SHOP VIDEO – DAY 2

Engineering Mindset. (August 27, 2019)

Single pole switch lighting circuits- How to wire a light switch. YouTube.

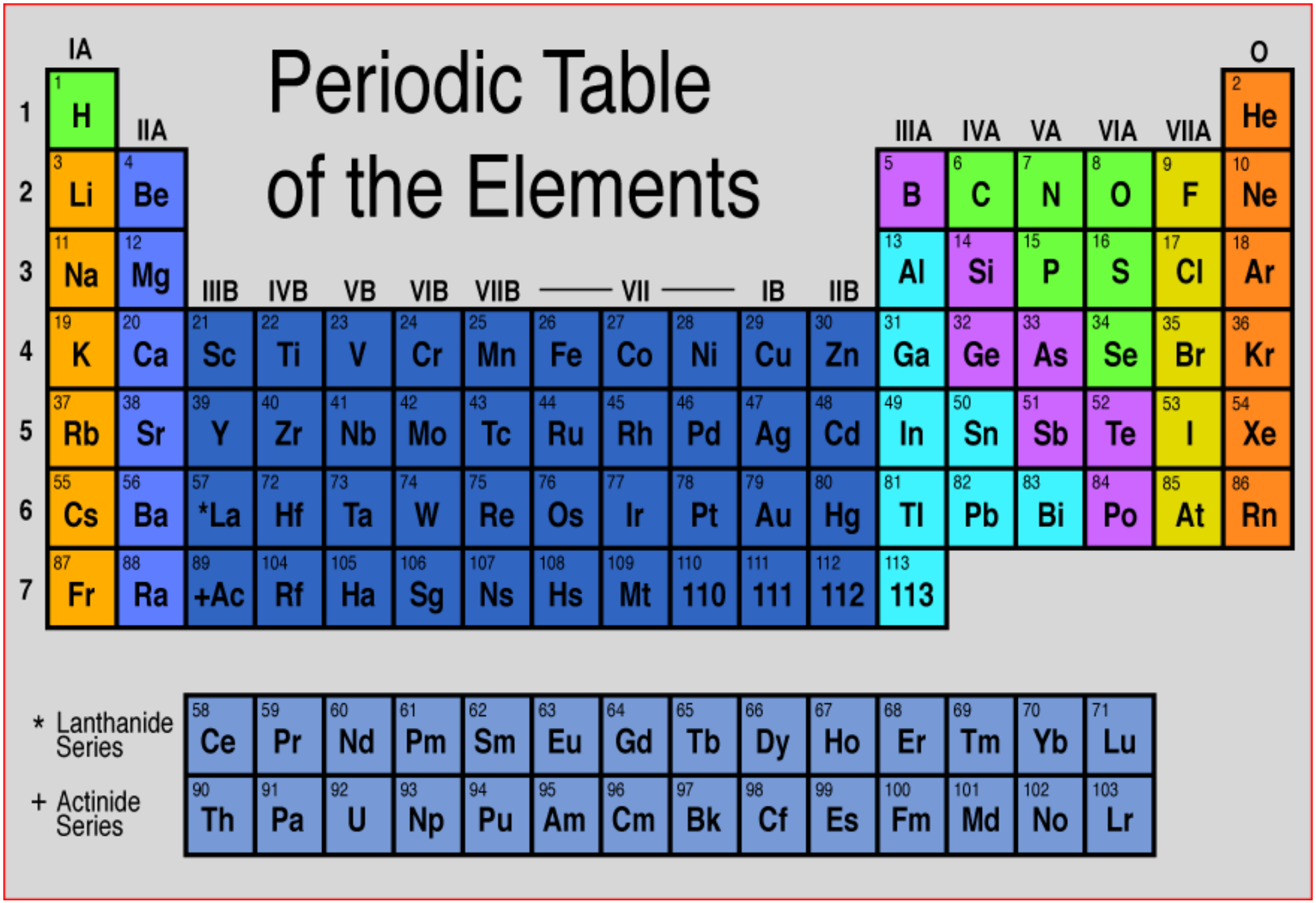
https://www.youtube.com/watch?v=CaaLw01fMo8

Part 1

Electricity Basics

Electricity Basics

The structure of matter


Periodic Table of the Elements
IA
IIA
IIIB
IVB
VB
VIB
VIIB
VII
IB
IIB
IIIA
IVA
VA
VIA
VIIA
O
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
37 Rb
38 Sr
39 Y
40 Zr
41 Nb
42 Mo
43 Tc
44 Ru
45 Rh
46 Pd
47 Ag
48 Cd
49 In
50 Sn
51 Sb
52 Te
53 I
54 Xe
55 Cs
56 Ba
57 *La
72 Hf
73 Ta
74 W
75 Re
76 Os
77 Ir
78 Pt
79 Au
80 Hg
81 Tl
82 Pb
83 Bi
84 Po
85 At
86 Rn
87 Fr
88 Ra
89 +Ac
104 Rf
105 Ha
106 Sg
107 Ns
108 Hs
109 Mt
110 110
111 111
112 112
113 113
* Lanthanide Series
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
+ Actinide Series
90 Th
91 Pa
92 U
93 Np
94 Pu
95 Am
96 Cm
97 Bk
98 Cf
99 Es
100 Fm
101 Md
102 No
103 Lr

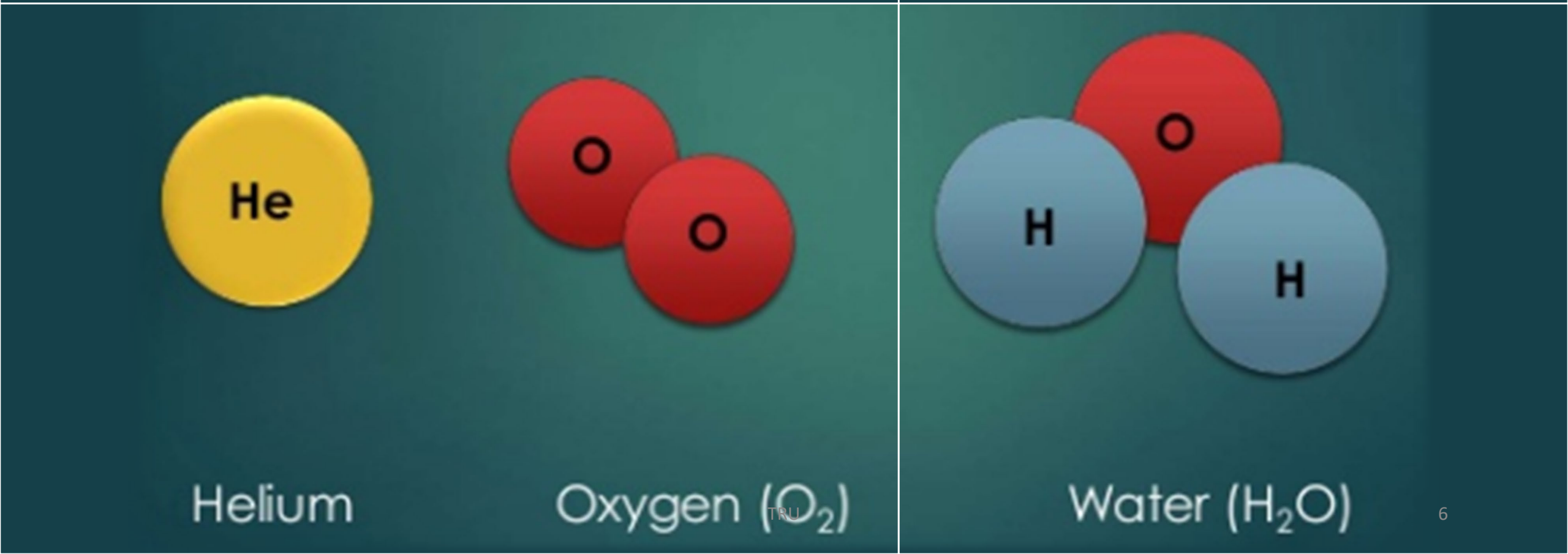
Elements

Atom

Atoms

Compounds

Molecule



Structure of matter

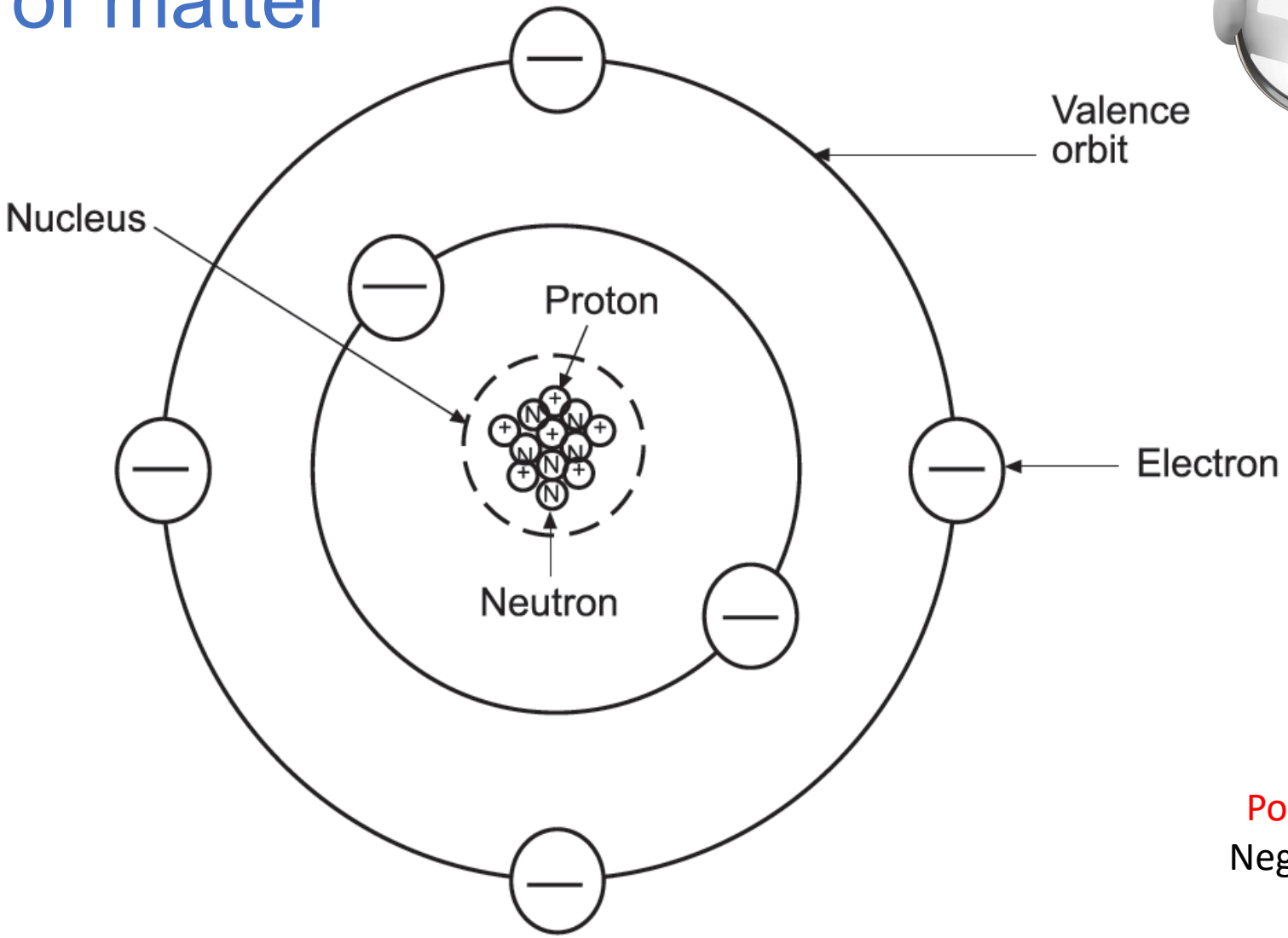
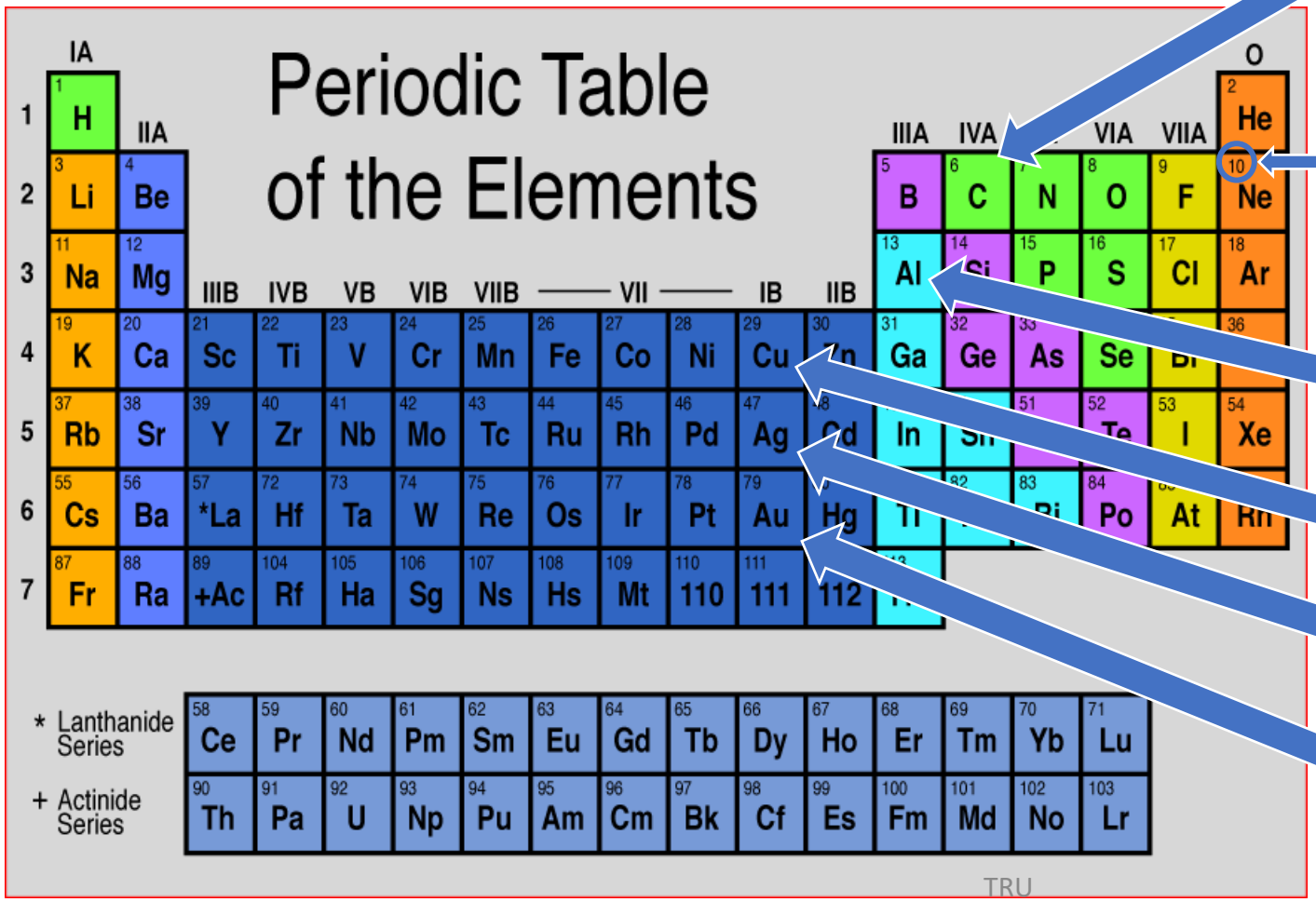


Figure 1—Carbon atom

Particles
Proton (+)
Electron (–)
Neutron no charge

Atom States
Positively Charged
Negatively Charged
Neutral

Structure of matter



Carbon

Atomic Number: (How many protons) Ne is neon.

Aluminum (13)

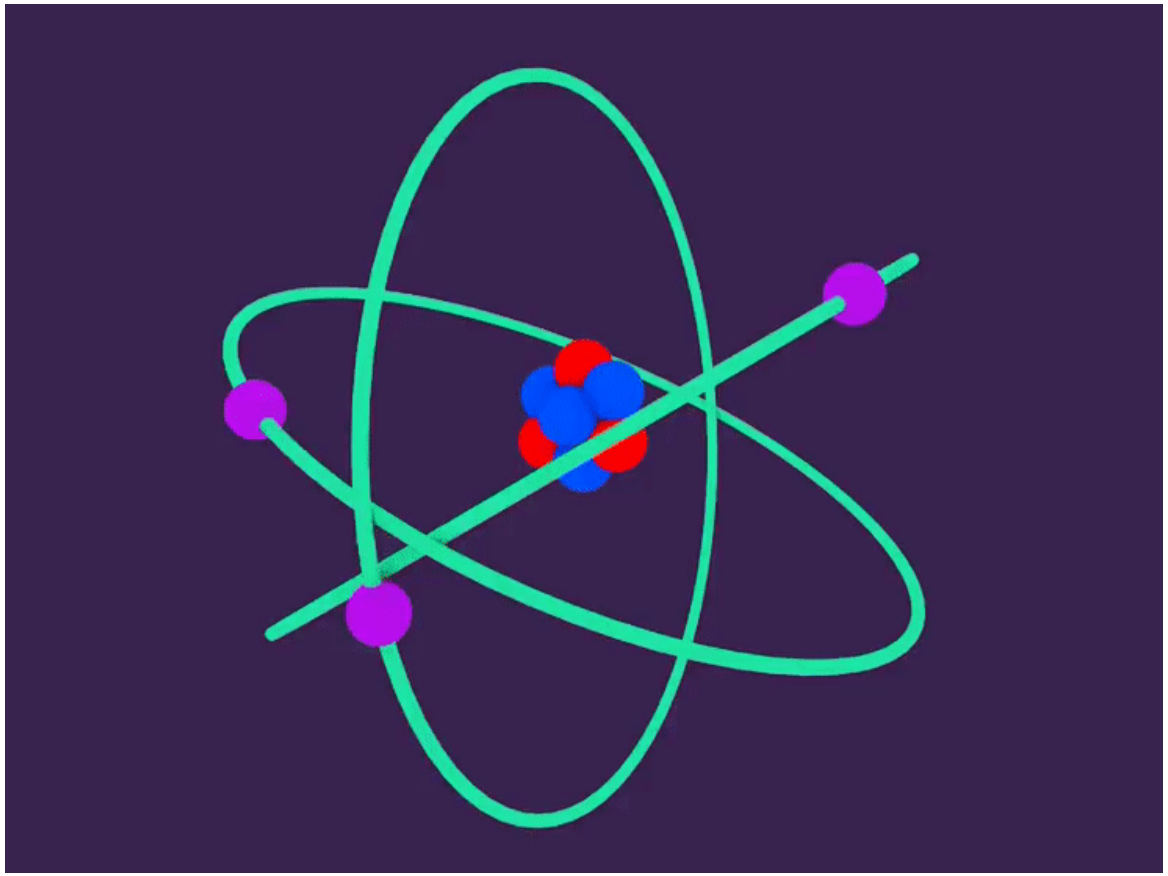
Copper (29)

Silver

Gold

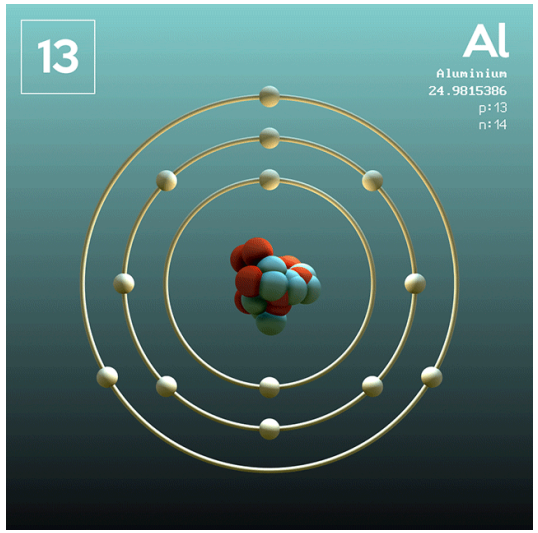
Structure of matter

- Orbital Motion
- Centrifugal Force
- Electron orbitals



Structure of matter

The outer valence orbit can never fill to more than eight electrons



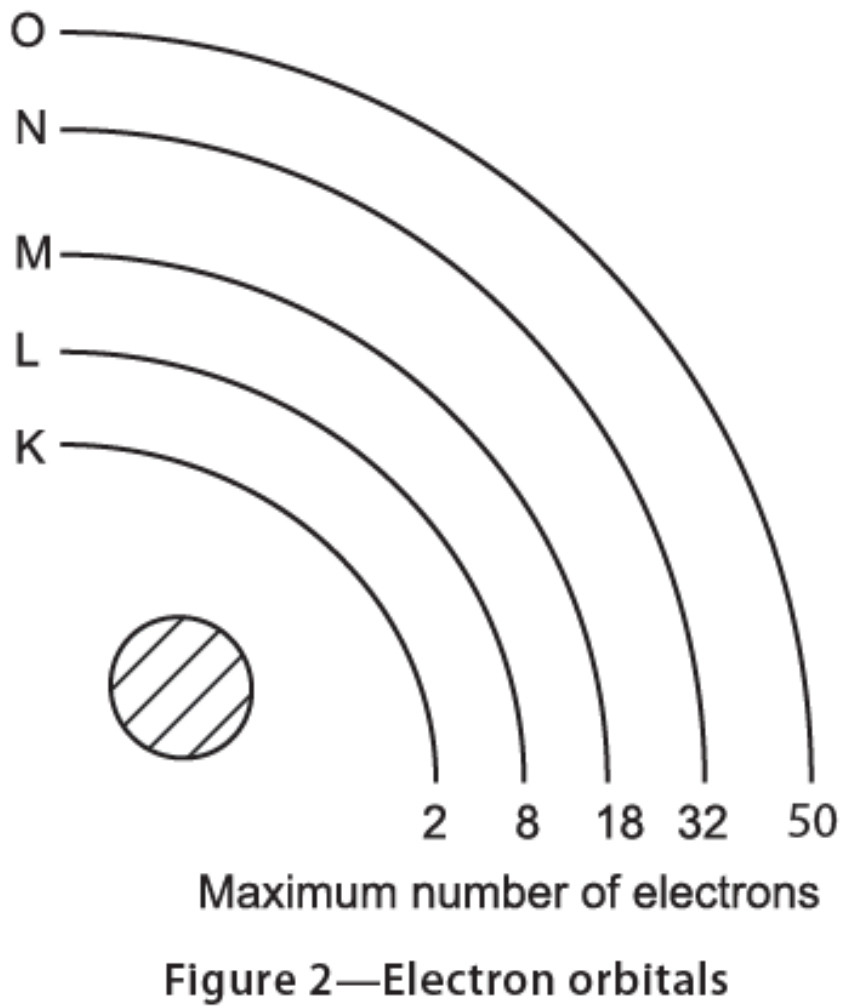


Figure 2—Electron orbitals

Structure of Matter

Why do electricians care about this?

Conductors

1 - 3 valence electrons

Silver
Copper
Gold
Aluminum
Iron

Semi-Conductors

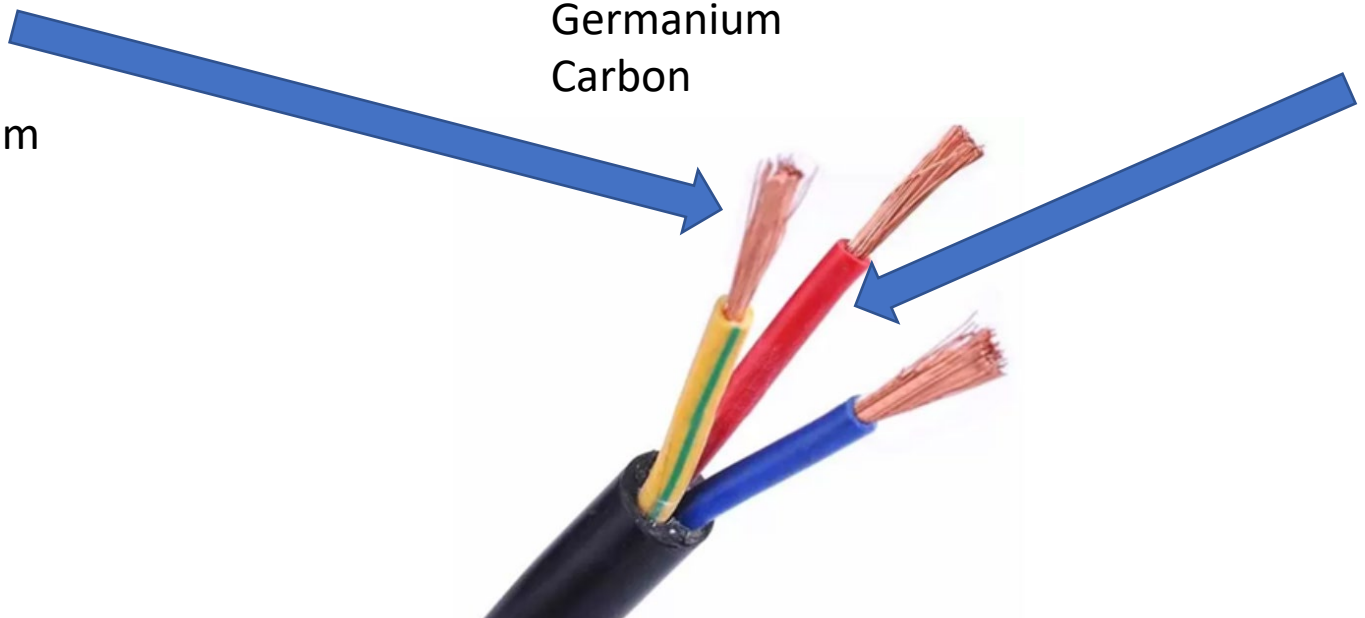
4 valence electrons

Silicon
Germanium
Carbon

Insulators

5 – 8 valence electrons

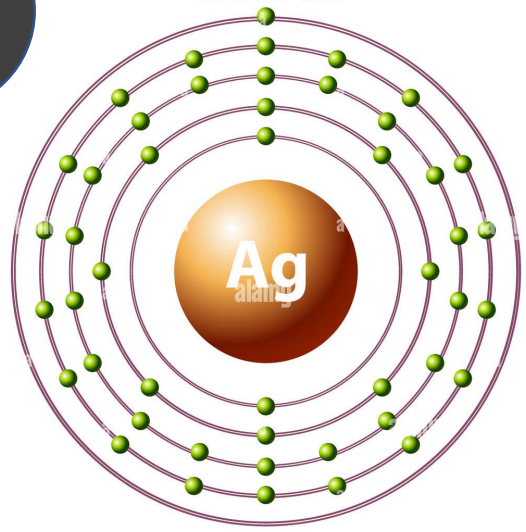
Glass
Mica
Plastic
Porcelain



Structure of Matter

47

Silver Ag



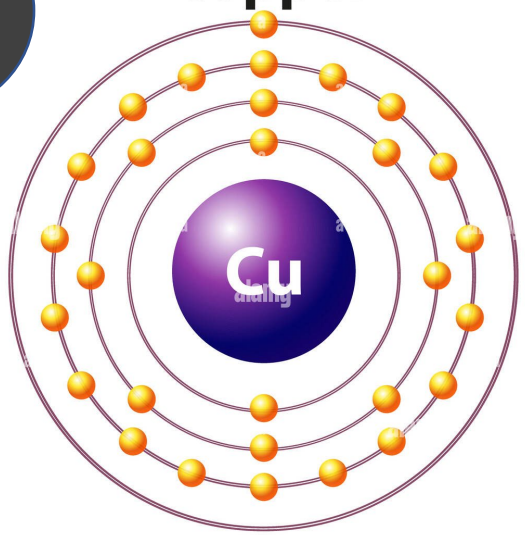
Atomic mass: 107.86

Electron configuration: 2, 8,18,18,1

VS.

29

Copper Cu



Atomic mass: 63.546

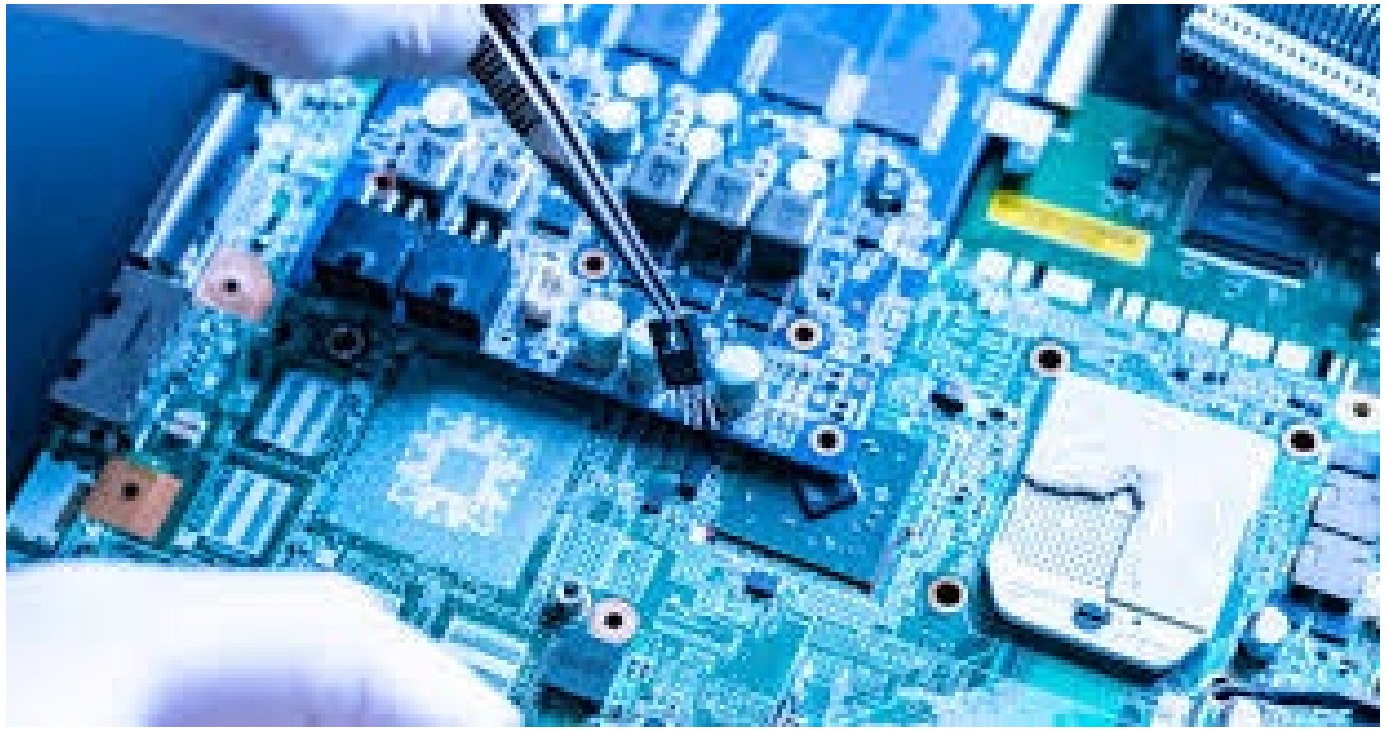
Electron configuration: 2, 8,18,1

Structure of Matter

Semiconductors

Exactly 4 valence electrons

- Silicon
- Germanium
- Carbon



VIDEO

Engineering Mindset. (October 18, 2017)

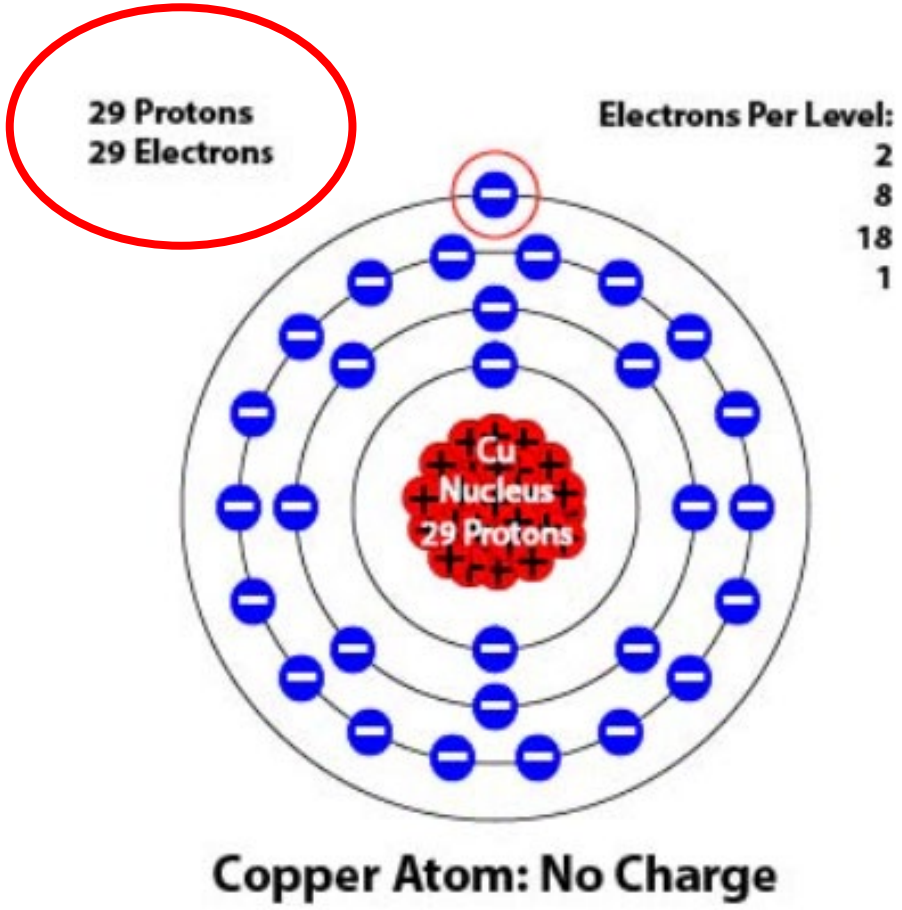
How electricity works – Working principle. YouTube.

https://www.youtube.com/watch?v=mc979OhitAg&list=PLWv9VM947MKjuqlJVp5m_Edf66SrFSHx2

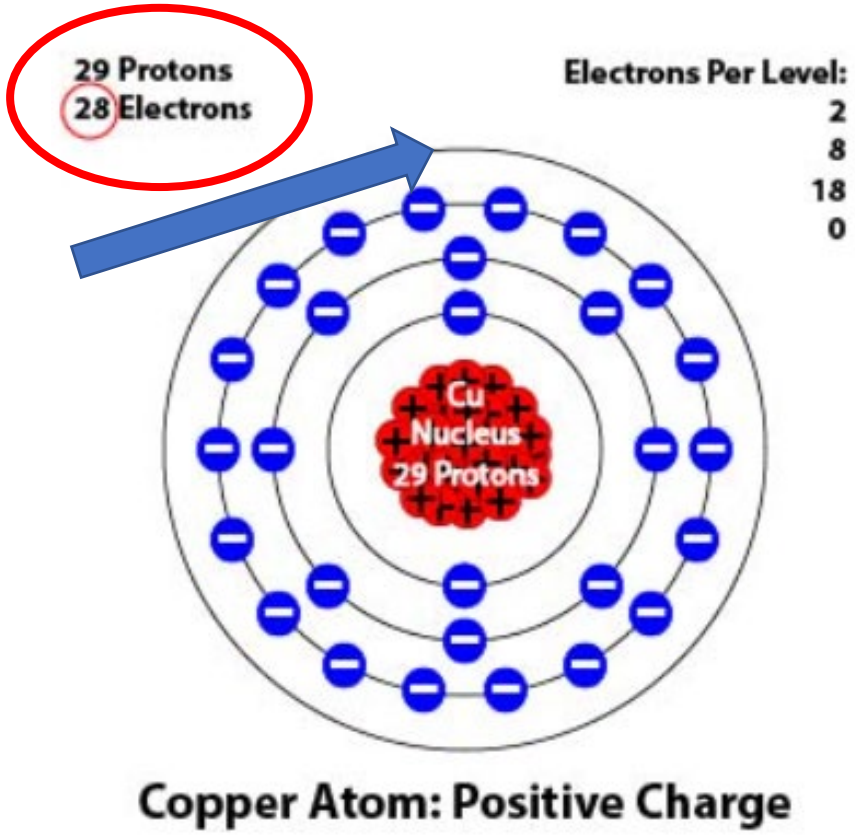
Electricity Basics

The basic concepts of electrical charge and current flow

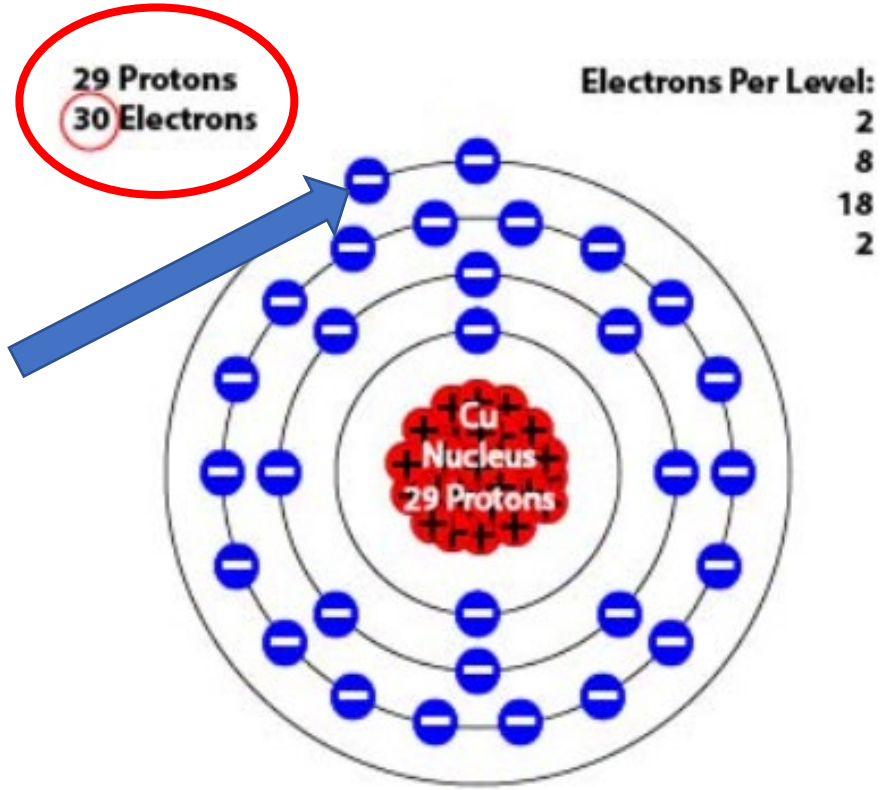
Charged bodies



Charged bodies



Copper Atom: Positive Charge



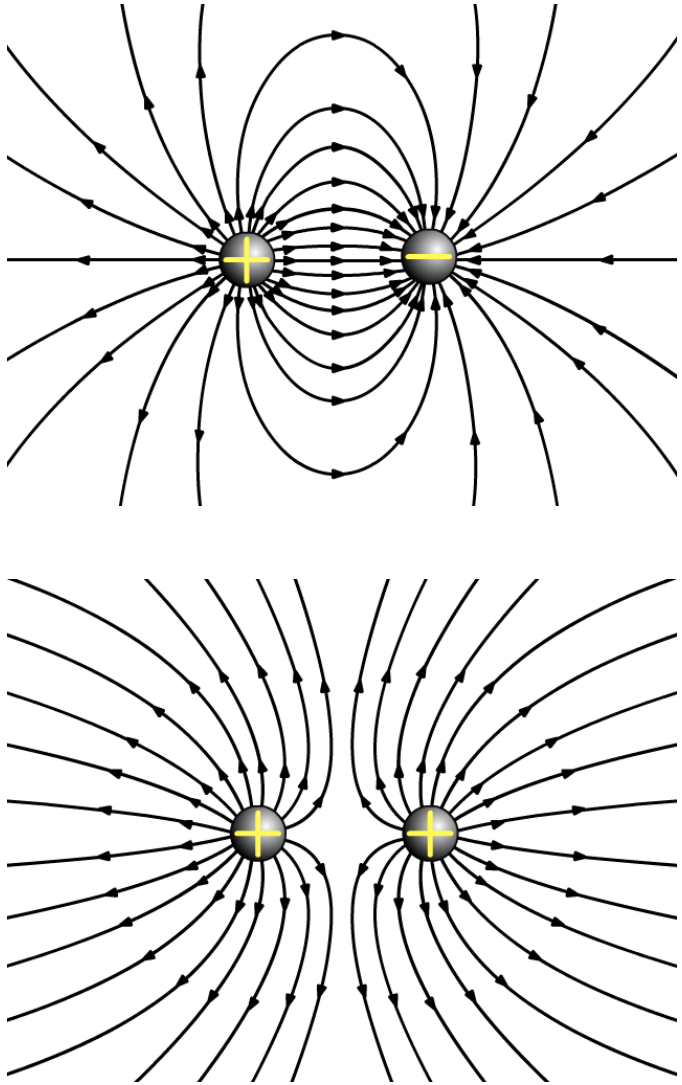
Copper Atom: Negative Charge

Field forces

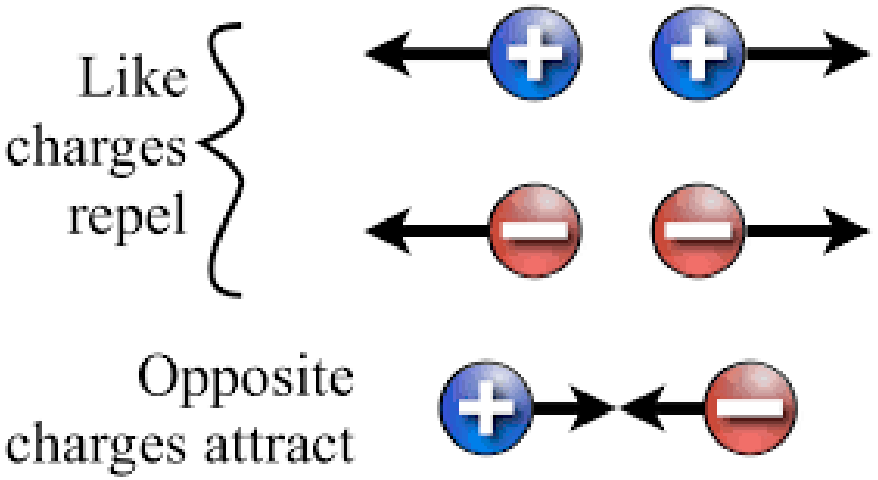
Fundamental laws of charged bodies

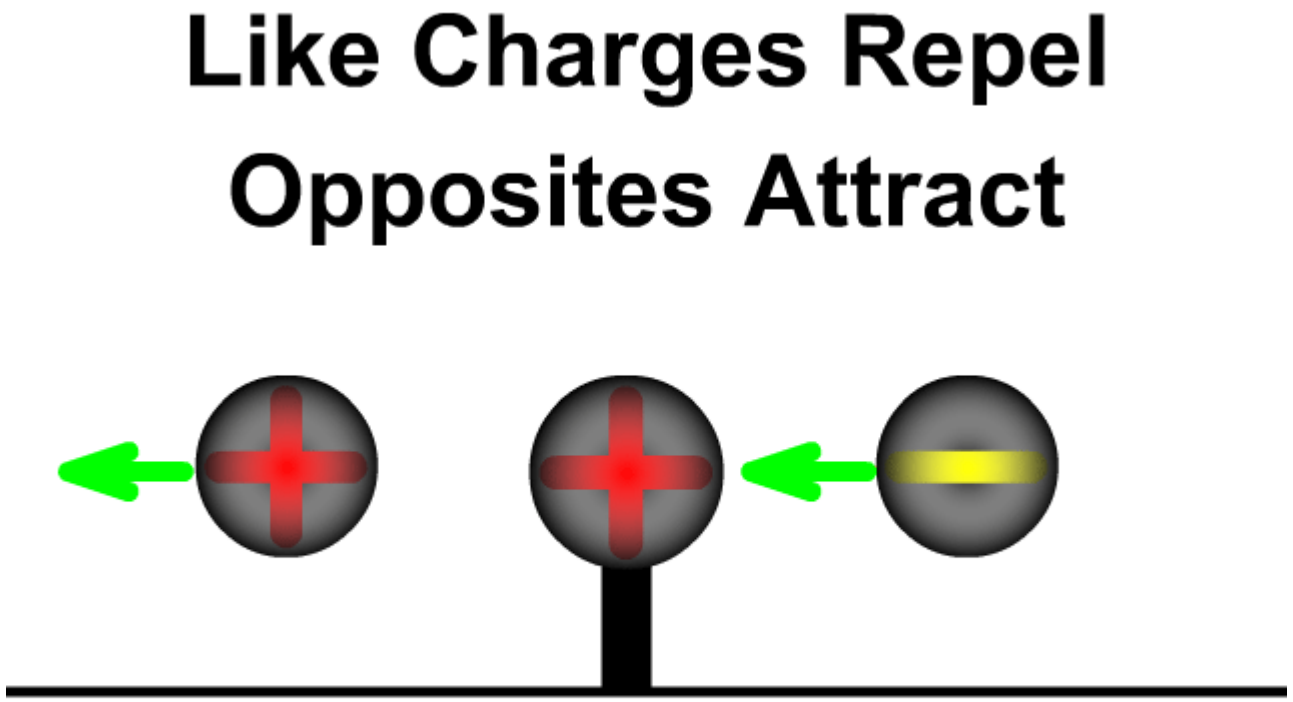
- Like charges repel
- Opposites attract
- Force proportional to charge on bodies
- Force inversely proportional to the square of the distance between the bodies

$$F = \frac{k * Q_1 * Q_2}{d^2}$$

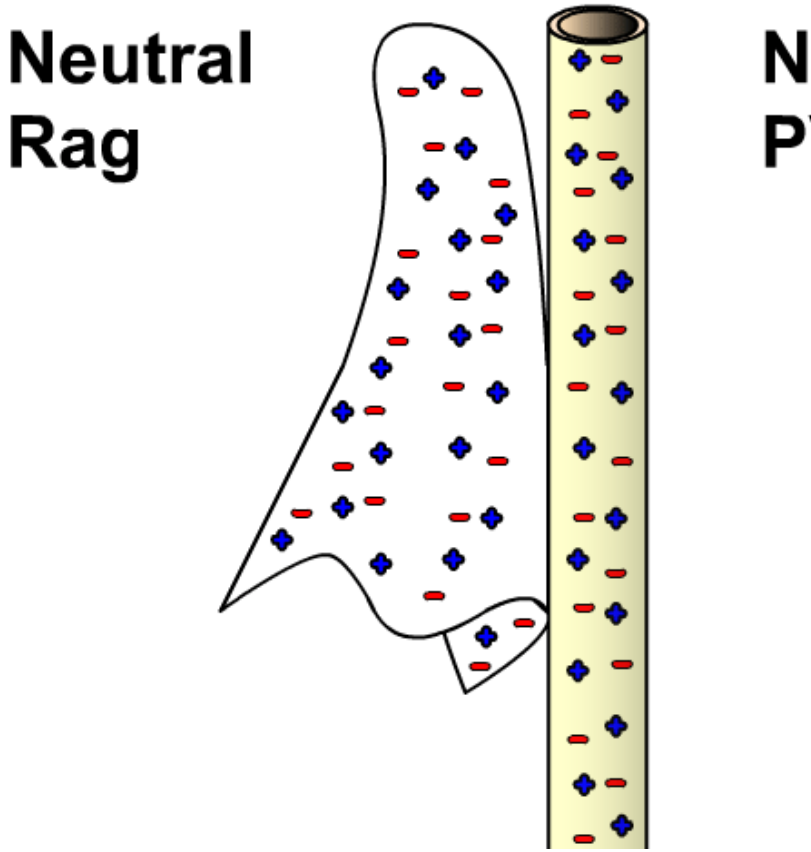


Charged bodies



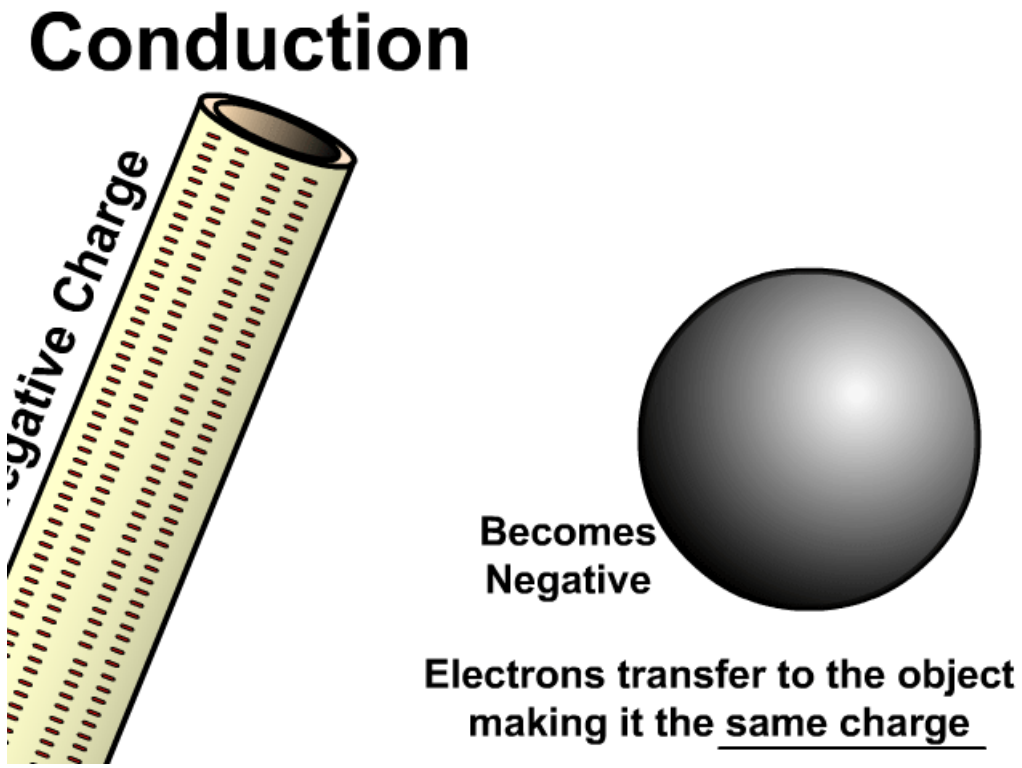


How to create a charge – Friction

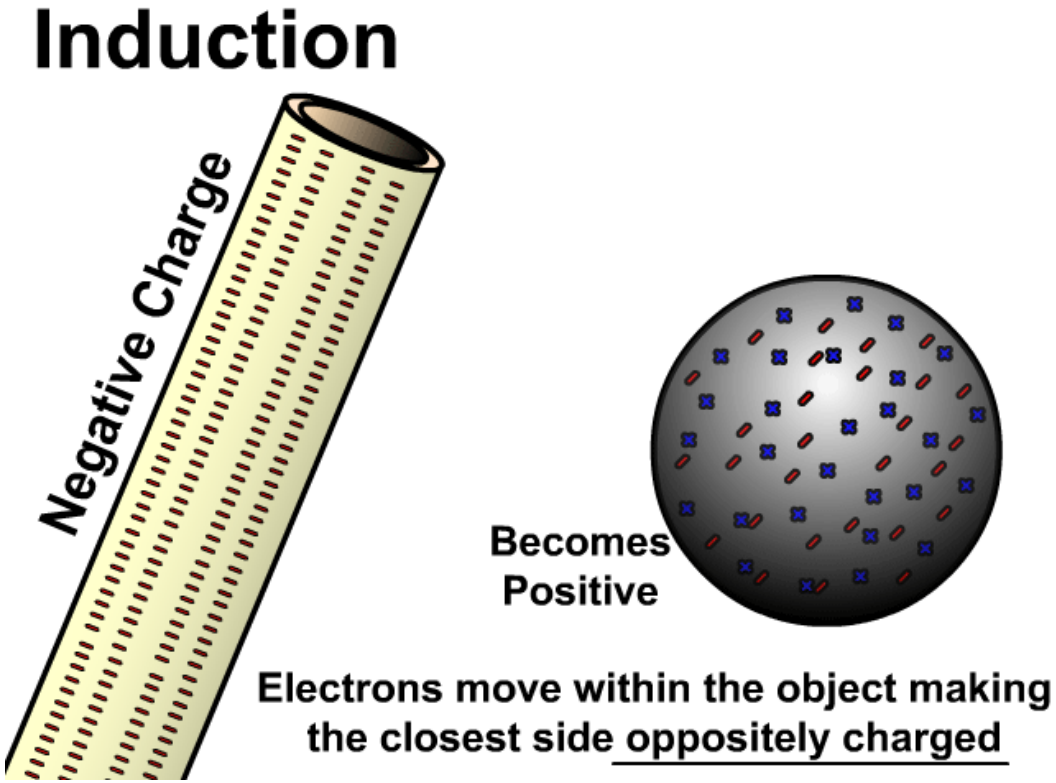


https://www.youtube.com/watch?v=F28hOSjJDX8&feature=emb_logo

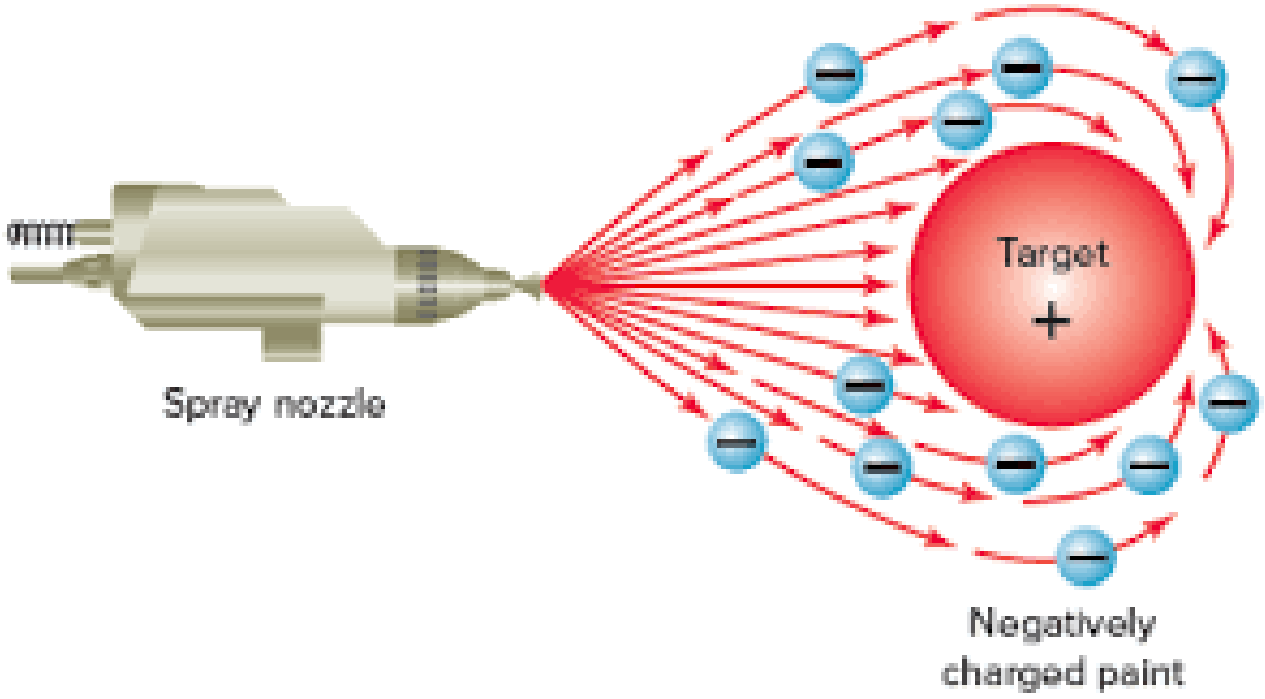
How to create a charge – Conduction



How to create a charge – Induction

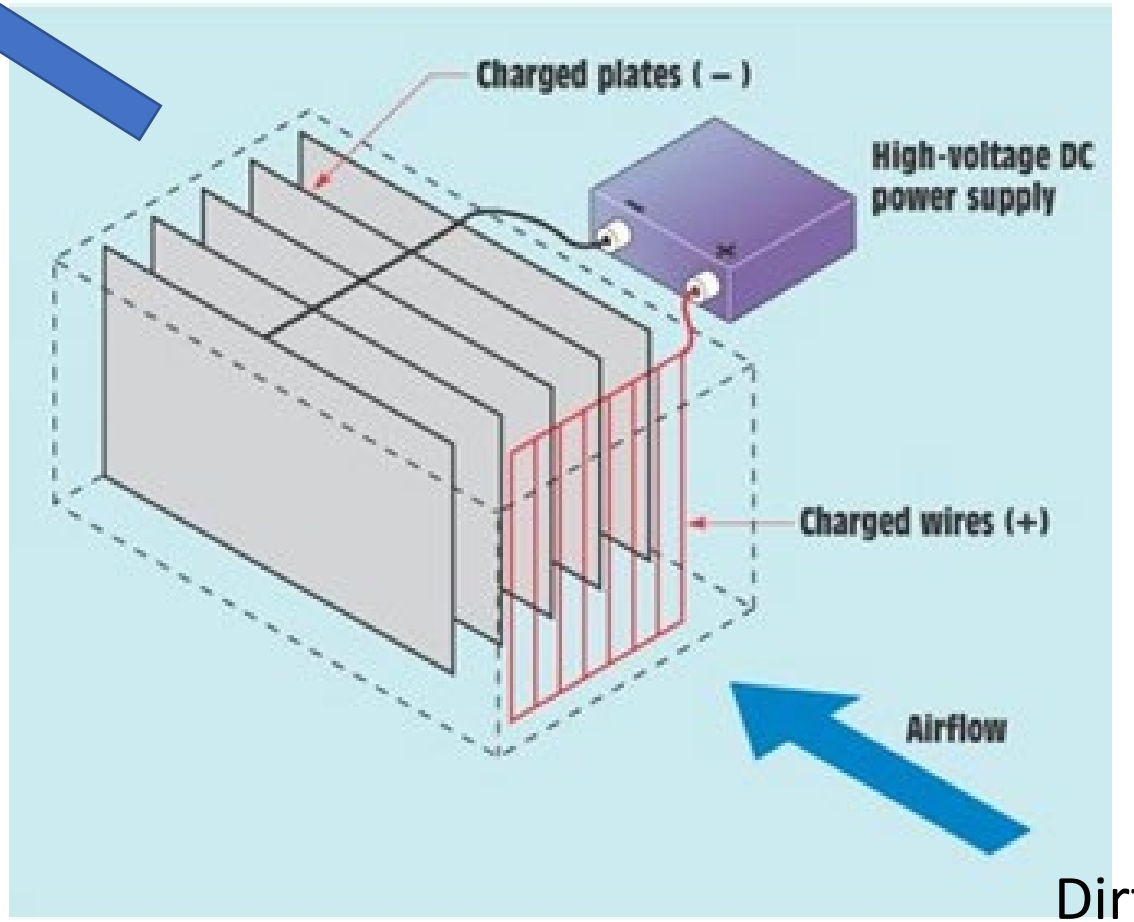


Uses of static charge – Spray Painting



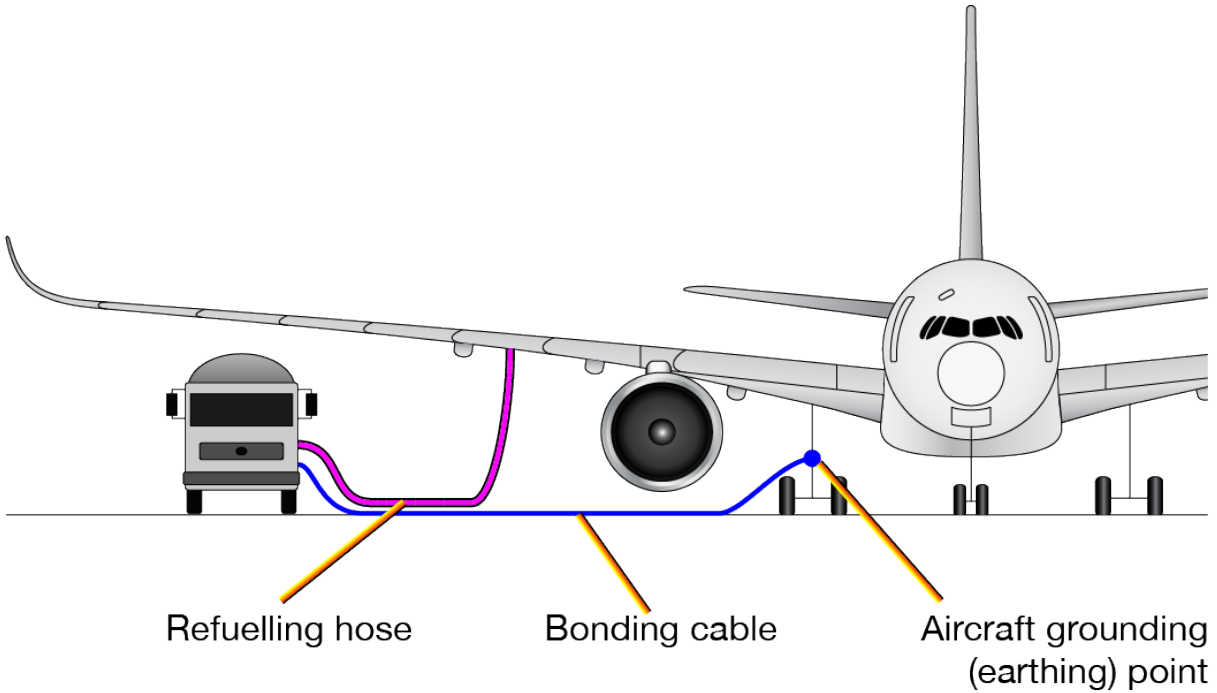
Uses of static charge – Electrostatic Air Filter

Clean air out

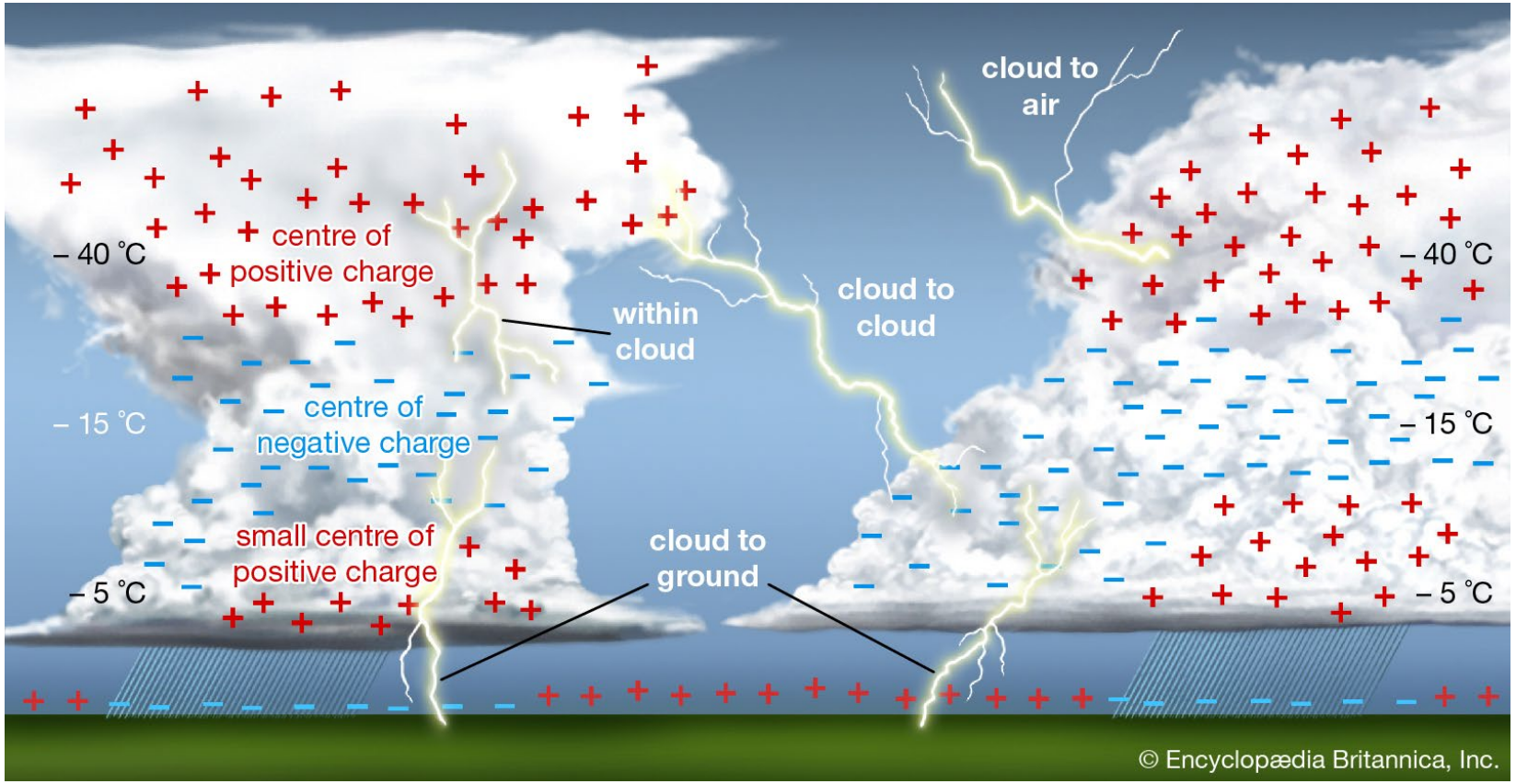


Dirty air in

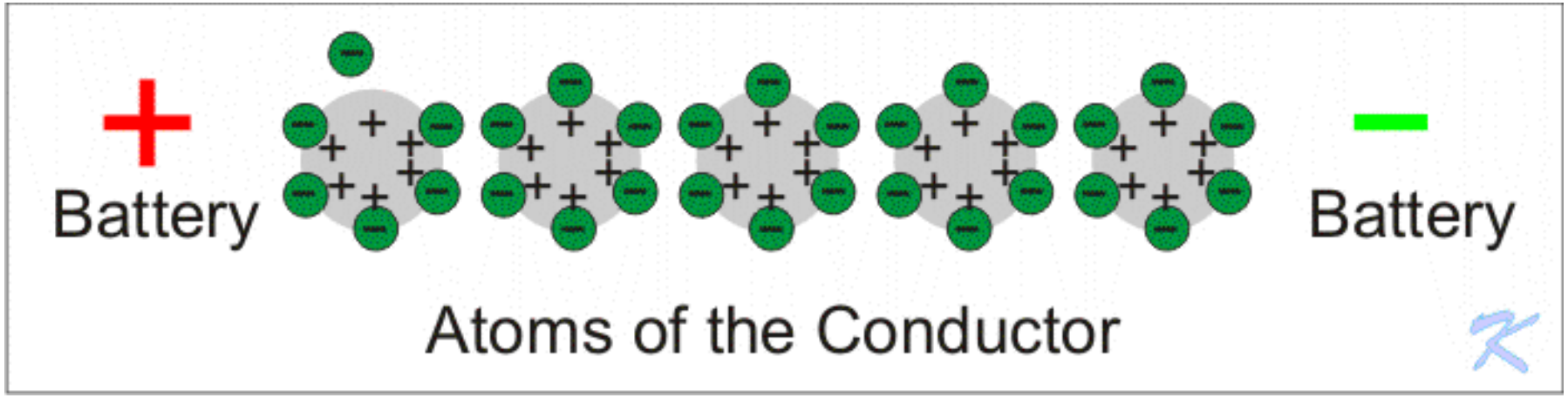
Hazards of static charge – Fuel Transfer



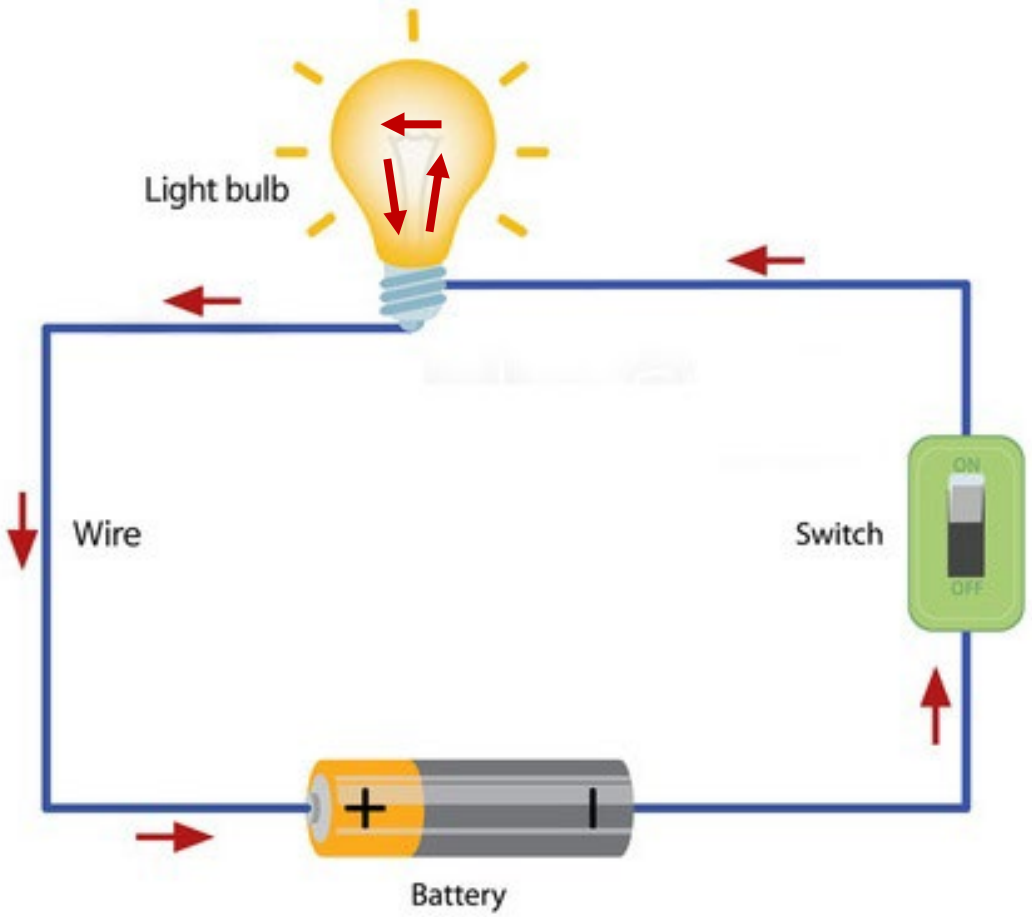
Hazards of static charge - Lightning



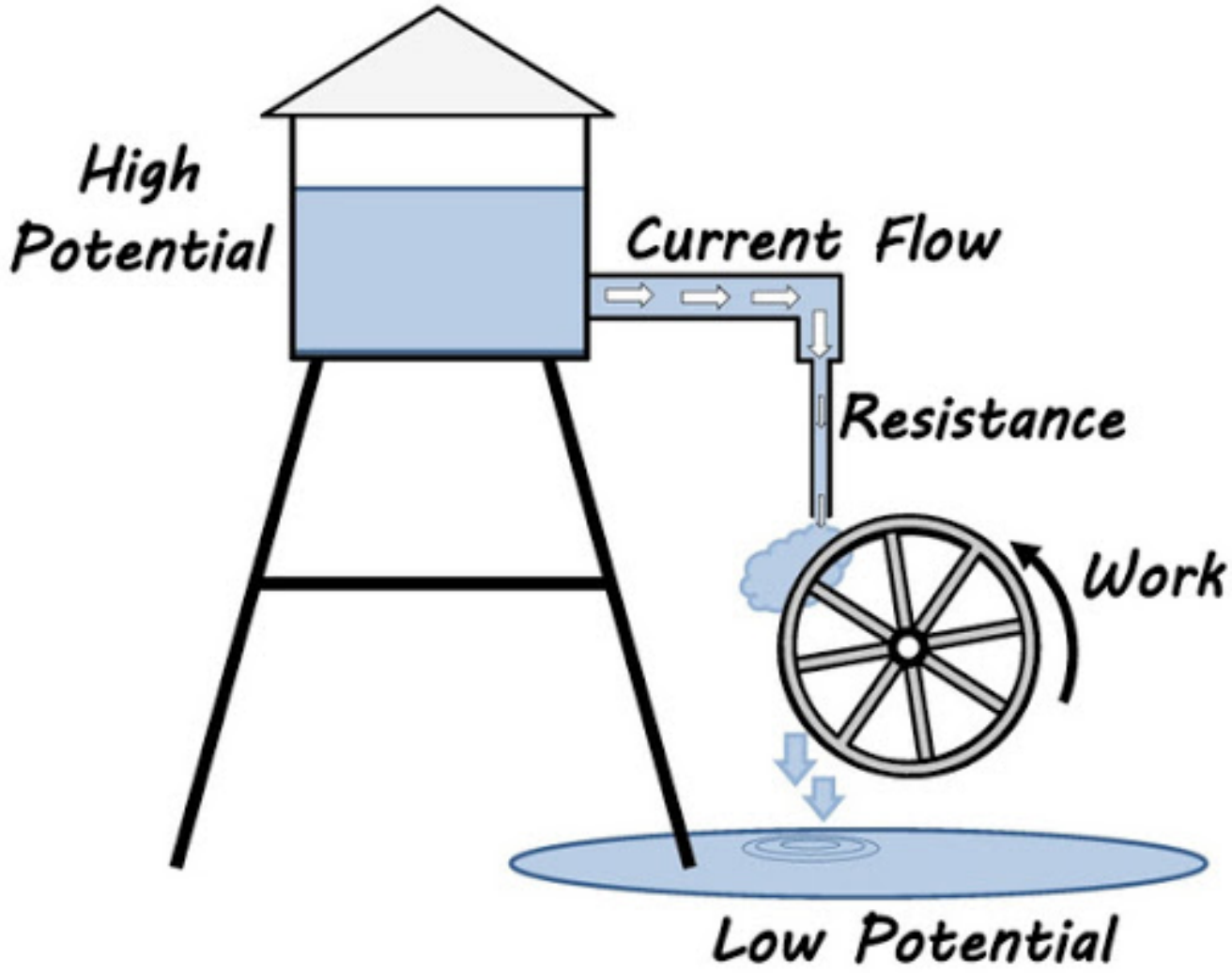
Electron flow



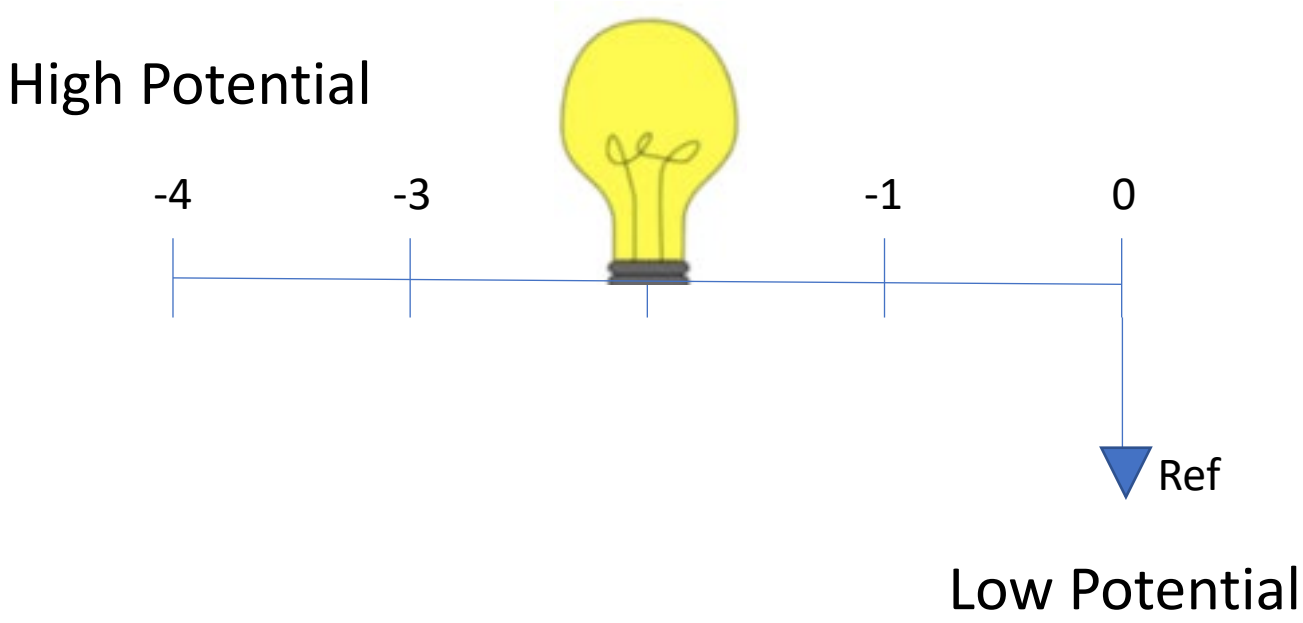
Electron flow



Gravitational Potential Energy

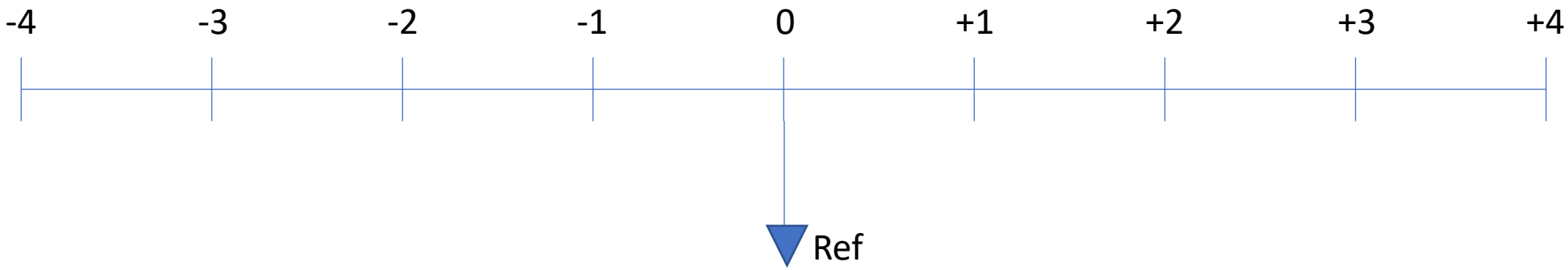


Electrical Potential Energy



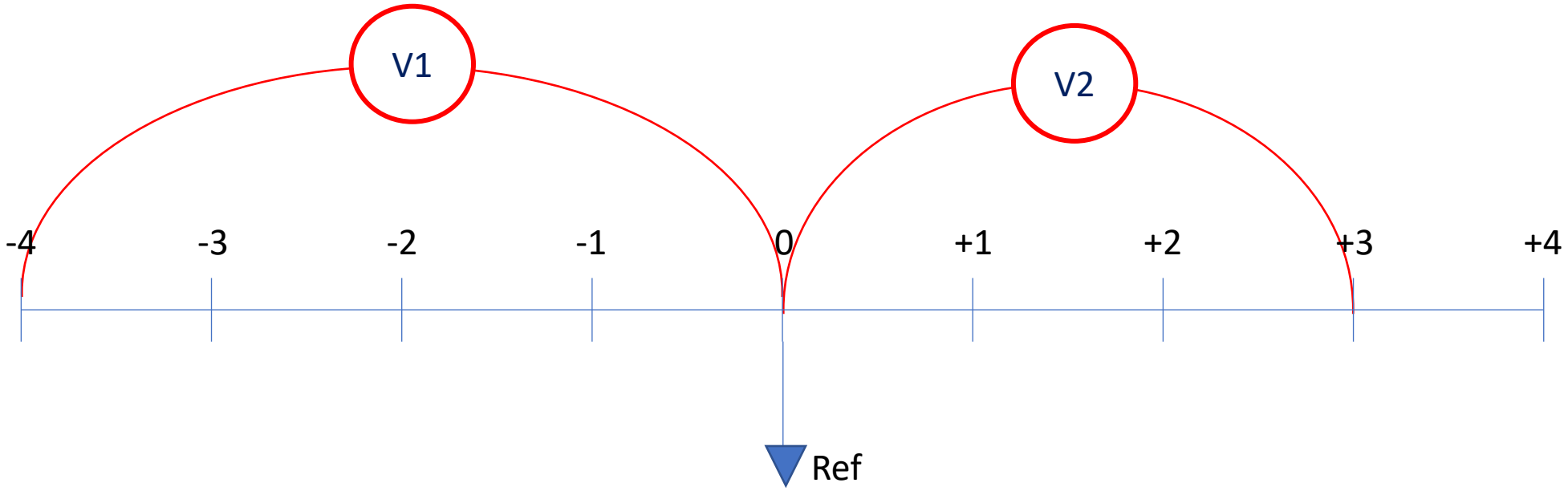
Electrical Polarity

- *Polarity* is a very important electrical concept.



Electrical Polarity

What would the following voltmeters read?



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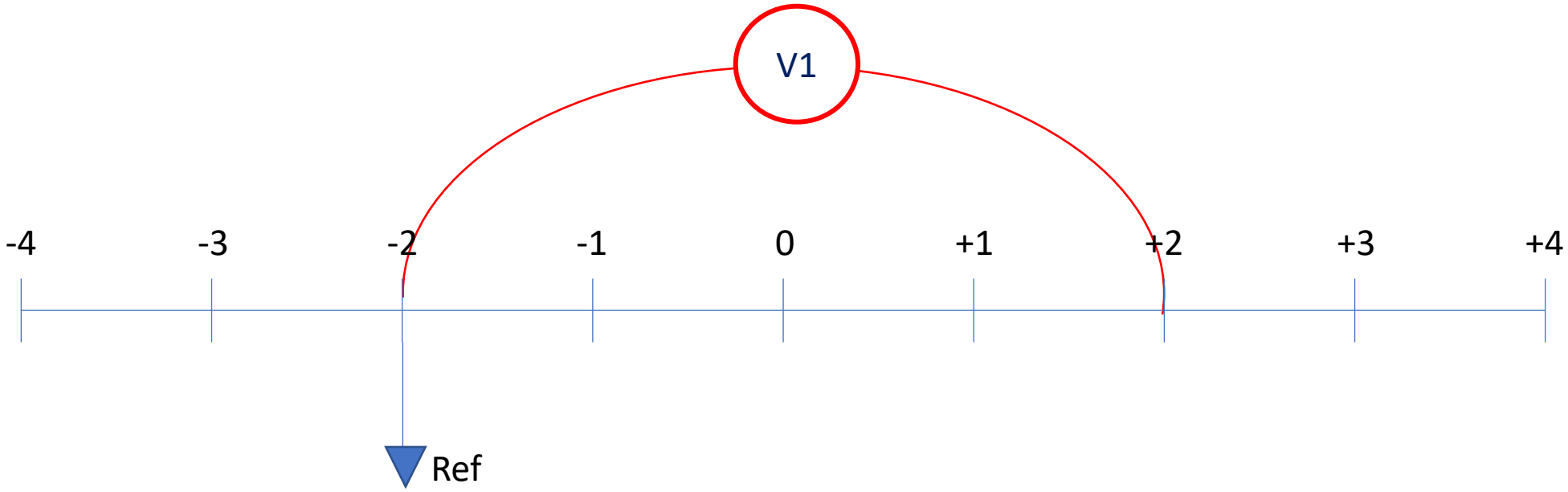


VIDEO

Engineering Mindset. (November 12, 2018)

Voltage explained – What is voltage? YouTube.

https://www.youtube.com/watch?v=w82aSjLuD_8&list=PLWv9VM947MKjuqlJVp5m_Edf66SrFSHx2&index=2

Electricity Basics

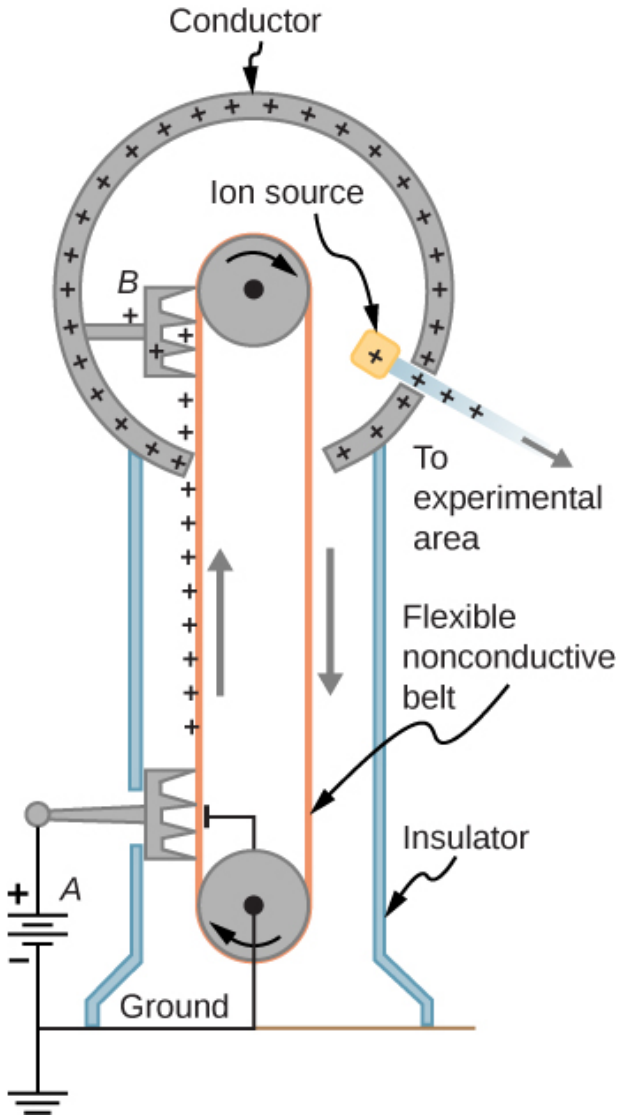
The methods of producing electricity

Six Methods of Producing Electricity

- Friction aka triboelectric
- Chemical aka electrochemical
- Pressure aka piezoelectric
- Heat aka thermoelectric
- Light aka photovoltaic
- Magnetism aka magnetoelectric

Friction, AKA triboelectric

Van de Graff Generator



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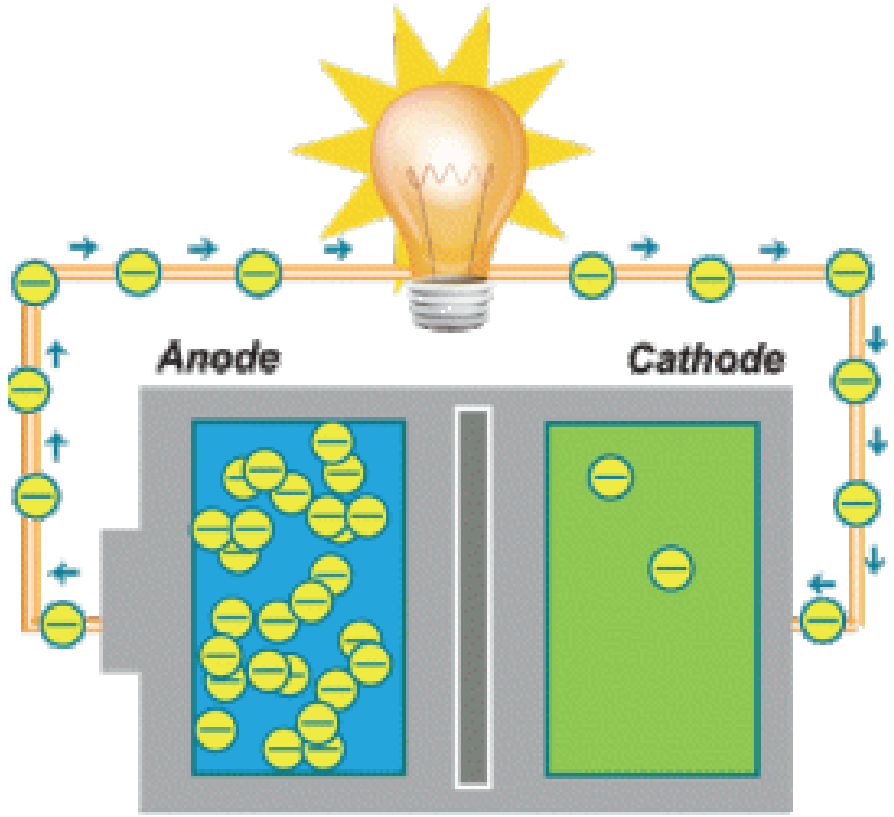
Chemical, AKA electrochemical



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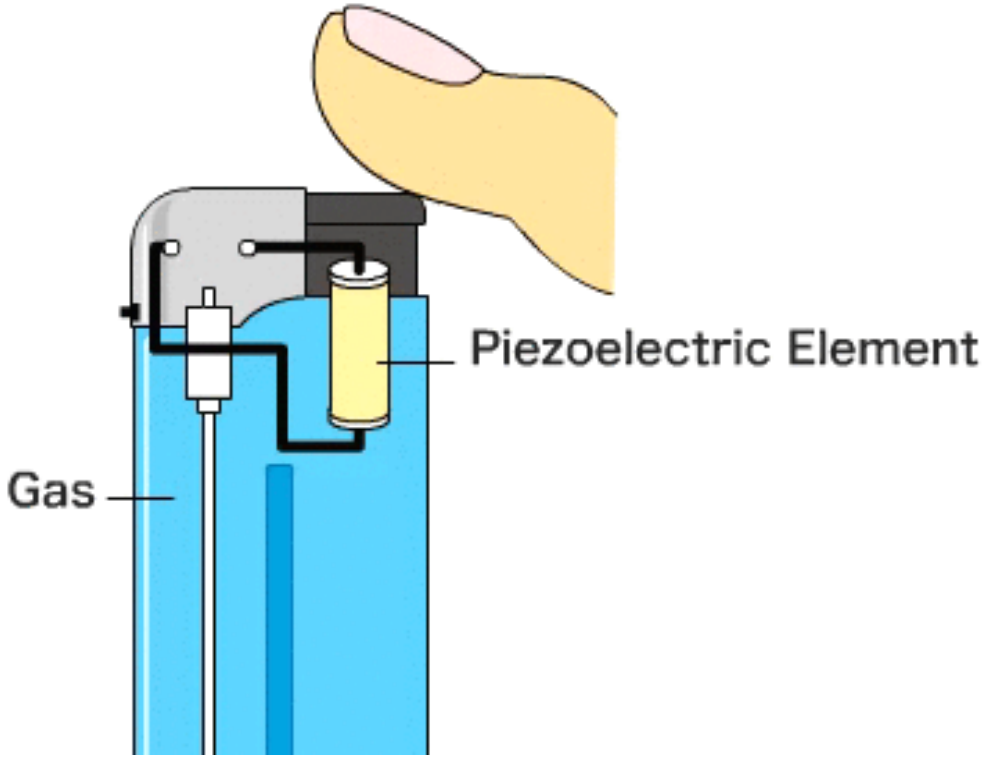
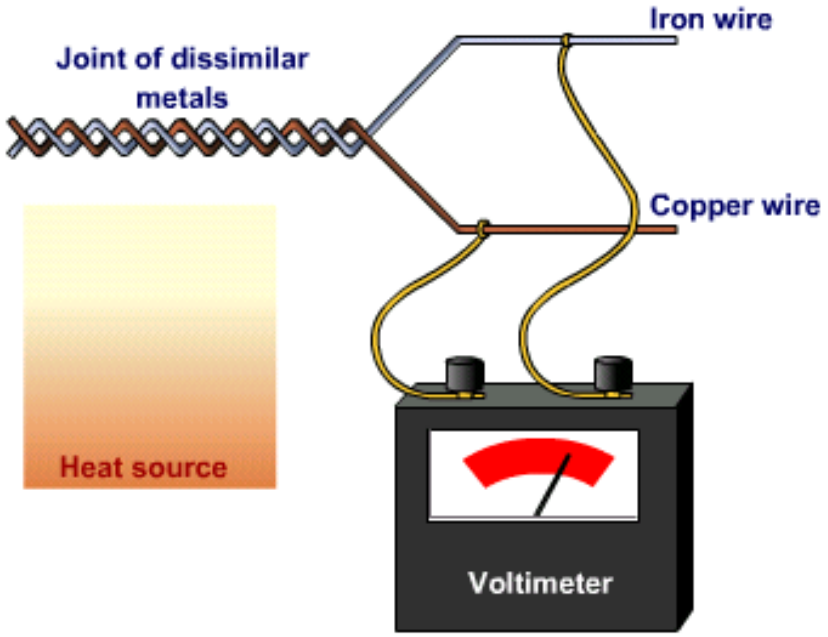
Pressure, AKA piezoelectric



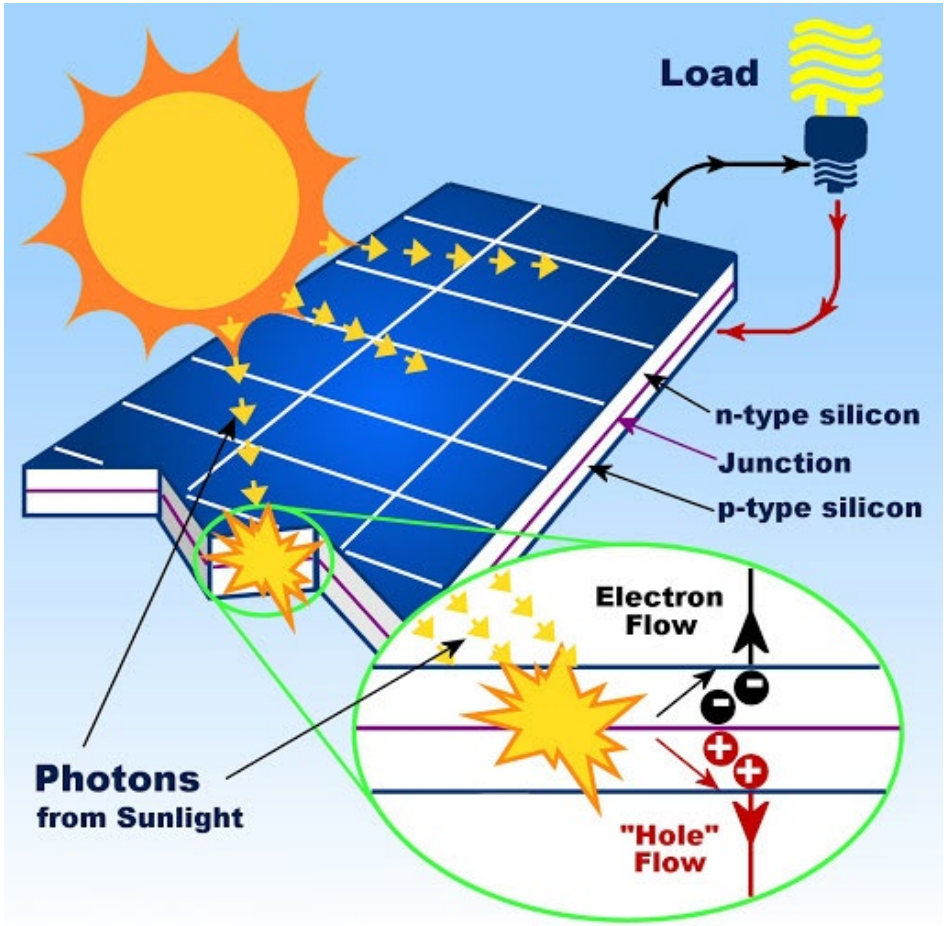
https://www.google.com/search?q=how+does+a+piezoelectric+element+work&source=lmns&tbm=vid&bih=667&biw=1407&rlz=1C5GCEM_en&hl=en&sa=X&ved=2ahUKEwjWr5eP0pH9AhW_MDQIHeU1CNgQ_AUoAnoECAEQAg#fpstate=ive&vld=cid:7a30442d,vid:_XABS0dR15o

Heat, AKA thermoelectric



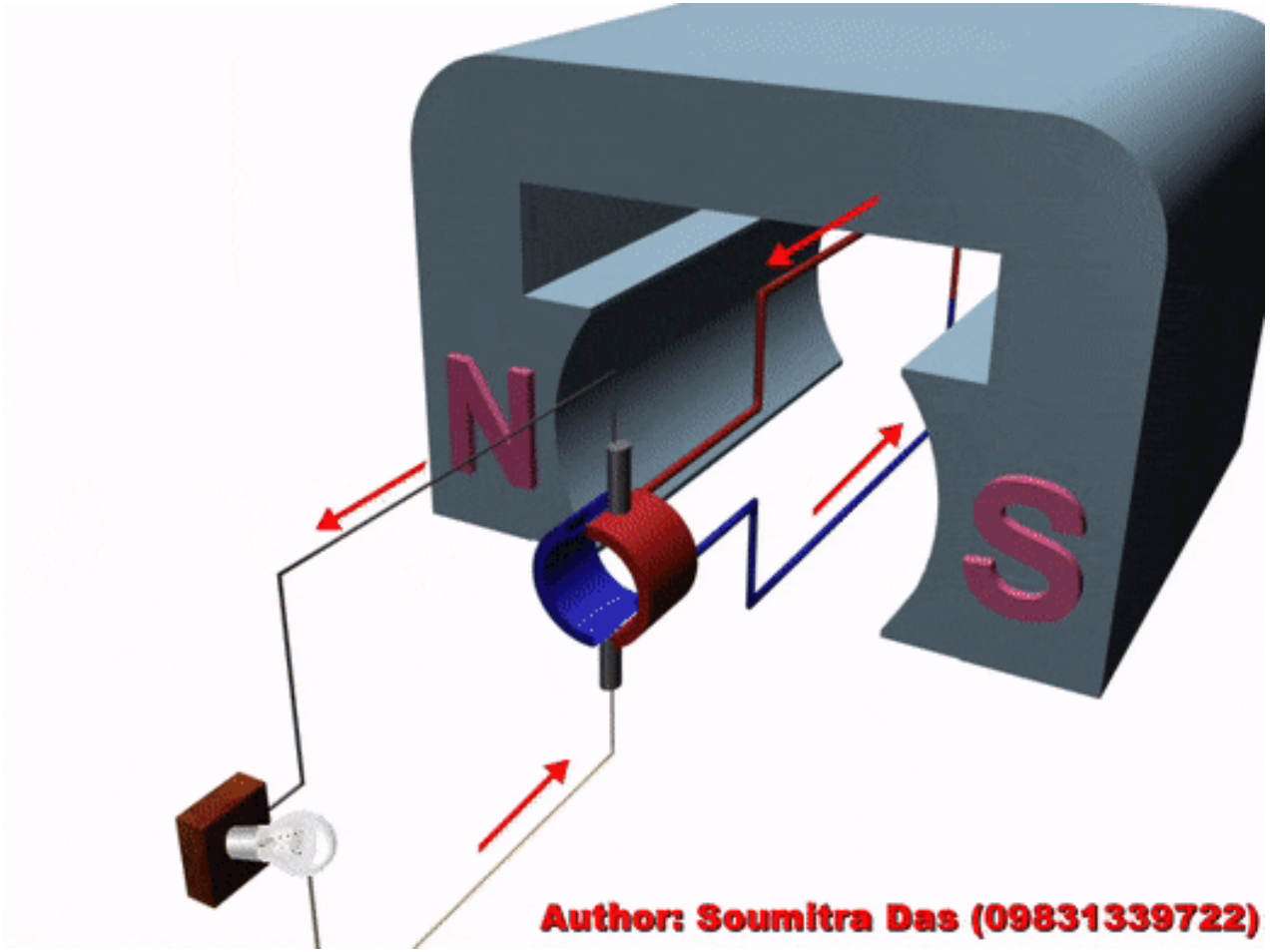
YouTube Video

Light, AKA photovoltaic effect



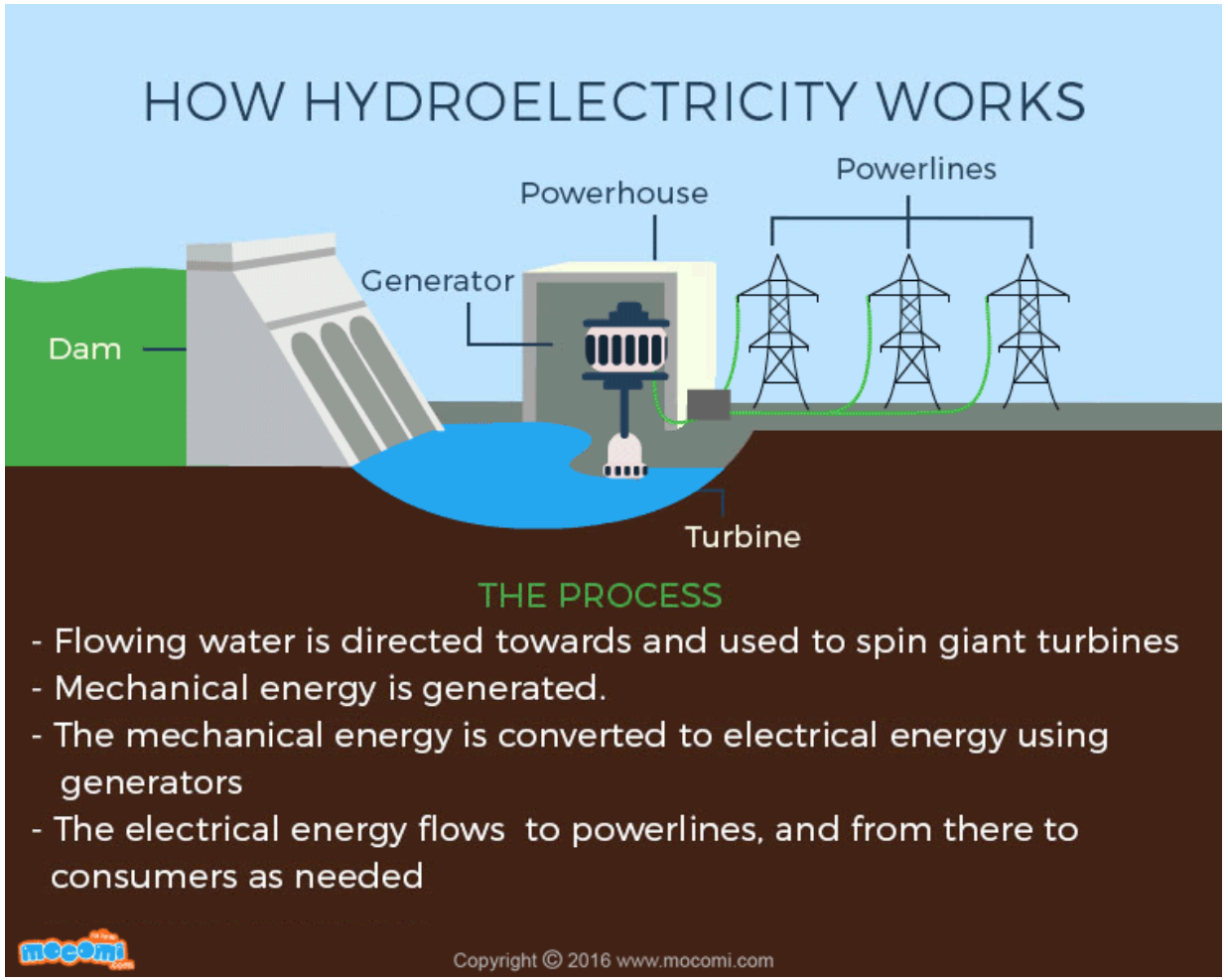
https://www.google.com/search?q=how+does+the+photovoltaic+effect+work&rlz=1C5GCEM_en&source=lnms&tbm=vid&sa=X&ved=2ahUKEwjLv6nL1pH9AhU4ADQIHc7sDWsQ_AUoAXoECAEQAw&biw=1281&bih=667&dpr=1#fpstate=ive&vld=cid:29375676,vid:iBH9ZKSvWHk

Magnetism, AKA magnetoelectric effect.



YouTube Video

Magnetism, AKA magnetoelectric effect.



Six Ways to Produce a Voltage / Difference of Potential / Electromotive Force (EMF)

Simple Name	Technical Name	Example
Friction	Triboelectric	Van de Graff
Chemical	Electrochemical	A battery
Pressure	Piezoelectric	BBQ lighter
Heat	Thermoelectric	Thermocouple
Light	Photovoltaic	Solar panel
Magnetism	Magnetoelectric	Generator

VIDEO

Engineering Mindset. (November 19, 2018)

What is current – Electric current explained, electricity basics. YouTube.

https://www.youtube.com/watch?v=8Posj4WMo0o&list=PLWv9VM947MKjuqlJVp5m_Edf66SrFSHx2&index=3

Do you recall?

SHOP VIDEO – DAY 3

Engineering Mindset. (May 9, 2019)

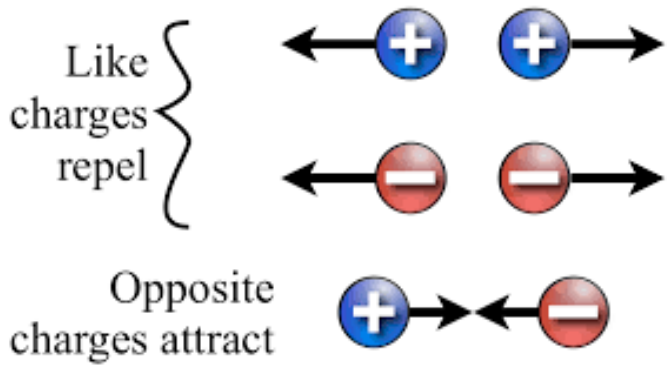
3 way switches explained – How to wire 3 way light switch. YouTube.

https://www.youtube.com/watch?v=_u5ORnhqn8g

Electricity Basics

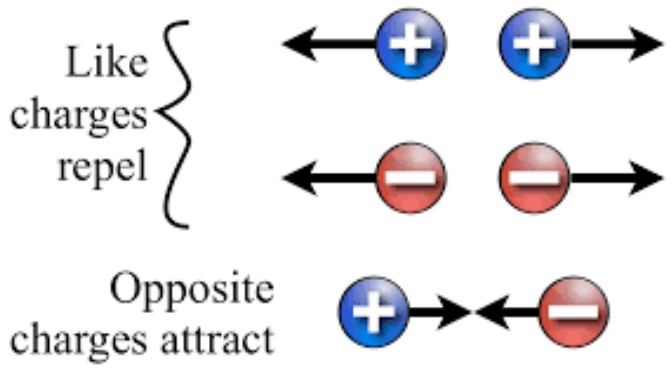
Electrical quantities, units, symbols and prefixes

How is a charge measured?



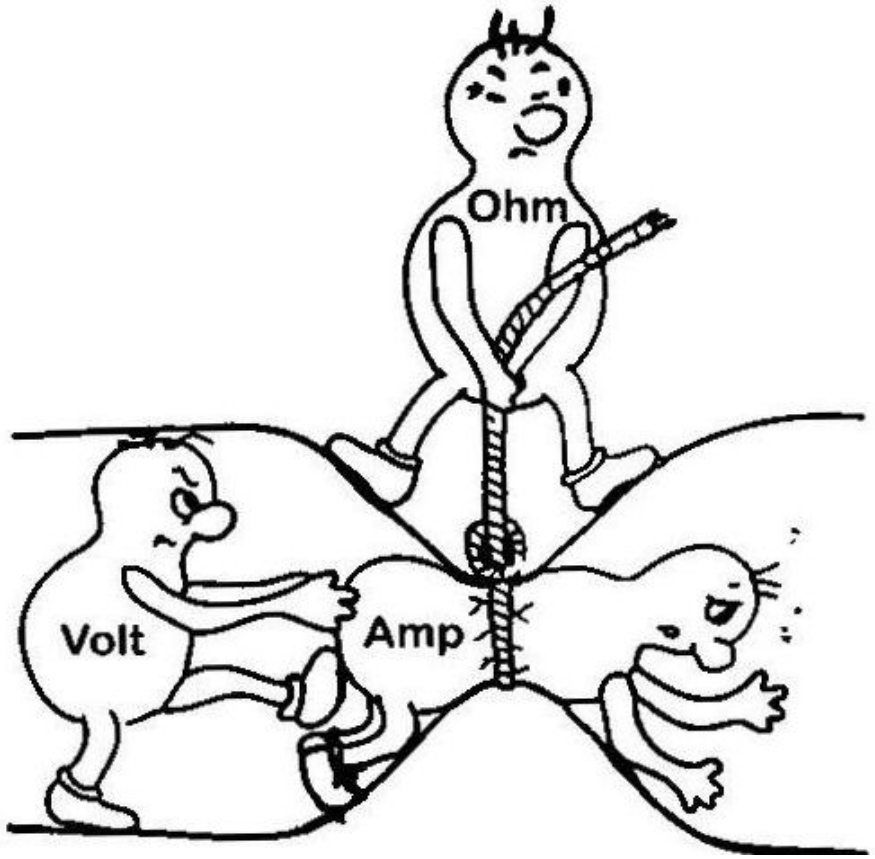
- Represented by the letter Q
- 6.24 x 10^{18} electrons equals 1 Coulomb
- Therefore, the abbreviation for the unit of charge is C

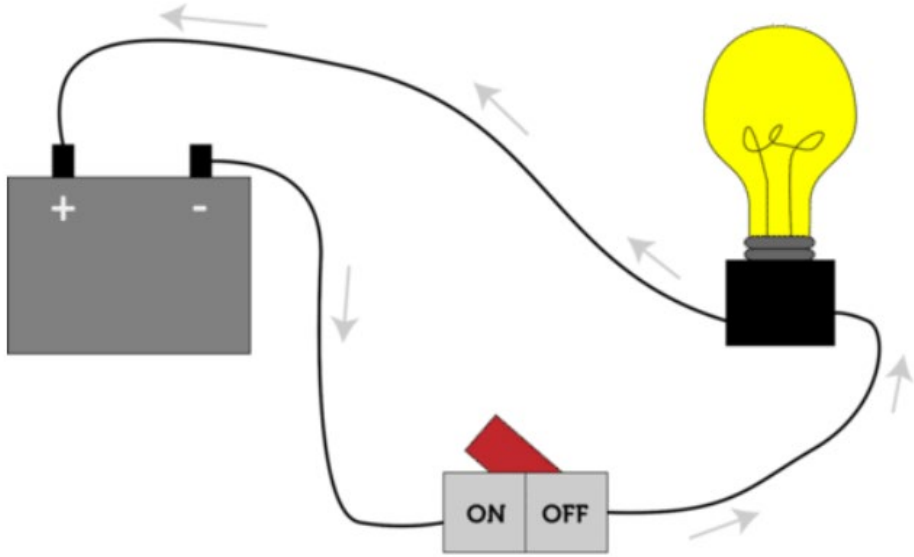
How is a charge related?



- Joules is the unit used to measure energy or work.
- Voltage is the amount of energy (J) per unit charge (C). [J/C]
- 1 volt is exactly 1 joule of energy done by 1 coulomb of charge. [1V = 1J/1C]

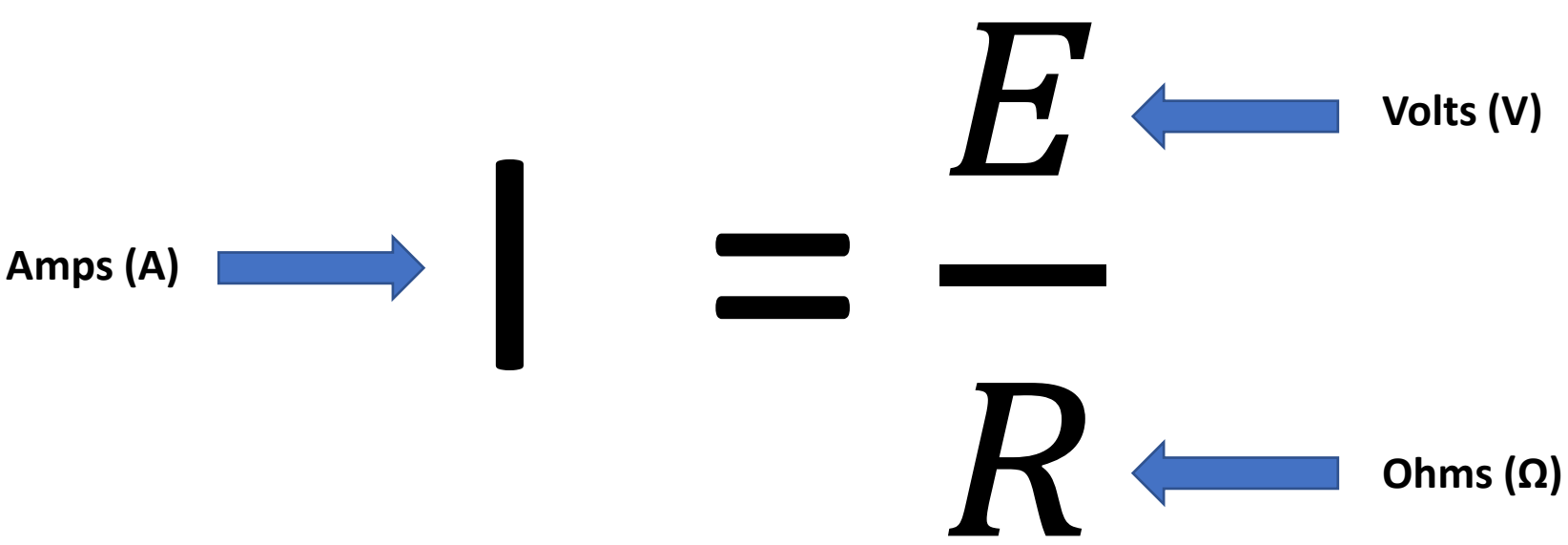
Units of Electrical Circuits





Electrical quantity	Symbol	Electrical unit	Abbreviation
EMF or PD (Voltage)	E	Volt	V
Resistance	R	Ohm	Ω
Current	I	Amp	A

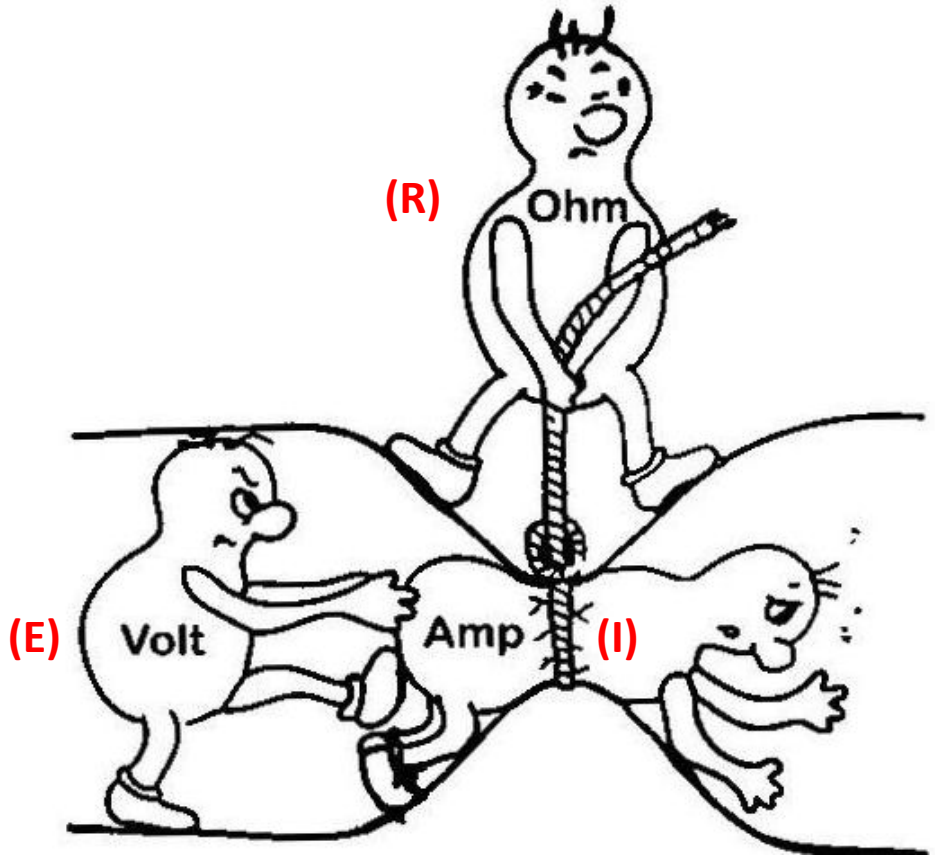
Ohm’s Law



Ohm’s law states that for any circuit the electric current is directly proportional to the voltage and is inversely proportional to the resistance.

Ohm’s Law

Rearranged

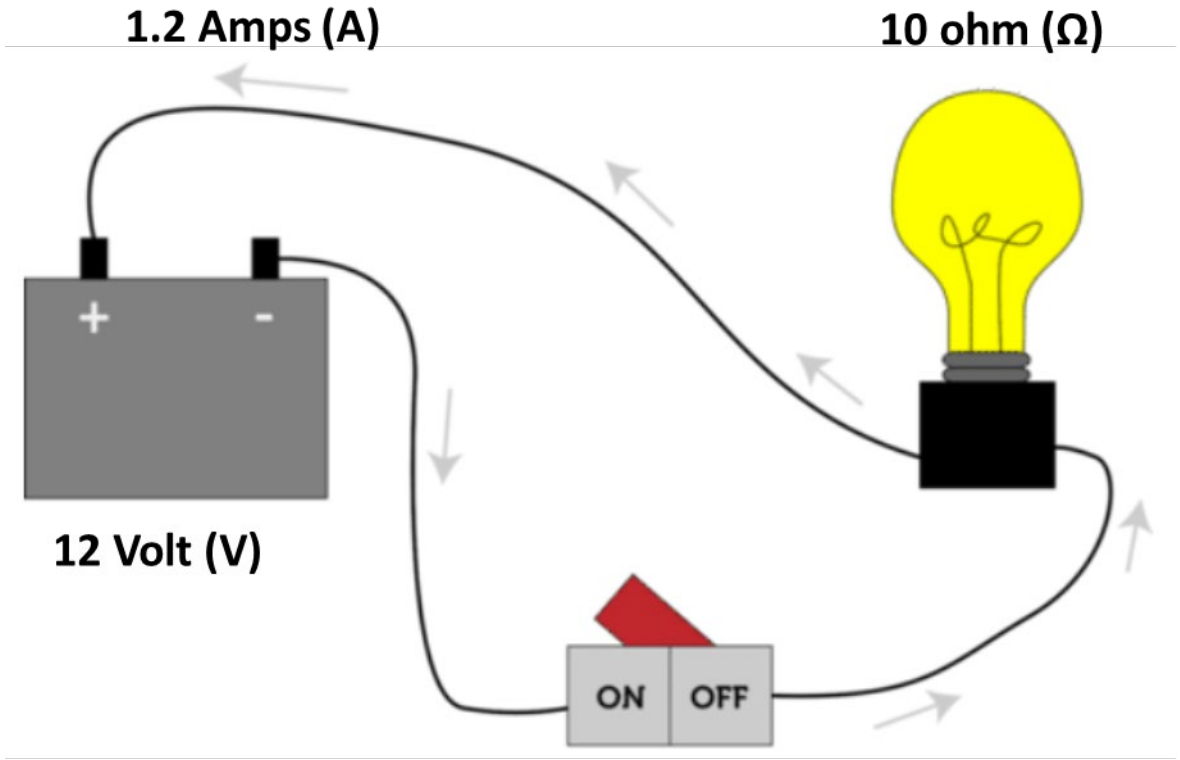


$$I = \frac{E}{R}$$

$$E = I\,R \qquad R = \frac{E}{I}$$

Ohm’s Law

Example



$$E = I\,R$$

$$I = \frac{E}{R} \qquad R = \frac{E}{I}$$

Power

The rate at which the work is being done in an electrical circuit is called ‘power’.

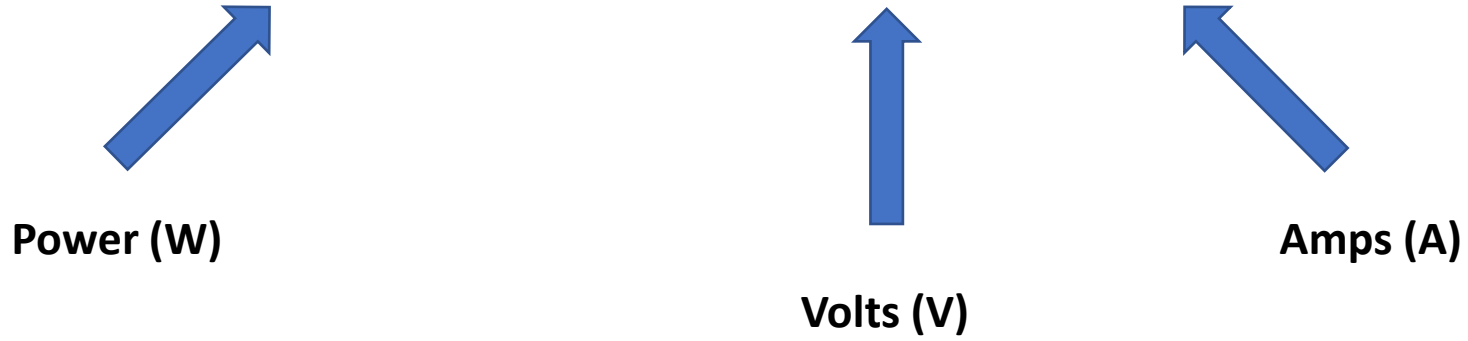
In other words, the electric power is defined as the rate of the transferred of energy.

Electrical power is converted to other forms of useful energy (light, heat, motion…)

Electrical quantity	Symbol	Electrical unit	Abbreviation
Power	P	Watt	W
Voltage (EMF)	E	Volt	V
Resistance	R	Ohm	Ω
Current	I	Amp	A

Watt’s Law

$$P = E\ I$$



Watts Law states that the power of an electrical circuit is the product of its voltage and current.

Watt's Law

$$P = E\ I$$

Work **Pressure** **Flow**

Consider the following scenarios:

a) Low volume of water (up to ankles), fast moving stream
b) High volume of water (up to waist), slow moving river
c) High volume of water, fast moving river

When does the river have more power to move you?

Watt's Law

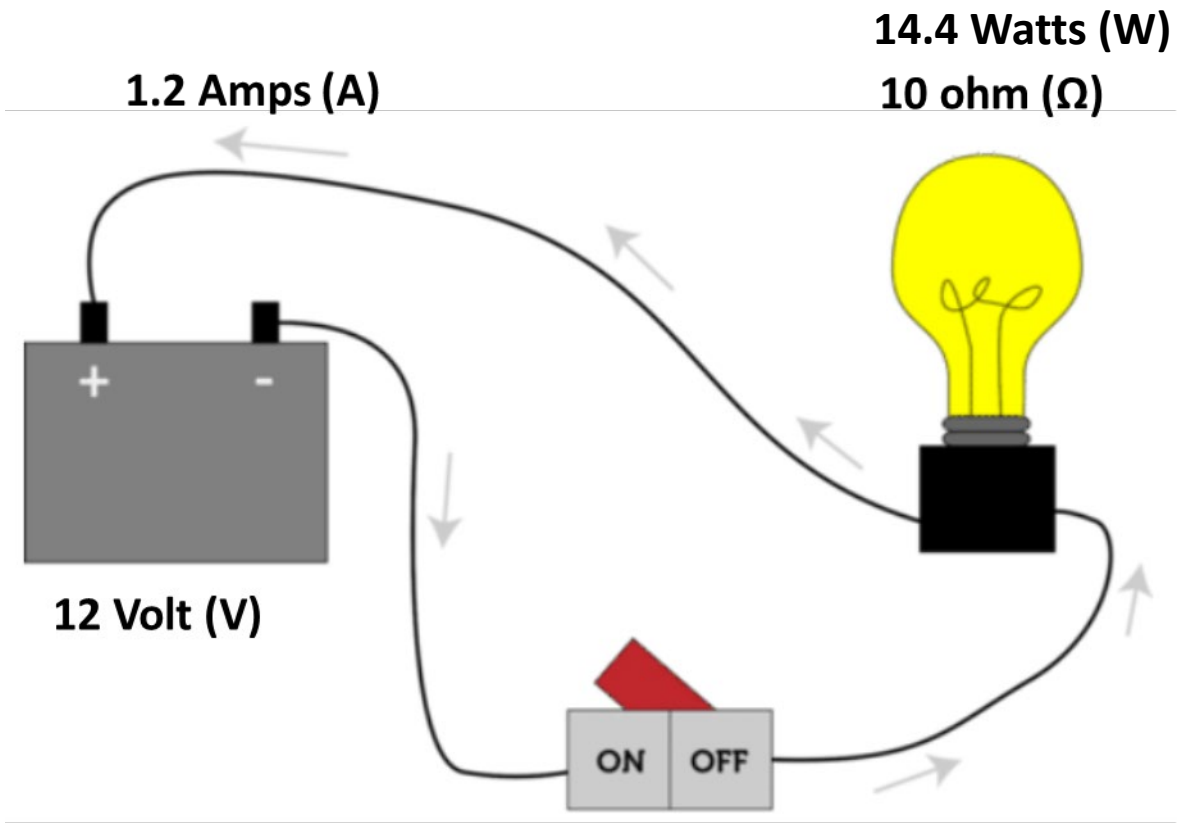
Rearranged

$$P = E\,I$$

$$I = \frac{P}{E} \qquad E = \frac{P}{I}$$

Watt's Law

Example

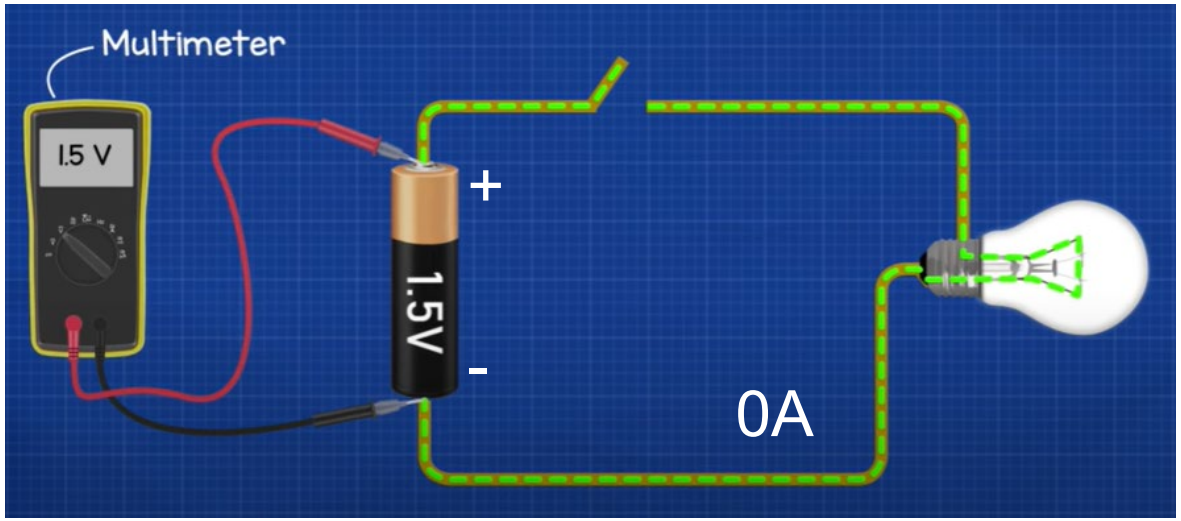


$$P = E\,I$$

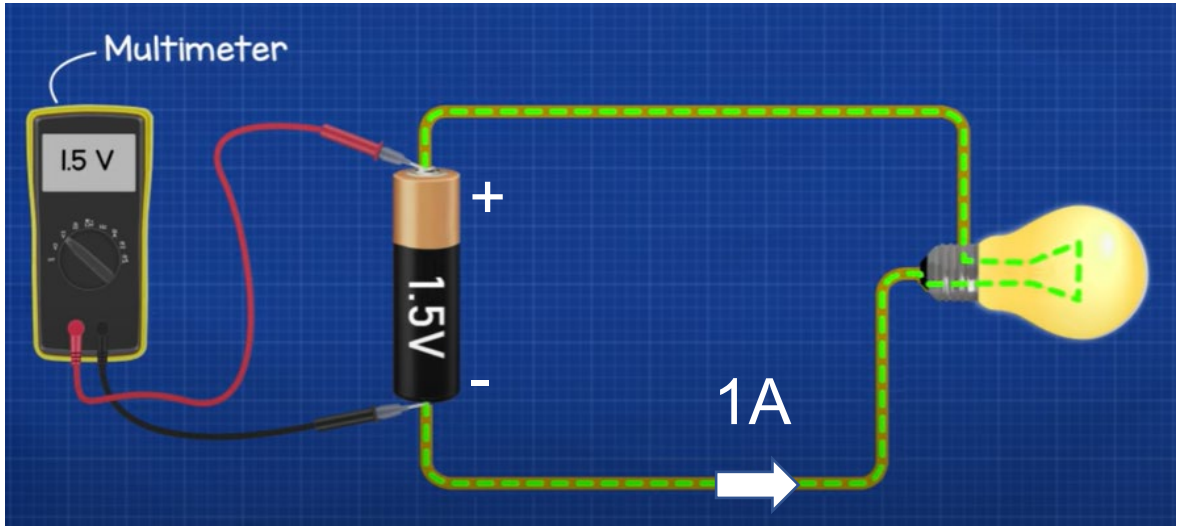
$$I = \frac{P}{E} \qquad E = \frac{P}{I}$$

* Voltage can exist without current, but current cannot exist without voltage.

With the switch open there is voltage, but no current. The light is off.



With the switch closed there is voltage and current. The light is on.



How are the values for each quantity justified?

Electrical quantity	Symbol	Electrical unit	Abbreviation	Justification
Power	P	Watt	W	1 W = 1 V x 1 A
EMF or PD	E	Volt	V	1 V = 1 J / 1 C
Resistance	R	Ohm	Ω	1 Ω = 1 V/A
Current	I	Amp	A	1 A = 1 C/sec
Charge	Q	Coulomb	C	1 C = 6.24 x 10^{18} electrons

Board Examples

Power (W)	Current (I)	Voltage (E)	Resistance
	20A	120V	
		240V	16Ω
2500W	50A		
4800000 W		600V	
	20A		24Ω

$$E = I\,R \qquad P = IE$$

Watt's Law and Ohm's Law combined.

They can also be combined to create six more formulas.

$$E = \sqrt{P \times R} \qquad P = I^2 \times R \qquad P = \frac{E^2}{R}$$

$$R = \frac{P}{I^2} \qquad R = \frac{E^2}{P} \qquad I = \sqrt{\frac{P}{R}}$$

AT THE VERY LEAST
REMEMBER ONE OF THESE TWO!!

VIDEO

Engineering Mindset. (November 5, 2019)

Ohms law explained – The basics circuit theory. YouTube.

https://www.youtube.com/watch?v=HsLLq6Rm5tU&list=PLWv9VM947MKjuqlJVp5m_Edf66SrFSHx2&index=10

1.1 Beginning Basics Worksheet
and
1.2 Ohms Law #1

SHOP VIDEO – DAY 4

Electrician U. (May 12, 2021)

Shorts – How 4 way switches work – without the fluff. YouTube.

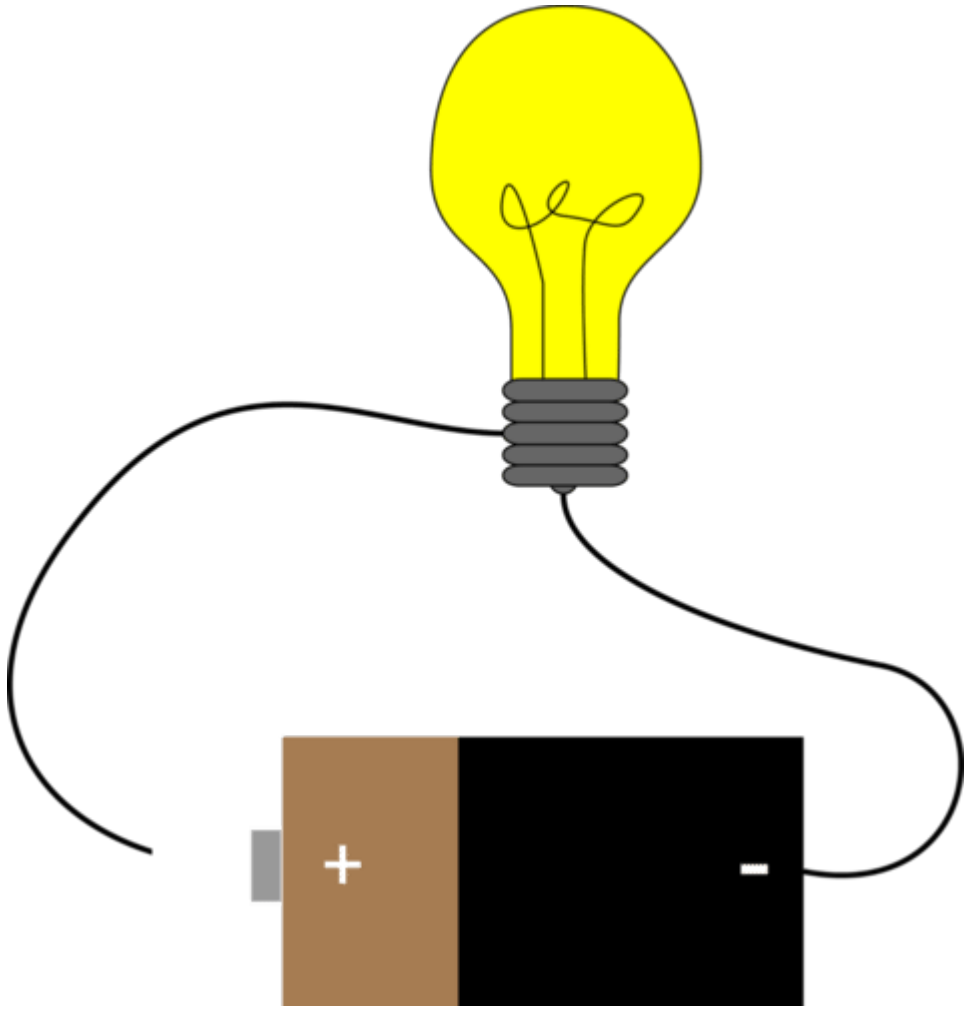
TBD

Electricity Basics

The basic operation of an electrical circuit

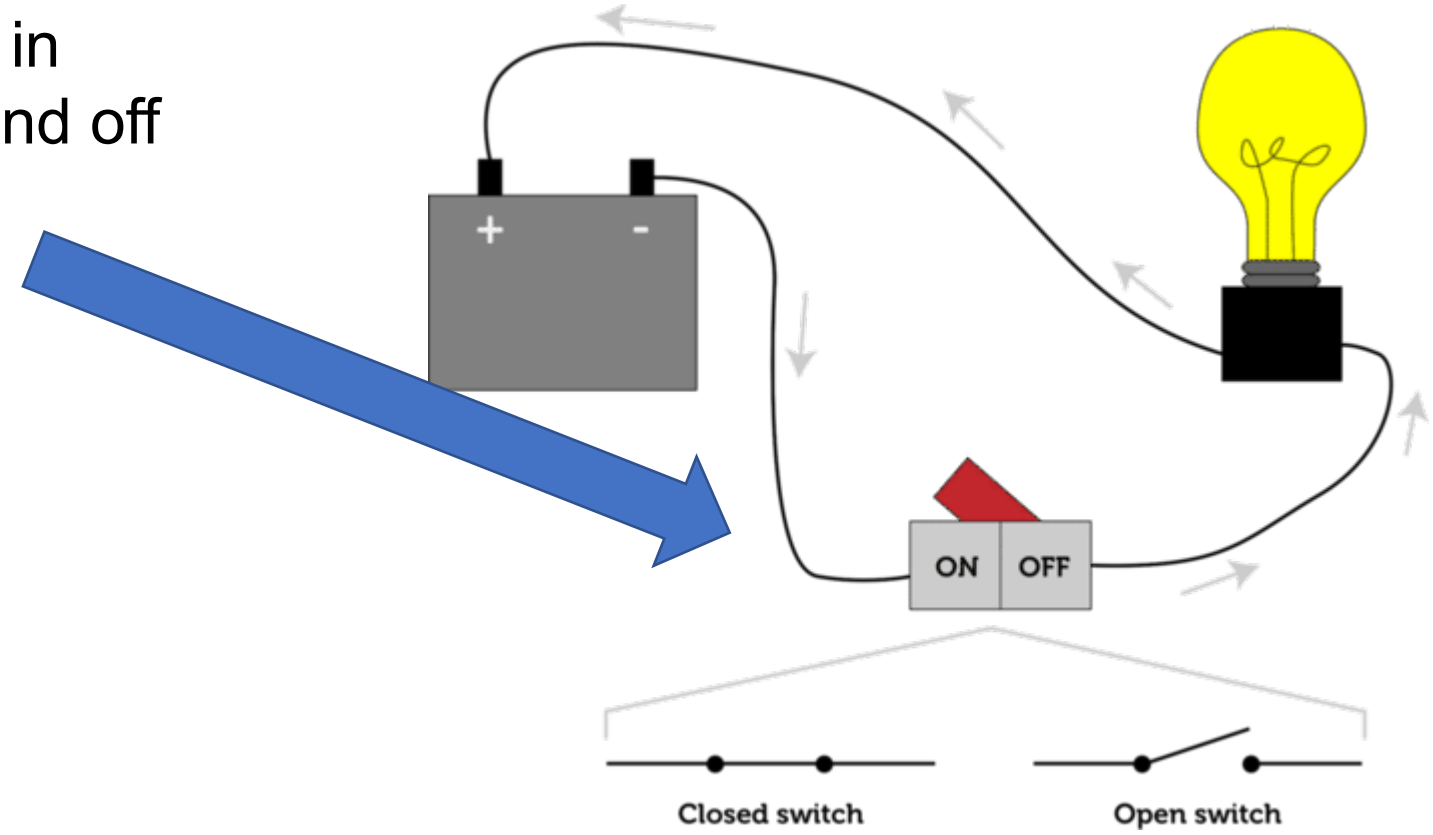
The most basic circuit need:

1. A source
   - Battery, generator, solar panel…
2. A load
   - The thing that does something for us.
   - Lightbulb, motor, heater…
3. Conductors
   - The connect the load to the source.
   - Wires, busbars…



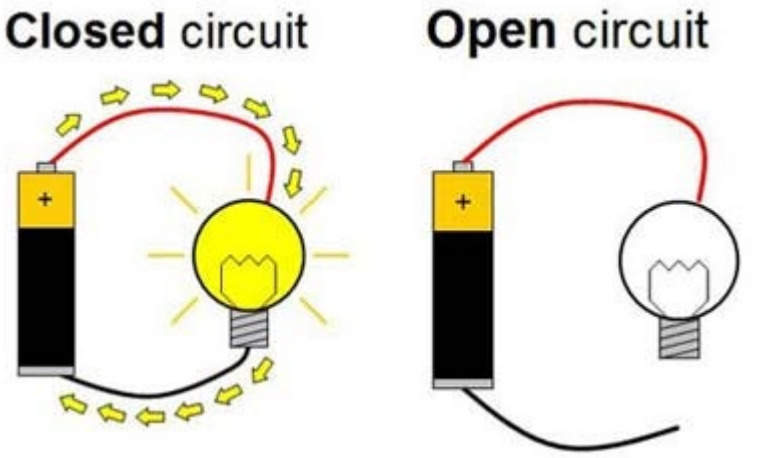
The most basic circuits need:

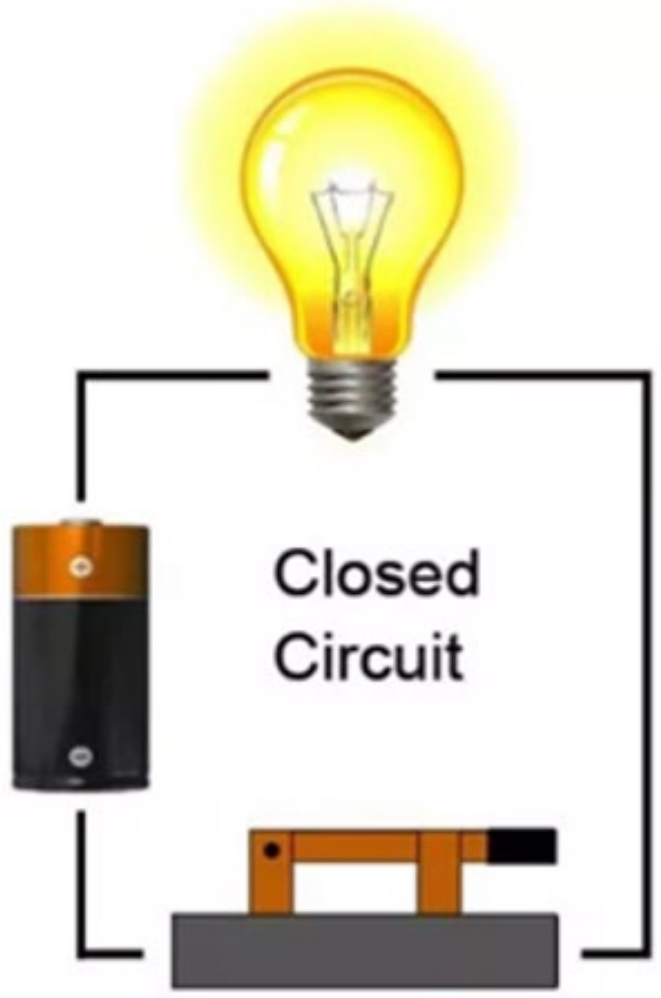
There's probably a switch in there to turn the load on and off too.



Closed circuit:

If the three things (source, load, conductors) exist we have a closed circuit.
It works.

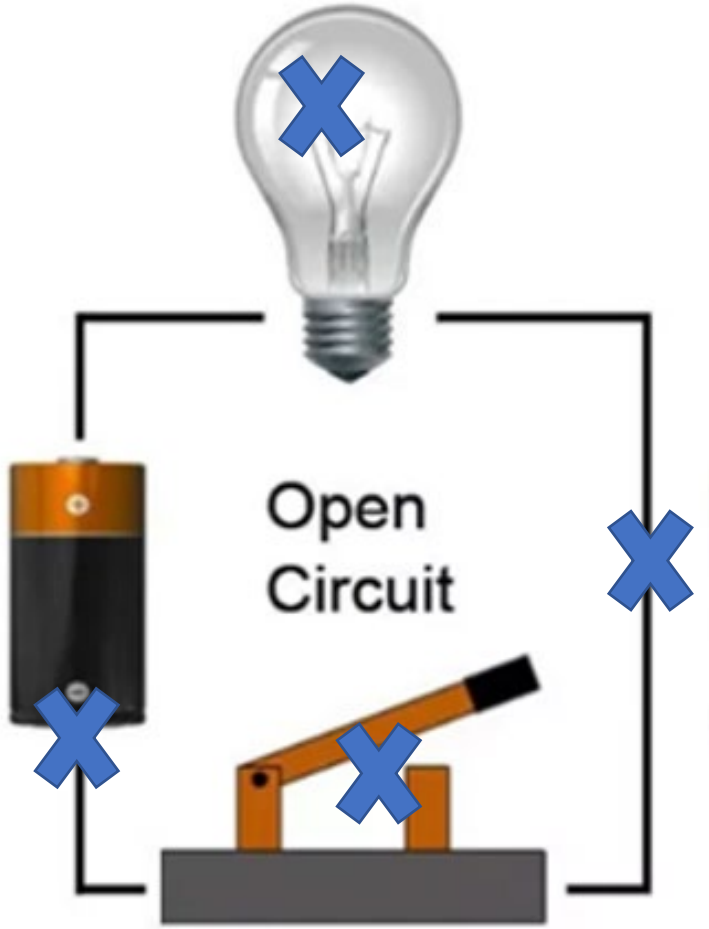




Open circuit:

If one or more of those things does not exist, we have an open circuit. It' not going to work!

An open circuit could be due to an open switch, cut wire, burned out light filament, loose connection…



Short circuit:

If two wires somehow come into contact with each other (stripped insulation, metal object across the positive and negative terminal…) we have what's called a 'short circuit'.

Not good!

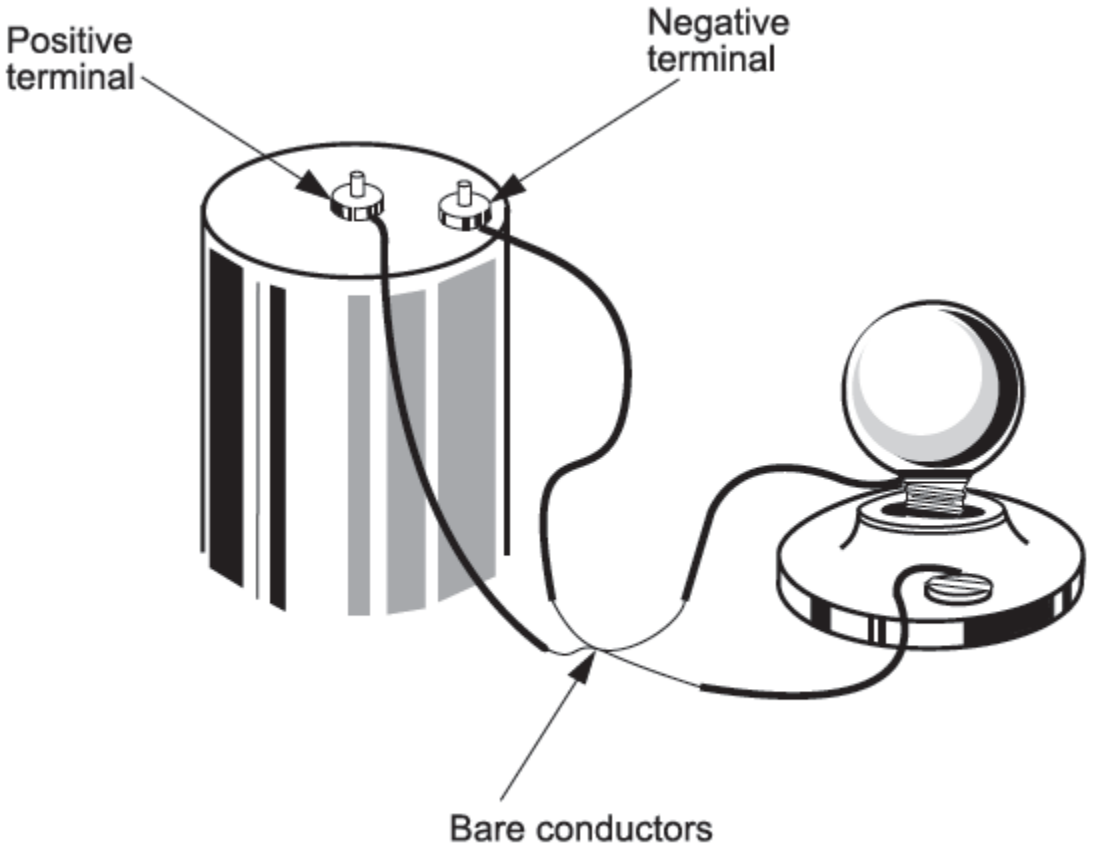


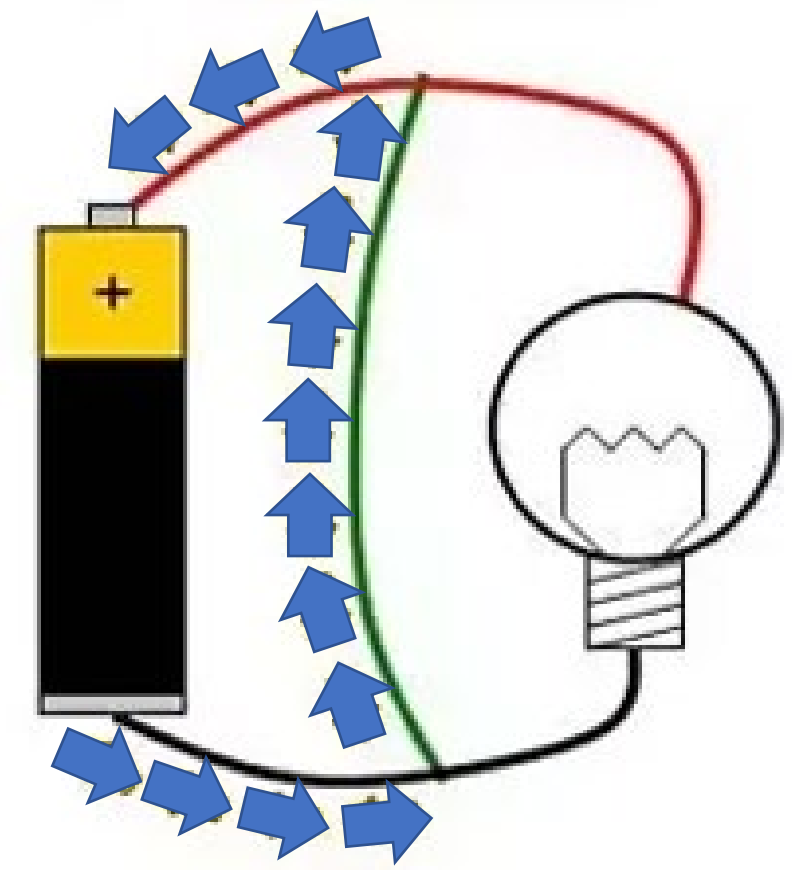
Figure 3—A short circuit

Short circuit:

A short circuit is gives a path with a much lower resistance than the load.

Current tends to take the path of least resistance.

Very little current through the load (no worky), and a whole bunch of current through the other path (not good).



Other stuff in a circuit:

- Switches
  - Turn the load on and off
- Fuses and circuit breakers
  - Shut the circuit down if too much current flows.

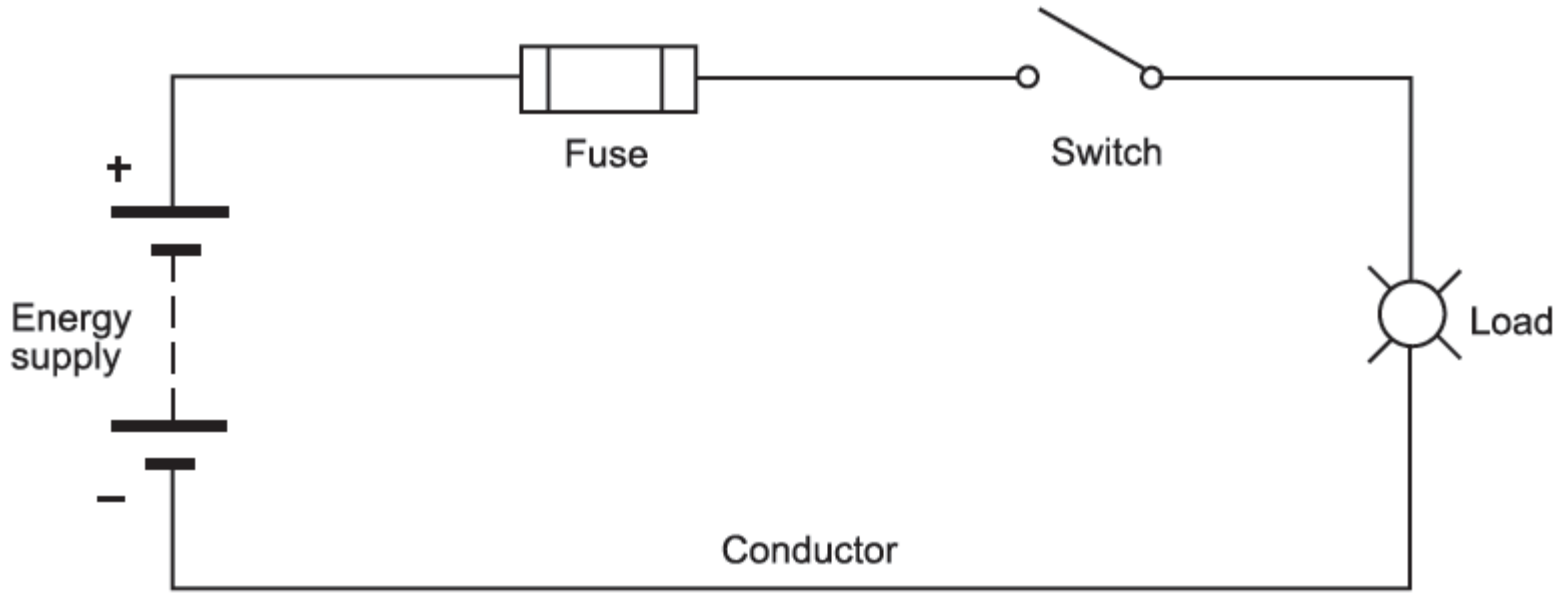


Figure 5—A fused circuit

Circuit polarity:

Electrons (-) leave the negative of the supply and travel back to the positive.

This is a theory we use called ‘electron flow’.

Some textbooks do it the other way (+ to -). This is called ‘conventional flow’.

We always use ‘electron flow’ (- to +)!!!!!!!!!!!!!!!!!!!!!

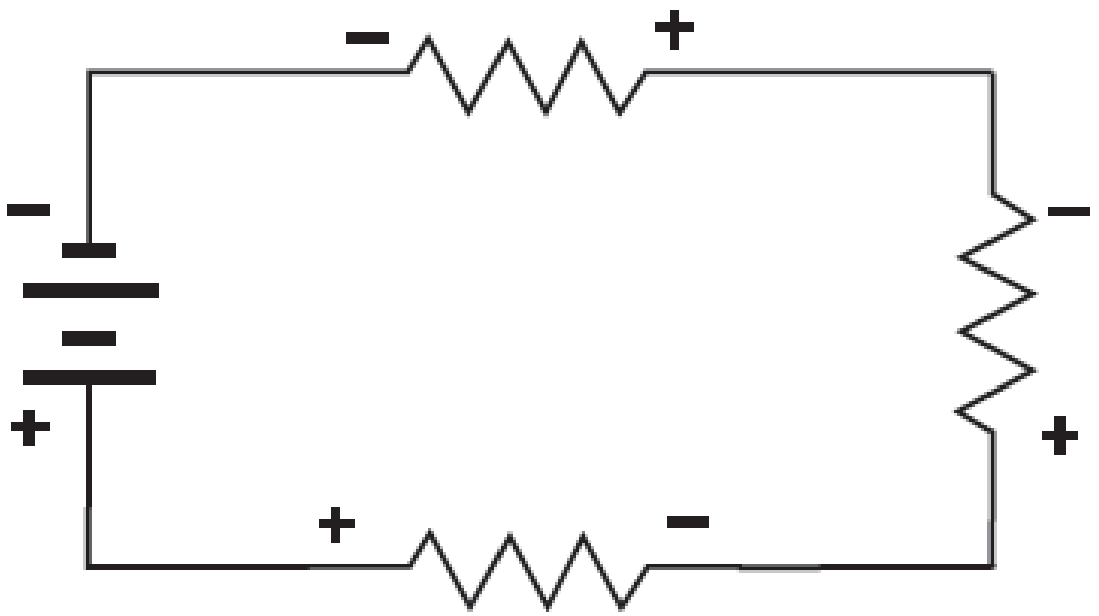


Figure 6—Polarity

Circuit polarity:

Current is traced through loads (resistors) from negative to positive.

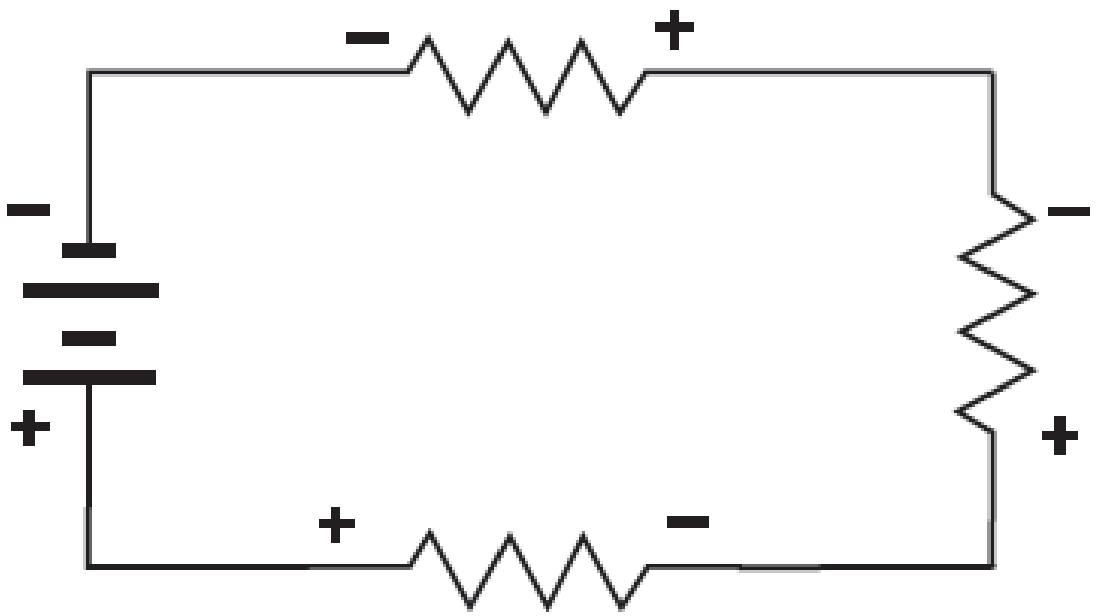


Figure 6—Polarity

Series Connections

Loads connected in series.

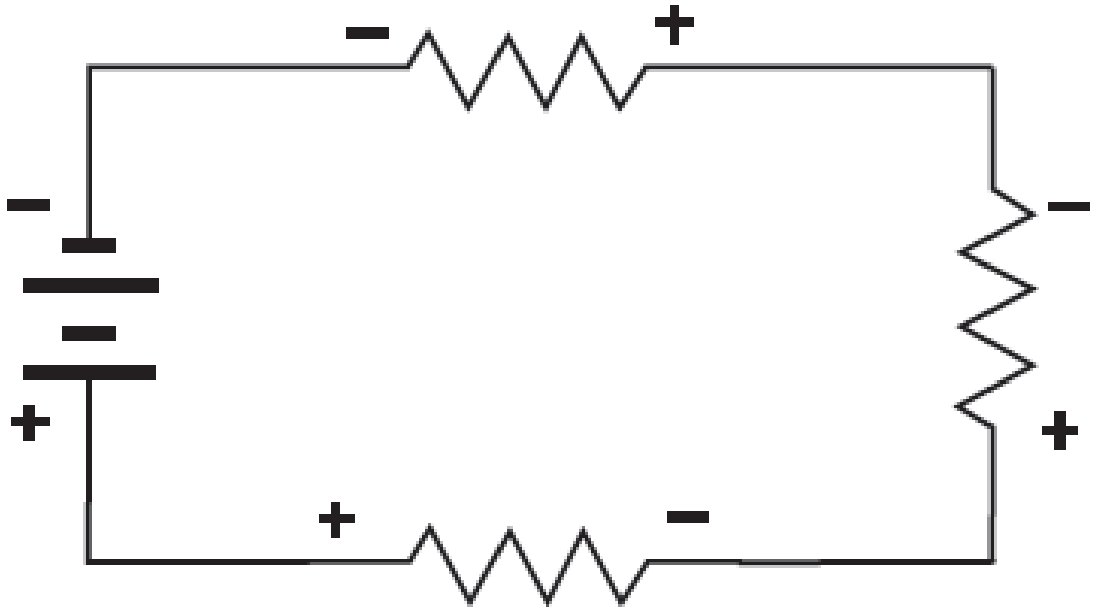


Figure 6—Polarity

Series Connections

Voltage supplies connected in series.

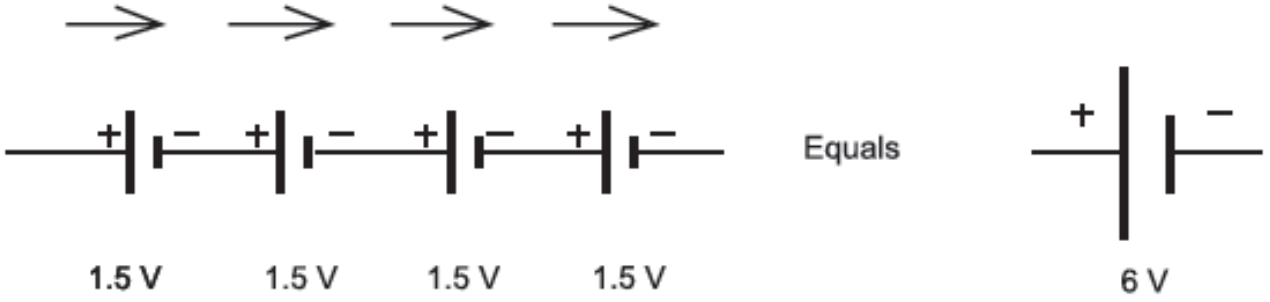


Figure 1—Emfs connected series aiding

Parallel Connections

Loads connected in parallel.

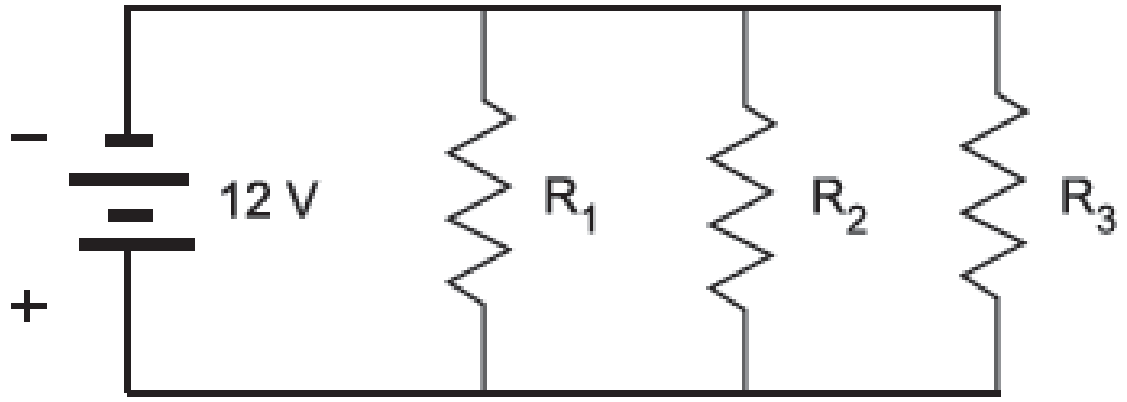
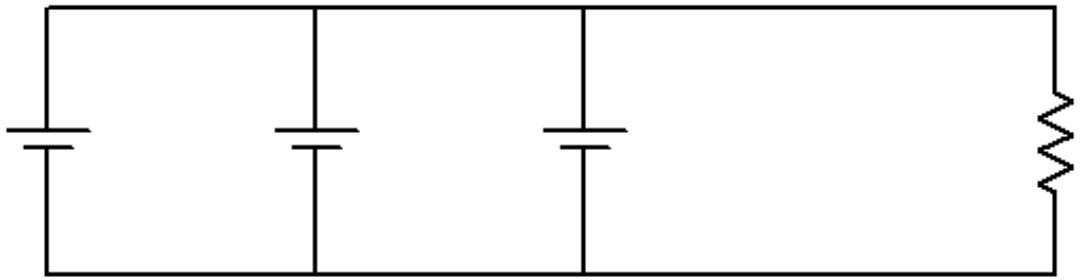


Figure 2—Usual representation of parallel circuit

Parallel Connections

Voltage supplies
connected in parallel.

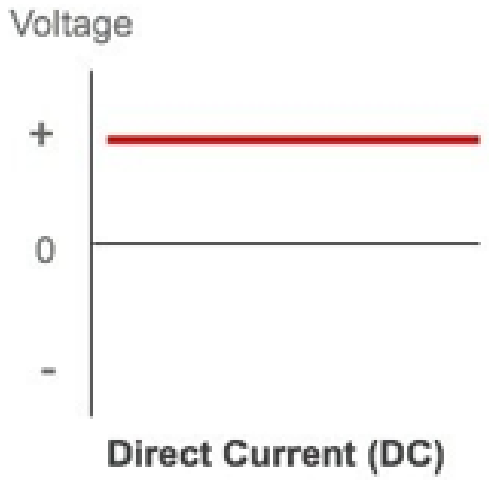


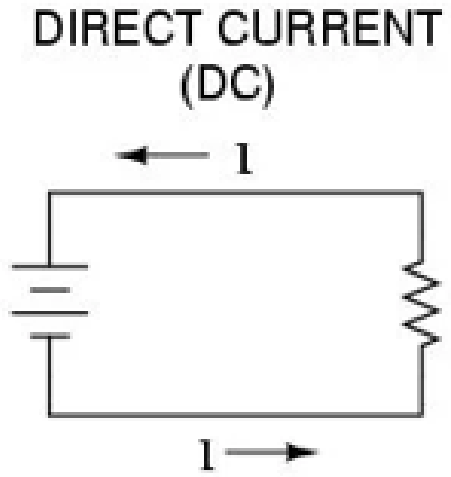
DC vs. AC

DC is direct current.

Current only ever flows in one direction through the circuit.

An example of a DC supply is a battery.



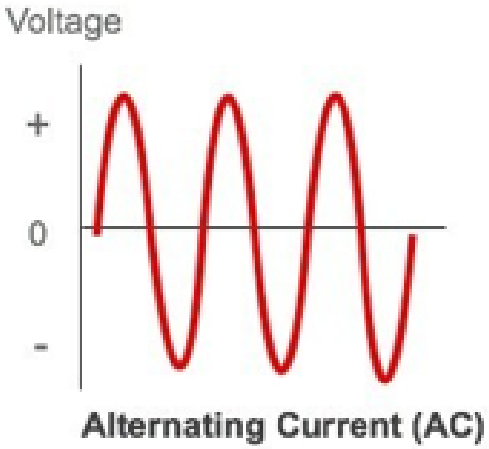


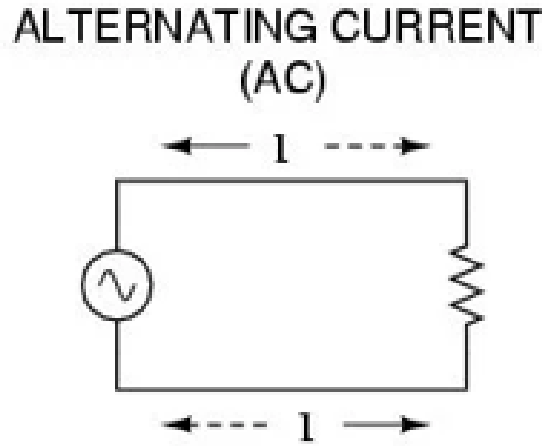
DC vs. AC

AC is alternating current. The polarity of the supply is always changing direction with AC.

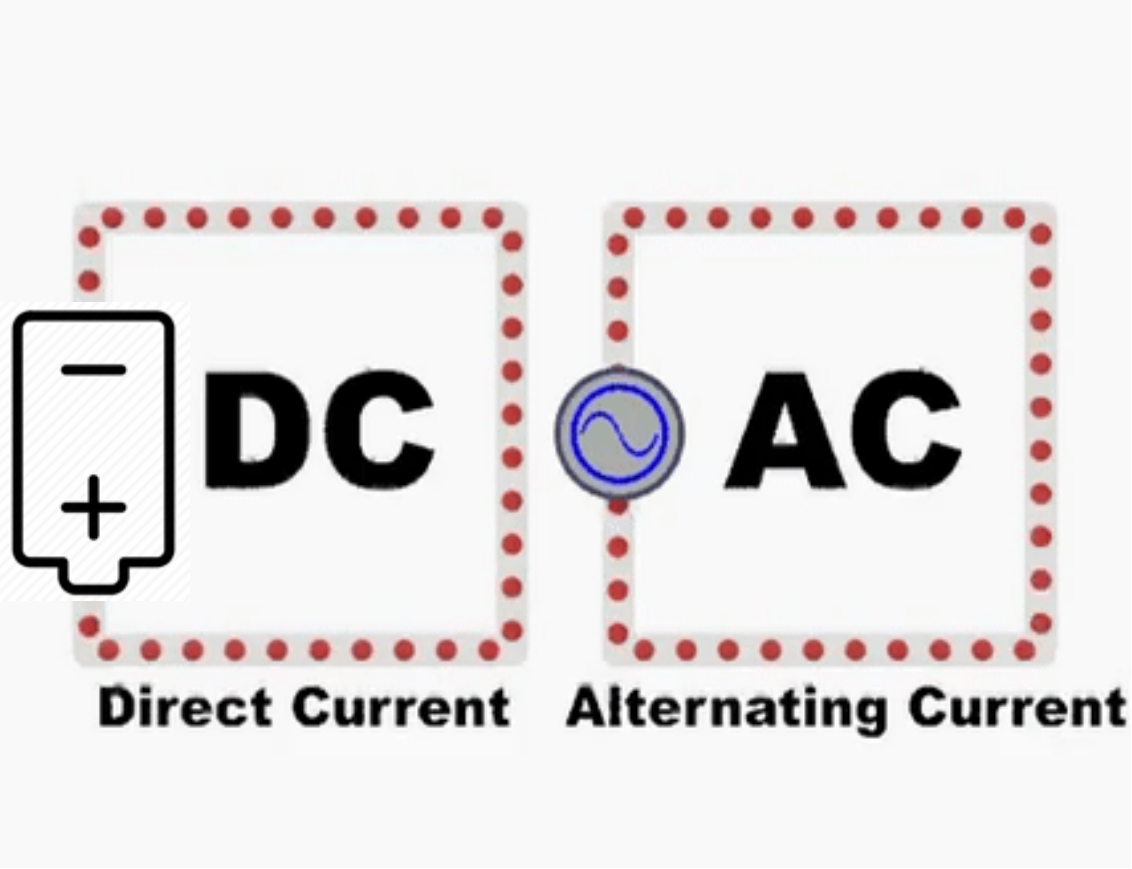
Current flows through a circuit one way, and then a fraction of a second later it goes the other.

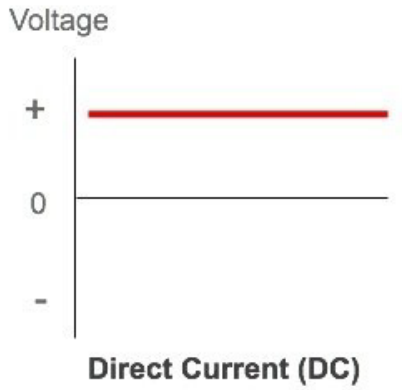
AC is what supplies your house.

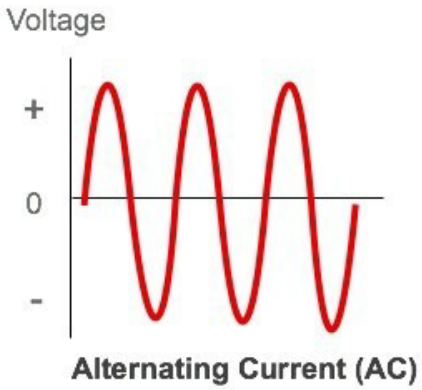


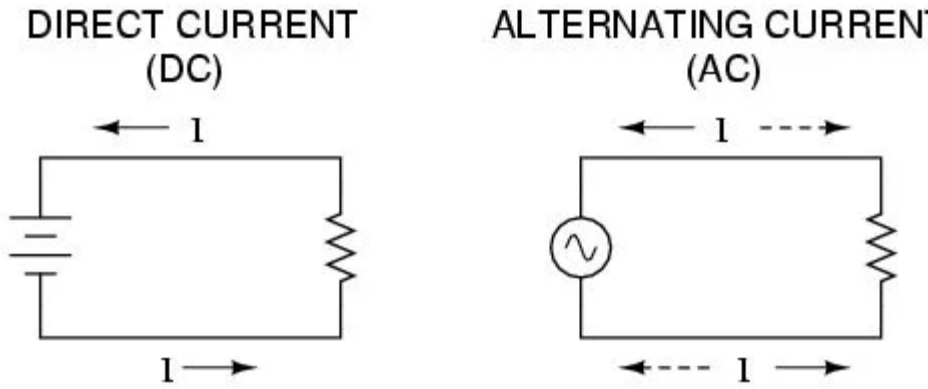


DC vs. AC









Direct vs alternating current

DC vs. AC

In this course we will mostly look at DC circuits.

More on this later.

VIDEO

Engineering Mindset. (May 6, 2019)

120V 240V Electricity explained - Split phase 3 wire electrician. YouTube.

https://www.youtube.com/watch?v=fJeRabV5hNU&list=PLWv9VM947MKjuqlJVp5m_Edf66SrFSHx2&index=4

Electricity Basics

Expressing numbers with an appropriate prefix

Metric prefixes.

Sometimes the numbers we deal with are very high (like 500,000 volts), or very low (like 0.000006 amps).

These numbers get quite cumbersome to write down, or you might write it down wrong.

1-999.

We want to express our answers in a number between 1-999

For example: 2,400 V is not between 1-999, so we convert it to 2.4 kV.

Or 0.056 is not between 1-999 to we convert it to 56 mA.

Engineering notation.

To avoid this, we use a system called ‘engineering notation’.

It’s similar to scientific notation, except that the power of ten can only be a multiple of three.

P	pico	10^{-12}
N	nano	10^{-9}
μ	micro	10^{-6}
m	milli	10^{-3}
◄—— No prefix ——►		$10^{0} = 1$
k	kilo	10^{3}
M	mega	10^{6}
G	giga	10^{9}

Engineering notation.

Mostly, we'll use:

micro (μ)
milli(m)
no prefix
kilo(k)
mega(M).

P	pico	10^{-12}
N	nano	10^{-9}
μ	micro	10^{-6}
m	milli	10^{-3}
← No prefix →		$10^{0} = 1$
k	kilo	10^{3}
M	mega	10^{6}
G	giga	10^{9}

Engineering notation.

For example 7,000 V (no prefix) is equal to 7 kV.

Or 3,000,000 V (no prefix) is equal to 3 MV.

	P	pico	10^{-12}
	N	nano	10^{-9}
0.000,001	μ	micro	10^{-6}
0.001	m	milli	10^{-3}
	← No prefix →		$10^{0} = 1$
1,000	k	kilo	10^{3}
1,000,000	M	mega	10^{6}
	G	giga	10^{9}

Engineering notation.

Another trick can be to lay the units out horizontal and move the decimal place in that direction.

0.000,001	P	pico	10^{-12}
	N	nano	10^{-9}
0.001	μ	micro	10^{-6}
	m	milli	10^{-3}
	← No prefix →		$10^{0} = 1$
1,000	k	kilo	10^{3}
1,000,000	M	mega	10^{6}
	G	giga	10^{9}

mega	kilo	NO PREFIX	milli	micro
10^{6}	10^{3}	$10^{0} = 1$	10^{-3}	10^{-6}
1,000,000	1,000	1	0.001	0.000,001

Examples.

7,500V	kV
0.005A	mA
500,000V	kV
10,000,000V	kV
10,000,000V	MV
0.000,05A	mA
0.000,05A	µA

P	pico	10^{-12}
N	nano	10^{-9}
µ	micro	10^{-6}
m	milli	10^{-3}
← No prefix →		$10^{0} = 1$
k	kilo	10^{3}
M	mega	10^{6}
G	giga	10^{9}

mega	kilo	NO PREFIX	milli	micro
10^{6}	10^{3}	$10^{0} = 1$	10^{-3}	10^{-6}
1,000,000	1,000	1	0.001	0.000,001

Review Examples.

2,200V	kV
0.007A	mA
649,000V	kV
95,000,000V	kV
95,000,000V	MV
0.000 65A	mA
0.000 65A	µA

P	pico	10^{-12}
N	nano	10^{-9}
µ	micro	10^{-6}
m	milli	10^{-3}
← No prefix →		$10^{0} = 1$
k	kilo	10^{3}
M	mega	10^{6}
G	giga	10^{9}

mega	kilo	NO PREFIX	milli	micro
10^{6}	10^{3}	$10^{0} = 1$	10^{-3}	10^{-6}
1,000,000	1,000	1	0.001	0.000,001

Rule of Thumb *

If the numerical value gets bigger, the unit gets smaller.

If the numerical value gets smaller, the unit gets bigger.

Rounding numbers.

We want to express our answers rounded to three significant figures.

For example: 0.0566666.

First let's convert it so it lands between 1-999.

56.6666 mA

Now let's round it to three significant figures. Round the third significant figure up or down as necessary.

56.7 mA

Board Examples

Power (W)	Current (I)	Voltage (E)	Resistance
	30A	100V	
		240V	12Ω
1.8.kW	40A		
3.9MW		480V	
	15A		22Ω
		240V	11Ω

$$E = I\,R \qquad P = IE$$

1.3 Electrical Units with Metric Prefixes
and
1.4 Ohms Law #2

VIDEO

Engineering Mindset. (July 28, 2021)

Conventional current v electron flow – electricity explained. YouTube.

https://www.youtube.com/watch?v=MUh_dOcqgVw&list=PLWv9VM947MKi_7yJ0_FCfzTBXpQU-Qd3K&index=5

SHOP VIDEO – DAY 5

Electrician U. (May 12, 2021)

Shorts – How 4 way switches work – without the fluff. YouTube.

TBD

Electricity Basics

Calculating electrical energy costs

Power vs. Energy

It’s common for people to use the words “power” and “energy” interchangeably. But there is a difference:

Power is Watts. (volts x amps)

Energy is Watt-hours. (volts x amps x time)

In other words, power is the rate of work, and energy is the output of that rate of work over time.

Calculating energy costs

- Most of BC is supplied by BC Hydro. They sell us ‘energy’ by the kWh.
- BC Hydro has 2 rates for residential customers.
- One rate, Step 1 is $0.0935 per kWh for first 1,350 kWh.
- The second rate only applies if you use more than 1,350 kWh in a (two month) billing period. You’re then charged $0.1403 per kWh for the amount over 1,350.

Calculating energy costs

- It’s actually pretty cheap in BC compared to around the world.

Place	How they do it.	Cost per kWh
BC	92% hydroelectric	10.3 ¢
Australia	76% coal	31.4 ¢
New York	48% gas	28.9 ¢
Germany	45% coal	42.8 ¢

Calculating energy costs

Example: Write this down.

A house uses 1,693 kW/h hours over the course of a month. The cost is $0.0935 per kW/h, and there is a monthly service charge of $17.

What is the cost before taxes?

Calculating energy costs

Example:

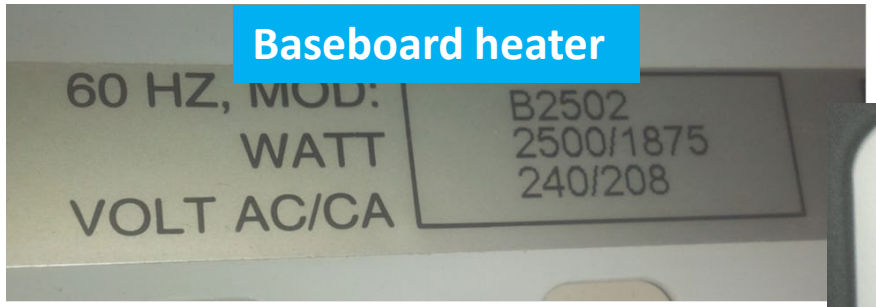
A house uses 1,693 kW/h hours over the course of a month. The cost is $0.0935 per kW/h, and there is a monthly service charge of $17.

What is the cost before taxes?

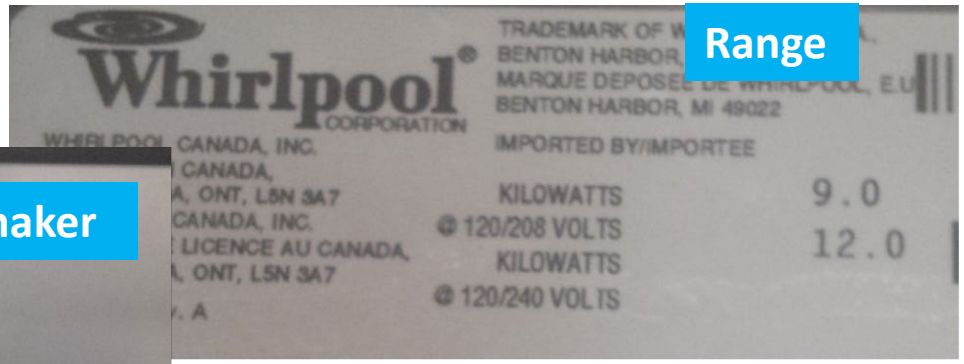
Answer.

1,693 kW/h x 0.0935 = $158.3 + $17 = $175.3

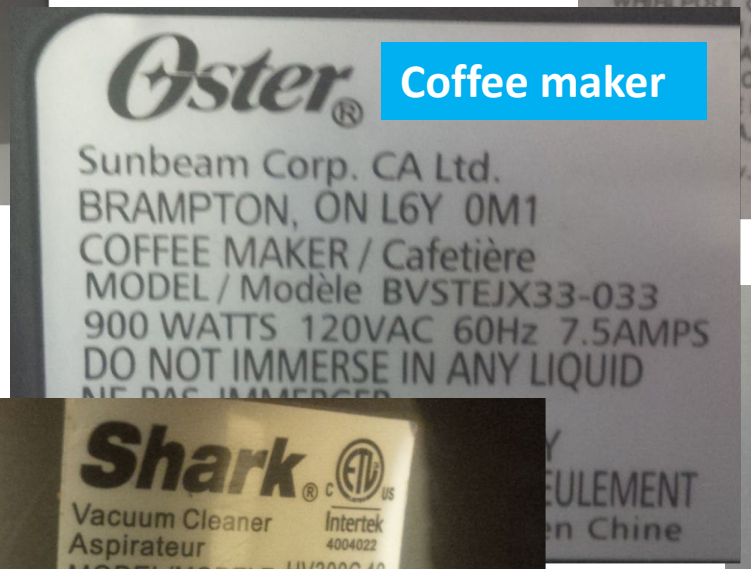
Calculating energy costs



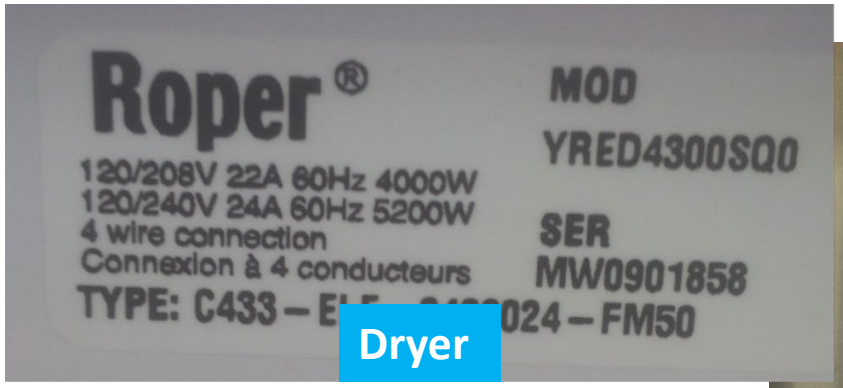
Baseboard heater



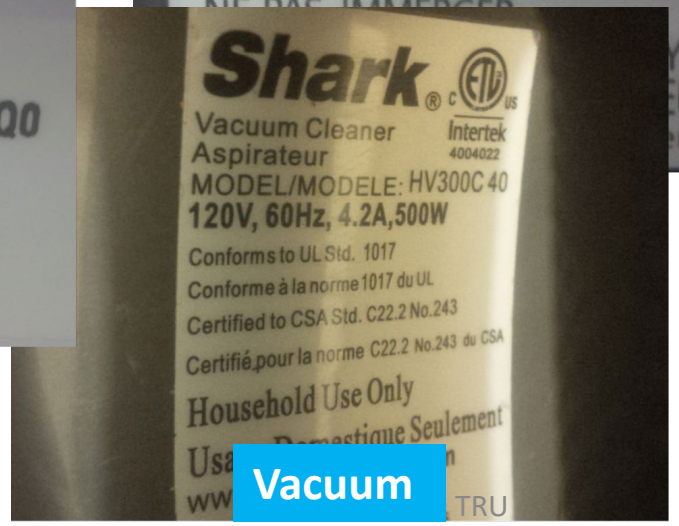
Range



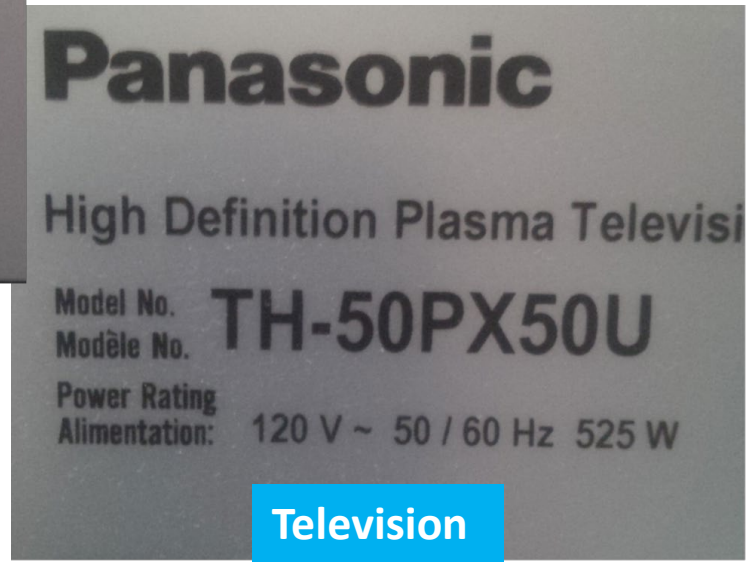
Coffee maker



Dryer



Vacuum



Television

Calculating energy costs

kW x h x $(per hour) = Cost of Electricity

LOAD	WATTS (kW)	TIME (h)	COST ($)
Range	12 kW	2 hrs a day x 30 days	
Baseboard heater	2.5 kW	6 hrs a day x 30 days	
Coffee maker	900 W	1 hr a day x 30 days	
Vacuum	500 W	1 hr a week for 4 weeks	
Dryer	5.2 kW	3 hrs a week for 4 weeks	
TV	525 W	2 hrs a day for 30 days	

Steps:

1. Determine rate in **dollars**
2. Determine load in **kW**
3. Determine time in **hours**
4. Multiply together *1,2,3*

BC Hydro rate: $0.0935 / (kW/h)

*Remember to use kW rather than W when calculating for kW/h

More Board Examples

Example #1: If a household dryer draws 25 amps from the supply at a voltage of 240 volts for a period of ½ an hour, what power is the dryer operating at and what is the energy required to dry the clothes?

Example #2: If the supply authority charges $.07 per kilowatt hour, how much does it cost to dry the clothes?

Example #3: If the supply authority charges $.07 per kilowatt hour of energy, what does it cost to leave a 40-watt porch light on for 24 hours?

Example #4: A 240 V water heater draws 18A from the source for a period of 25 minutes. Answer the following questions. (1) What is the power rating of the water heater? (2) What was the energy consumption of the water heater during this time?

VIDEO

Engineering Mindset. (October 23, 2017)

What is a kWh – kilowatt hour + calculations. YouTube.

https://www.youtube.com/watch?v=SMPhh8gT_1E

1.5 Cost of Energy Worksheet

KAHOOT!

QUIZ 1