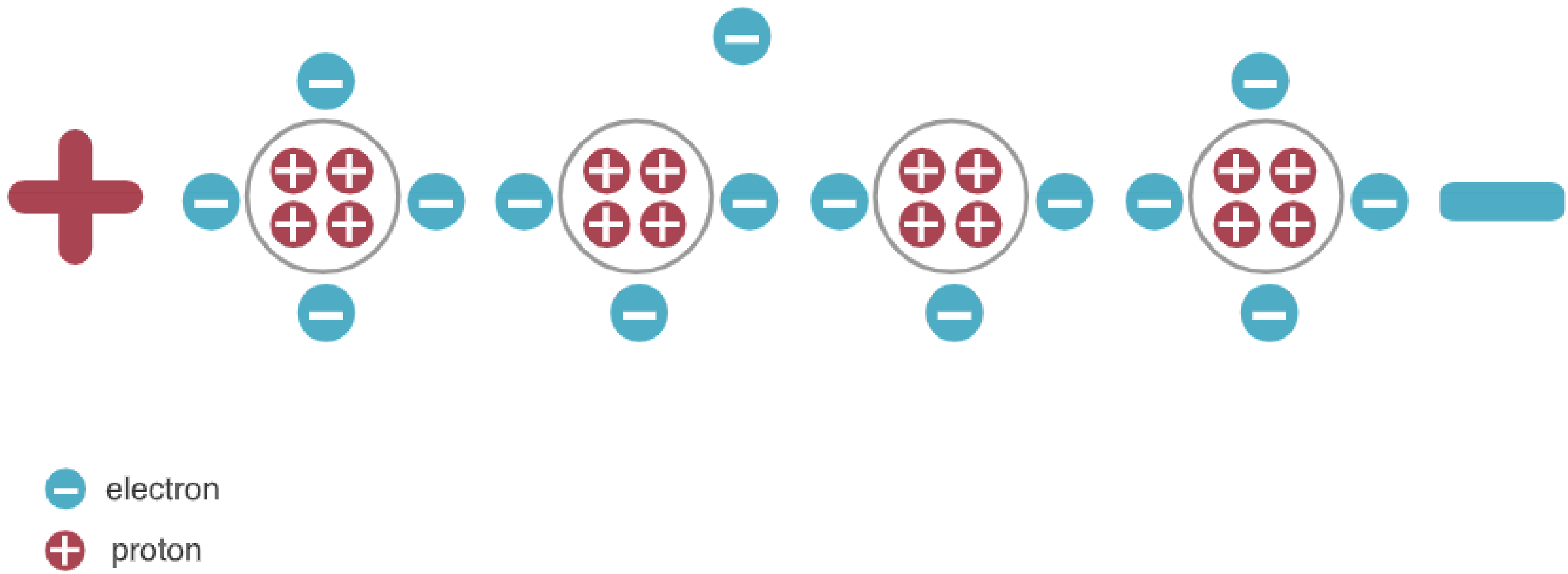
- Most hardware involved in the IoT uses electrical energy to work.
- All elements are made up of atoms.
- Atoms have a nucleus which contains positively charged protons and neutrally charged neutrons, usually the same amount of each. Orbiting around the nucleus are negatively charged electrons forming a cloud that occupies a volume 10,000 times larger than the nucleus.



Electron Flow

Electricity occurs when electrons in atoms jump from one atom to another.

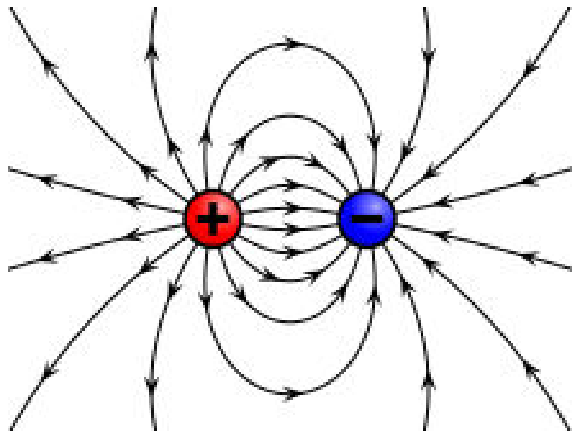
- Materials can accumulate and lose electrons. A material that has accumulated an excess of electrons is described as **negatively charged**. On the other hand, when a material has a deficit of electrons, it is described as **positively charged**. Another word used to describe the state of charge is **electrical potential**.



Electron Flow (cont.)

Things in nature tend to a state of equilibrium; hence electrons will flow wherever there is a difference in charge between two points.

- The number of electrons flowing depends on the difference of charge between two points.

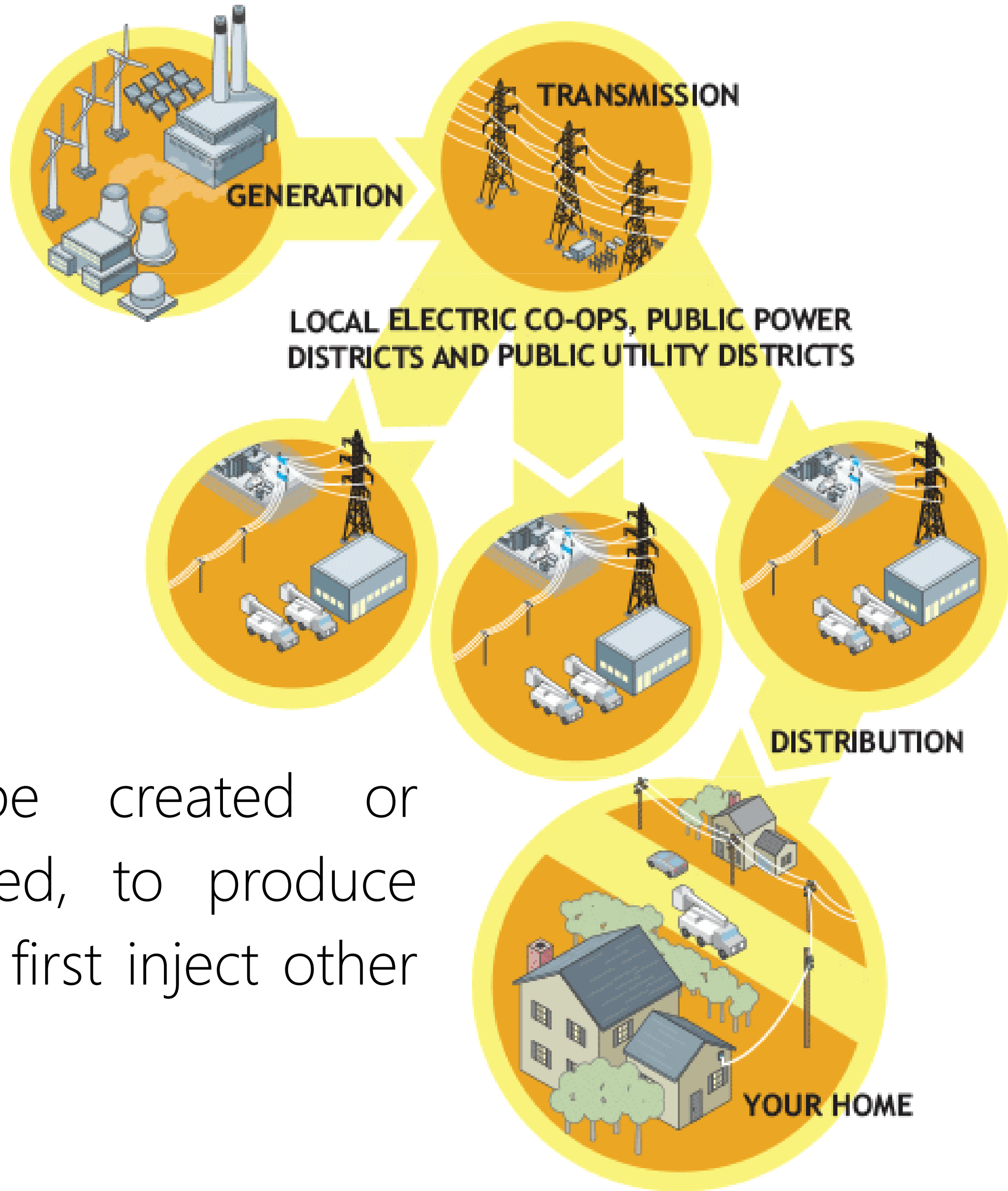


- The unit for electric charge is the **Coulomb**. One Coulomb is equal to the electric charge of 6.24 x 1018, or 6.24 quintillion electrons.

It is worth noting that although electrons physically move from a negatively charged point to a positively charged one, it is conventionally accepted that for the purpose of analysis and design, electric current flows from a positively charged to a negatively charged point.

Electron Flow

Where does electricity come from?

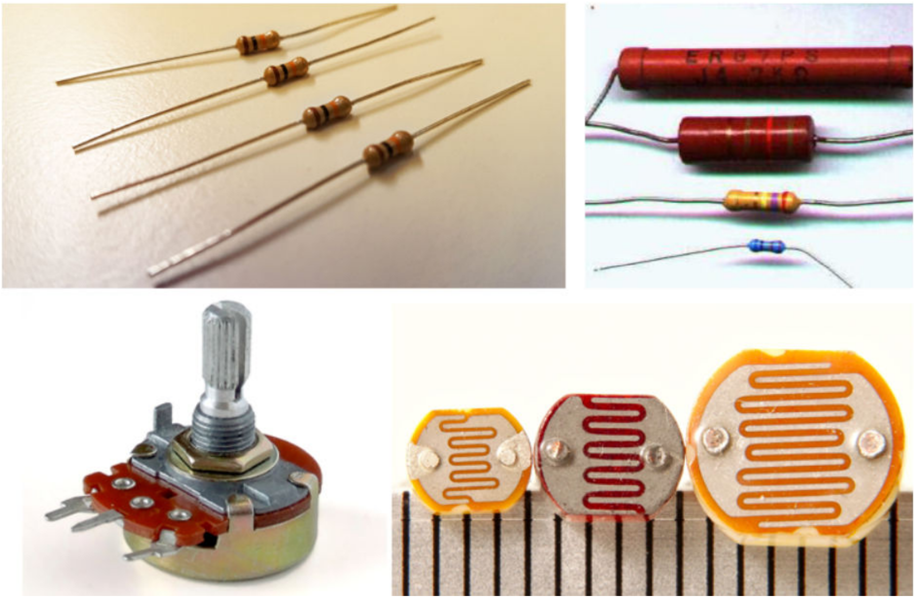


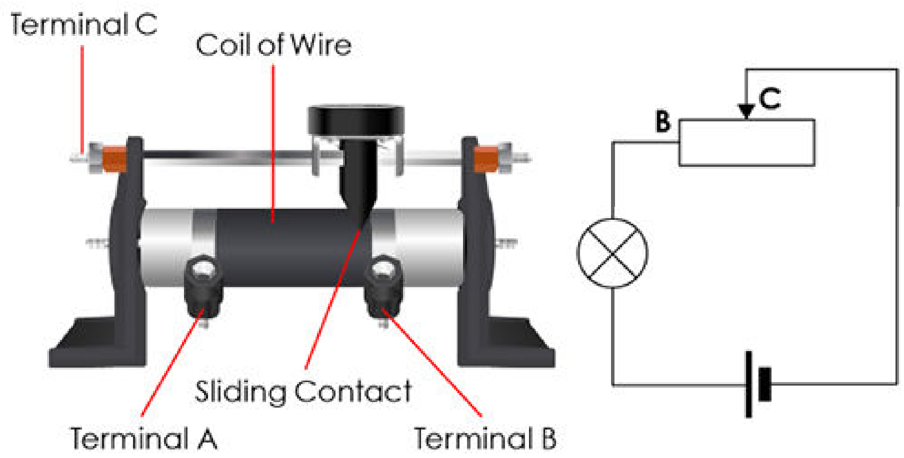
- Electricity, i.e. the flow of electrons, can be produced in many ways.
- Since energy cannot be created or destroyed, only transformed, to produce electric energy we need to first inject other forms of energy.

Current, Voltage, Resistance

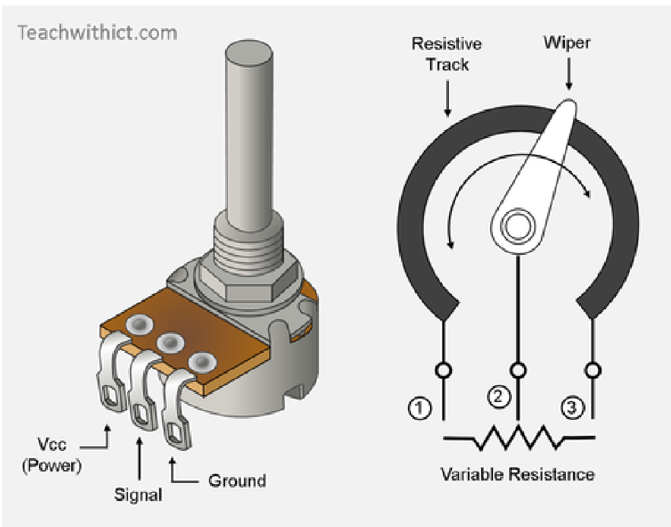
- Electric current: The flow of electrons jumping between atoms from a negatively charged to a positively charged point is called electric current (I). You may think of electric current as like water flowing from a higher to a lower point. Electrical current is measured in Amperes. One Ampere represents the flow of one Coulomb of charge per second.
- Voltage: The difference in electric charge between two points is called voltage (V). The greater the charge difference (voltage) between two points, the higher the electrical current that will flow. The unit for voltage is the Volt.
- Resistance: Since all materials are made out of atoms, all of them have electrical properties. One important property is the ability to conduct electricity. This property is called resistance (R). Good electrical conductors have low resistance, while materials that are not very good at conducting electric currents have high resistance. The unit for resistance is the Ohm (Ω).
- Resistors: In electrical circuits, resistance is often provided by resistors.

Current, Voltage, Resistance (cont.)

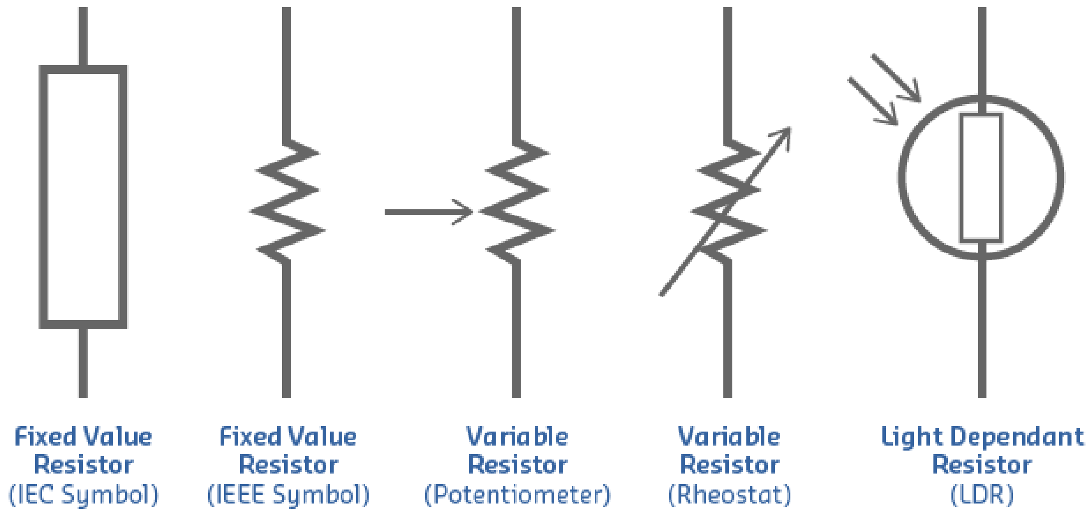




[**Rheostat**]

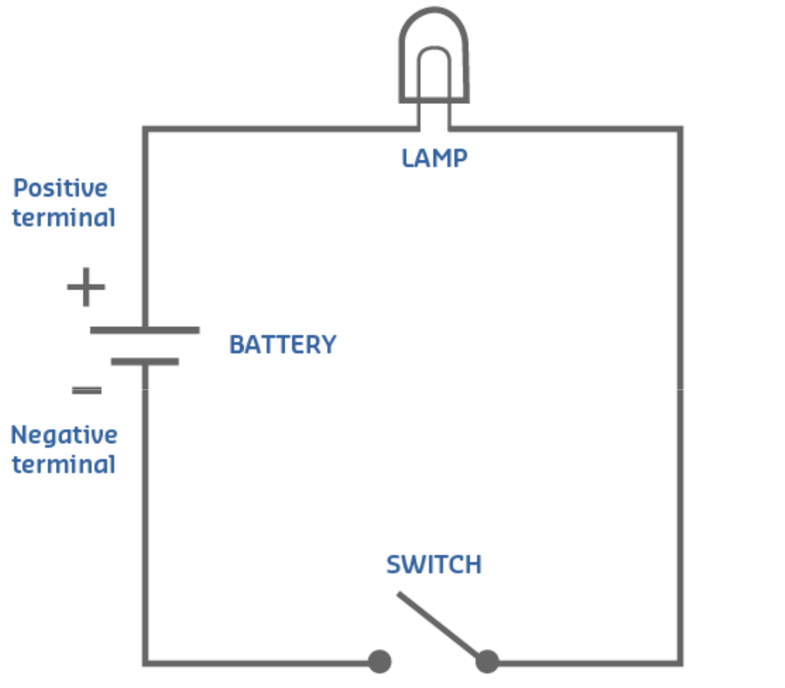


[**Potentialmeter**]



Electric Circuits and Schematic Diagrams

- Electric currents are made useful by inserting components between two points with different potentials. This means that when the current flows, components are activated or deactivated.
- An electric circuit is an arrangement of components that performs a particular function by means of electricity.



ELECTRIC CIRCUIT USING A LAMP, A SWITCH AND A BATTERY

Ohm's Law

- The definition of a Volt describes this relationship:

One Volt can push a current of one Ampere through a resistance of one Ohm.

- This relationship was studied by a German physicist called Georg Ohm. For simplicity, Ohm's Law is expressed as:

$$I = V / R$$

where electric current (I) equals voltage (V) divided by resistance (R).

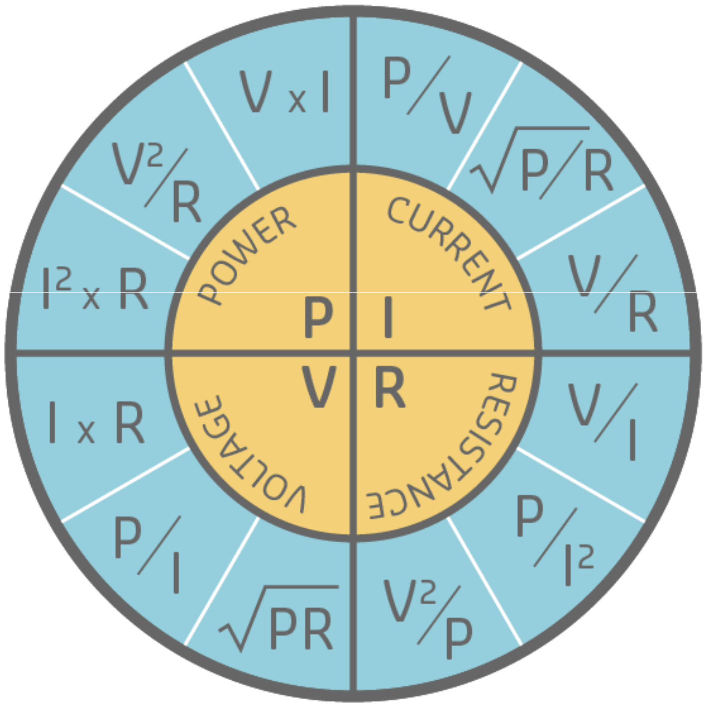
- Observe this expression and notice that if the voltage increases, the current increases; while if the resistance increases the current decreases.

Ohm's Wheel and Electric Power

- **Power** (P) is the rate at which energy is transferred or transformed over time; e.g. the power dissipated from a heating coil. Power is measured in **Joules per second** or **Watts**.
- Electric power is the product of voltage and current, or:

$$P = V \times I$$

where power (P) equals voltage (V) multiplied by electrical current (I).

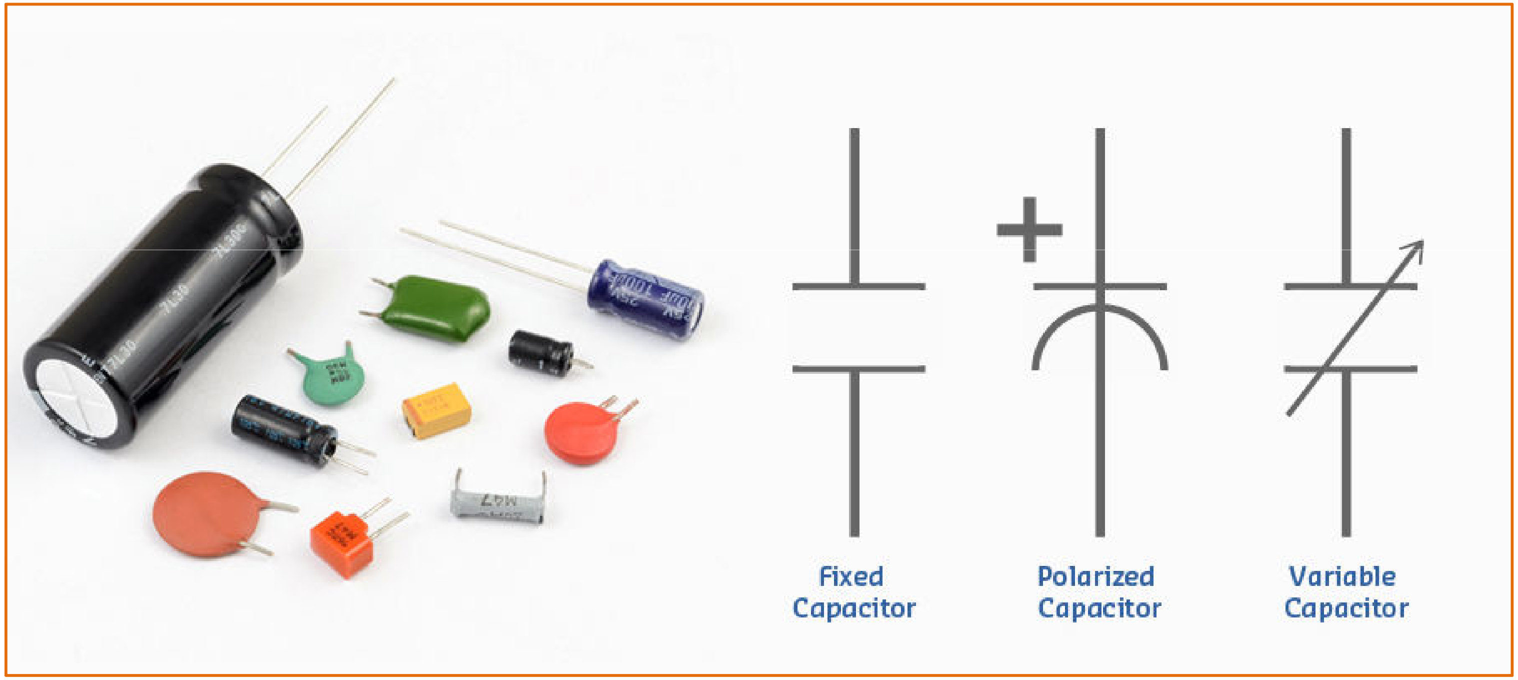


[Ohm's Wheel and 12 formulas]

1) $P = V \times I$	2) $P = V^2/R$	3) $P = I^2 \times R$
4) $V = I \times R$	5) $V = P/I$	6) $V = (P \times R)$
7) $R = V^2/P$	8) $R = P/I^2$	9) $R = V/I$
10) $I = V/R$	11) $I = \sqrt{P/R}$	12) $I = P/V$

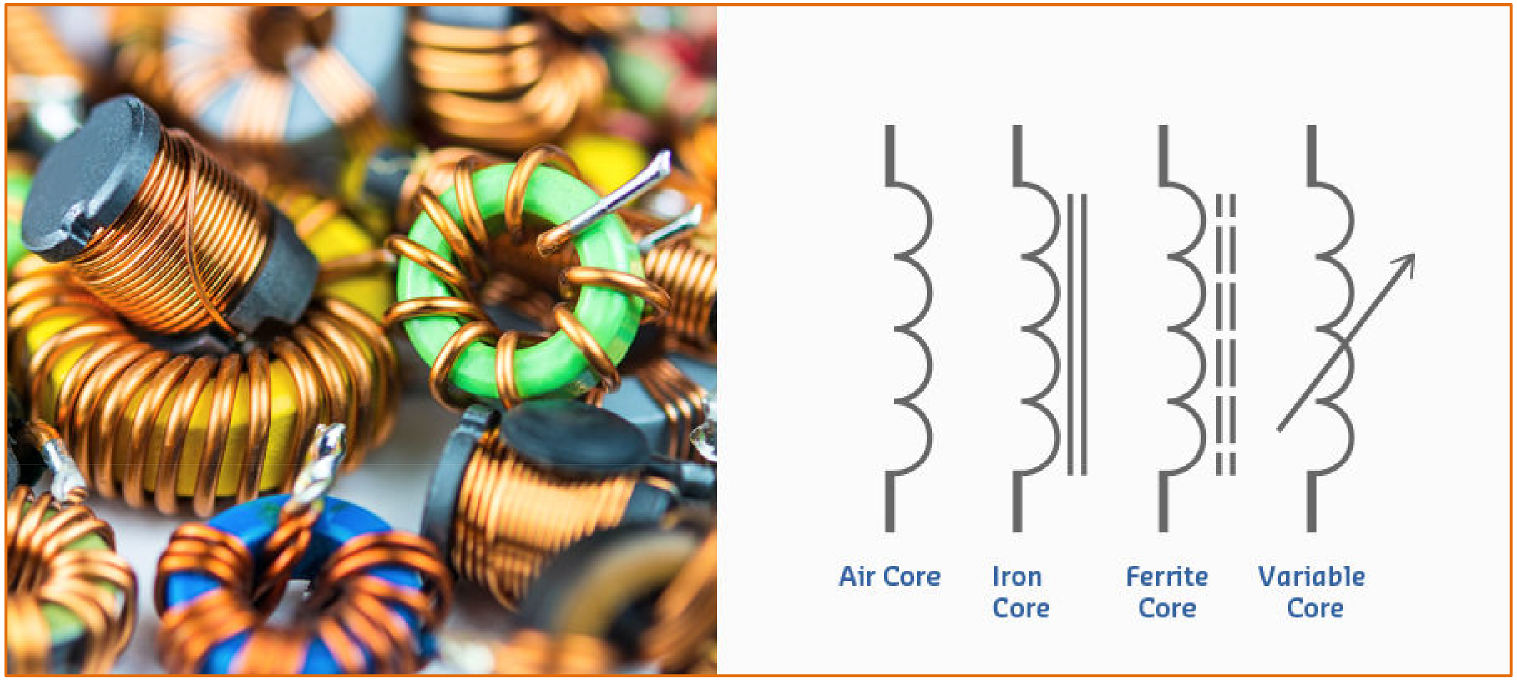
Ohm's Wheel and Electric Power

- Resistors are called passive components because they do not need an external power supply to show their electric properties, nor do they produce any power. Other passive components are:
- Capacitors – These devices have the ability to store energy as electric charge. The ability to store charge is called capacitance. The unit of capacitance is the farad, however one farad is too big and commercial capacitors are measured in micro (10-6) or nano (10-9) farads.



Ohm's Wheel and Electric Power (cont.)

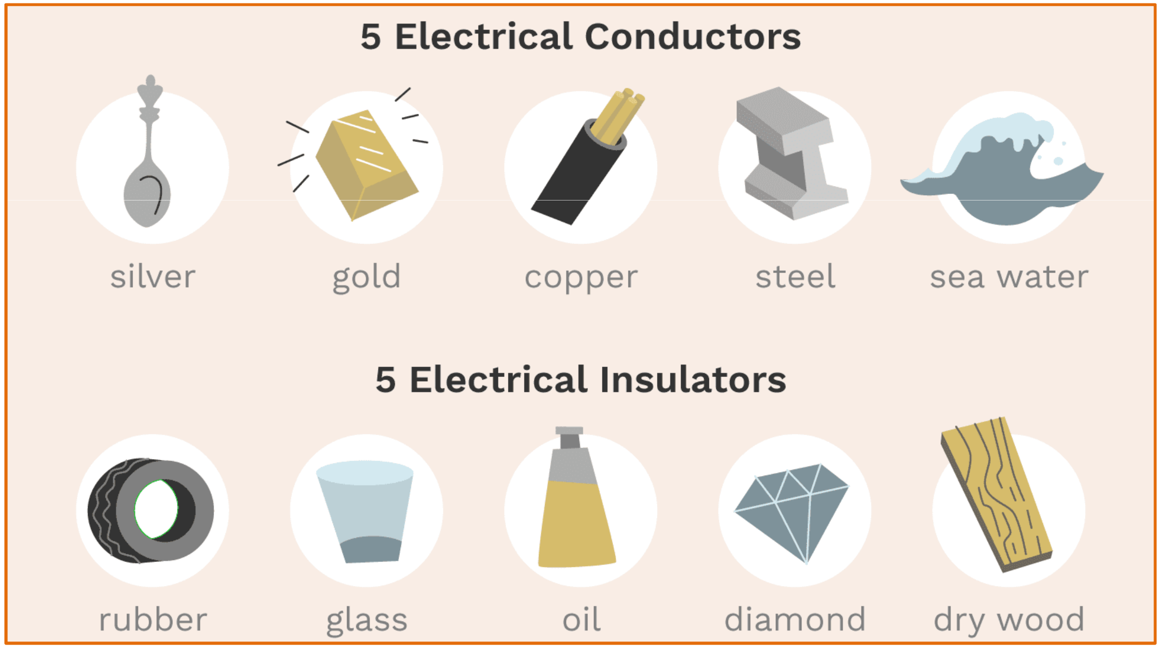
- Inductors – These devices have the ability to store energy as magnetic fields when an electric current flows through them. The unit of inductance is the henry, but like capacitors one henry is too big and commercial inductors are rated in milli (10-3) or micro (10-6) henrys.



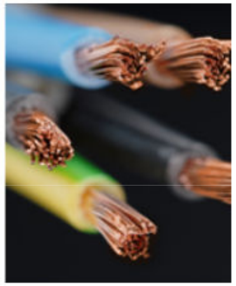
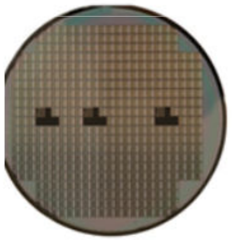
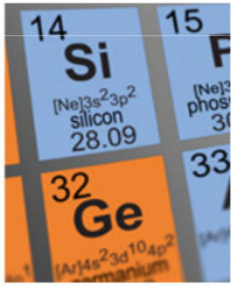
- For further information: https://www.youtube.com/watch?v=OEL5laB3hfU

Semiconductors

- In some materials, electrons are free to move and they are called conductors. Most metals are very good conductors.
- In other materials, electrons are not free to move and they are called insulators. Rubber and glass are examples of good insulators.
- Other materials are neither good conductors nor insulators; they are called semiconductors. You may think of semiconductors as materials that need a little help to become good conductors.



Semiconductors

 	**Conductors**	Electrons free to move.	E.g. metals
 	**Insulators**	Electrons not free to move.	E.g. glass, rubber
 	**Semi-conductors**	With a little help electrons can move.	E.g. Silicon, Germanium

Learn more about semiconductors at https://www.youtube.com/watch?v=gUmDVe6C-BU

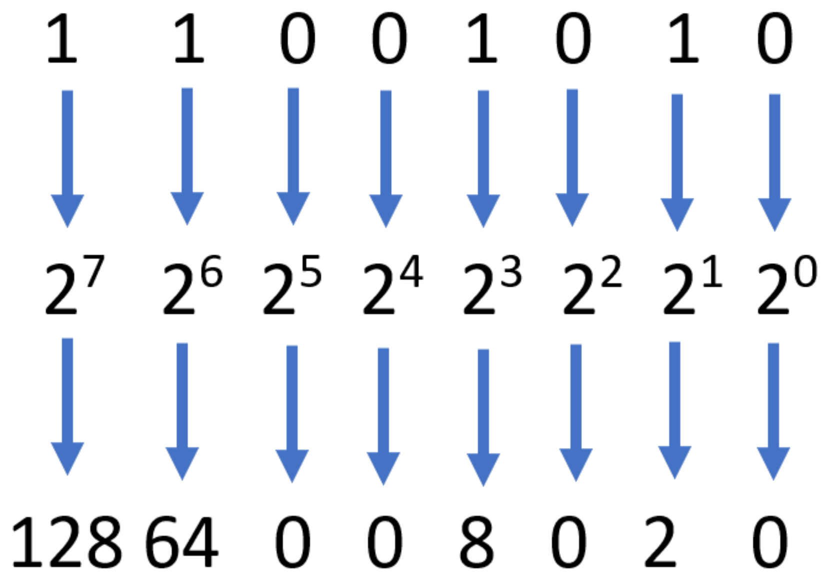
Binary

- The world around us is analogue. Think of today's weather.
- Computers do not work like this. By acting like switches, transistors are good at representing only two states: one associated with the on condition, and one associated with the off condition.
- Conditions like this are called binary, and the unit used to describe binary variables is the bit. One transistor can represent one bit of binary information. One bit can represent only two numeric values: 0 and 1.

Binary (cont.)

- To be able to represent more values, bits are formed into groups of 8, 16, 32 or 64. These numbers are not arbitrary, they are powers of 2.

Power of 2	Possible binary combinations
2^0	1
2^1	2
2^2	4
2^3	8
2^4	16
2^5	32
2^6	64
2^7	128
2^8	256
2^9	512



PRACTICE: How we would represent the number '37' in binary?

Binary (cont.)

Power of 10	10^6	10^5	10^4	10^3	10^2	10^1	10^0
Possible decimal combinations	1000000	100000	10000	1000	100	10	1
Example						3	7

Power of 2	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Possible binary combinations	512	256	128	64	32	16	8	4	2	1
Example					1	0	0	1	0	1

- The number 37 is represented by: (3 x 10) + (7 x 1) or 3 lots of 10 and seven units.
- In binary 37 would be represented as: 100101 or (1 x 32) + (0 x 16) + (0 x 8) + (1 x 4) + (0 x 2) + (1 x 1)

THANK YOU ALL FOR LISTENING

QUESTIONS AND ANSWERS