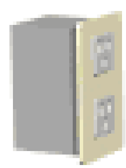
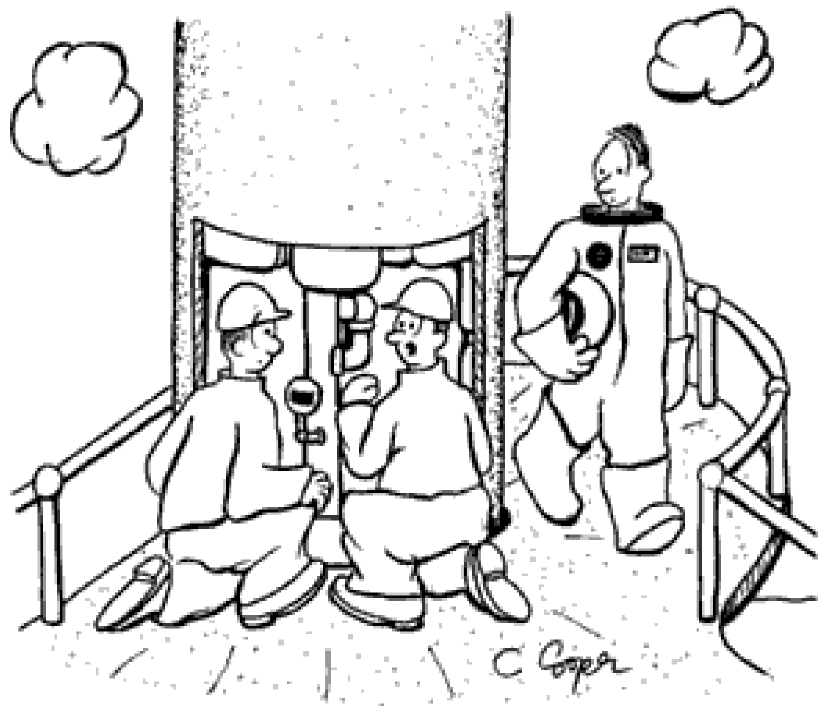
Physics 3204

UNIT 2

SECTION 2: CURRENT ELECTRICITY



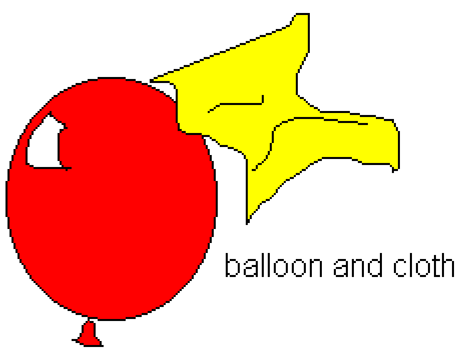
Text: Unit 14

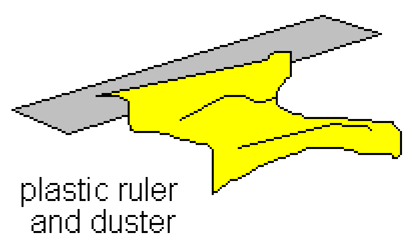


“Don’t worry about it. This isn’t exactly rocket science, you know.”

Introduction

Electrostatic Charge refers to charge just piled up somewhere (on balloons, spherical conductors, etc.) Occasionally, a single test charge was allowed to move, but only for a very short time.

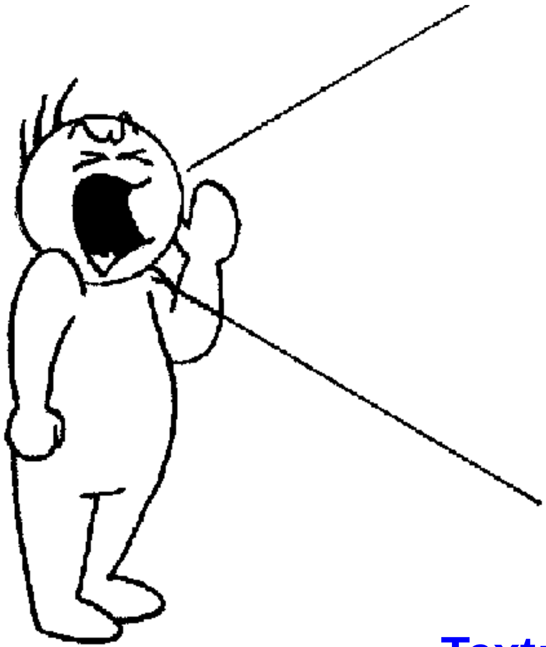


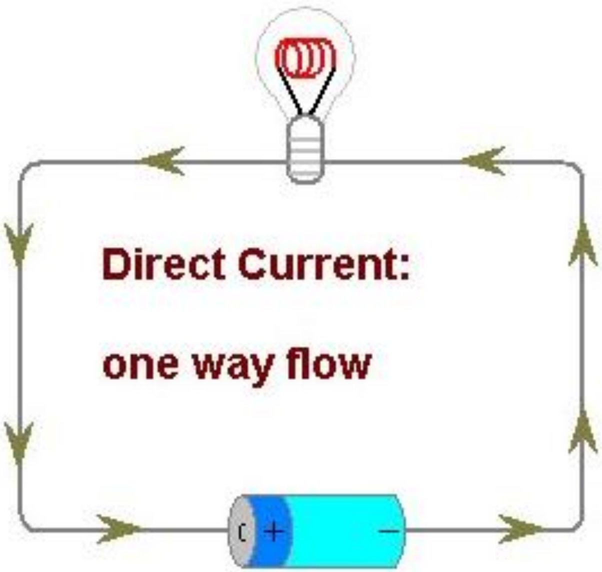


Physics 3204

Unit 2 : Section 2 – Current Electricity

Topic 1 : Electric Current

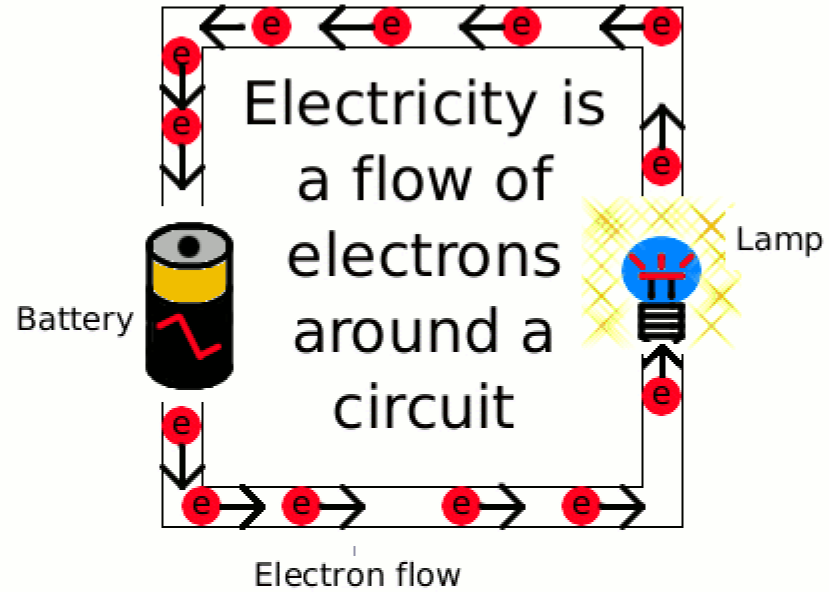




Text: Unit 14.2

CURRENT ELECTRICTY

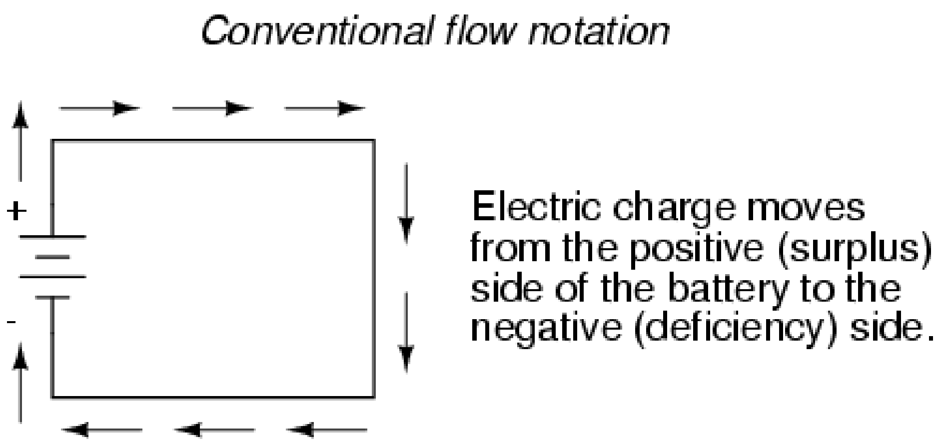
Current Electricity: Electricity produced due to the flow of electric charge from one place to another in a conductor.



Energy from another source is needed to produce current electricity.
(Ex. Chemical Battery, generator).

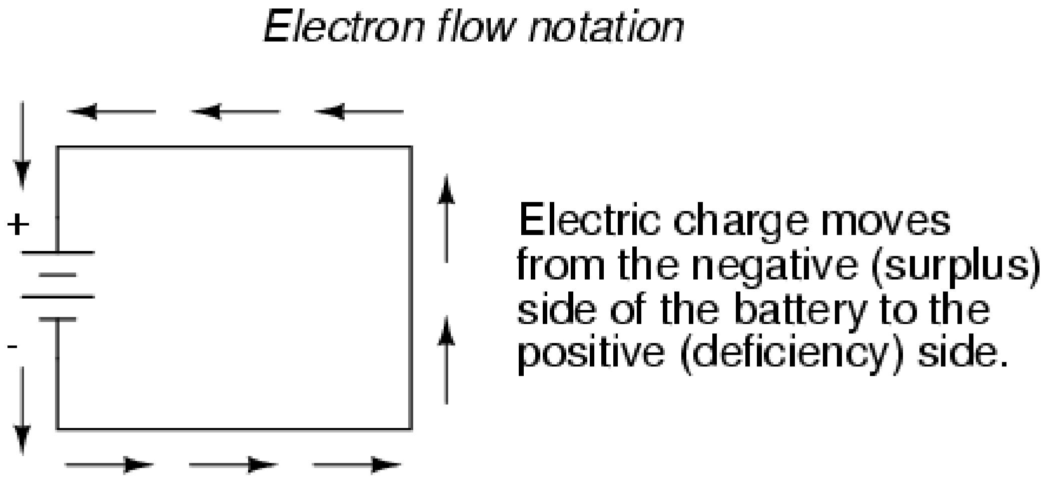
Unlike Electrostatic charge **Electric Current** is always on the move.

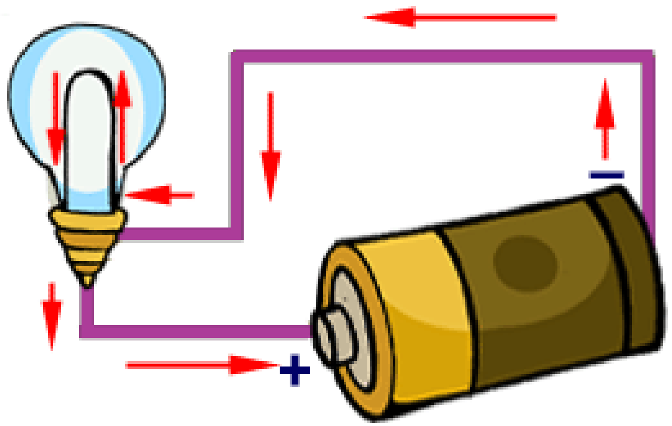
100 yrs ago Benjamin Franklin determined that there was an excess of charge on the positive terminal of a battery and a deficiency on the negative terminal. He concluded that electric current flowed from the positive terminal ,through a circuit, and back to the negative terminal. This became known as **conventional current**.



Much mathematics and Physics, was built on this concept ...But…
He was WRONG!

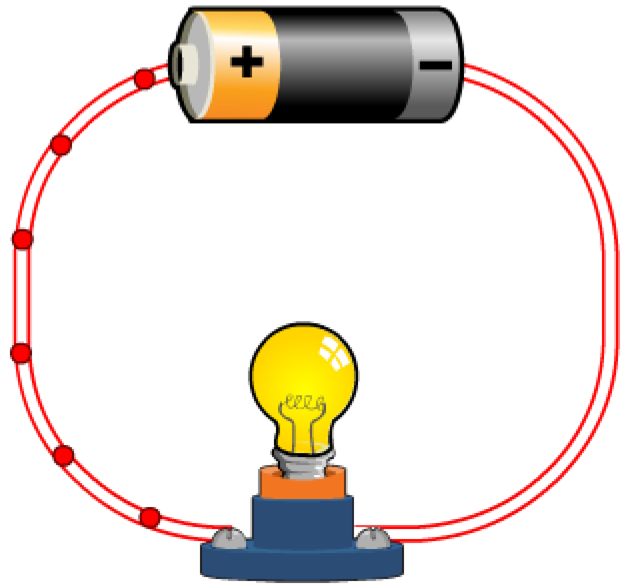
Electron Flow is what actually happens. Electrons flow out of the Negative terminal, through the circuit and into the positive terminal of the source.





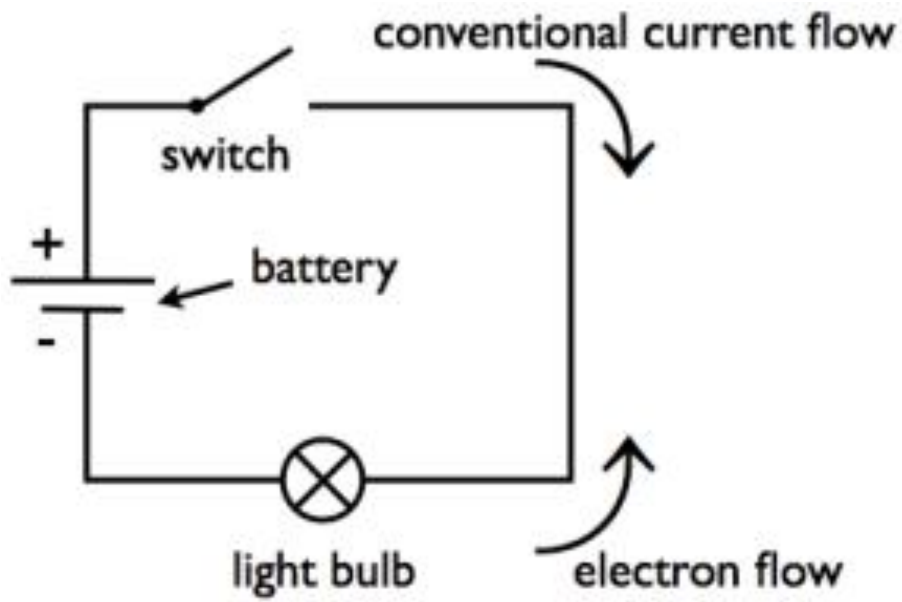
Electricity model

The charges do not come out of the cell and disappear when they get to the lamp. This idea is wrong. Click Next to see the next idea.



Next

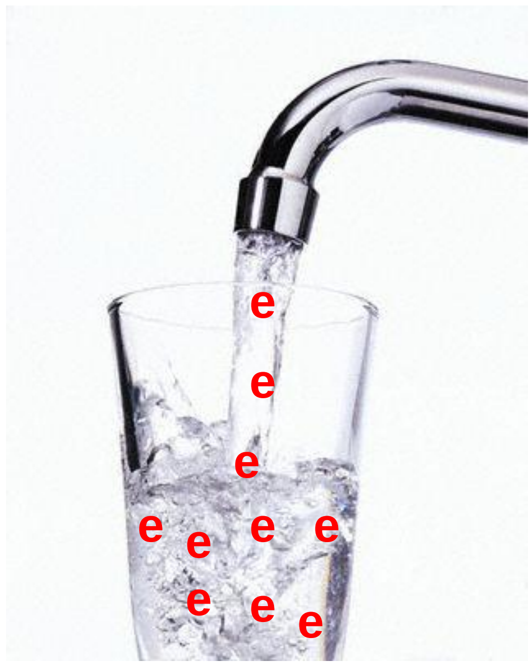
Both Conventional Current and Electron Flow are used by industry. In fact, it makes no difference which way current is flowing as long as it is used consistently. The direction of current flow does not affect what the current does.



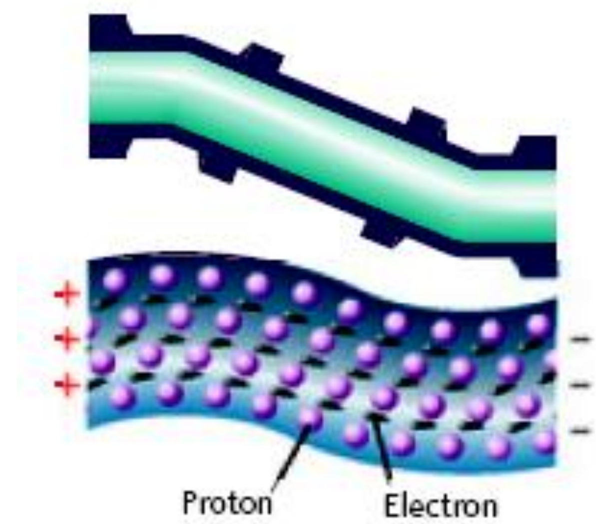
CURRENT

- **Current (I) refers to t**he flow of charges in a circuit.

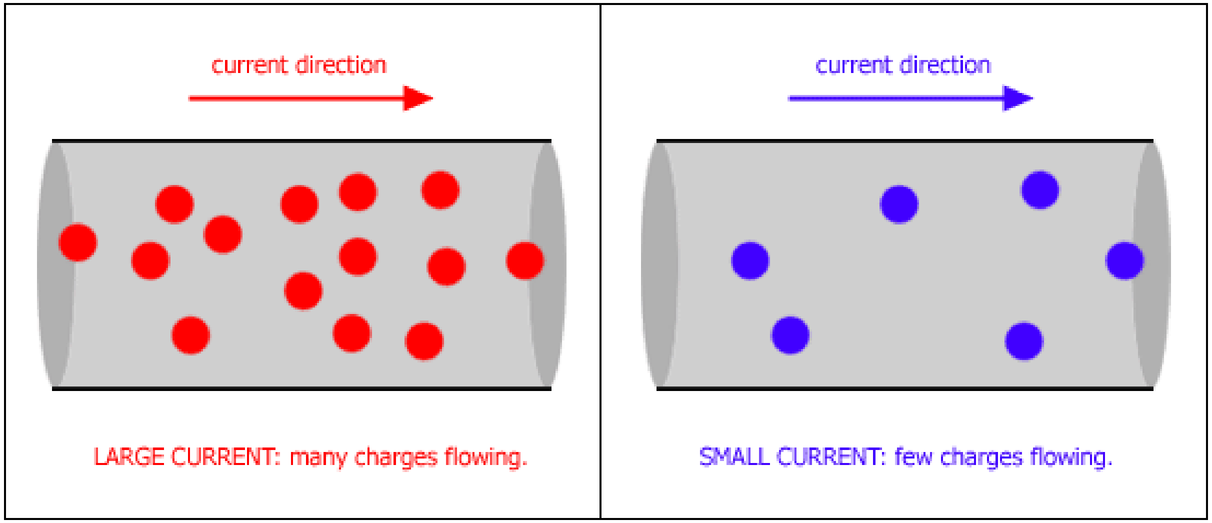
- It is the amount of charge passing a point every second.



Instead of water, we will be looking at the flow of electrons



- is measured in Amperes or Amps (A).



Formula:

Current is the total amount of charge moving past a point in the conductor divided by the time.

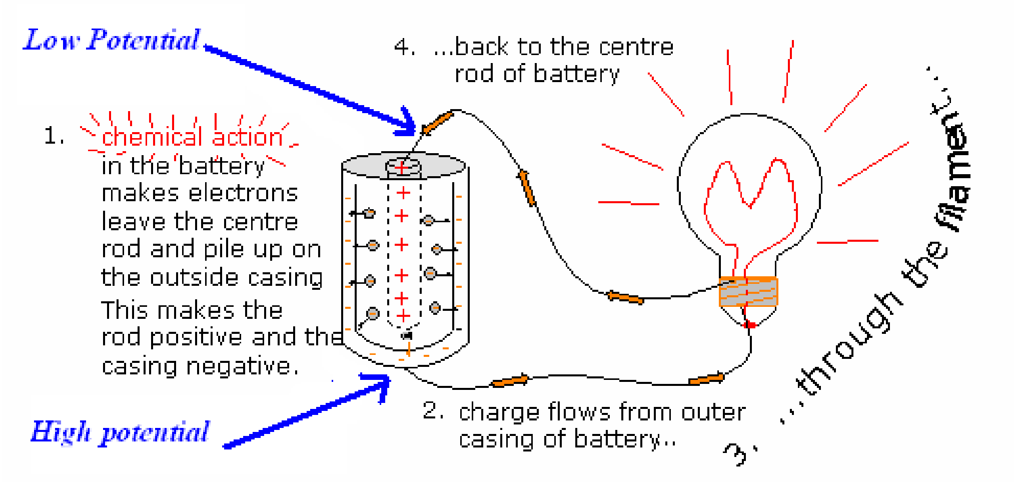
$$I = \frac{Q}{t}$$

Units: C/s or Amperes, A

The unit C/s is named in honour of André Marie Ampere (1775-1836). When a wire has a flow of charge equal to 1 C/s, we say that there is 1 ampere of current in the wire.

Example 1:

If the light in circuit is connected to the cell for 100 seconds and a charge of 10 C flows in that time, how much charge flows through the wires in 1.0 second?



Answer

The amount of charge that flows in 1.0 second is 10 C ÷ 100 s which is 0.1 C/s. We say the current is 0.1 C/s.

This is exactly the same as saying that the current of water in a water pipe is 0.1 litres per second if 10 litres flows through in 100 s.

Example 2

How much current passes through a toaster if 1500 C of charge pass through it in 2.5 minutes?

Given and unknown:

q = 1500 C
t = 2.5 min = 2.5 min x 60 s/min = 150 s
I = ?

$$I = \frac{q}{t} = \frac{1500\ \text{C}}{150\ \text{s}} = 10\ \text{C/s} = 10\ \text{A}$$

The toaster draws 10 A of current.

Example 3

If you have a clock radio on your night table, it probably draws about 5.0 x 10^{-2} A of current. How much charge passes through it while you sleep from 11:00 PM to 7:00 AM?

Solution

$I = 5.0 \times 10^{-2}$ A $= 5.0 \times 10^{-2}$ C/s

$t = 8.0$ hr $= 8.0 \times 3600$ s/hr $= 2.9 \times 10^{4}$ s

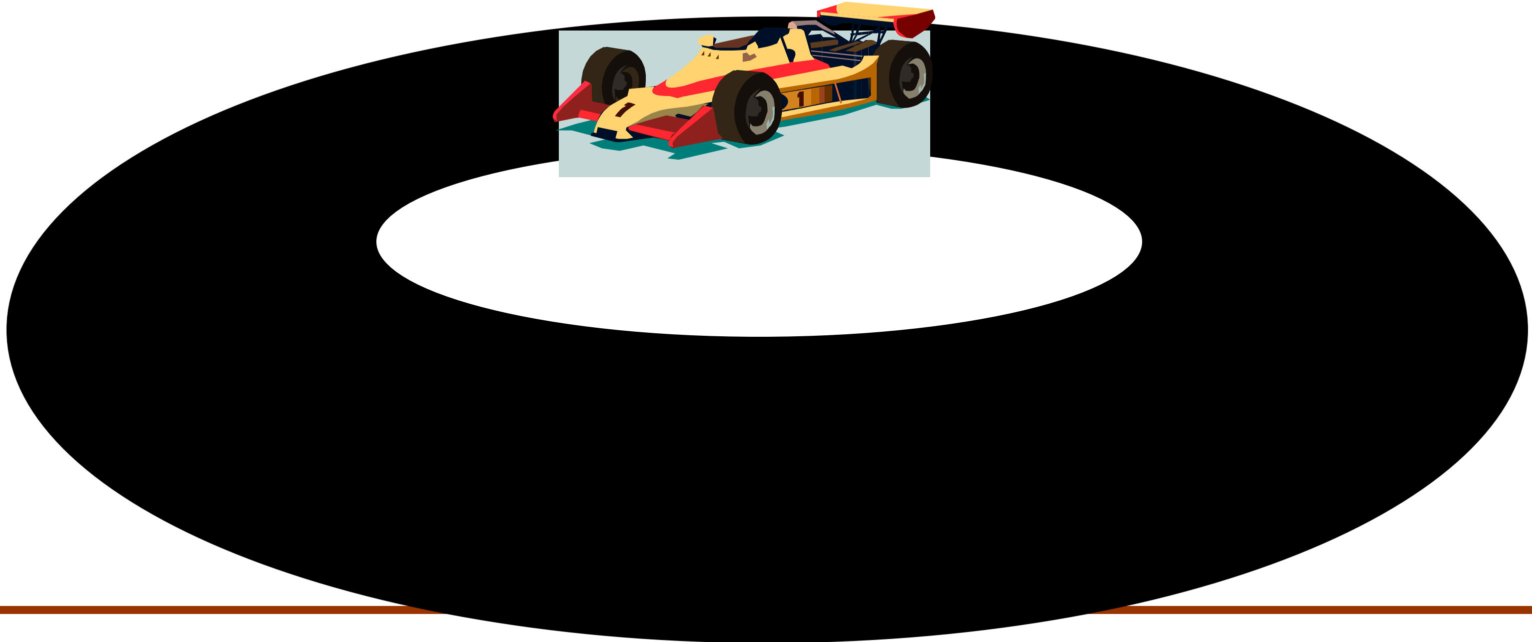
$q = ?$

$q = It = 5.0 \times 10^{-2}$ C/s $\times 2.9 \times 10^{4}$ s

$q = 1450$ C $= 1.5 \times 10^{3}$ C.

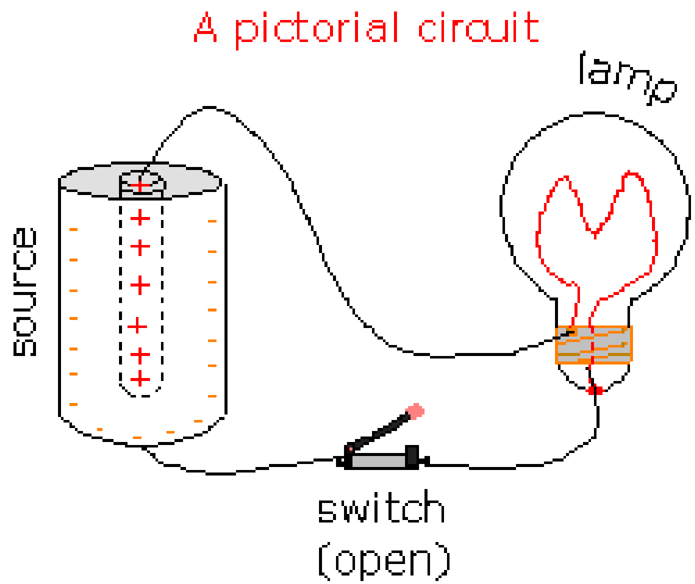
How can we control currents?

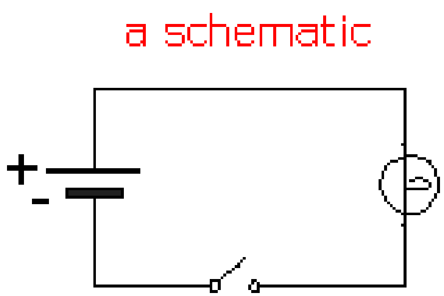
- With circuits.
- Circuit: is a path for the flow of electrons. We use wires.



Electric Circuit: a complete uninterrupted pathway for an electric current, from the source and back again. In order for electrons to move, there must be a complete pathway through which they can flow.

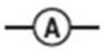
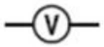
Schematic Diagram: a circuit diagram which shows the logic of the connections rather than the actual layout of the components. A diagram using graphic symbols to show how a circuit functions electrically.





SAMPLE ELECTRICAL CIRCUITS AND SYMBOLS

Table 11.2 Circuit Symbols

Symbol	Component	Function
	wire	conductor; allows electrons to flow
	cell, battery	electrical source; longer side is the positive terminal, shorter side is the negative terminal
	lamp (light bulb)	specific load; converts electricity to light and heat
	resistor	general load; converts electricity to heat
	switch	opens and closes the circuit
	ammeter	measures current through a device, connected in series
	voltmeter	measures voltage across a device, connected in parallel

See p. 593 of your text for more

RULES for Drawing Circuit Diagrams

1. Always use a ruler to draw straight lines for the conducting wires
2. Make right-angle corners (∟) so that your finished diagrams is a rectangle

- Contain 4 basic parts:
  - Electrical source
  - Switch
  - Load
  - Conducting wire

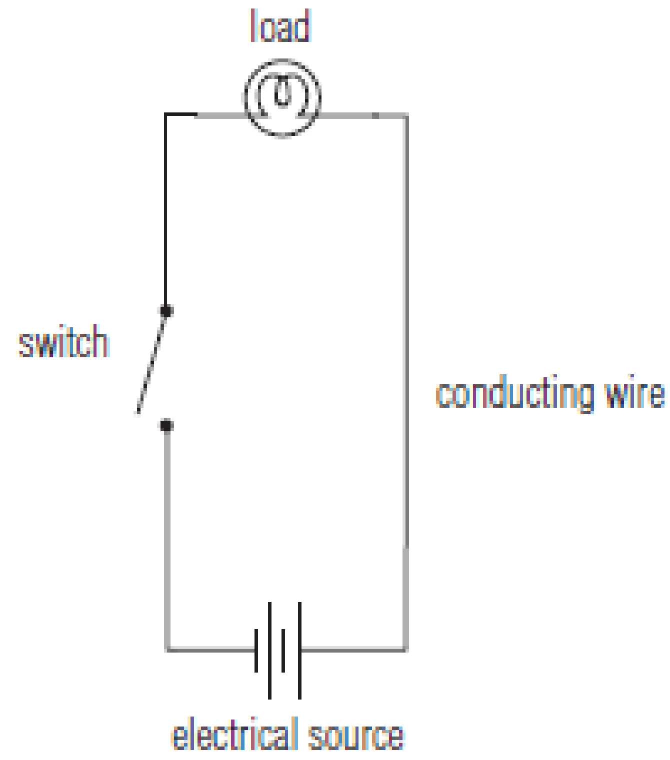
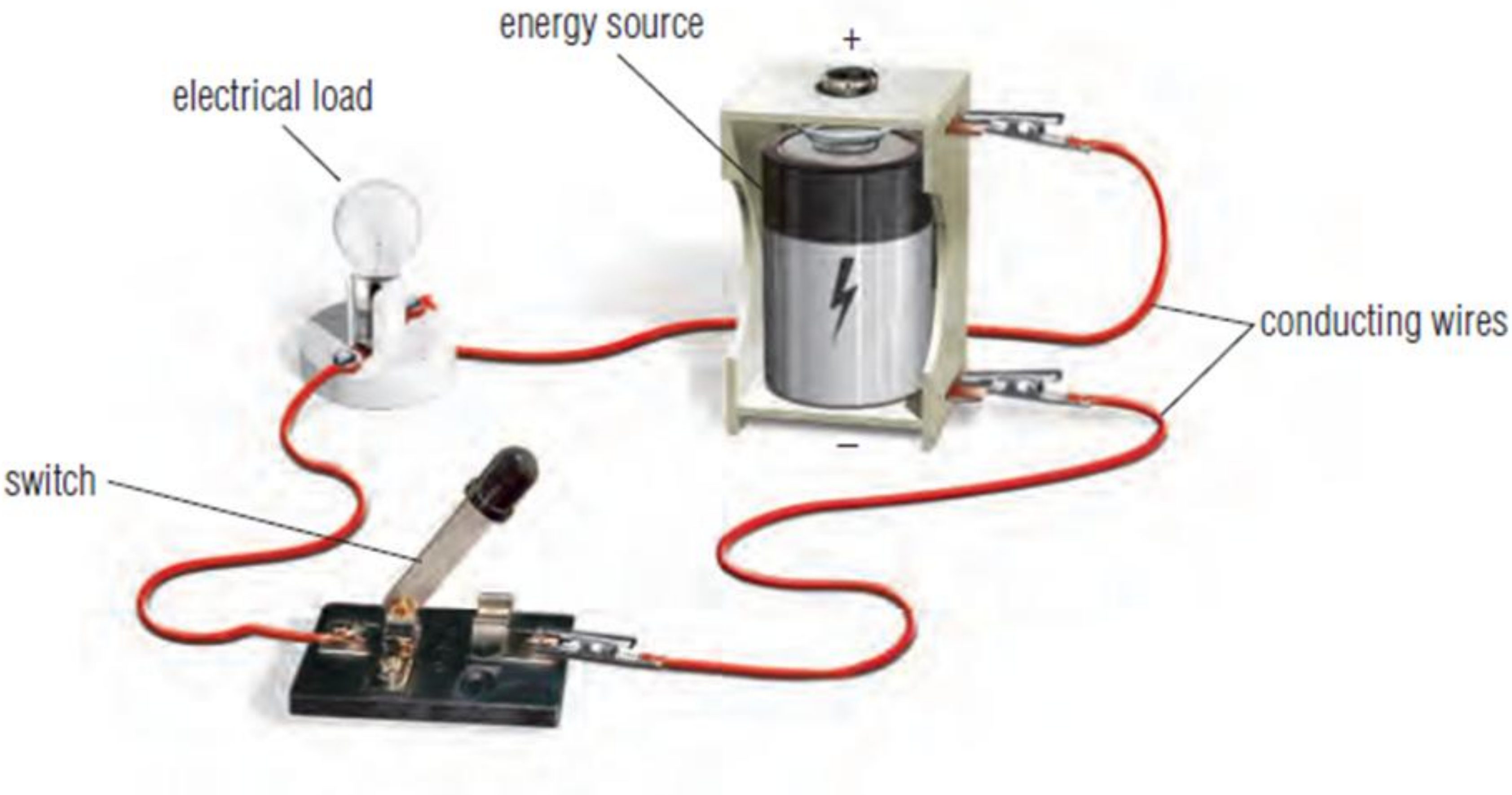


Figure 11.26 The four basic parts of a circuit



- Electric current is the movement of electrons from a negative terminal back to the positive terminal of a battery (potential drop).

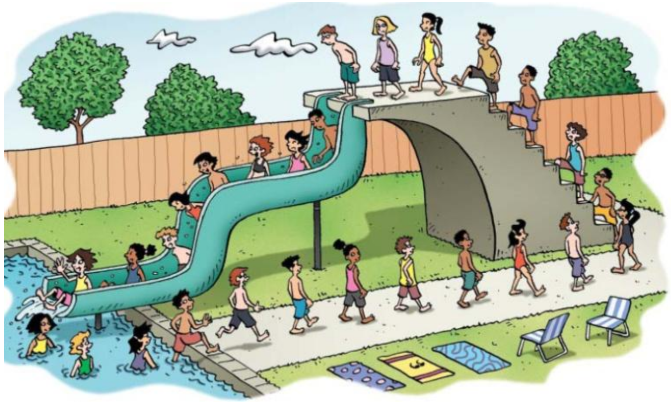
Fundamental Parts of An Electric Circuit

An electric circuit can be considered a system consisting of four subsystems:

1. *Source*	a device which changes one type of energy into electrical energy, example a chemical cell or generator.
2. *Conductor*	a material which allows electric current (electrons) to pass through it easily, example copper wire
3. *Control*	starts and stops the flow of electrons in an electric circuit, example switch
4. *Load*	the device which changes electrical energy into some other form of energy, example motor, light bulb

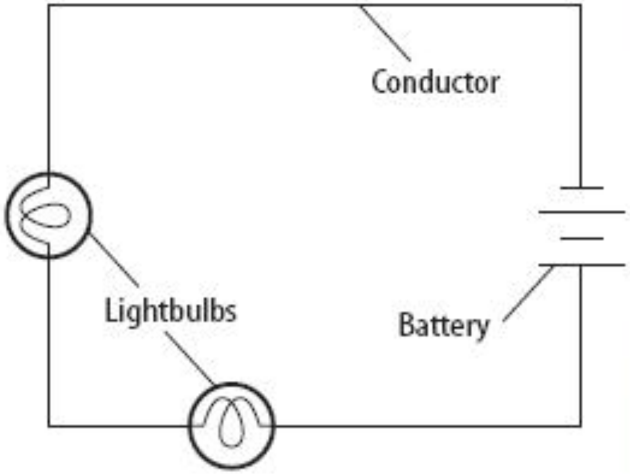
SERIES CIRCUIT

- provides a single pathway for the current to flow.



- If the circuit breaks, all devices using the circuit will fail.

A series circuit provides only one path for the current to follow. *What happens to the brightness of each bulb as more bulbs are added?*

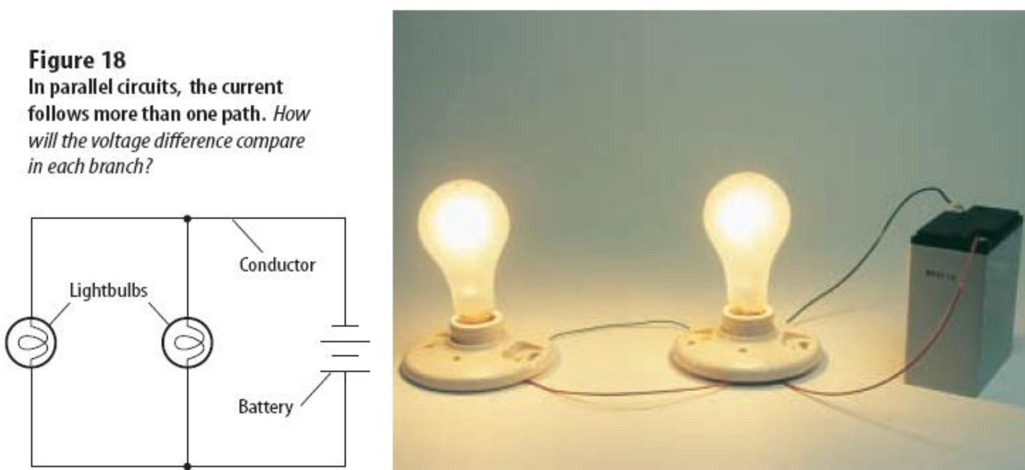


PARALLEL CIRCUIT

- has multiple pathways for the current to flow.

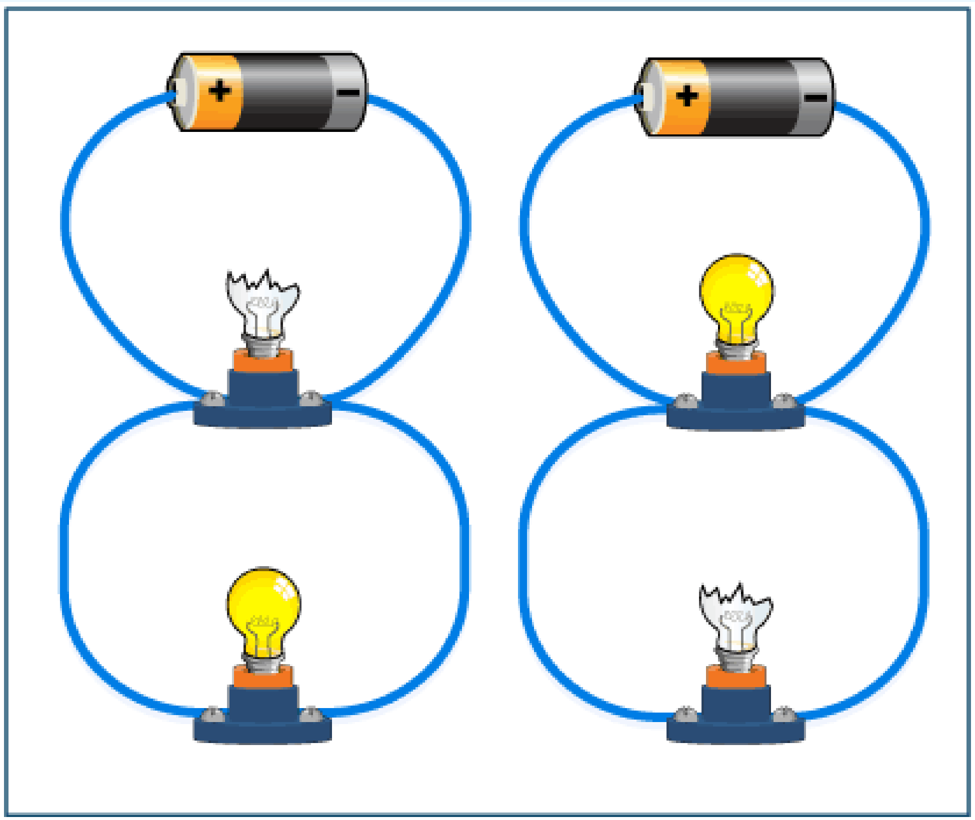
- If the circuit is broken the current may pass through other pathways and other devices will continue to work.

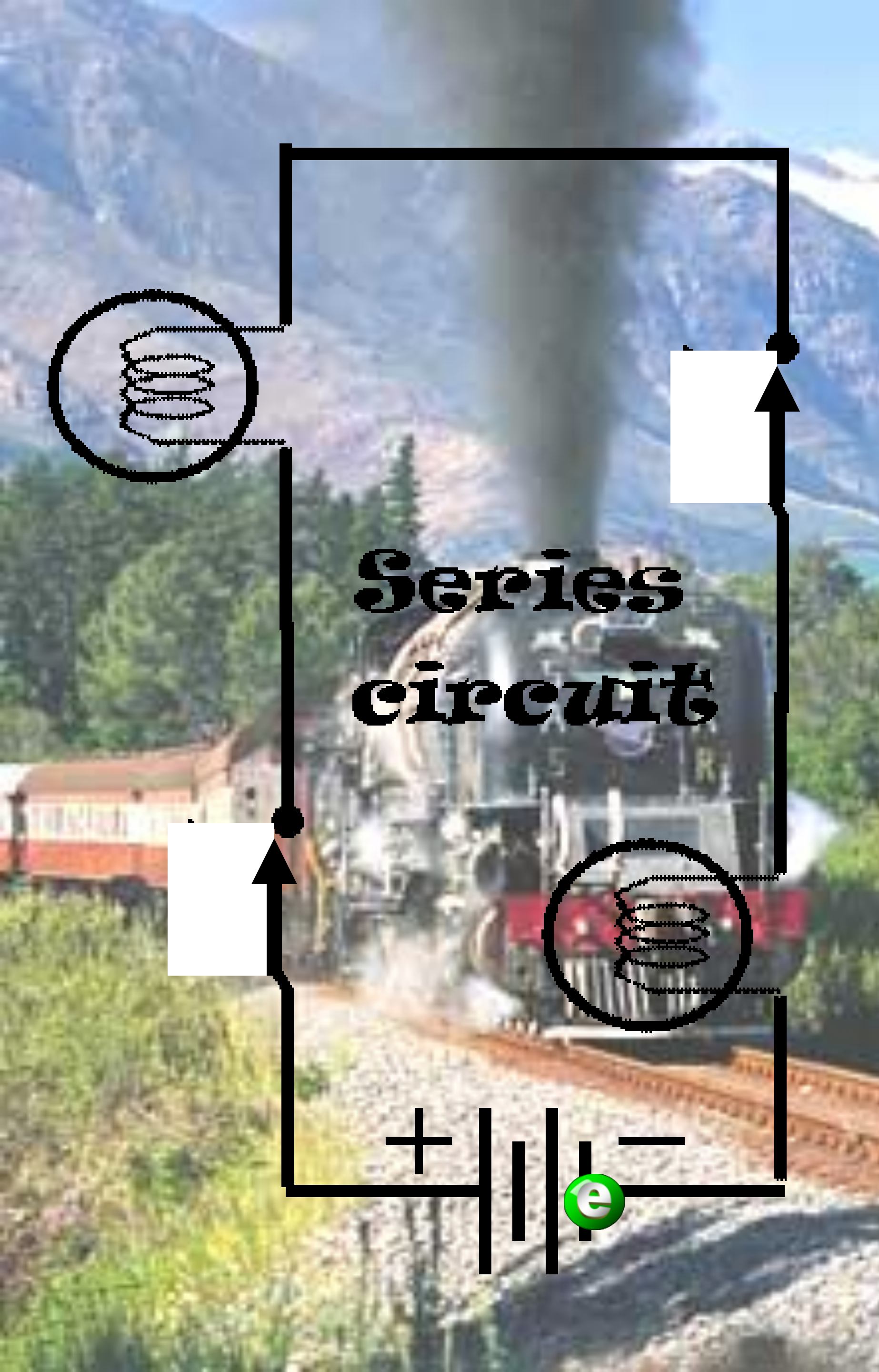
Figure 18
In parallel circuits, the current follows more than one path. *How will the voltage difference compare in each branch?*



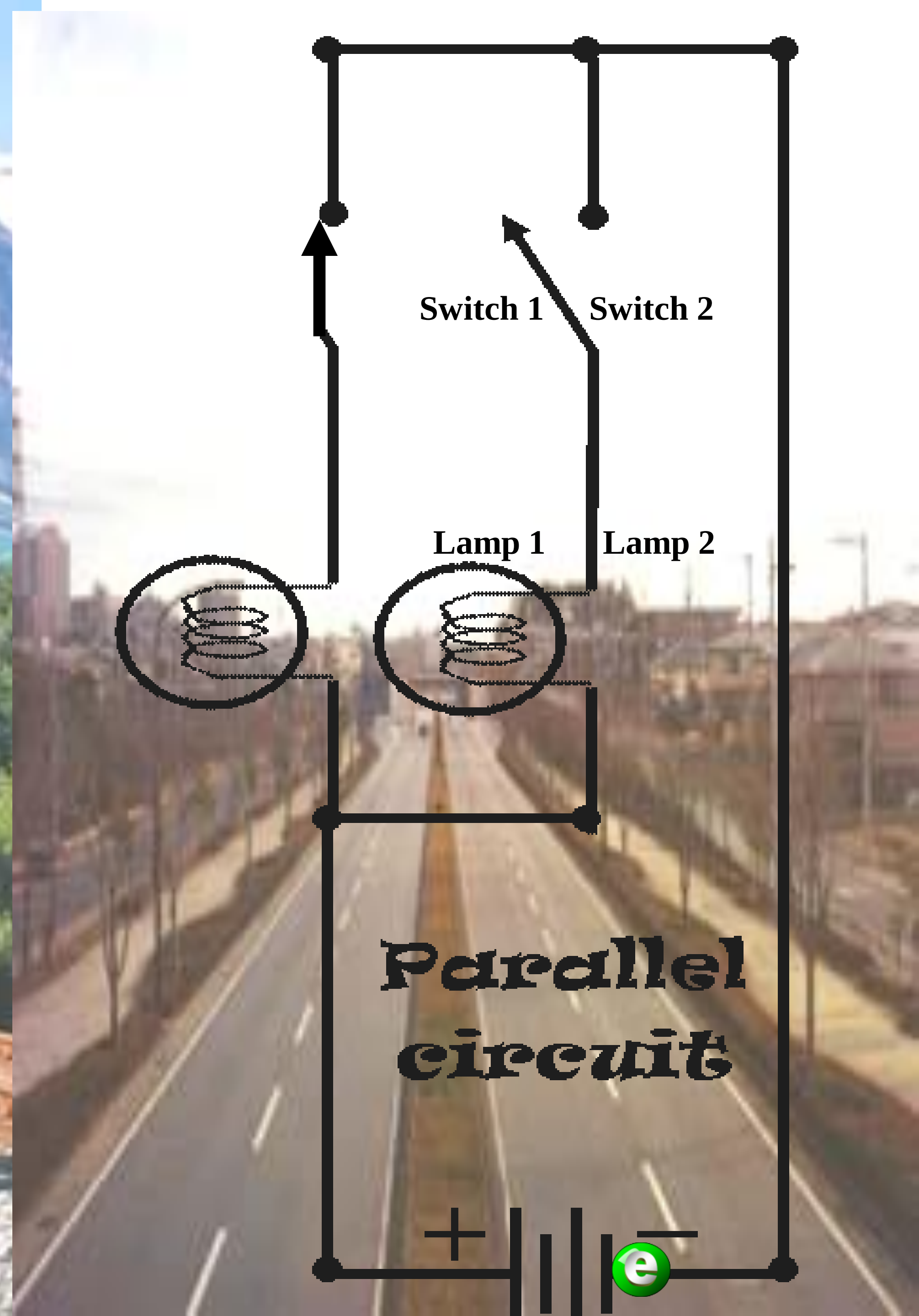
Ex. Expensive Christmas lights, If you remove a bulb from a the string they remain lit !

PARALLEL CIRCUIT





Series circuit
+
–
e

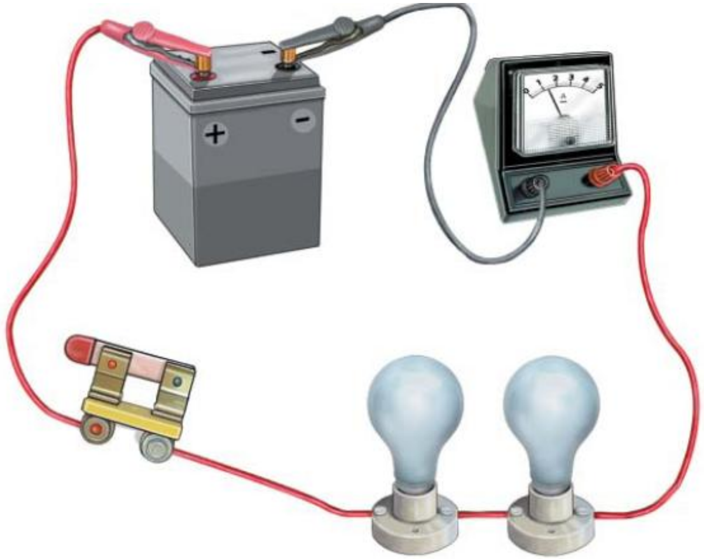


Switch 1
Switch 2
Lamp 1
Lamp 2
Parallel circuit
+
–
e

MEASURING CURRENT

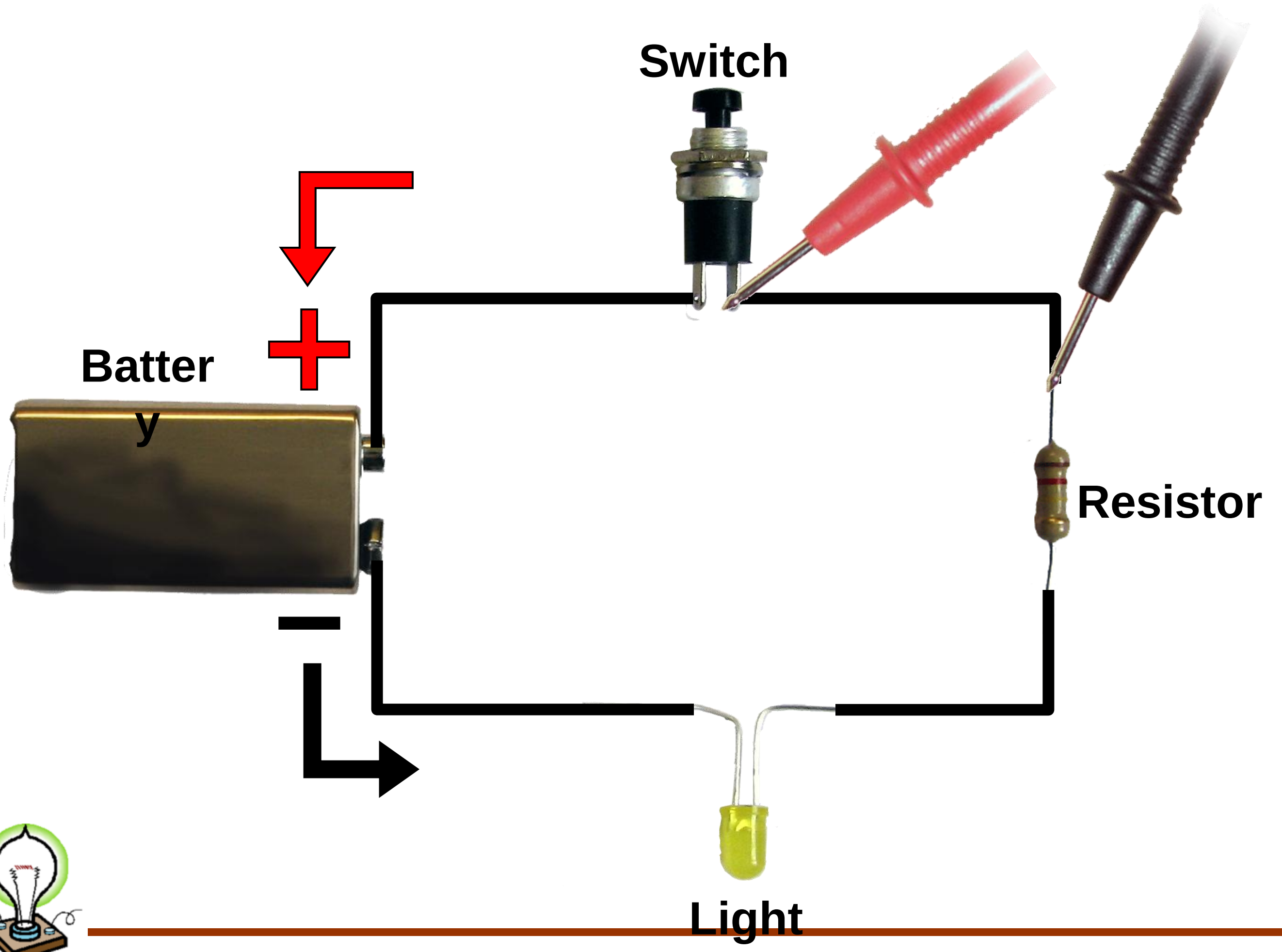
- Current is measured with an instrument called an ammeter.

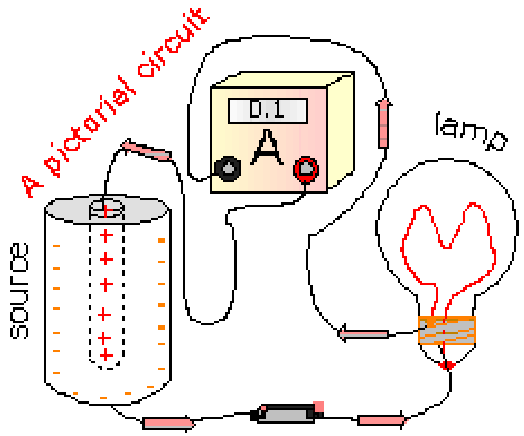
- the ammeter is always connected in series with the other elements of the circuit. An ammeter typically has a red terminal and a black terminal. Connect the red terminal to the positive terminal of the battery.

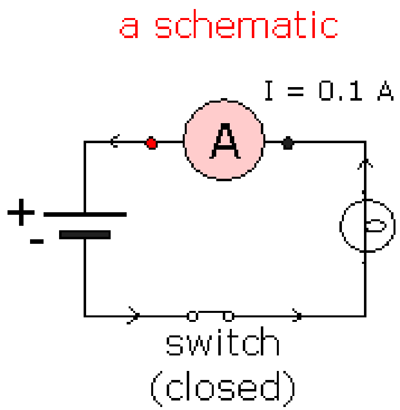


Measuring Current

Circuit flow must go through the meter.







In the schematic, the resistance of the ammeter is much, much, much smaller than the resistance of the lamp. *This is important because the ammeter must not affect the circuit in an appreciable way.*

Activity

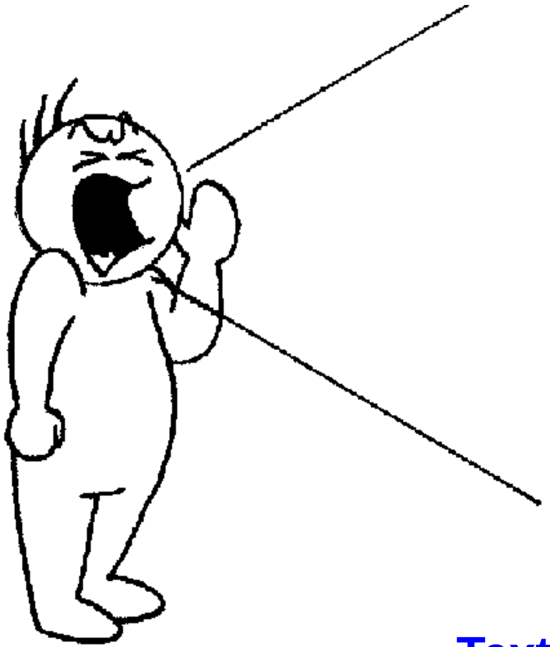
- Read Text: Sec 14.2 Pages 590-594
- Worksheet 1: Electric Current

- DO Extra Practice Questions: Text In your textbook:
- 594--do #1 --#4
- on. p. 620--do #1, #2, #4
- on pp. 620-do #9--#10

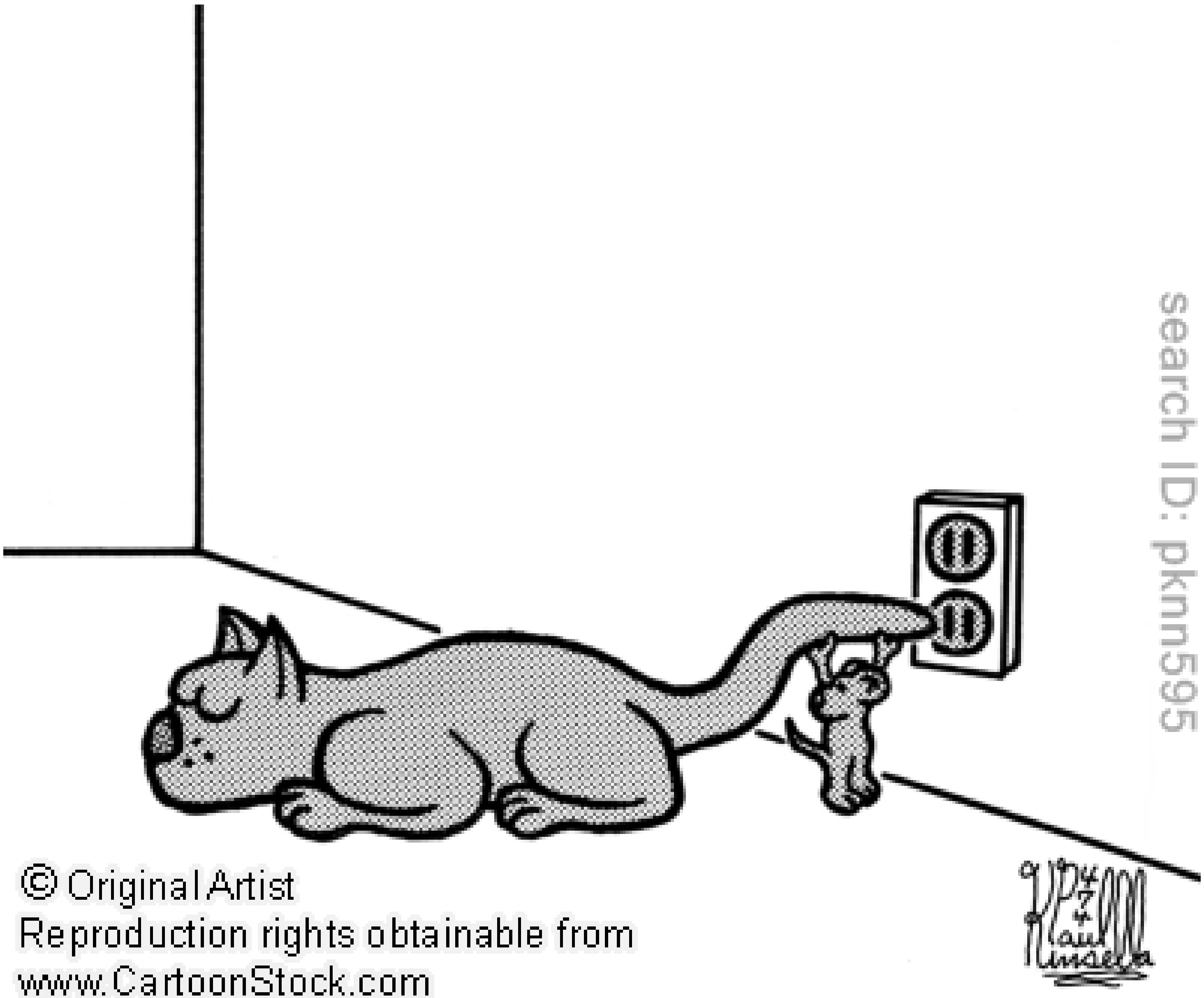
Physics 3204

Unit 2 : Section 2 – Current Electricity

Topic 2 : Electric Voltage



Text: Unit 14.3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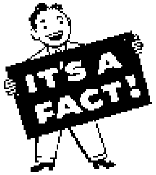
Electric Potential Energy

Electric Potential Energy refers to electric energy stored in the battery that can be given to electrons to enable them to do work within a circuit.

Electric Potential Energy is measured in Joules

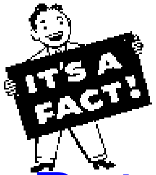


Electric potential energy is another name for work (W) when we are dealing with electricity is the change in.

VOLTAGE

Charge does not flow on its own. To produce an electric current in a circuit, a difference in potential is required. Voltage is just another name for potential difference (V) and the units are volts.
(named after Alessandro Volta (1745-1827).

Electric potential refers to the amount of energy per unit charge.



$$\text{Electric Potential} = \frac{\text{Electric Potential Energy}}{\text{Charge}}$$

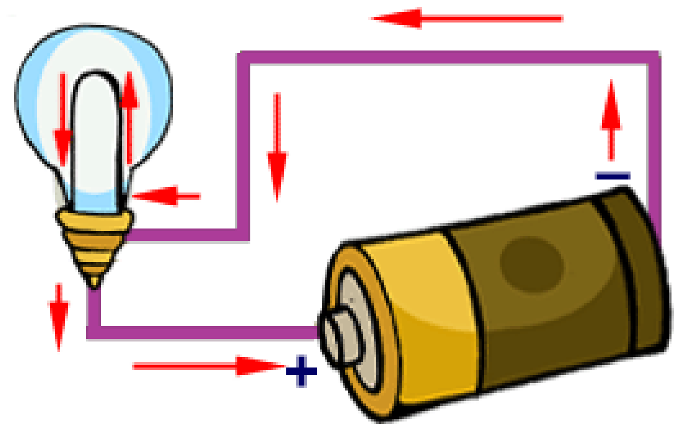
$$= \frac{\text{Joules}}{\text{Coulomb}}$$

$$= \text{Volts}$$

Don't forget that another name for work (W) when we are dealing with electricity is the change in electric potential energy (E_e).

Example 1:

What is the voltage of an AA dry cell if the internal chemical action does 15 J of work while supplying 10 C of charge to operate a small bulb?



Givens:

W = E_e = 15 J

q = 10 C.

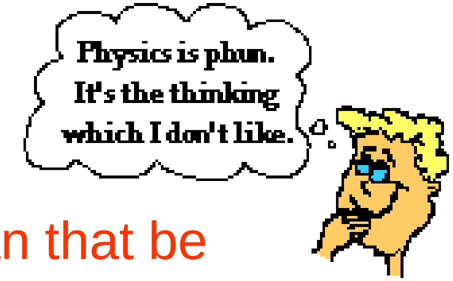
V = ?

Solution:

V = E_e /q = 15 J / 10 C = 1.5 J/C = 1.5 V.

But, you knew that all time. All AA dry cells have a voltage of 1.5 V.

Think:



All AAA, C, and D cells have the same voltage. How can that be when the D cell is very much larger than the AAA cell?

Voltage depends only on the materials that make up the cell. For example, if the rod is carbon and the casing is zinc, and the paste is the same in the cell, then you could make the cell as big as a barn and the voltage would still be 1.5 V.

What's the advantage of using a D cell over using a AAA cell?

A D cell is bigger--the rod is bigger, the casing is bigger, there is a lot more paste. Therefore it will keep pumping electrons to a higher potential on the casing for a much longer time than will a AAA cell.

The D cell will operate the light bulb for a much longer time before its chemical action becomes all used up. The larger the cell, the longer it can supply a certain amount of current.

Example 1:

The battery required by a smoke detector can provide 10 C of charge when the chemical action in the battery expends 90 J of energy. How many dry cells would it take to operate the smoke detector?
(Note: For a dry cell that voltage is typically 1.5 volts)

Givens:

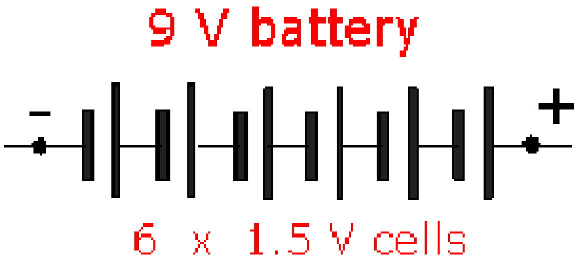
$W = E_e = 90\text{ J}$

$V = ?$

$V = E_e / q = 90\text{ J} / 10\text{ C} = 9\text{ J/C} = 9\text{ V.}$

A smoke detector battery is rated at 9 V. 6 dry cells would provide the equivalent voltage (6 x 1.5 = 9).

A 9.0v battery is nothing more than 6 dry cells in one casing.

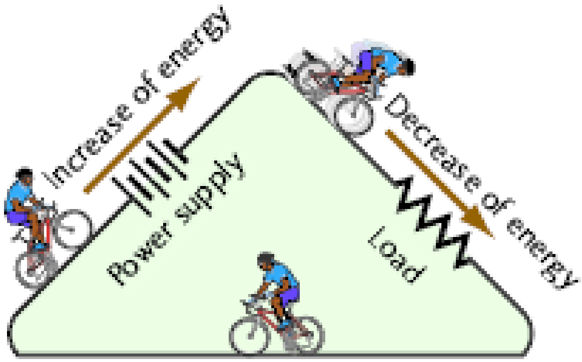


What is Voltage? Confused??

Whatever the source, it helps to picture potential difference or voltage as the force behind the current--the force making the electrons move. In fact, another name sometimes used for potential difference and voltage is electromotive force (emf).

Analogy

Voltage may be viewed as a hill. Think of this analogy: the steeper the hill, the faster a line of balls will roll down. The "current of balls" will deliver more balls to the bottom of the hill faster when the hill is steep. Likewise, when voltage is high, it seems reasonable to predict that a larger current of electrons will roll through the circuit.



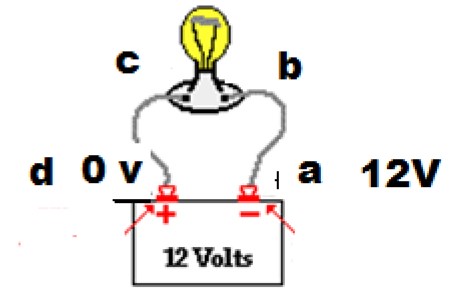
Sources of Potential Difference (Voltage)

Voltaic Cell 	Chemical potential energy is released during a reaction as electrons are driven between two different metal plates.
Piezo - electrcity 	Quartz and Rochelle salt crystals create small electric potential when mechanical force or stress is applies to them.
Thermoelectricity 	Two pieces of difference metals joined together and subject to a temperature difference transfers thermal energy in to electric potential energy in what is called a <u>thermocouple.</u>
Photoelectricity 	light energy is absorbed by elections of certain metal that cause electrons to flow.
Electromagnetic Induction 	Kinetic energy of water or steam forces conductors to move in magnetic field

Electric Potential Difference

Electric potential difference refers to the difference in electric potential from one location in a circuit to another.

***The units are still volts*.**



Voltage at point A is 12 V

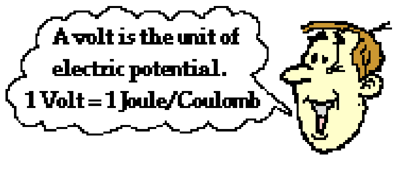
Voltage at point B is 0 V

Electric Potential Difference = Voltage at A - Voltage at B

= 12 V - 0 V

= 12 V

To produce an electric current in a circuit, a diff... in potential is required



Example 1:

If the potential difference across a battery is 6.0 V, how much work is done to move 6.0×10^2 C of charge through a circuit?

Example 2:

The work required to move an electric charge between two points in an electric field is 0.0045 J. If the potential difference between these points is 12 V, what amount of charge is moved?

Example 3:

If 4.8×10^{-17} J of work is required to move an electron between two points in an electric field, what is the electric potential difference between these points?

What is Electrical Potential Energy, Electrical Potential, Electrical Potential Difference Confused??

Money represents the amount of energy you have!

Money = Electrical Potential Energy

People represent Charge

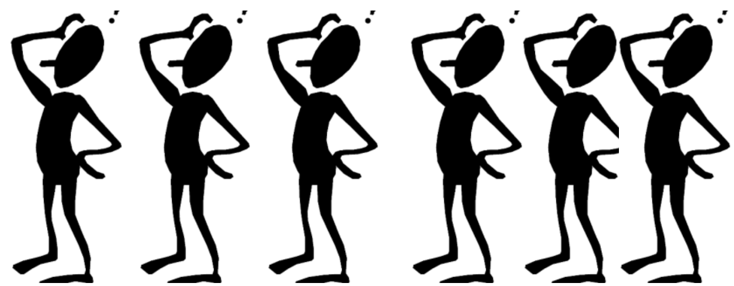
More People = More Charge

battery 1

Energy 6 J

Charge = 2 C

battery 2



Energy 12 J

Charge = 6 C

Electric Potential = 6 /2 = 3V

Electric Potential = 12 /4 = 2V

The amount of money per person is like electric potential. However, in a circuit electric potential represent the amount of energy per charge.

What is electric potential difference?

Remember battery 1, each person had $3 dollars per person or 3 V.

ELECTIC POTENTIAL DIFFERENCE $= V_{IN} - V_{OUT}$

$= 3V - 1V$

$= 2\ V$

Figure 8.16A Both ends of the tube are at the same potential (height). The marbles in the tube do not all flow in the same direction.

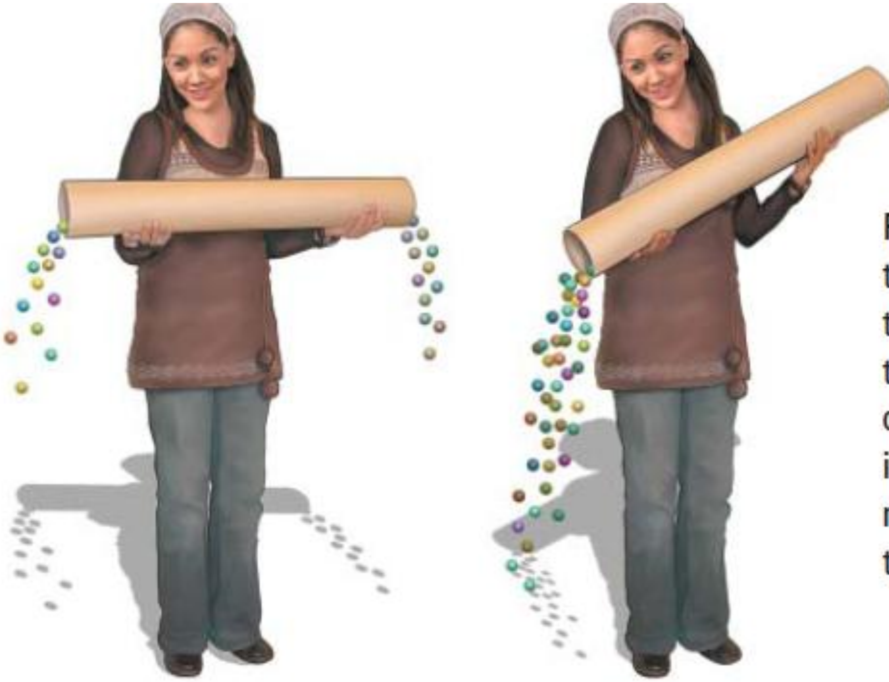
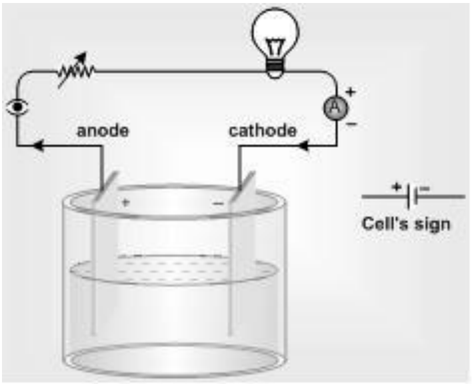


Figure 8.16B Because of the difference in height of the ends of the tube in (B), there is a greater potential difference than in (A). There is a greater "current" of marbles in tube (B) than in tube (A).

Cells and Batteries

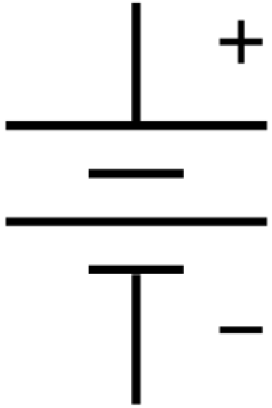
Current can not be produced or electrons can not flow on their own, some force has to get the electrons moving. One way that we looked at was through the use of an electrochemical cell.

Cell: a device that converts chemical energy into electrical energy. Generally speaking the "batteries" that you buy in the store to run your portable appliances are chemical cells.

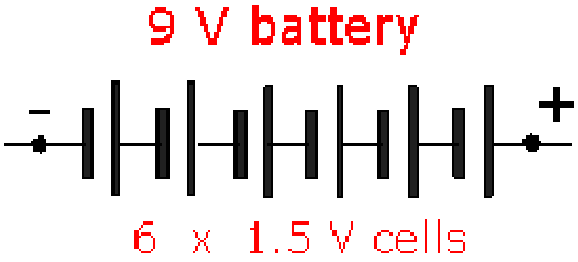


What is a Battery

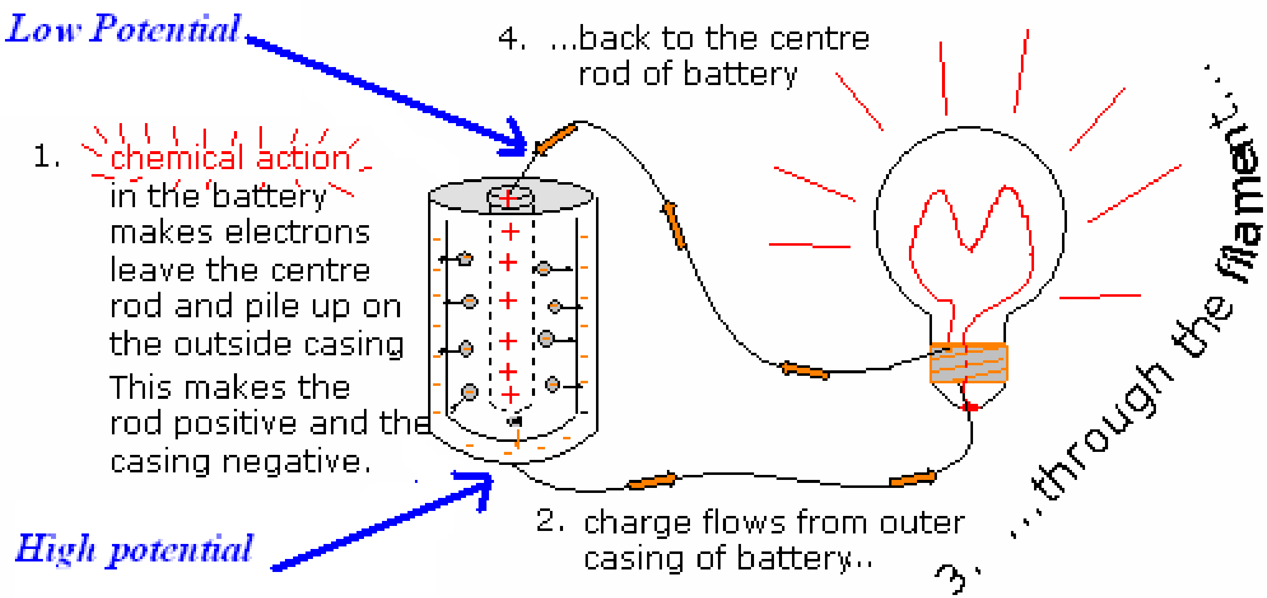
Battery: made up of one or more electrochemical cells that are joined together to provide an electric current.



SYMBOL FOR BATTERY

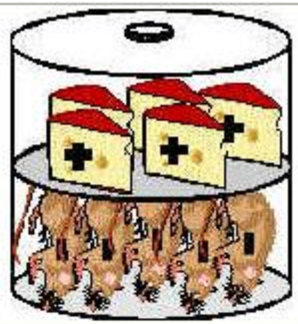


Electrons flow from regions of high potential to regions of low potential (something like a rock falling from a location of high potential to a location of lower potential).



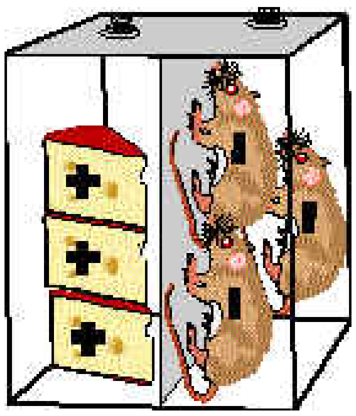
The Mouse Cheese Battery (cell)

The battery goes "dead" when all the negative charges make it through the circuit and get to the positive charges.



D cell
1.5 volts

AA cell
1.5 volts



lantern battery
6 volts
hungrier mice

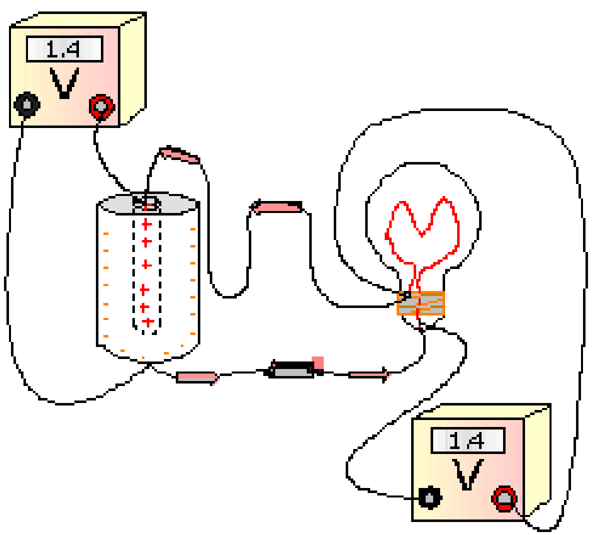
slightly flawed: the lantern battery would also have many more mice than the D cell, but that is not related to it being 6volts

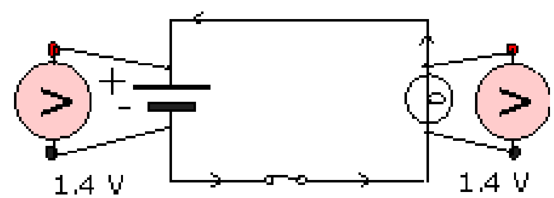
MEASURING VOLTAGE

The instrument used to measure voltage is called a **voltmeter**.

A voltmeter can measure the increase in potential at the terminals of the dry cell, and the decrease in potential as the electrons give up their energy in the lamp.

Voltmeters must be hooked up in parallel

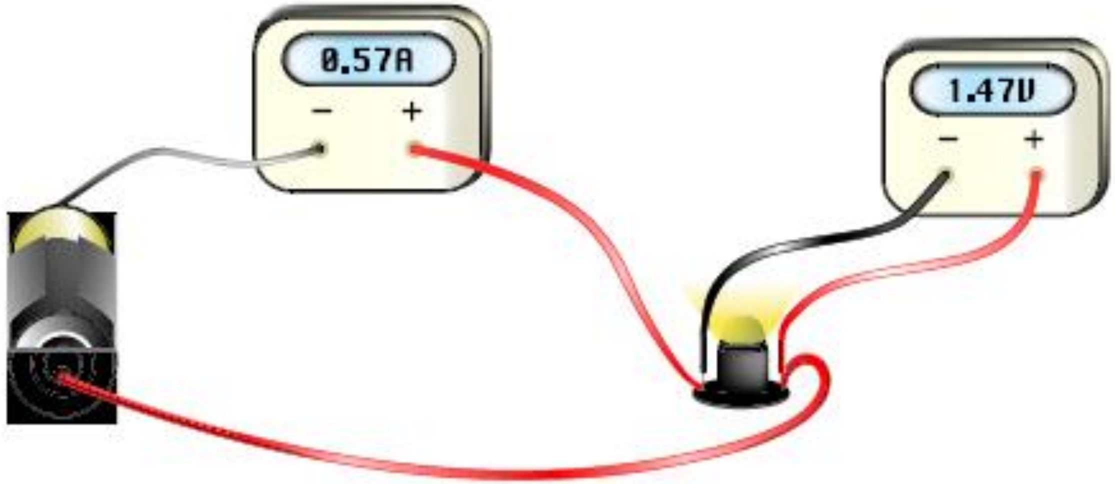




Unlike the ammeter the circuit is not broken to connect a voltmeter.

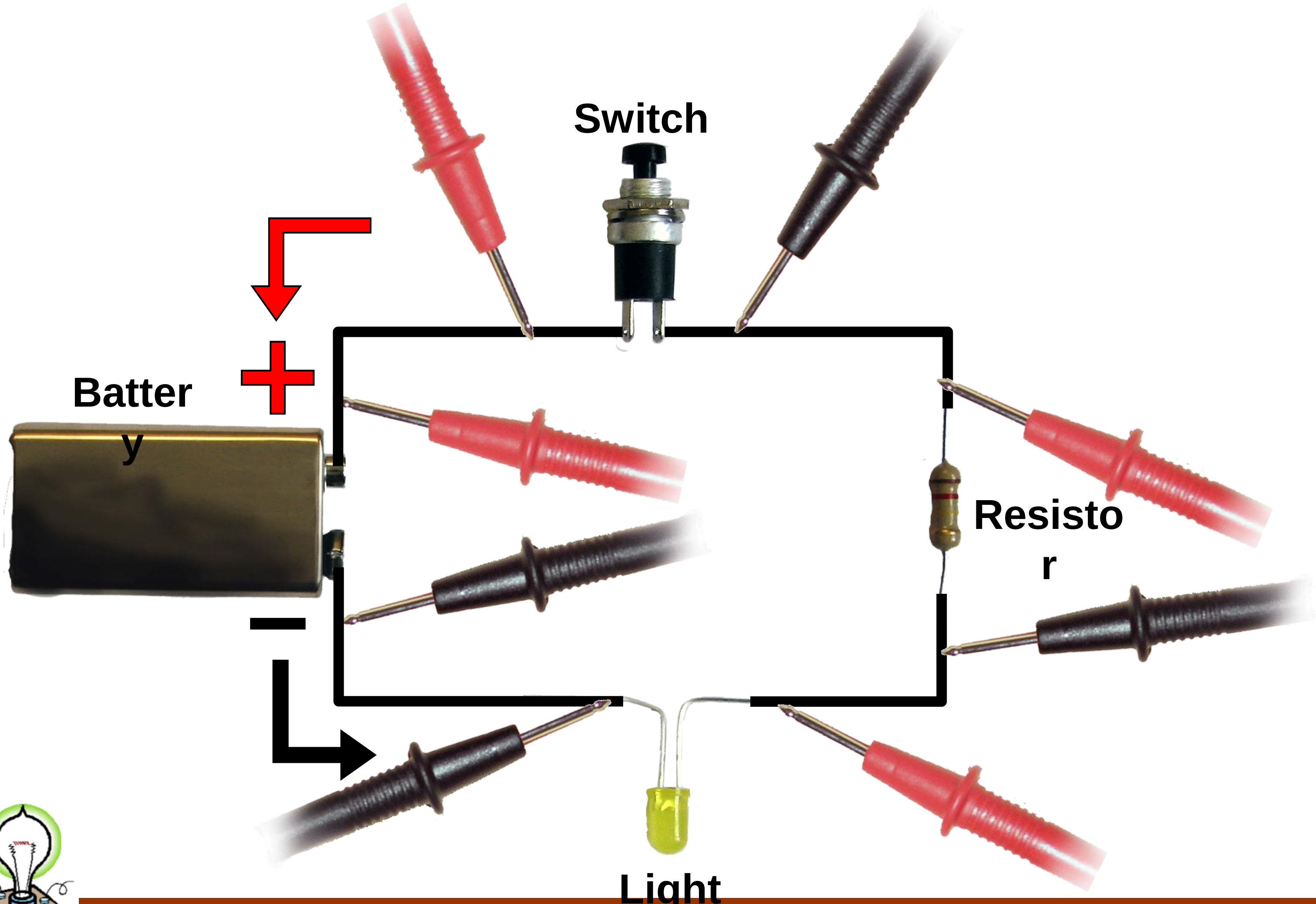
- The red terminal of the voltmeter is connected to the positive terminal of the cell. (However, the red terminal of the voltmeter must be connected to the terminal of the bulb that is towards the positive terminal of the dry cell.)
-

a)



Measuring Voltage

Measure across a component.



SUMMARY

	Current	Voltage
Measured in	Amps, A	Volts, V
Measured with	Ammeter in series	Voltmeter in parallel
Circuit symbol of measuring devise		

Activity

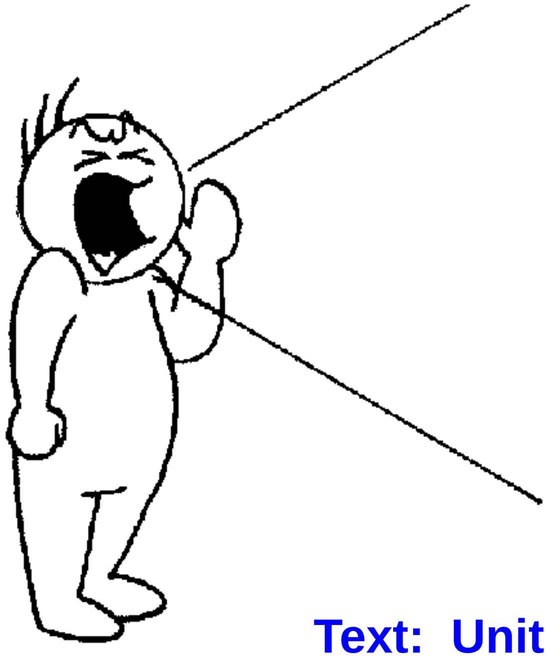
- Read Text: Sec 14.3 Pages 594-598
- Worksheet 2: Electric Voltage

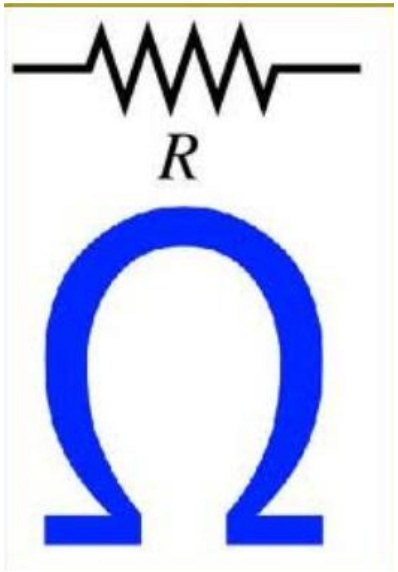
- DO Extra Practice Questions: Text In your textbook:
- on p. 597--do #1--#4
- on pp. 621do #11--#22

Physics 3204

Unit 2 : Section 2 – Current Electricity

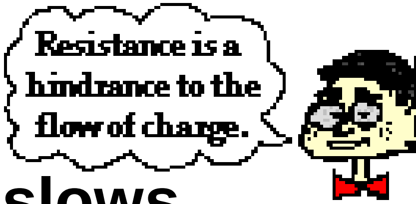
Topic 3 : Electrical Resistance





Text: Unit 14.5

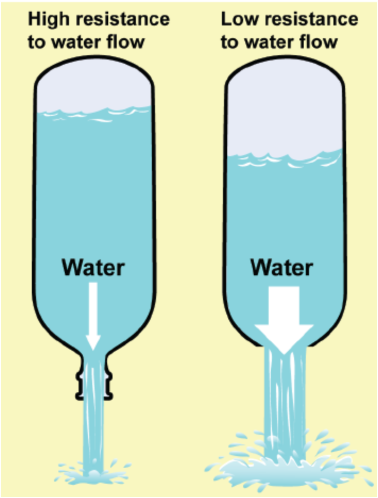
RESISTANCE



Resistance is the property of any material that slows down the flow of electrons and converts electrical energy into other forms of energy.

Electrical resistance is measure in ohms (Ω). The symbol for ohm is an omega ,

Resistance is like an obstacle in the road. Electrons like to going to places of least resistance.

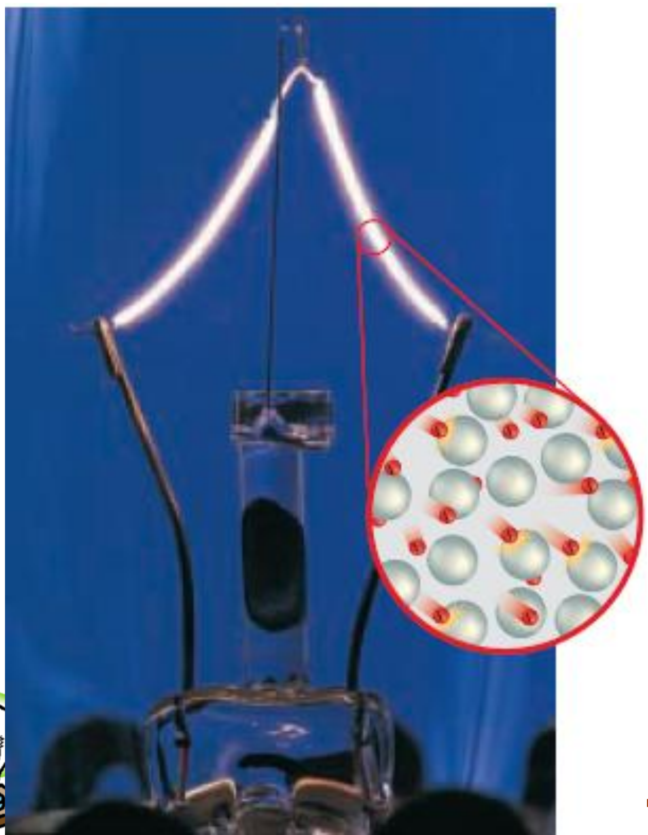


The wire that connects the battery to the light bulb has very little resistance, and therefore the electrons travelling through this wire lose almost no electrical energy

What is electrical ***resistance***?

Resistance (R)is the opposition to the flow of an electric current, causing the electrical energy to be converted to thermal energy or light.

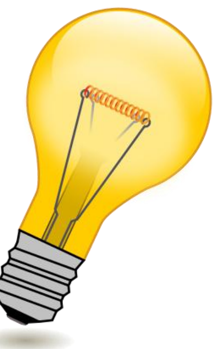
As electrons move through the filament in a lightbulb, they bump into metal atoms. Due to the collisions, the metal heats up and starts to glow.



The metal which makes up a light bulb filament or stovetop eye has a high electrical *resistance*. This causes light and heat to be given off.

Electric load provided resistance in a circuit. It transforms electrical energy into other forms of energy.

Examples:



Four Factors That Affect Resistance:

1) TEMPERATURE.

Higher the temperature, larger is the resistance.

Since moving charge is impeded by molecules, greater molecular motion at higher temperatures tends to increase the resistance.

2) LENGTH

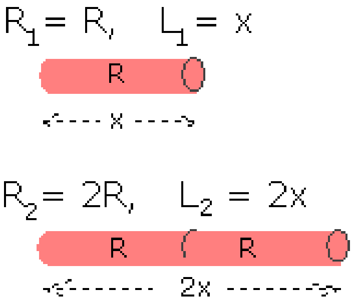
longer the wire greater will be the resistance and shorter the wire smaller will be the resistance.

Think about a water pipe. As water scrapes along the inside of the pipe, water traveling through a long pipe will experience greater drag than through a short pipe.

$R \propto L$ or $R = kL$ where k is some constant of proportionality.

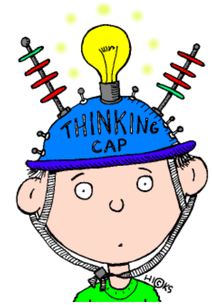
Write $R_1 = kL_1$ and $R_2 = kL_2$, and divide one equation by the other so that the k's cancel:

$$\frac{R_1}{R_2} = \frac{L_1}{L_2}$$



identical resistors except for length (same diameter, same material, same temp.)

3) THICKNESS OF WIRE



Think: Will water run more freely through a fat pipe or a skinny one?

Answer:

The water will run through the pipe with the larger cross-sectional diameter. The larger the cross-sectional area the easier the flow. In other words: large cross-sectional area (A) means small resistance (R). Double the area and the resistance becomes one-half of what it was; triple the area and the resistance becomes one-third of what it was;

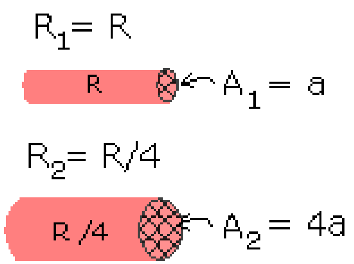
Thinner the wire, greater the resistance and thicker the wire, lower the resistance.

$R \propto \frac{1}{A}$ or, $R_1 = \frac{k}{A_1}$ and $R_2 = \frac{k}{A_2}$

Dividing one equation by the other so that the k's cancel:

$$\frac{R_1}{R_2} = \frac{k/A_1}{k/A_2} = \frac{k}{A_1} \times \frac{A_2}{k}$$

$$\frac{R_1}{R_2} = \frac{A_2}{A_1}$$

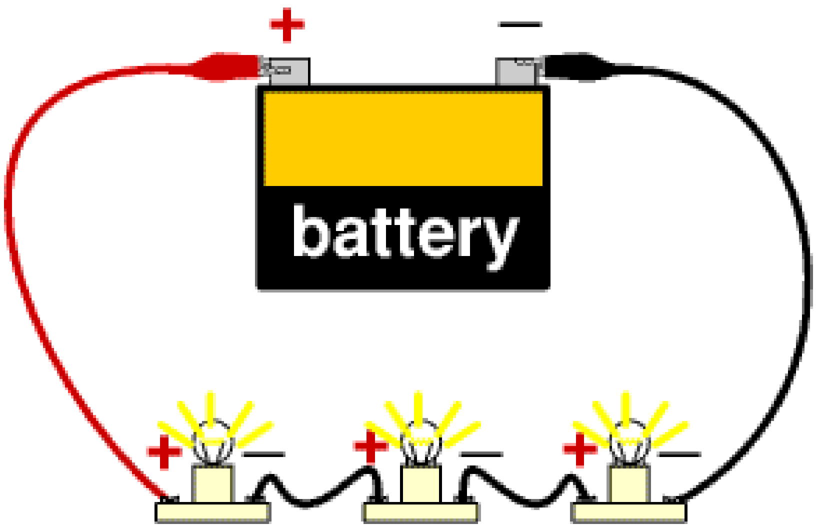


identical resistors except for cross-sectional area (same length, same material, same temperature)

4) TYPE OF MATERIAL.

Good conductors have low resistivity

Silver and copper are extremely good conductors. Glass and hard rubber are non-conductors or insulators.



In Summary….

Table 14.4
Factors that Affect Resistance

Factor	Description	Proportionality
Length	The longer the conductor, the greater the resistance.	If the length is doubled, then the resistance is doubled $\frac{R_1}{R_2} = \frac{L_1}{L_2}$.
Cross-sectional area	The larger the cross-sectional area or thickness of the conductor, the less resistant it is to charge flow.	If the cross-sectional area is doubled, the resistance goes to half of its original value $\frac{R_1}{R_2} = \frac{A_2}{A_1}$.
Type of material	Some materials are better conductors than others. The general measure of the resistance of a substance is called the **resistivity**. Resistivity has units Ω·m.	If the resistivity (ρ) is doubled, then the resistance is also doubled. $\frac{R_1}{R_2} = \frac{\rho_1}{\rho_2}$
Temperature	Since moving charge is impeded by molecules, greater molecular motion at higher temperatures tends to increase the resistance.	An increase in temperature of the conductor usually contributes to an increase in the resistance, but not for all substances.

FIX THIS SLIDE

Summary

Combine R ∝ L and R ∝ 1/A to get R ∝ L/A. This expression changes to an equation by substituting a constant of proportionality. This constant is the Greek letter rho (ρ) , and the equation is

$$R = \rho \frac{L}{A} = \rho \frac{L}{\pi r^2}$$

The units of ρ are Ωm and ρ is named resistivity. The resistivities of silver and copper are extremely tiny at 1.59 x 10-8 m and 1.68 x 10-8 Ωm, respectively. The resistivity of hard rubber is extremely large: 1013 to 1015 Ωm. From these values you can see that for a good conductor, **ρ is very tiny; and for a good insulator ρ is very large.**

Solution Example 1:

What is the resistivity of a piece of wire that is 1.8 m long, 1.2 mm in diameter, and having a total resistance of 0.027 Ω?

Solution

L = 1.8 m

r = 0.6 mm = 0.0006 m

R = 0.027 Ω

ρ = ?

$$\rho = \frac{RA}{L}$$

$$= \frac{R\pi r^2}{L}$$

$$= \frac{0.027\,\Omega \times \pi \times (0.0006\,\text{m})^2}{1.8\,\text{m}}$$

$$= 1.6 \times 10^{-8}\ \Omega\text{m}$$

Example 2

Two wires are identical except that wire 1 has a cross-sectional area that is 3.5 times that of wire 2. If the resistance of wire 1 is $1.2\ \Omega$, what is the resistance of wire 2?

Solution

$A_1 = 3.5\ A_2$

$R_1 = 1.2\ \Omega$

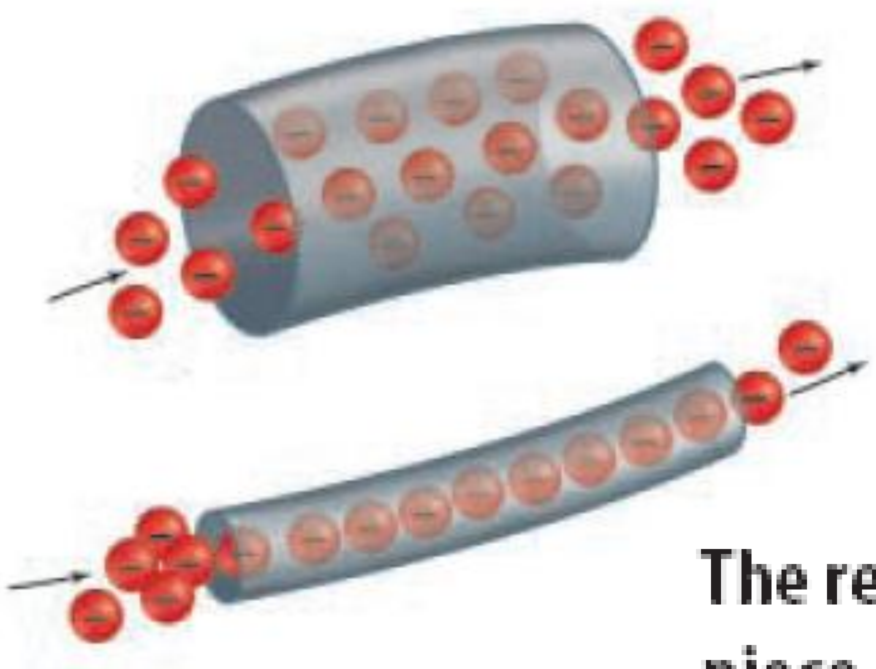
$R_2 = ?$

Use the mathematical expression (from factor 3) that relates A and R and solve for R_2:

Solve $\frac{R_1}{R_2} = \frac{A_2}{A_1}$ for R_2 to get $R_2 = \frac{R_1 A_1}{A_2} = \frac{1.2\,\Omega \times 3.5\,A_2}{A_2} = 4.2\,\Omega$

Common sense says that the resistance of wire 2 will be 3.5 times larger.

Which wire has the greatest resistance?



The resistance of a short, thick piece of wire is less than the resistance of a long, thin piece of wire.

In Summary….

Factors that affect Resistance		
Factor	Description	Proportionality
Length	The longer the conductor, the greater the resistance.	If the length is doubled, then the resistance is doubled.
Cross-sectional areas	The larger the cross-sectional area or thickness of the conductor, the less resistant is has to charge flow.	If the cross-sectional area is doubled, the resistance goes to half its originals value.
Type of material	Some materials are better conductors than others. The general measure of the resistance of a substance is called the resistivity. Resistivity has units Ωxm	If the resistivity(p) is doubled, then the resistance is also doubled.
Temperature	Since moving charge is impeded by molecules, greater molecular motion at higher temperatures tend to increase the resistance.	An increase in temperature of the conductor usually contributes to an increase in the resistance, but not for all substances.

Activity

- Read Text: Sec 14.5 , Pages 599-598

- Worksheet 3: Electric Resistance

DO Extra Practice Questions: Text In your textbook:
604 --do #2 --#3
on pp. 620-621--do #26--#28

Summary Look at it this way: The Mouse Cheese Analogy

Negative charges are attracted to positive charges the same way mice are attracted to cheese. The negative charges (mice) will gladly do work in order to get to the positive charges (cheese).

Voltage:

The amount of work that each charge (mouse) will do as it goes through the circuit. Can also be thought of as the amount of push on the charges or how hungry the mice are.

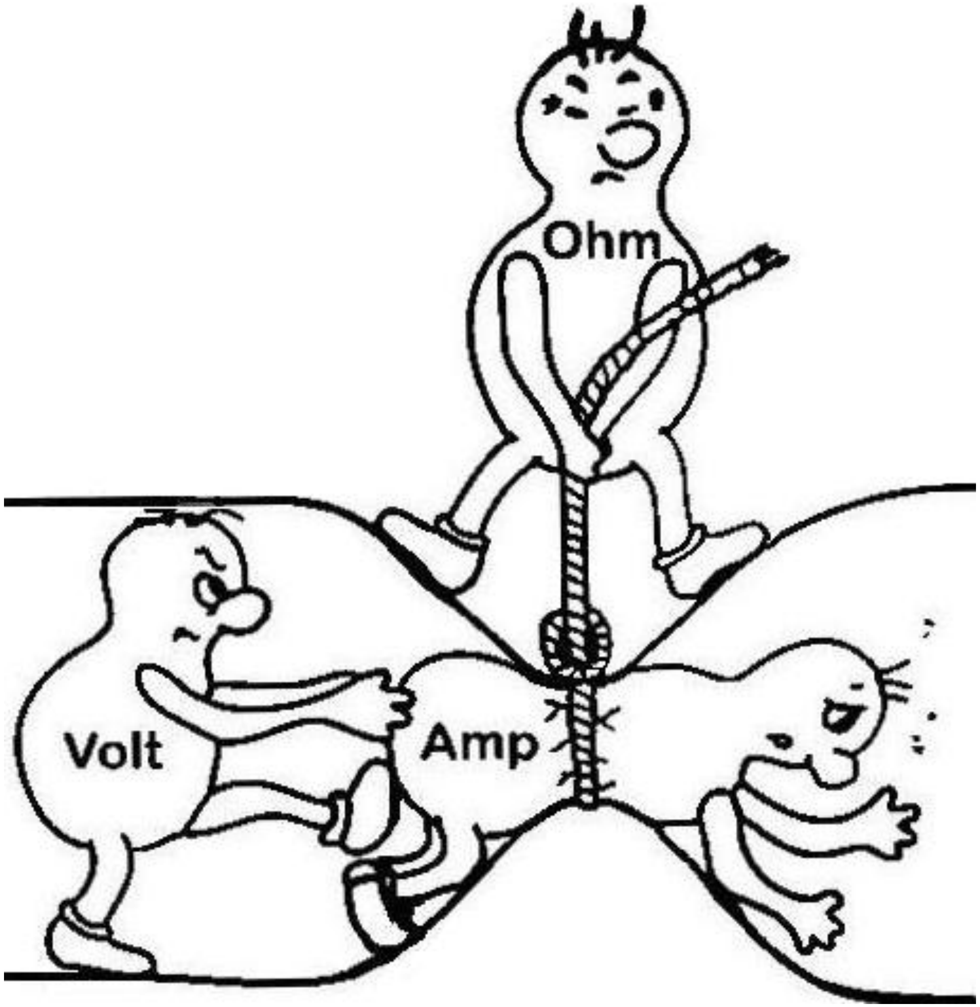
Current:

The number of charges (mice) passing a point per second. The rate of flow of charges.

Resistance:

The opposition to the flow of charge. Any appliance that asks the charge (mouse) to do work will slow it down.

Term	Symbol	Definition	Measured in (Units)
CURRENT	I	- the flow of electrons through a conductor	Amperes (A)
VOLTAGE	V	- also known as "Potential Difference" - "push/force" of electricity - Potential energy per quantity of electrons	Volts (V)
RESISTANCE	R	- measures how easily electricity flows along a certain path	ohm


Ohm
Volt
Amp

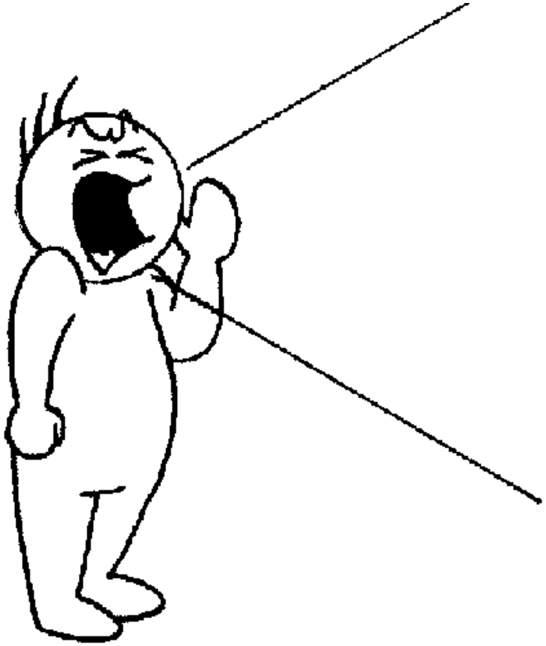
Video

- Physics 3204 Current Electricity

Physics 3204

Unit 2 : Section 2 – Current Electricity

Topic 4 : Ohm's Law



Text: Unit 14.5

OHM'S LAW: RESISTANCE:

Georg Simon Ohm 1789-1854

German Physicist / School Teacher

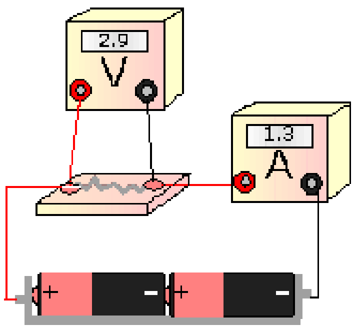
Discovered the mathematical relationship between current, voltage, and resistance

RESISTANCE: OHM'S LAW

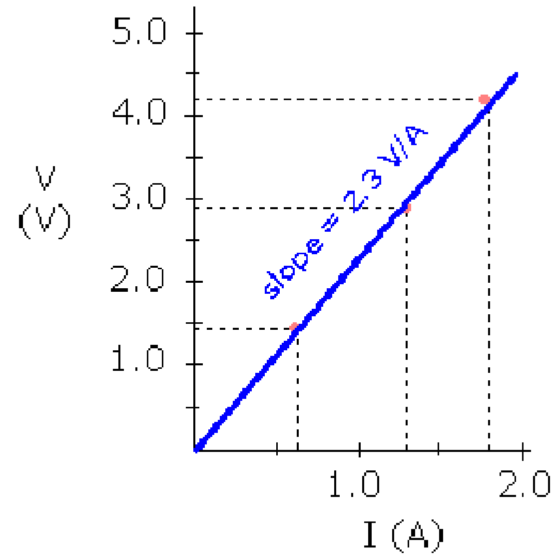
Ohm's Law

Ohm determined that there was a relationship between the potential difference across a load and current through it.

Sample data:



V (V)	I (A)	V/I (V/A)
1.4	0.61	2.3
2.9	1.3	2.2
4.2	1.8	2.3



The ratio of is known as Resistance.

Ohm's Law

V = I R

Potential
In volts
(joules / coul)

Current
In amperes
(coul / second)

Resistance
In ohms
(volts / amp)

Drop across a resistance

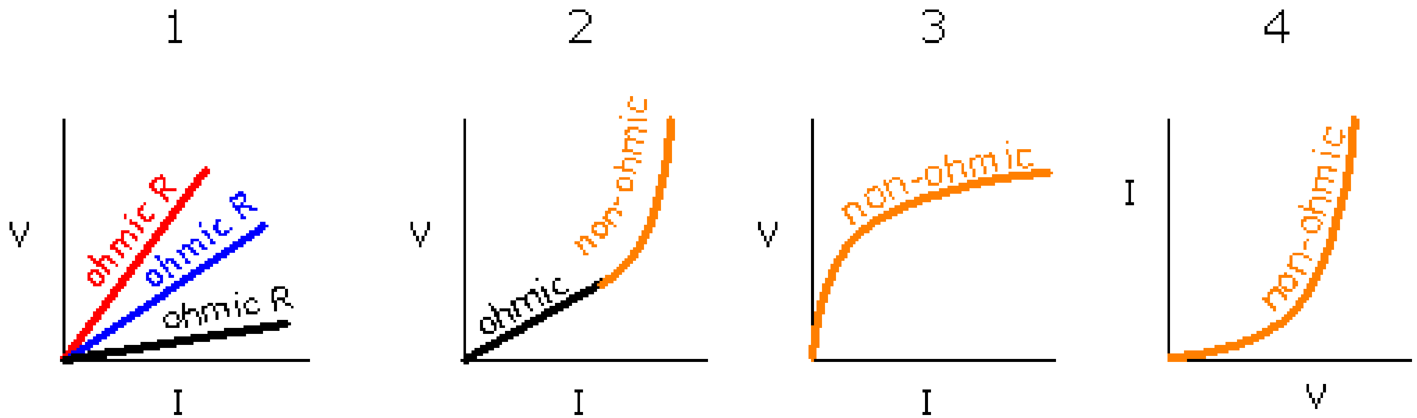
Current passing Through the resistor

OHMIC AND NON-OHMIC RESISTORS

Whenever a graph of V versus I results in a straight line, the resistor has a constant resistance. Such resistors are said to be ohmic because they obey Ohm's law.

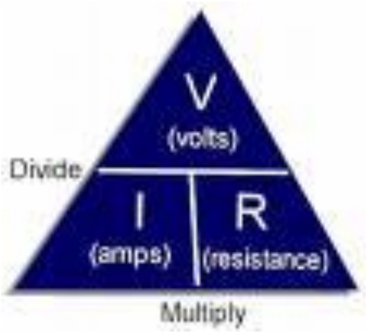
The best way to determine if a piece of material is ohmic or non-ohmic is to connect it to a variable voltage source, measure the current through it as you increase the voltage, and then plot a graph.

Some possible graphs are shown below.



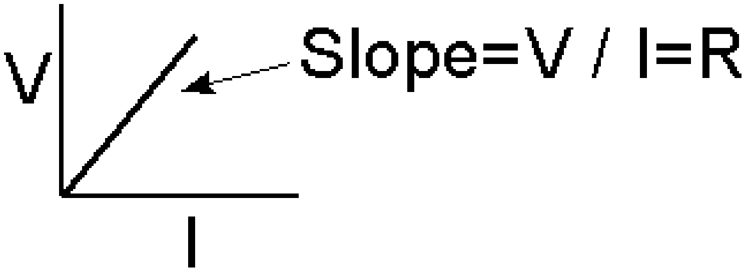
Ohm's Law can be written as:

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

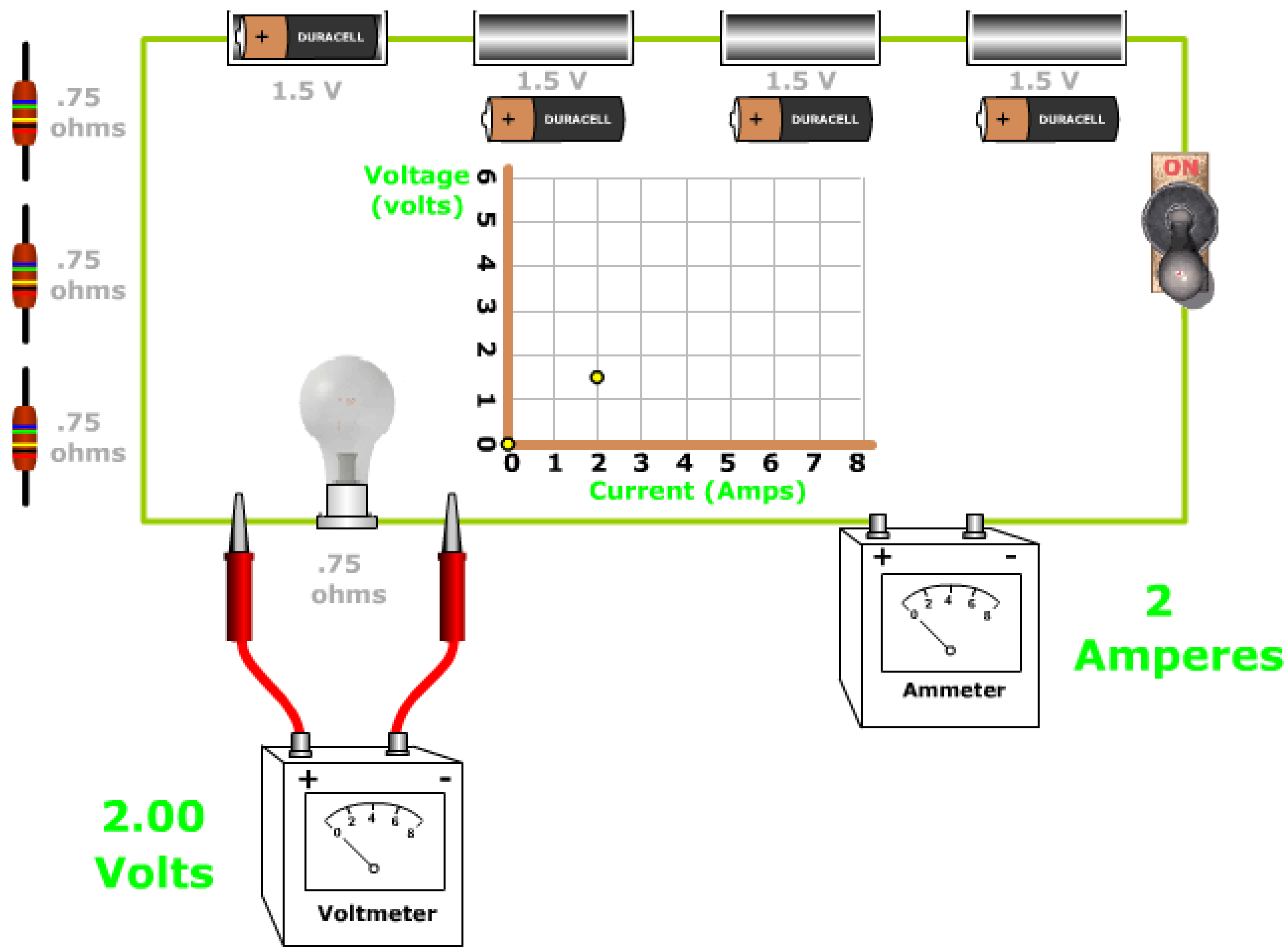


Units: V / A or Ohms,

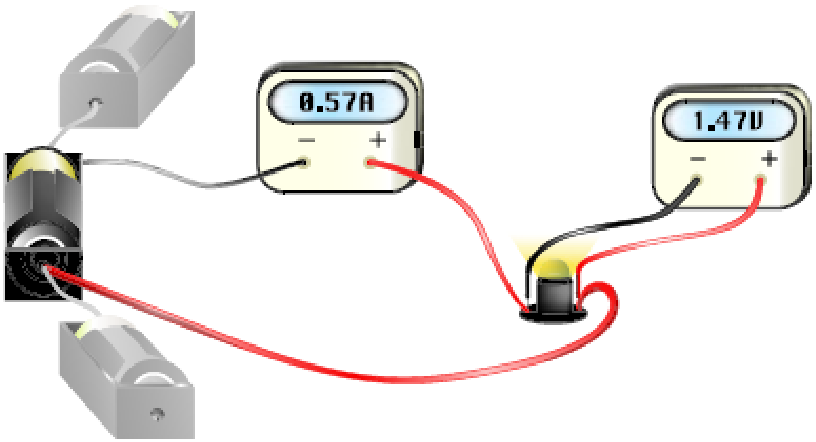
A graph of V vs. I gives a straight line for linear circuit elements (eg: most "common materials").

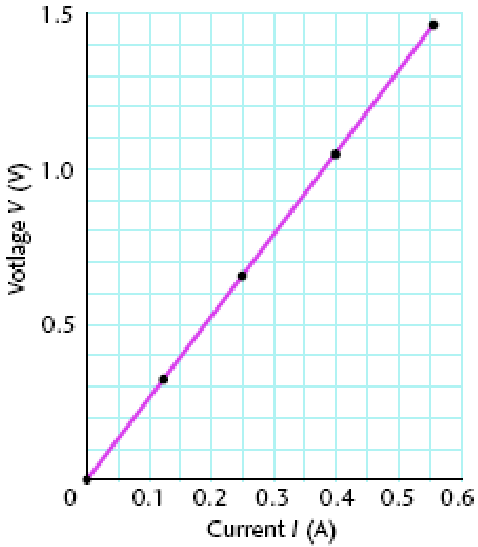


Voltage / Resistance / Current



• EXAMPLE 1 VOLTAGE VERSUS CURRENT





1. Is this a Ohmic circuit?

2. What is the resistance?

• EXAMPLE 2: FIND RESISTANCE

A small flashlight bulb draws 250 mA in a flashlight that has two 1.5 V dry cells in series. What is the resistance of the bulb filament?

Solution

$I = 250\text{ mA} = 250 \times 10^{-3}\text{ A} = 2.5 \times 10^{-1}\text{ A}$

$V = 2 \times 1.5\text{ V} = 3.0\text{ V}$ (because the cells are in series)

EXAMPLE 3 FIND VOLTAGE

If a circuit has 2A of current running through it and the total resistance in the circuit is 19Ω, then what is the total voltage?

EXAMPLE 4: FIND CURRENT

A toaster oven has a resistance of 12 ohms and is plugged into a 120-volt outlet.

How much current does it draw?

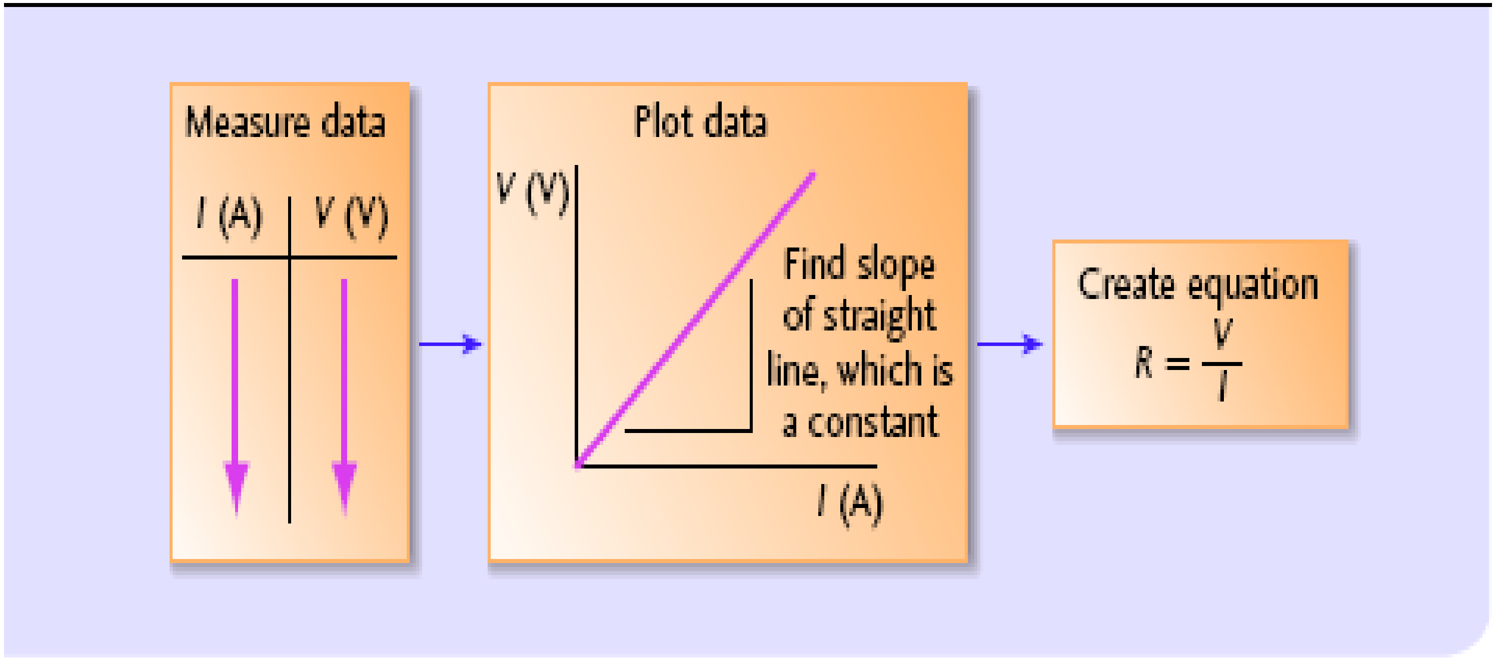
Electric toaster

EXAMPLE 5: FIND RESISTANCE

If a computer uses 5A of current and is supplied with 120V of voltage, then what is the total resistance of the computer?

Summary

Fig.14.11 Generating the Linear Equation for Ohm's Law from Data



Activity

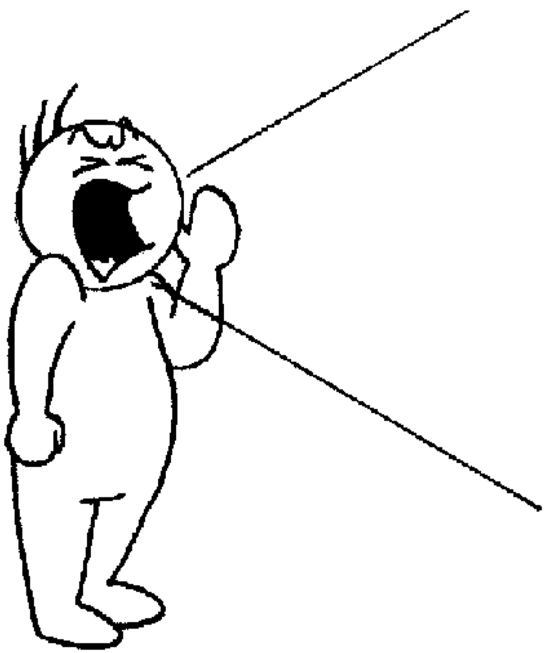
- Read Text: Sec 14.5, Pages 599-600
- Worksheet 3: Ohm's Law
-

DO Extra Practice Questions: Text In your textbook:
604 --do #1
on pp. 620-621--do #23--#25

Physics 3204

Unit 2 : Section 2 – Current Electricity

Topic 5 : Electric Energy, Electrical Power and the Cost of Electrical Energy



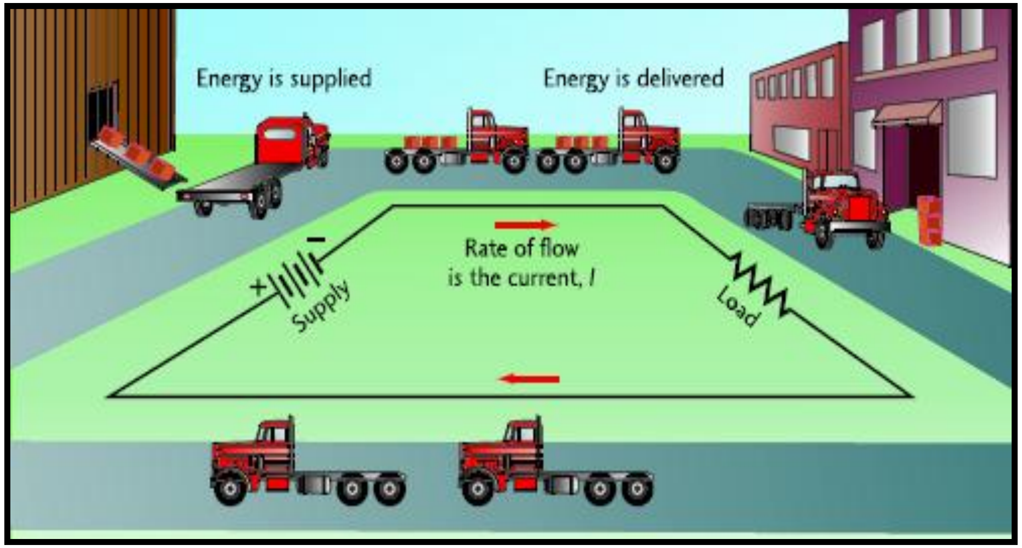
Text: Unit 14.3, 14.8, 14.9

Electrical energy

Electrical energy is useful because it is easy to transform into useful forms of energy.

Relating Current (I) and Voltage (V) to Electrical Potential Energy (E_e)

Each cell in the loading line adds a package of energy to a coulomb "truck."



Just as trucks deliver products to a store over a road, so a circuit delivers energy to a load.

The carrier of the energy is a coulomb of charge, which delivers its energy cargo in joules per coulomb (V).

Cont'

EXAMPLE 1: Electric Energy

A 3.7 V battery is used in an iphone that draws 5.7×10^{-3} A of current for about 6.0 hours before it runs out. How much energy does the battery transfer?

EXAMPLE 2: Electric Energy

A coffee maker draws about 5.0A of current for 270 s using 1.6×10^{5} J of energy. What is the potential difference across the coffee maker?

ELECTRIC ENERGY

A store requires a certain amount of goods to be delivered. The amount delivered depends on the size of the trucks' loads and their speed. The energy delivered to the load depends on the potential (energy per charge) and the rate at which the charge is delivered (the current). The energy transferred by charge flow is

$$E = VIt$$

The electrical energy produced in a circuit is dependent on the product of 3 factors:

(i) the voltage or potential difference across the circuit,
(ii) the current flowing through the circuit
(iii) the time that the circuit is being used.

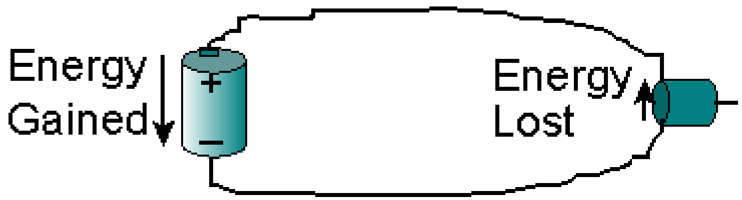
ENERGY TRANSFORMATIONS IN A CIRCUIT

- Electrons gain energy in the voltage supply (eg. in battery).
- Electrons lose energy in the load (eg. in motor).

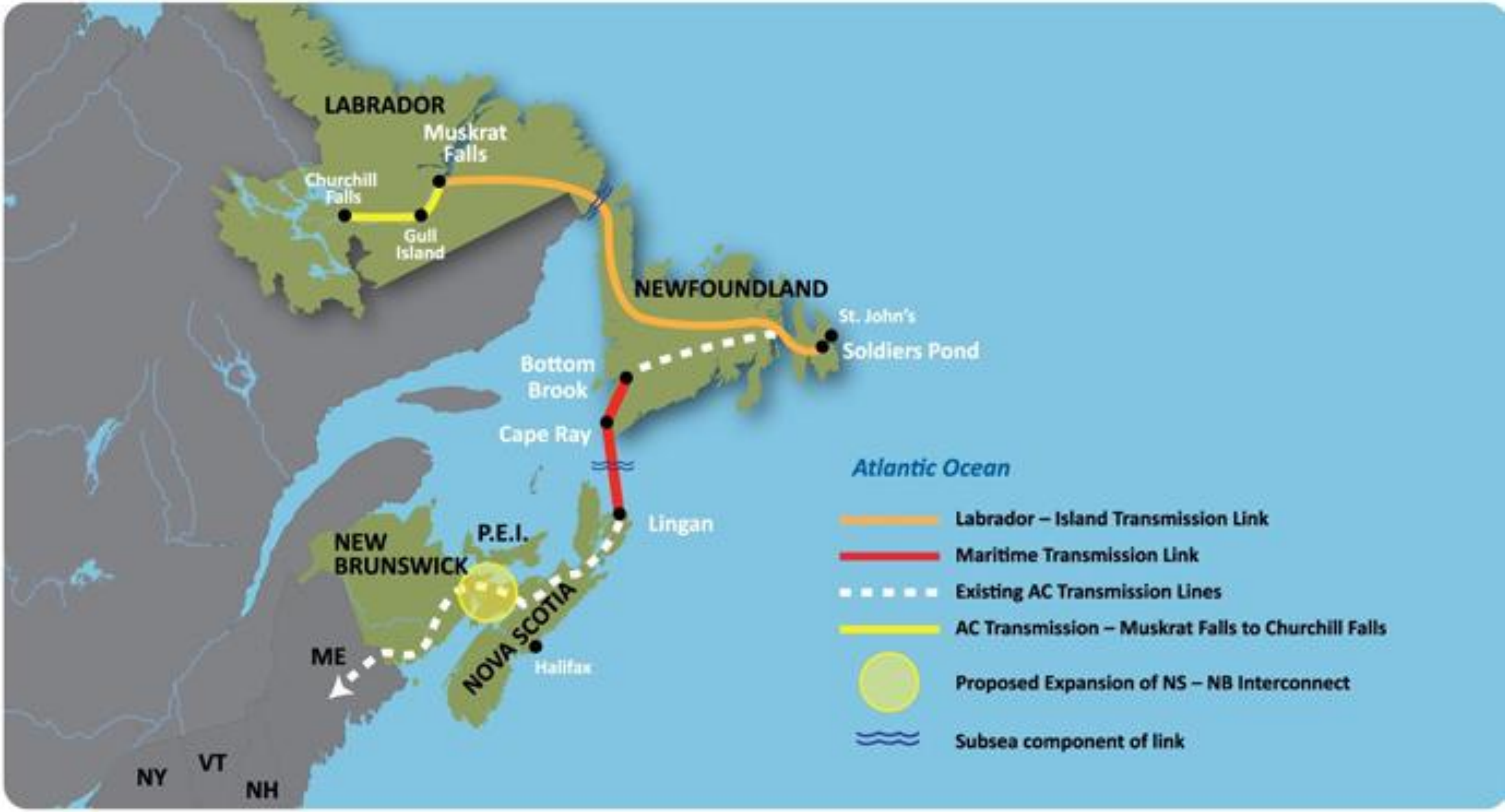
Remember the analogy of the truck delivery for stores

Conservation of Energy

Total Energy Gained = Total Energy Lost



Kirchoff's Voltage Law: the is a voltage rise in the supply equal the voltage drop in the load. (More later)


LABRADOR
Muskrat Falls
Churchill Falls
Gull Island
NEWFOUNDLAND
St. John's
Soldiers Pond
Bottom Brook
Cape Ray
Lingan
P.E.I.
NEW BRUNSWICK
NOVA SCOTIA
Halifax
ME
NY
VT
NH
Atlantic Ocean
Labrador – Island Transmission Link
Maritime Transmission Link
Existing AC Transmission Lines
AC Transmission – Muskrat Falls to Churchill Falls
Proposed Expansion of NS – NB Interconnect
Subsea component of link

Electrical Power

In an earlier physics course where things were being pushed and lifted, you learned that

Power (P) is the rate of doing work (W), or, in mathematical terms:

$$P = \frac{W}{t}.$$

While W is often used for mechanical work and mechanical energy, it is the letter E that is most often used for electrical work and electrical energy. Therefore, the expression for electrical power is

$$P = \frac{E}{t}.$$

As with mechanical energy, electrical energy is measured in joules. The units of power are therefore joule/s which is called a watt.

Remember: electrical potential (V) is the electrical energy (E) per unit charge (q) at a point. In mathematical terms:

$$V = \frac{E}{q} \quad \text{which means } E = Vq.$$

But, also by definition, current (I) is the rate of flow of charge (q). In mathematical terms we have

$$I = \frac{q}{t} \text{ which means } q = It.$$

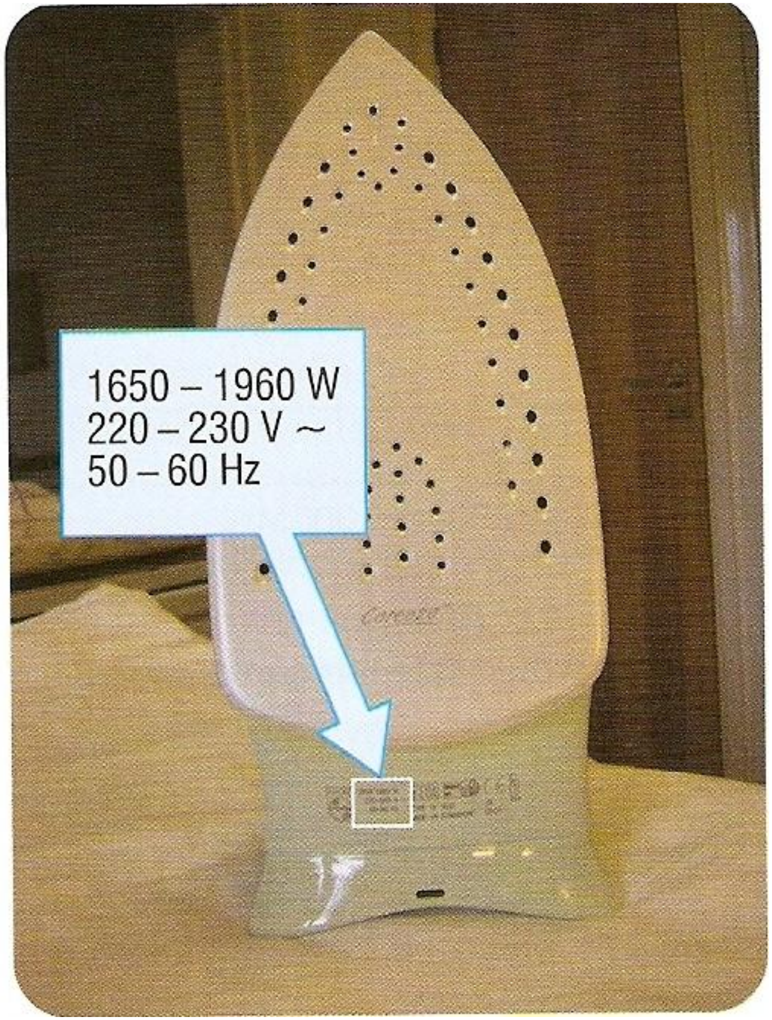
Substituting q = It into E = Vq, gives E = VIt

Finally, the expression for electrical power (P= E/t) can be written as

$$P = \frac{VIt}{t} = VI.$$

Electrical power ratings

These are always shown on an electrical device along with voltage and frequency requirements.



Power (watts) → $P = VI$ ← Current (amps)

(V: Voltage (volts))

Amps	One amp is a flow of one coulomb of charge per second
Volts	One volt is an energy of one joule per coulomb of charge

Voltage x **Current** = **Power**

$$\frac{\text{joules}}{\cancel{\text{amp}} \times \text{sec}} \times \cancel{\text{amp}} = \frac{\text{joules}}{\text{sec}}$$

$$1\ \text{Watt (W)} = 1\ \text{joule / second}$$

The expression for electrical power is more commonly written as

$$P = IV.$$

You should be able to see that Ohm's Law $V = IR$, or $I = V/R$ allows three different expressions for electrical power.

First, putting $V = IR$ into $P = IV$ gives $P = I\,(IR) = I^2R$.

Next, putting $I = V/R$ into $P = IV$ gives $P = (V/R)V = V^2/R$.

All of this gives 4 expressions for electrical power:

$P = E/t$ $P = IV$ $P = I^2R$ and $P = V^2/R$

Since all of this started with P = E/t, there are four expressions for electrical energy:

E = Pt   E = IVt   E = I^2Rt   and   E = (V^2/R)t .

Example 1 ELECTICAL POWER

What is an iPod's power in watts if it was on for 1.30 h and used 210 000 J of electrical energy?

Given:

t = 1.30 h x 3600

t = 4700s

E = 210 000 J

Example 2 ELECTICAL POWER

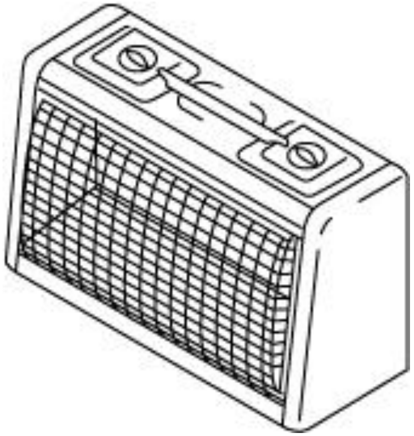
How much current is drawn by a 3.0 kW electric heater on a 220 V line?

Solution

$P = 3.0\ kW = 3.0 \times 10^3\ W$ (*kW is read as kilowatts*)

$V = 220\ V$

$I = ?$



Example 3 ELECTICAL POWER

Calculate the power rating of a stereo amplifier (not the speaker power) if it is plugged into a standard 120 V outlet and has a resistance of 120 Ω

Example 4 ELECTICAL POWER

How much power is dissipated in a circuit with a 15 Ω resistor that draws a current of 10.0A?

Example 5 ELECTICAL POWER

What is the resistance of a 1500 W electric kettle element that operates on a 115 V line?

Solution

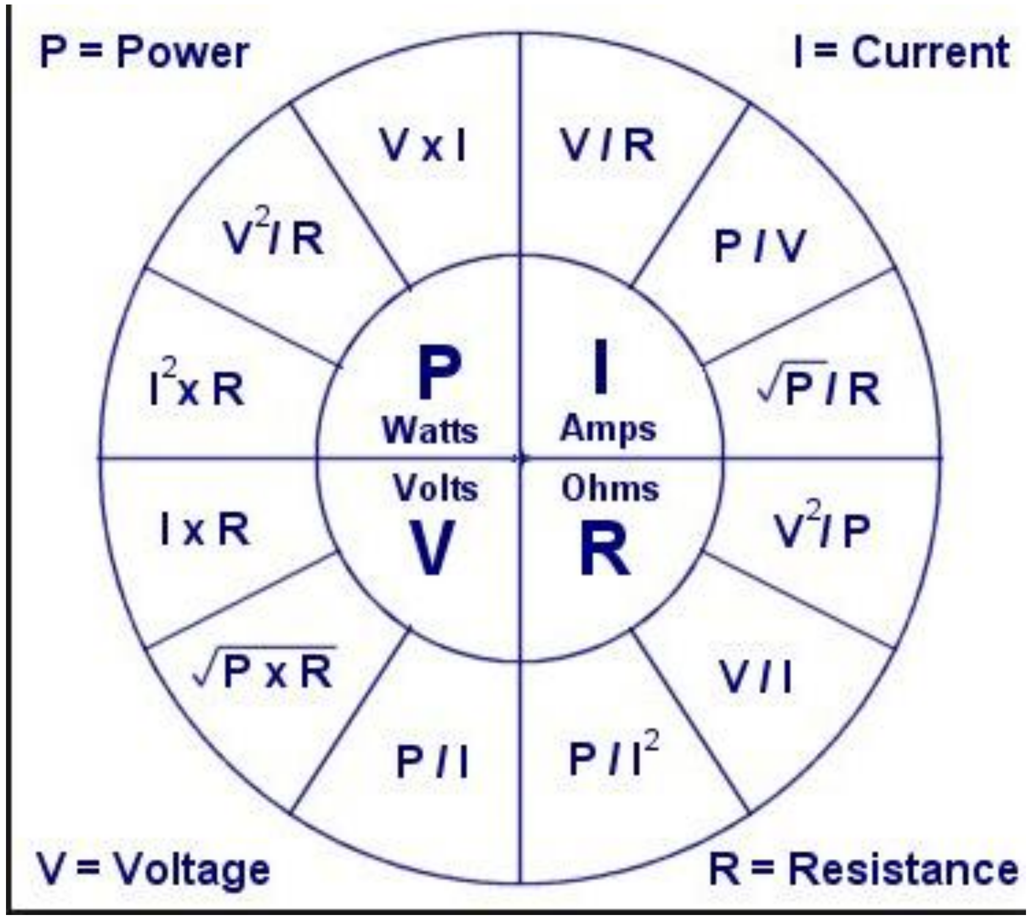
Givens and unknown

P = 1500 W

V = 115 V

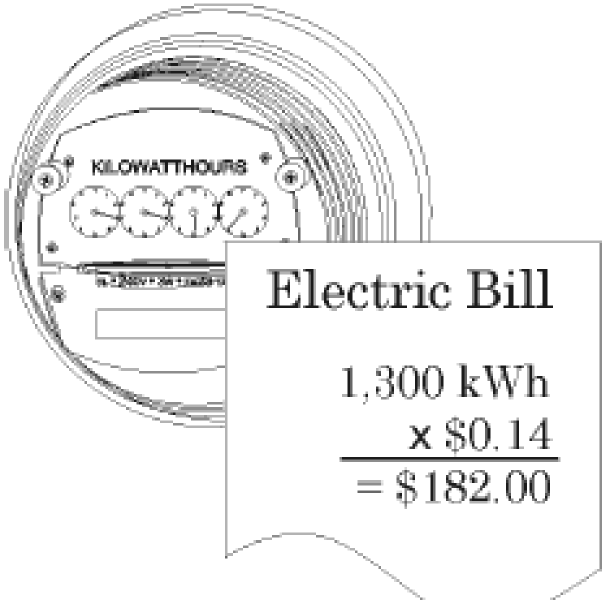
R = ?

SUMMARY


P = Power
I = Current
V = Voltage
R = Resistance
P
Watts
I
Amps
Volts
V
Ohms
R
V x I
V / R
V^2 / R
P / V
I^2 x R
$\sqrt{P / R}$
I x R
V^2 / P
$\sqrt{P \times R}$
V / I
P / I
P / I^2

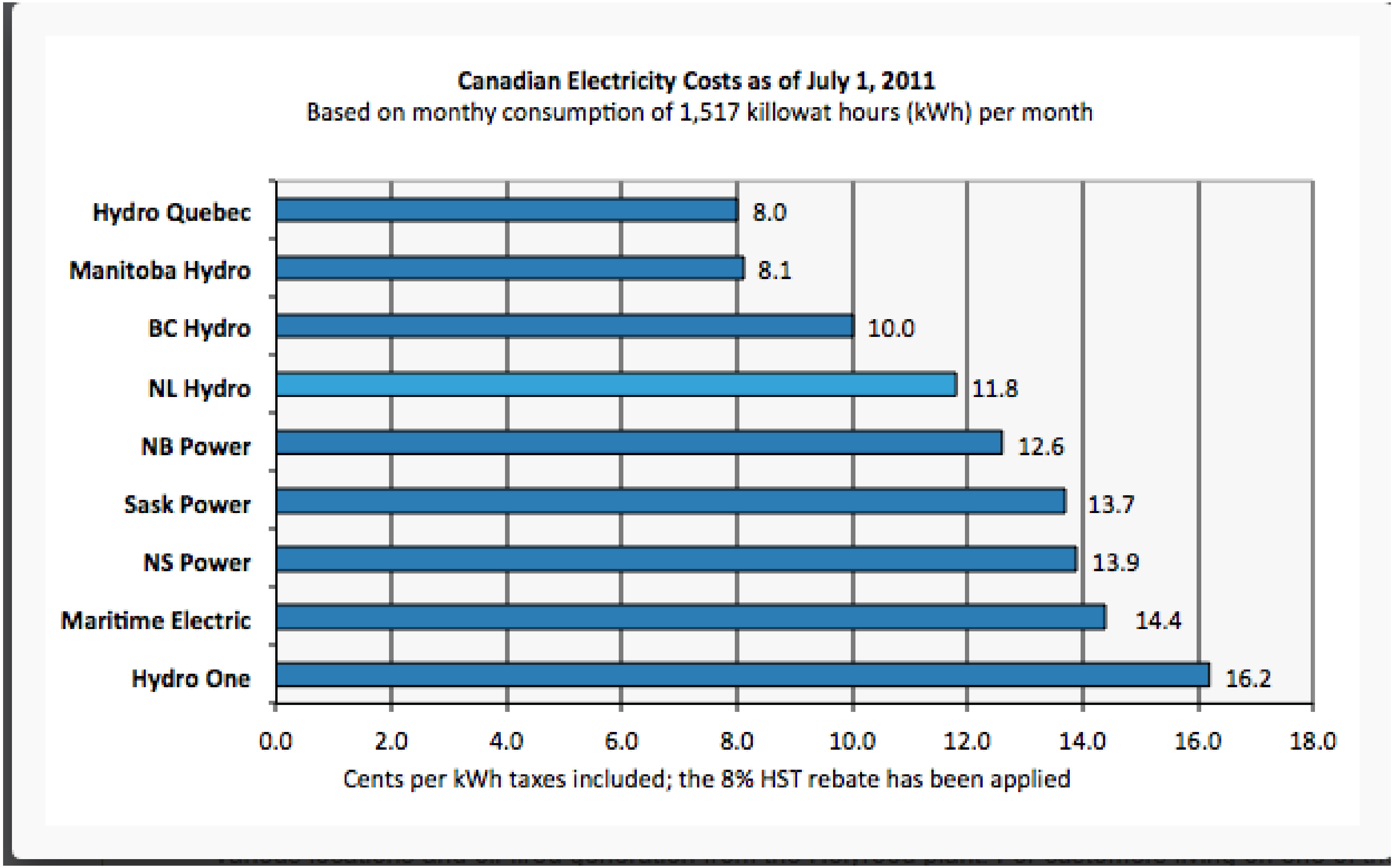
The Cost of Electricity

- Electric companies charge for the number of kilowatt-hours used during a set period of time, often a month.



An electricity meter is used to measure the usage of electrical energy.

The meter measures in **kilowatt-hours (kWh)**


Canadian Electricity Costs as of July 1, 2011
Based on monthy consumption of 1,517 killowat hours (kWh) per month
Hydro Quebec
Manitoba Hydro
BC Hydro
NL Hydro
NB Power
Sask Power
NS Power
Maritime Electric
Hydro One
8.0
8.1
10.0
11.8
12.6
13.7
13.9
14.4
16.2
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Cents per kWh taxes included; the 8% HST rebate has been applied

One can use the formula below to calculate electric cost:

Total Cost = P(in kiloWatts) x Time (hours) x Rate (Cost/ KiloWatt• hour)

Example 1 ELECTICAL COST

How much electrical energy (E) is consumed by a 100 W electric light bulb in one year if it is turned on for 6 hours a day? (Assuming it lasts that long!!)

Example 2 ELECTICAL COST

Your bedside radio clock draws 42 mA of current on a 120 V line. At a cost rate of 8.1 ¢ /kW-hr, how much does it contribute to your family's annual electricity bill?

Solution

Activity

- Read Text: Sec 14.3 , 14.8 – 14.9, Pages 594-596 and 613-617

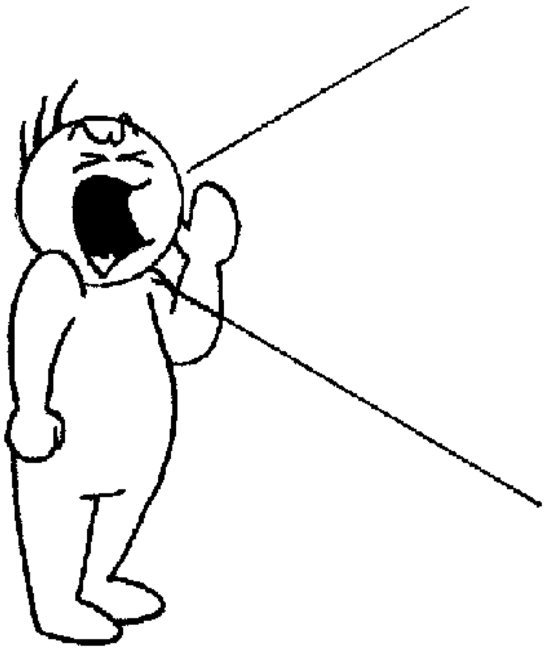
Worksheet 5: Electric Energy, Electrical Power and the Cost of Electrical Energy

- DO Extra Practice Questions: Text In your textbook:
- on p. 597--do #2--#4
- on. p. 615--do #1-- #4
- on. p. 621--do #11-- #22
- on pp. 623-624--do #36--#38

Physics 3204

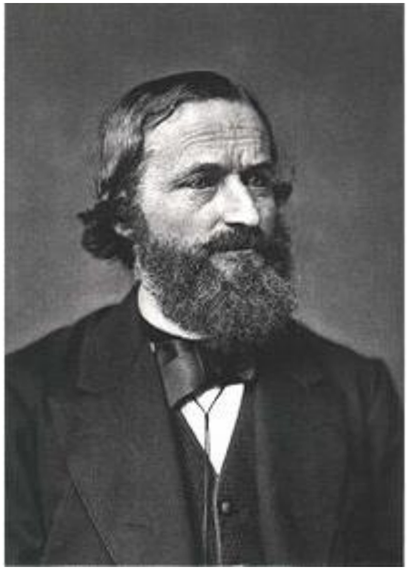
Unit 2 : Section 2 – Current Electricity

Topic 6 : Studying Series Circuits



Text: Unit 14.6

Gustav Robert Kirchhoff (1824 – 1887) was a German physicist who contributed to the fundamental understanding of electrical circuits



Kirchhoff's circuit laws dealt with two key components of circuits:

1) CURRENT

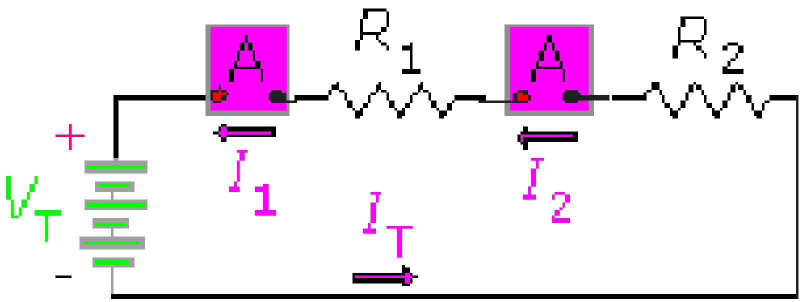
2) POTENTIAL DIFFERENCE (VOLTAGE)

These laws allowed him to calculate the voltages and currents in multiple loop circuits.

Part 1: Current in a Series Circuit

Kirchoff's current rule for series circuit:

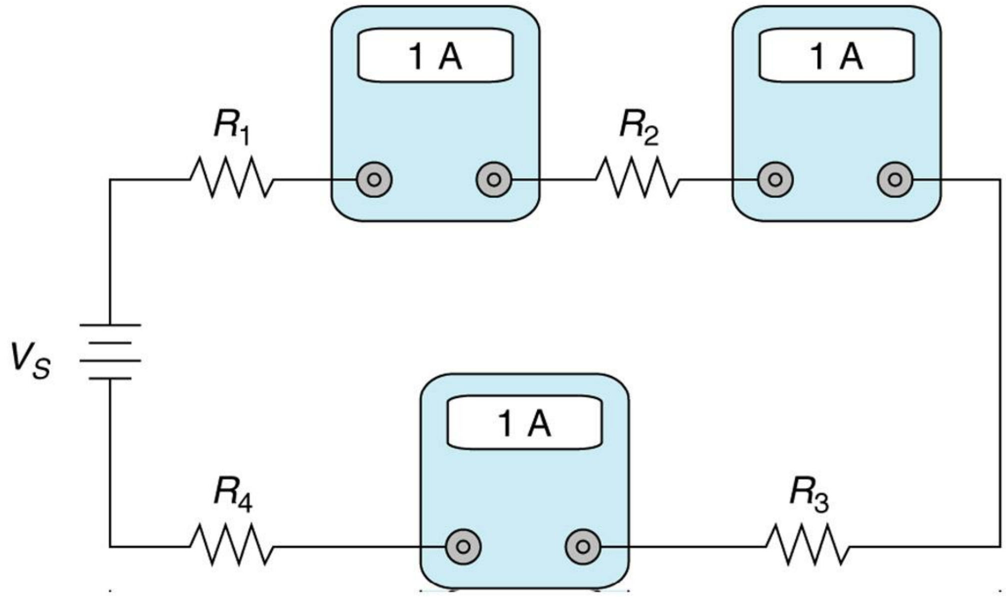
In a series circuit, the current is the same everywhere in the circuit. We write $I_1 = I_2 = I_{tot}$ for a series circuit.



Series (a single path)

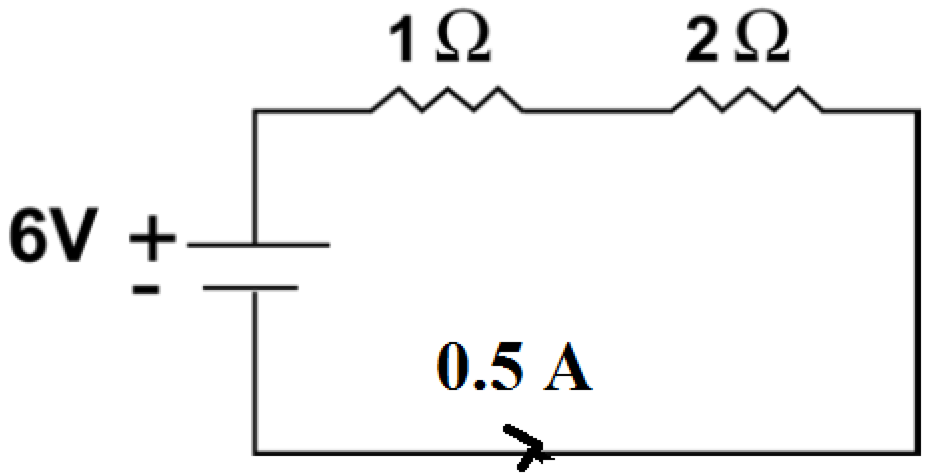
Same current passes through every element of a series circuit

- Current Characteristics – the current at any point in a series circuit must equal the current at every other point in the circuit



Example 1: CURRENT

A current of 0.5 A leaves the negative terminal of the battery.



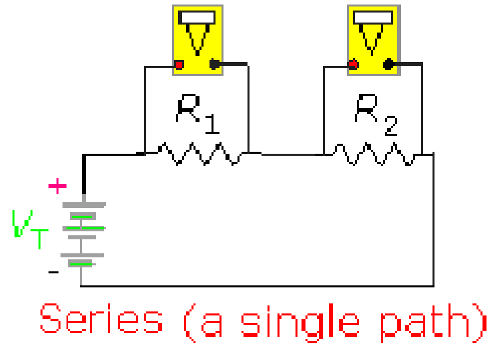
What amount of current:

(A) Passes through the 2 Ω resistor?
(B) Passes through the 2 Ω resistor?
(C) Returns to the battery?

Part 2: Voltage in a Series

Kirchoff's voltage rule for a series circuit.

When any closed circuit is transversed, the sum of the potential increase (V) must equal the sum of the potential decreases (V)

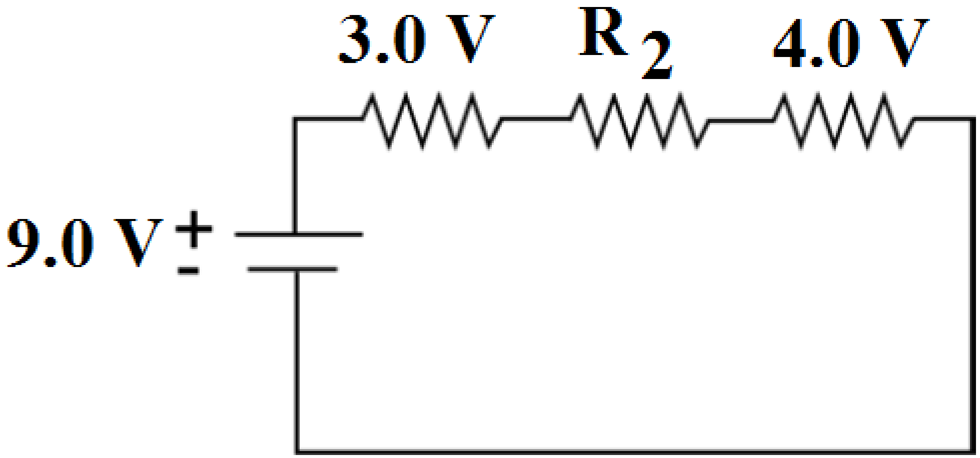


In the circuit above the sum of the voltage drops across R_1 and R_2 is the same as the voltage rise across the terminals of the power supply . We write:

$$V_T = V_1 + V_2$$

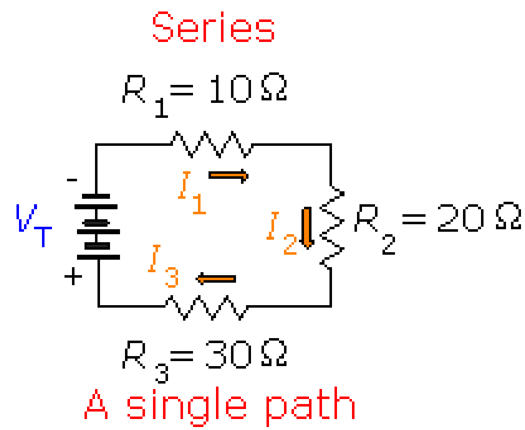
Example 2: VOLTAGE

What is the voltage of R_2 ?



PART 3 RESISTANCE IN A SERIES CIRCUITS

FOR A SERIES CIRCUIT



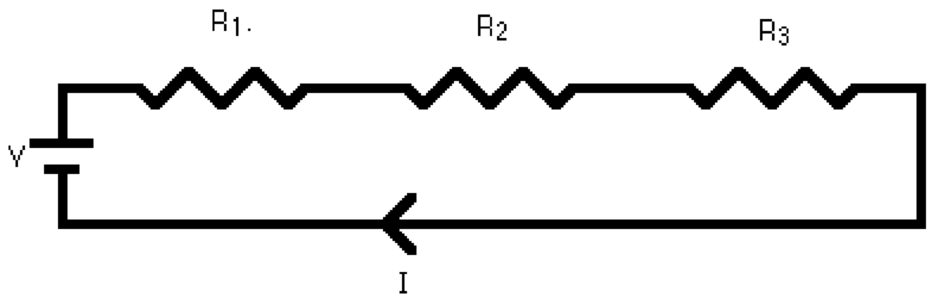
Total resistance (equivalent resistance) in a series circuit is equal to the sum of the original resistance .

Or

$$R_T = R_1 + R_2 + R_3 + \dots\dots\dots$$

Example 4: RESISTANCE

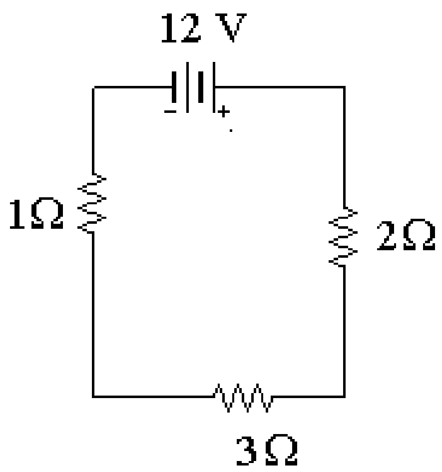
What is the equivalent resistance for the circuit below where $R_1 = 8\Omega$, $R_2 = 4\Omega$ and $R_3 = 4\Omega$:



Example 5: RESISTANCE

In order for a certain series circuit to work properly a resistor of 1.2Ω k is required. In your junk drawer you find two resistors with values of 350 Ω and 450Ω respectively. What is the size of a third resistor that would provide the required 1.2 kΩ?

Example 6: Putting It Together



A series circuit is shown to the left.

a) What is the total resistance?

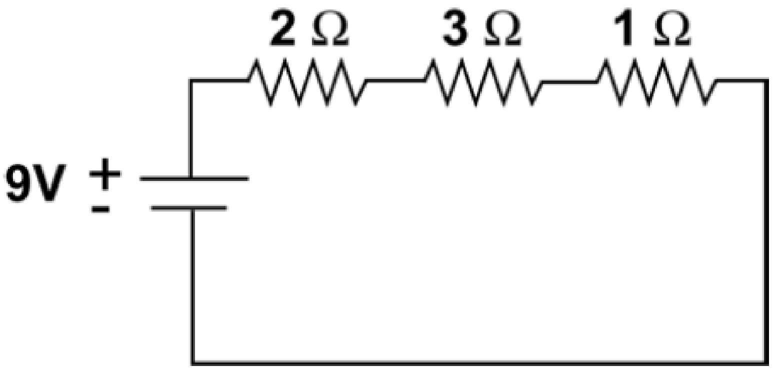
b) What is the total current?

c) What is the current across EACH resistor?

d) What is the voltage drop across each resistor?(Apply Ohm's law to each resistor separately)

Notice that the individual VOLTAGE DROPS add up to the TOTAL!!

Example 7: Putting It Together



a. What is the total resistance of the circuit?

b. What is the current in the circuit?

c. What is the voltage drop across each resistor?

d. What is the sum of the voltage drops across the three resistors? What do you notice about this sum?

Activity

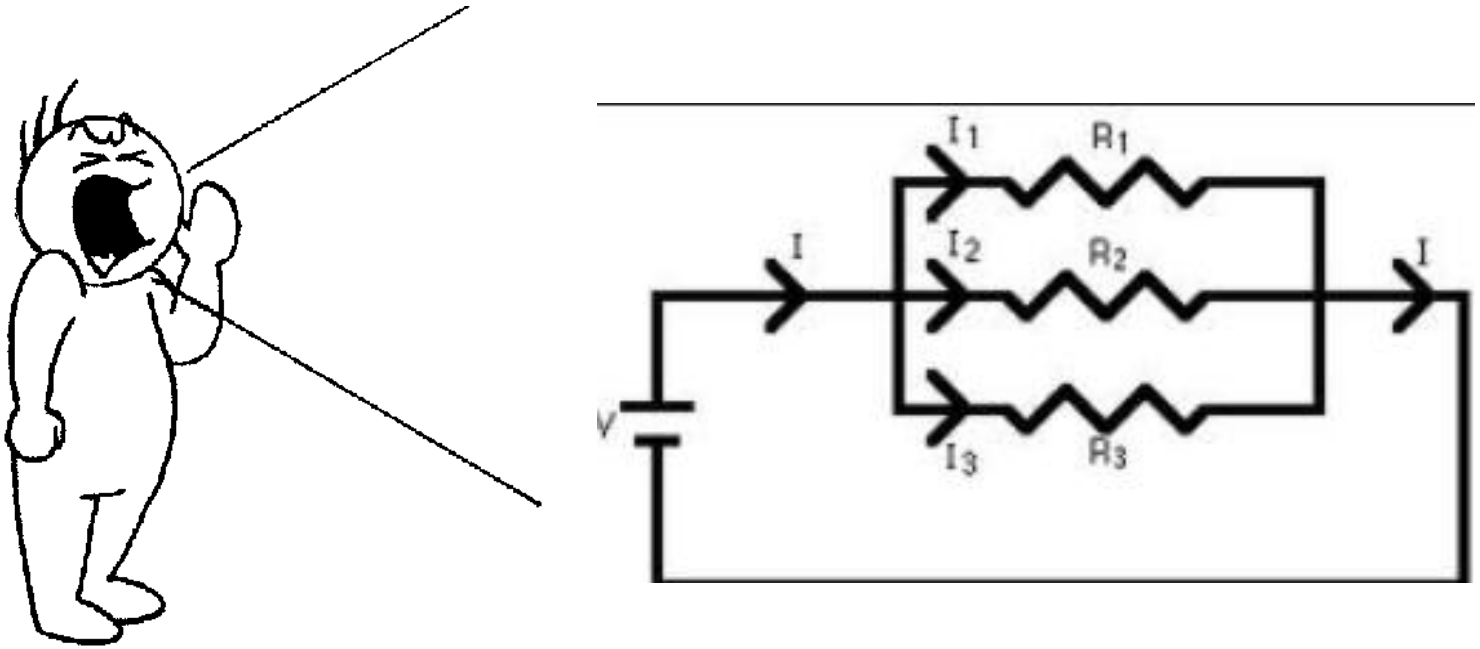
- Read Text: Sec 14.5, Pages 605-607
- Worksheet 6: Studying Series Circuits

- DO Extra Practice Questions: In your textbook:

Physics 3204

Unit 2 : Section 2 – Current Electricity

Topic 7 : Studying Parallel Circuits



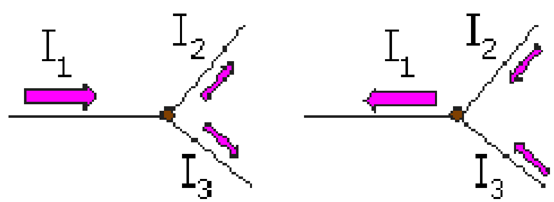
Text: Unit 14.6

Part 1: Current in a Parallel Circuit:

Kirchoff's current rule for a parallel circuit :

states that the current going into a junction point equals the current leaving the junction point.

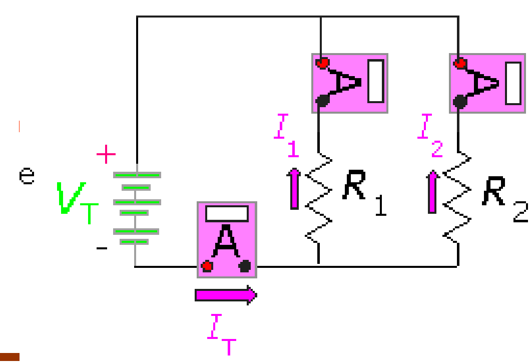
$$I_1 = I_2 + I_3$$



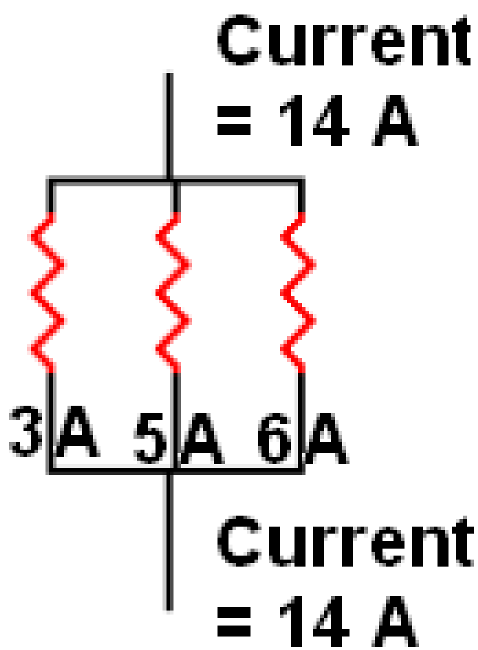
Kirchoff's current rule

The mathematical expression for Kirchoff's current rule in parallel branches is

$$I_T = I_1 + I_2 + \ldots$$



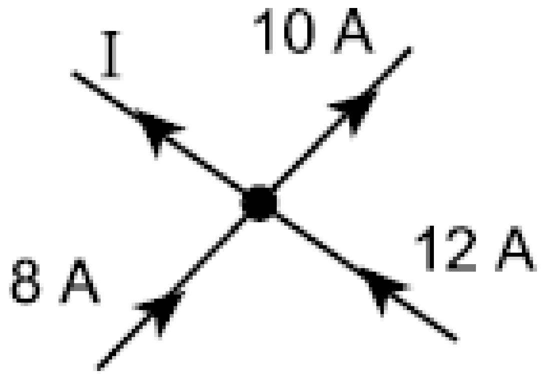
The total current is equal to the *sum of the currents in the branches.*



$$I_{total} = I_1 + I_2 + I_3 + \ldots$$

Example 1: CURRENT

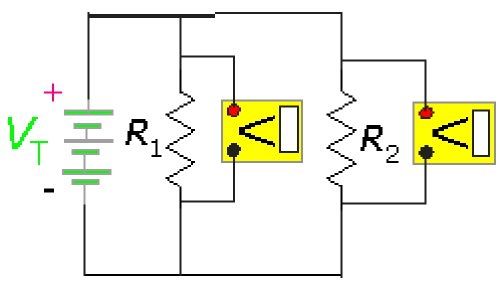
What is the value of I in the circuit junction below?



Part 2: Voltage in a Parallel

Kirchoff's voltage rule:

for every loop in a parallel circuit the sum of the voltages rises equals the sum of the voltage drops.

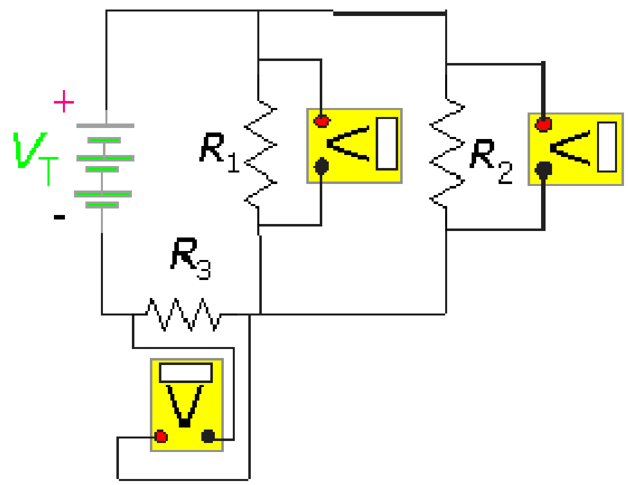


- $V_T = V_1 = V_2 = ...$

The voltage rise, V_T as is equal to the voltage drop across the branches.

For the circuit to the left it is OK to say that

$V_1 = V_2$. (they are parallel)

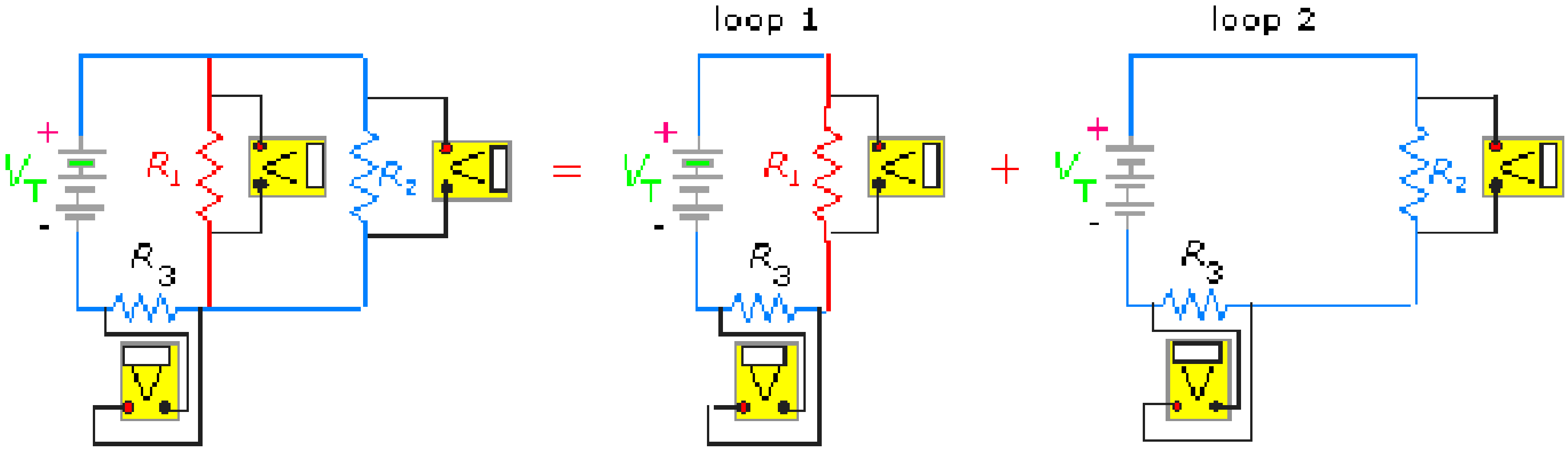


But it would be a big mistake to say that

$V_T = V_1 = V_2$.

This is because there is an extra voltage drop across R_3 which is connected in series.

Below the original circuit is split into its two distinct



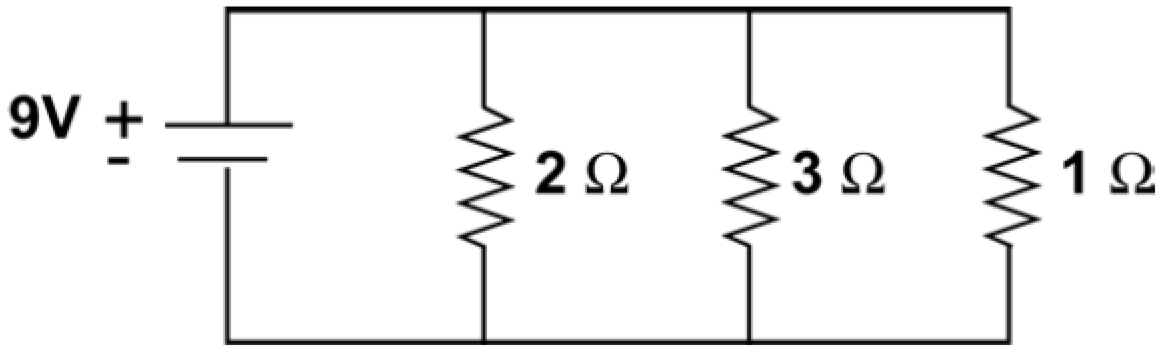
You should be able to see that it is OK to say

$$V_T = V_1 + V_3 \quad \text{(loop 1)}$$

or

$$V_T = V_2 + V_3 \quad \text{(loop 2)} .$$

Example 2: VOLTAGE



What is the voltage across:

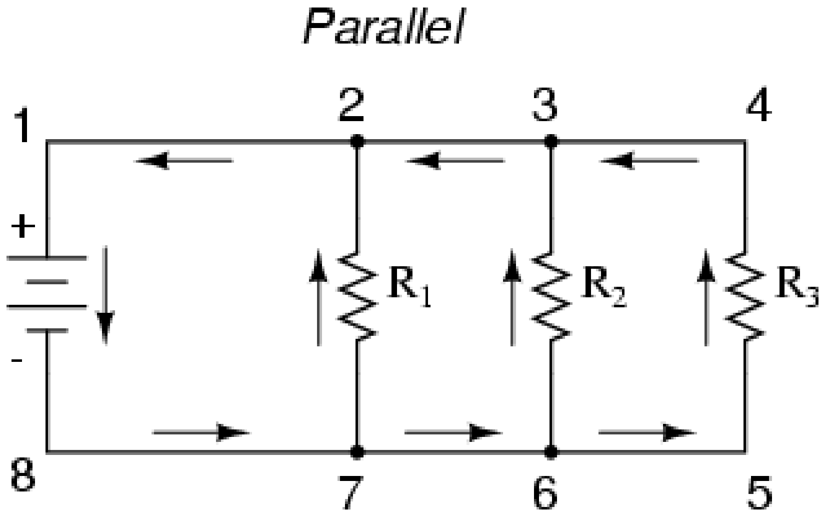
(A) The 2Ω resistor ?

(B) The 3Ω resistor

(C) The 1Ω resistor

PART 3: RESISTANCE IN A PARALELL CIRCUITS

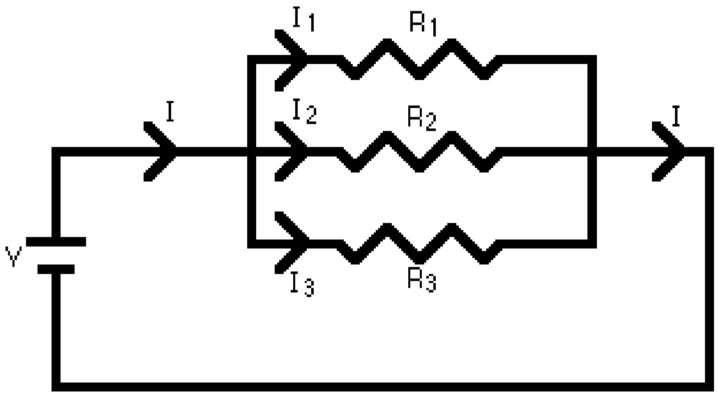
- Total resistance (equivalent resistance) in a parallel circuit is found by using the formula below:



$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots\ldots\ldots\ldots$$

Example 3: RESISTANCE

Find the total resistance for the circuit below where $R_1 = 8\Omega$, $R_2 = 8\Omega$ and $R_3 = 4\Omega$:



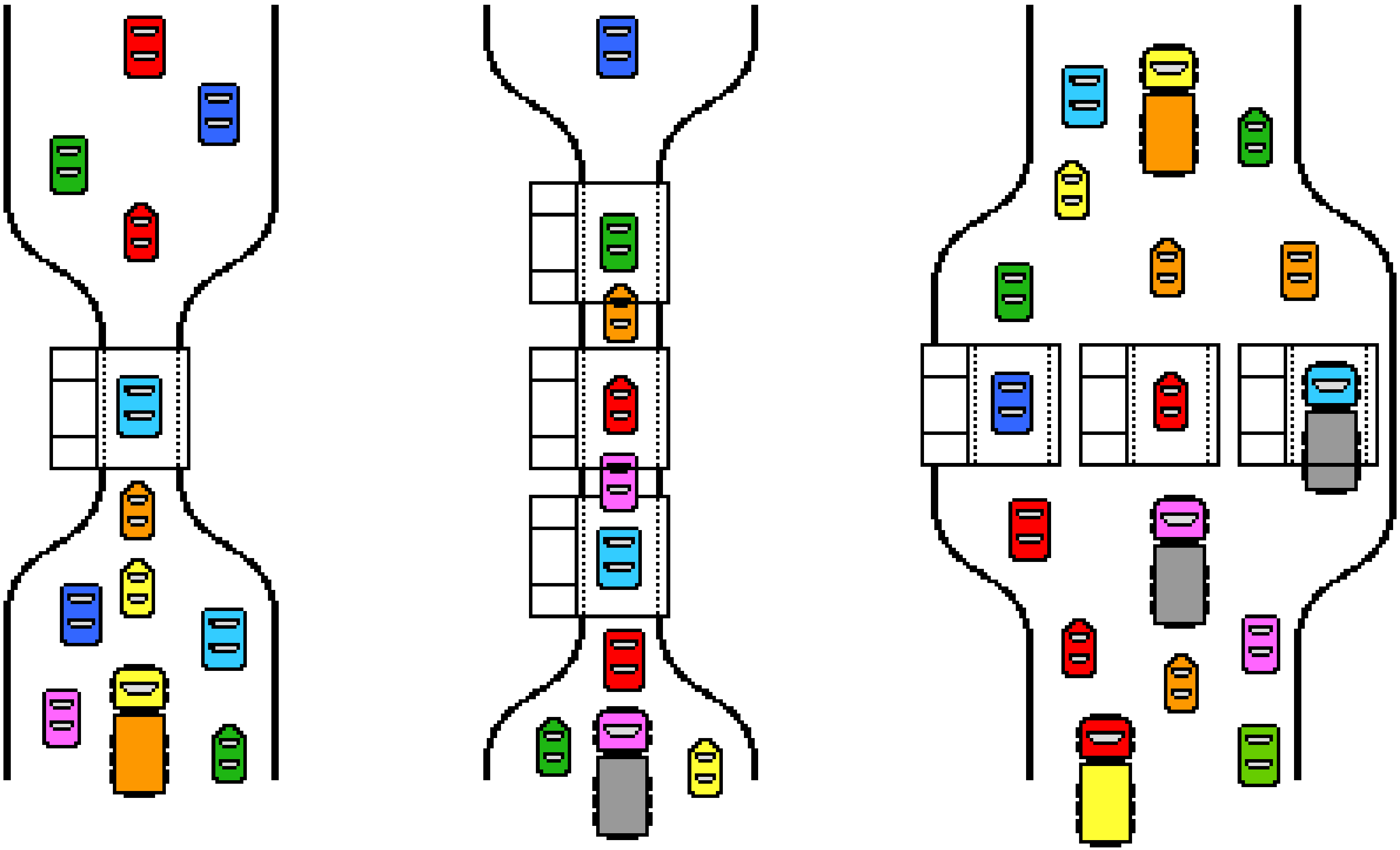
If a 10 V battery is placed in the circuit, What is the total current in the circuit?

Example 3: RESISTANCE

Find the total resistance when a 10Ω , 20 Ω , and 30 Ω resistor are connected in parallel.

You should notice that the single resistor that is equivalent to a number of resistors connected in parallel is always less than even the smallest parallel resistor.

Influencing the Flow Rate on a Tollway



A Single Resistor

Three Resistors Placed in Series

Three Resistors Placed in Parallel

SHORT CUT !

There's a short cut that's worth noticing when all the parallel resistors are identical. For example, if

$R_1 = R_2 = R_3 = 24\ \Omega$,

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

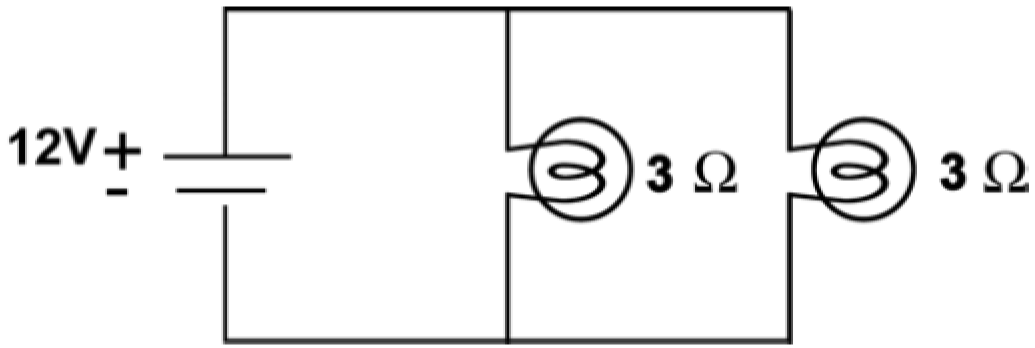
$$\frac{1}{R_T} = \frac{1}{24\,\Omega} + \frac{1}{24\,\Omega} + \frac{1}{24\,\Omega} = \frac{3}{24\,\Omega}$$

$$\therefore R_T = \frac{24\,\Omega}{3} = 8\,\Omega$$

The short cut is to divide the value of one resistor by the number of resistors. Another example: what is the total resistance of 5 identical resistors of 100 if they are connected in parallel?

Answer: RT = 100 /5 = 20 .

Example 4: Putting It Together



a. What is the voltage across each bulb?

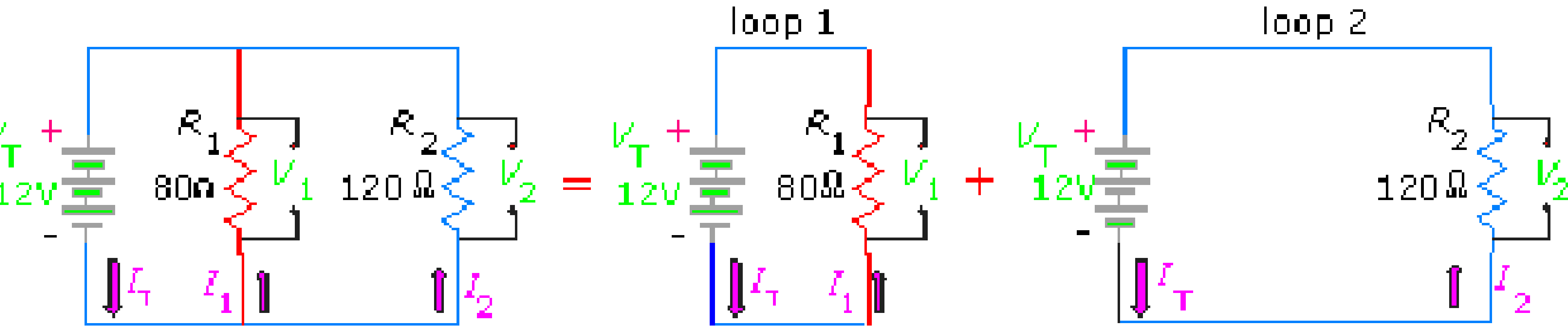
b. What is the current in each branch?

c. What is the total current provided by the battery?

d. Use the total current and the total voltage to calculate the total resistance of the circuit.

Example 5: Putting It Together

Apply Kirchoff's rules to solve for all the unknown parameters in the circuit



Video

- Physics 3204
- Kirchoff's Law

Activity

- Read Text: Sec 14.5, Pages 605-607
- Worksheet 7: Studying Paralell Circuits

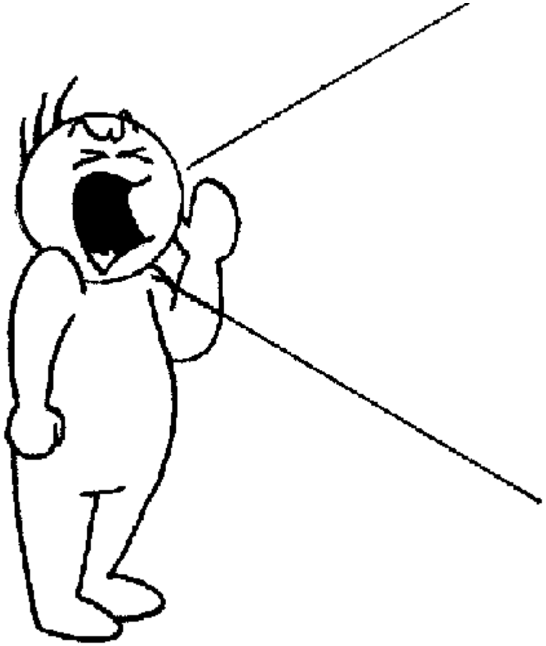
- DO Extra Practice Questions: In your textbook:

DO Extra Practice Questions:
Text textbook page 622 #29- 34

Physics 3204

Unit 2 : Section 2 – Current Electricity

Topic 8 : Circuit Analysis

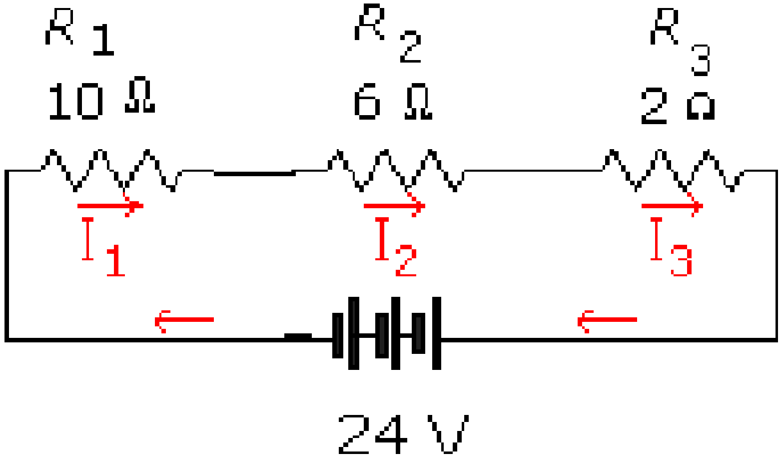


Text: Unit 14.7

Now we will use Ohm's law and Kirchoff's Rules to determine the value of unknown circuit parameters.

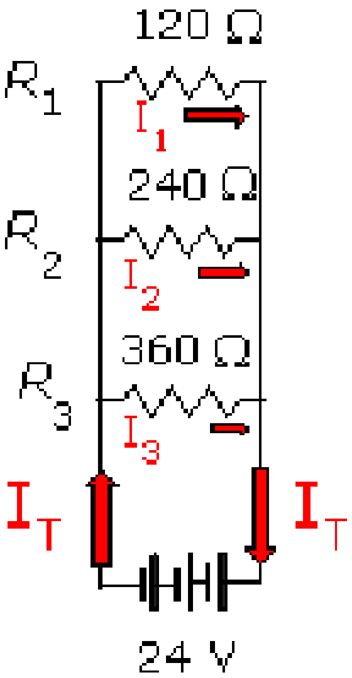
Example 1

Three resistors of 10.0 Ω , 6.0Ω and 2.0 Ω are connected in series across a 24 V battery. Find the current through and the voltage drop across each resistor.



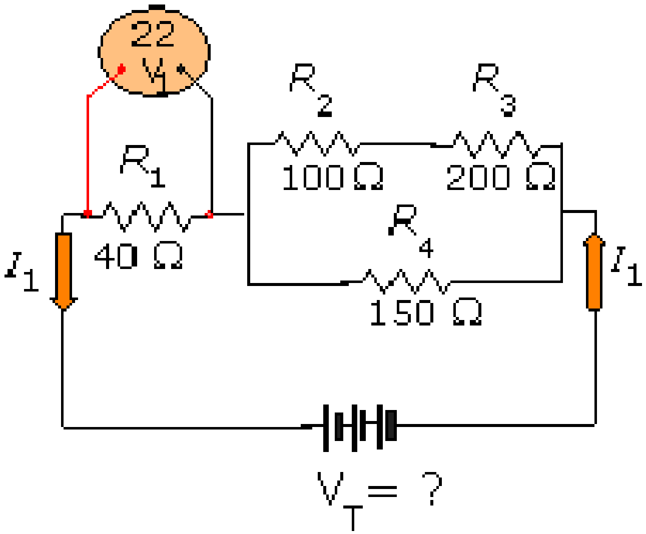
Example 2

A parallel combination of 120 Ω, 240 Ω, and 360 Ω is connected across a 24.0 V power supply. Find the total current supplied by the battery.



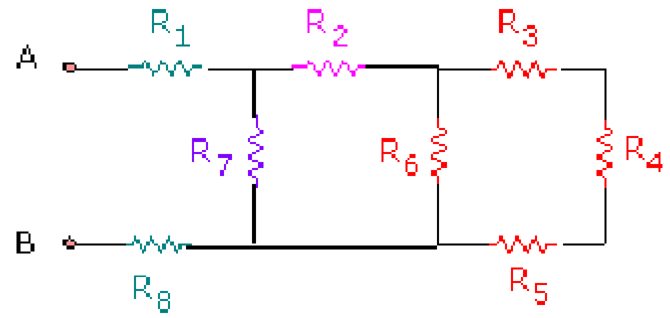
Example 3:

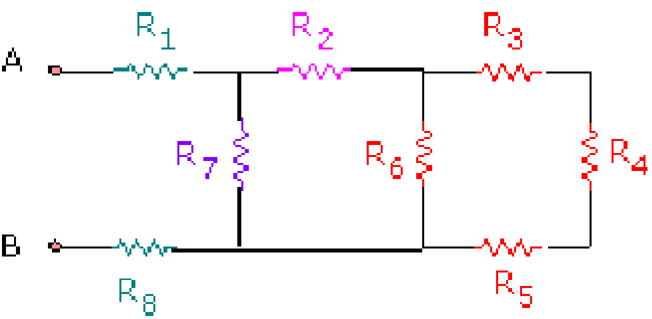
The voltmeter in the circuit to the right measures a potential difference of 22 V across the 40 Ω resistor. What is the voltage of the battery?



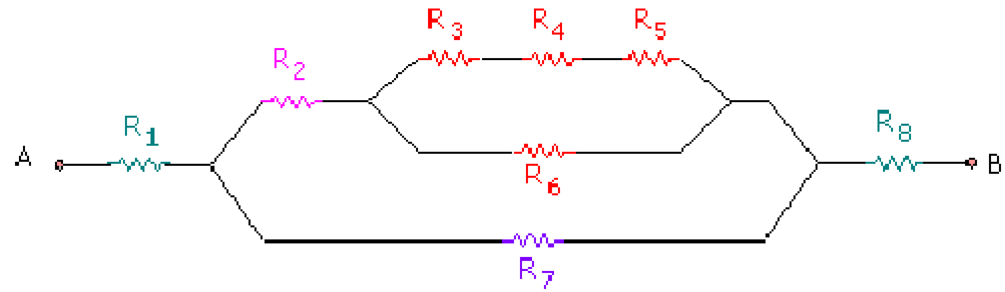
Example 4:

Find the total resistance between points A and B in the drawing to the right. Each resistor has a value of 10 Ω .



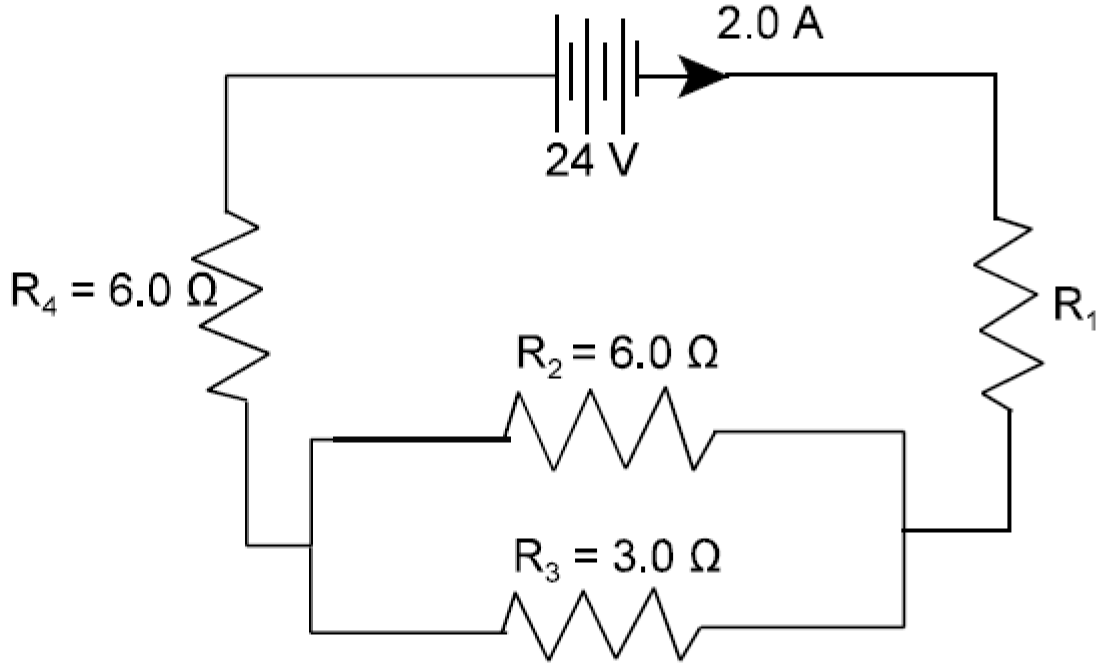

A
B
R1
R2
R3
R7
R6
R4
R8
R5

=>


R3
R4
R5
R2
R1
A
R6
R8
B
R7

Example 5:

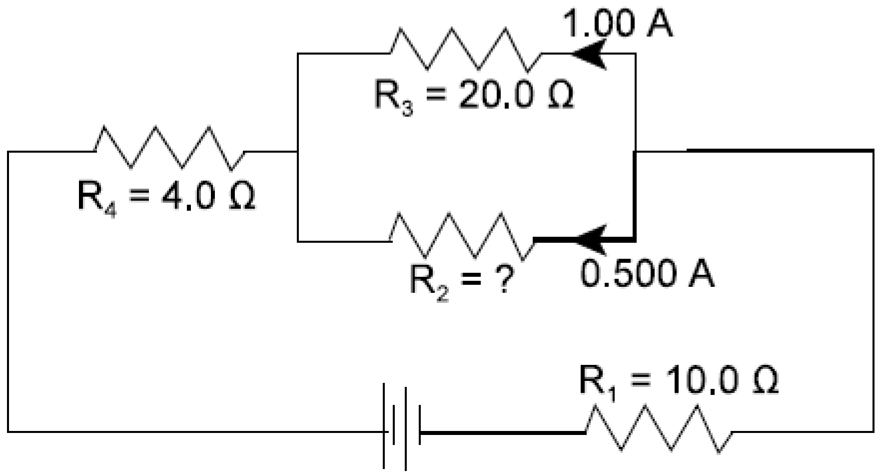
In the circuit shown, calculate: JUNE 2009



i) the voltage for R_4.
ii) the value of R_1.
iii) the power dissipated in R_3.

Example 6:

For the circuit below calculate: AUGUST 2008



i) the value of R_2.
ii) the power dissipated in R_4.
iii) the voltage across the source.
iv) Explain how the addition of another resistor in parallel will change the total resistance of the circuit.

Activity

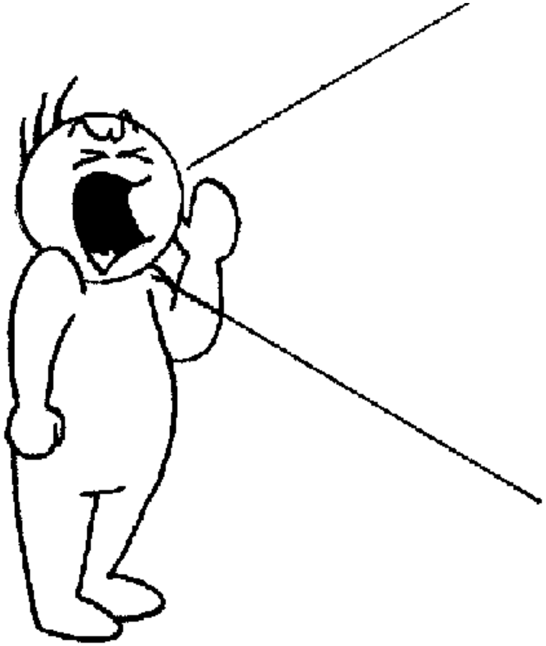
- Read Text: Sec 14.7, Pages 610 -613
- Worksheet: 9 Analyzing Circuits

- DO Extra Practice Questions:
- In your textbook:
- on p. 613--do #1, #2
- on p. 622-623--do #35 (a) - #35 (f) You may wish to carry some of these forward into the next lesson.

Physics 3204

Unit 2 : Section 2 – Current Electricity

Topic 9 : Electricity and safety in the home



Fuse **- a device used in electrical systems to protect against *excessive current*.**

Fuses are always connected in series with the component(s) to be protected, so that when the fuse *blows* (opens) it will *open the entire circuit and stop current through the component(s).*

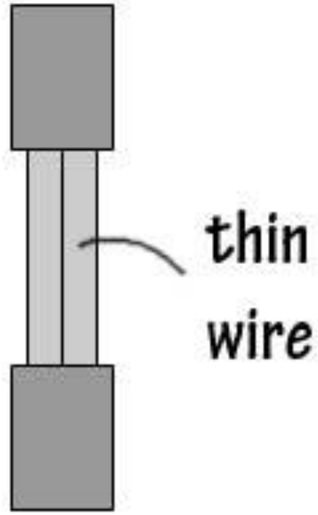
The fuse opens the circuit my melting a thin metal filament inside the casing.

Once a fuse is blown, it must be *replaced*.


A

NEVER replace a fuse with a fuse rated for higher current than the recommended fuse.

Glass Cartridge Fuses



Plug Fuses

Automotive Fuses

Automotive fuses are a class of fuses used to protect the wiring and electrical equipment for vehicles.

They are generally rated for circuits no higher than 24 volts [1 direct current, but some types are rated for 42 volt electrica systems.

The color of the fuse is an indication of its rating.

A ***circuit breaker*** automatically shuts off the power to the circuit in the event of a dangerous electrical overload or short circuit.

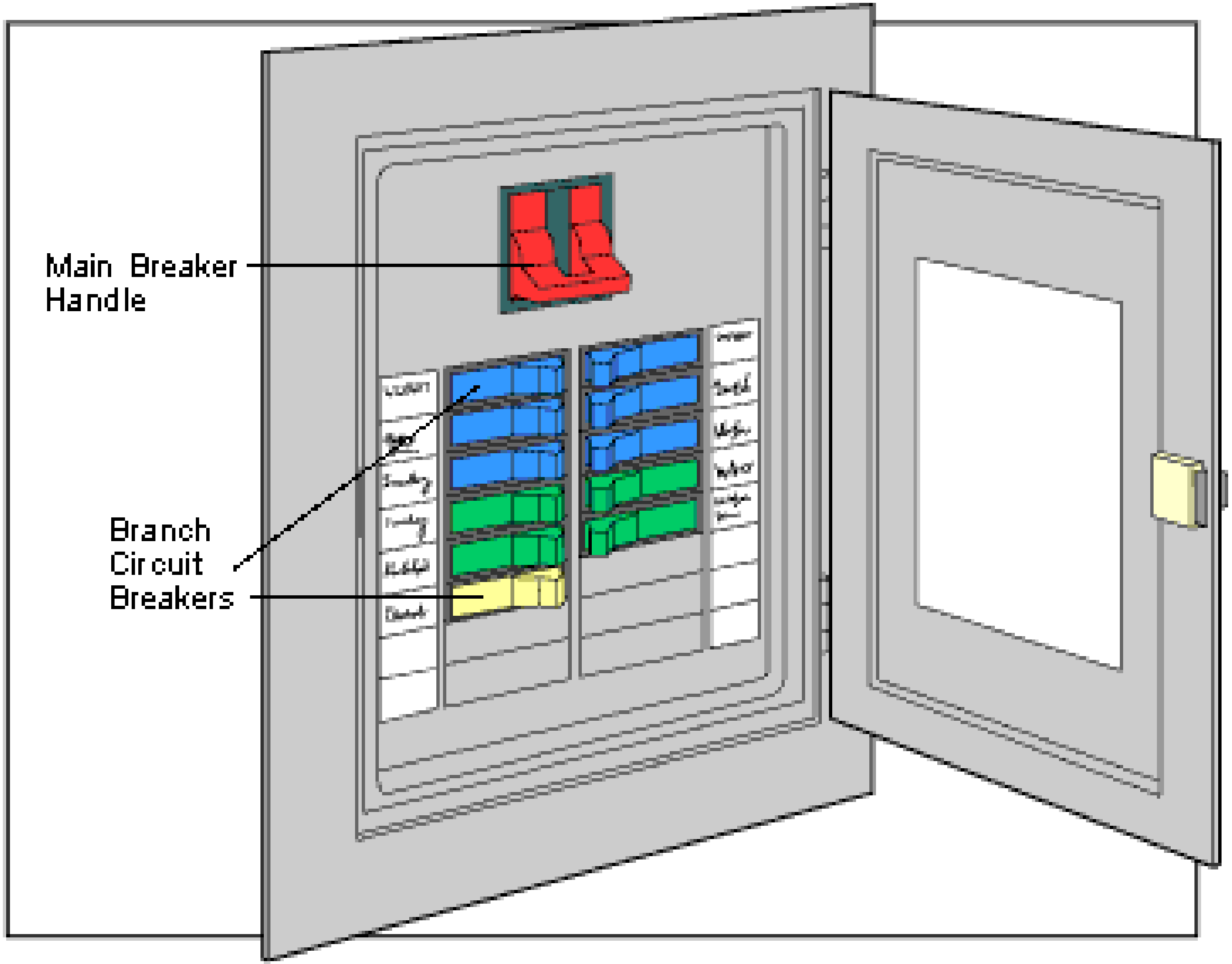
A circuit breaker can also be used manually to disconnect a circuit from incoming power so that you can repair or upgrade your receptacles, outlets, and fixtures.

Circuit breakers are much easier to fix than fuses.

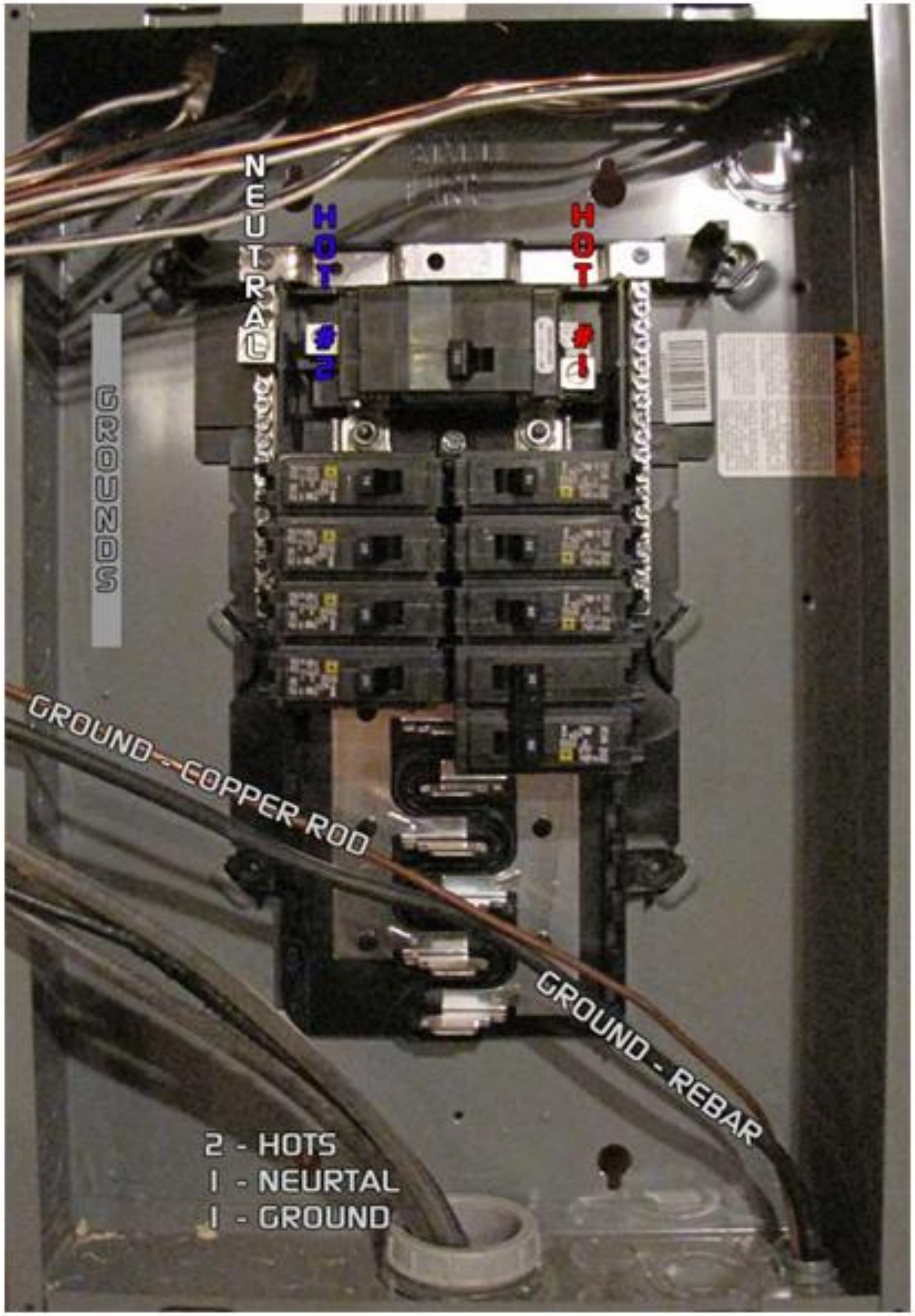
When the power to an area shuts down, the homeowner can look in the electrical panel and see which breaker has tripped to the "off" position.

The breaker can then be *reset* to the "on" position and power will resume again.

If the breaker continues to trip after you flip it, you may have a faulty breaker, a wiring problem, or there may be an issue with an electrical device that relies on that breaker. You should leave the breaker off and consult an electrician.



A main circuit breakers shuts off power to the whole house. Individual circuit breakers connect to circuits throughout the house.


NEUTRAL
HOT
#2
HOT
#1
GROUNDS
GROUND - COPPER ROD
GROUND - REBAR
2 - HOTS
1 - NEURTAL
1 - GROUND

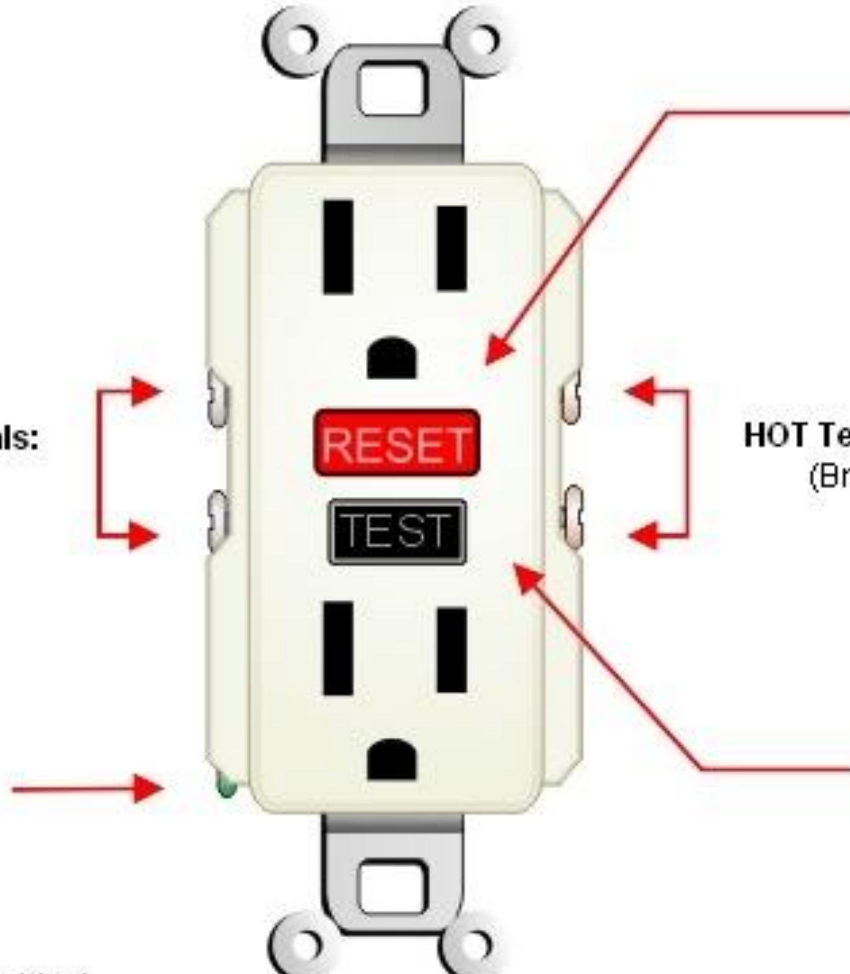
GFCI Receptacle *(Ground Fault Circuit Interrupter)*

GFCI receptacles are required when wiring:

-Garages
-Outdoors
-Kitchens
-Bathrooms
-Crawl Spaces
-Unfinished Basements

NEUTRAL Terminals:
(Silver)

GROUNDING Terminal:
(Green)



CIRCUIT RESET:
Press this button to return the outlet to normal functioning if it has been tripped or after a test.

HOT Terminals:
(Brass)

CIRCUIT TEST:
If power stops flowing when this button is pressed then the device is working properly.

For Your Safety:
GFCI receptacles protect you against electrical shock that can be caused by moisture, faulty electrical equipment and cords.

GFCI breakers are designed to protect people from *electrical shock*, rather than prevent damage to a building's wiring.

The GFCI constantly monitors the current in a circuit's neutral wire and hot wire. When a surge in current is detected on the how wire, the GFCI breaks the circuit, preventing electrocution.

Since it doesn't have to wait for current to climb to unsafe levels, the GFCI reacts much more quickly than a conventional breaker.