ARIZONA SCIENCE LAB

“HERE COMES THE SUN”

A STUDY OF ENERGY, ELECTRICITY AND *PHOTOVOLTAICS/SOLAR CELLS*

Institute Of Electrical And Electronic Engineers, Phoenix Section

Teacher In Service Program / Engineers In The Classroom (TISP/EIC)

“Helping Students Transfer What Is Learned In The Classroom To The World Beyond”

Research Sources

This presentation includes material from the following web sites:

HowStuffWorks: “How Solar Cells Work,”
http://http://science.howstuffworks.com/environmental/energy/solar-cell.htm

Explain that stuff! “Solar Cells”
http://www.explainthatstuff.com/solarcells.html

Wikipedia, http://en.wikipedia.org/wiki/Solar_cell

Tennessee Valley Authority, Coal-Fired Power Plant,
http://www.tva.gov/power/coalart.htm

The Electricity Book,
http://www.bgfl.org/bgfl/custom/resources_ftp/client_ftp/ks2/science/electricity_book1/index.htm

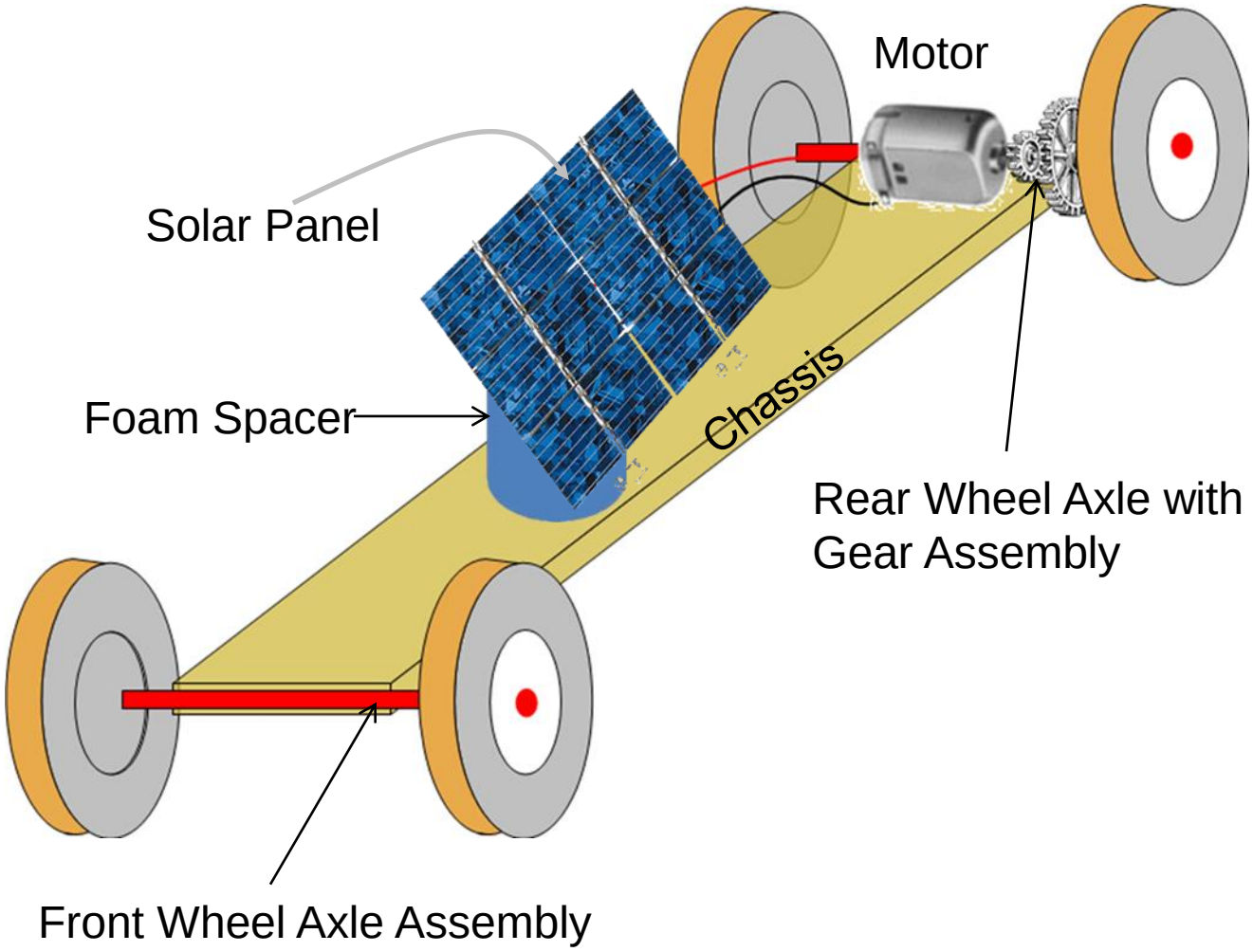
Our Sponsors

The AZ Science Lab is supported through very generous donations from corporations, non-profit organizations, and individuals, including:

Workshop Objectives

- Learn what an engineer does
- Discuss the Sun as a great energy source
- Investigate solar cells and their uses
- Learn a bit about electricity
- Engineer and build a solar car
- Have fun while learning!!!

The Solar Model Car You Will Build

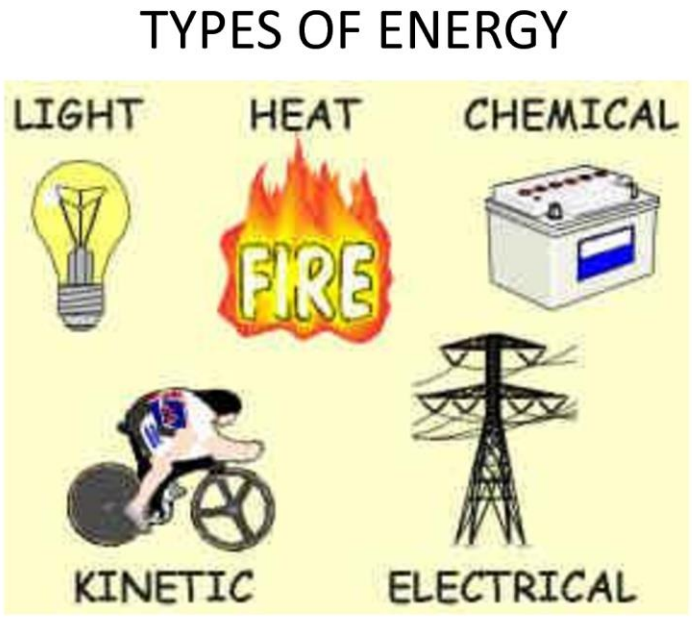


ENERGY

What is it?

Energy is the ability to do work.

Can you name some common forms of energy?



Properties of Energy

The Law of the Conservation of Energy

- ***Energy can be <u>neither</u> created nor destroyed, but can change form.***

Energy forms can be converted –

- Chemical to mechanical: car engine
- Potential (gravity) to kinetic: roller coaster
- Chemical to light/heat: burn a candle

What is the only source of energy we have on this earth?

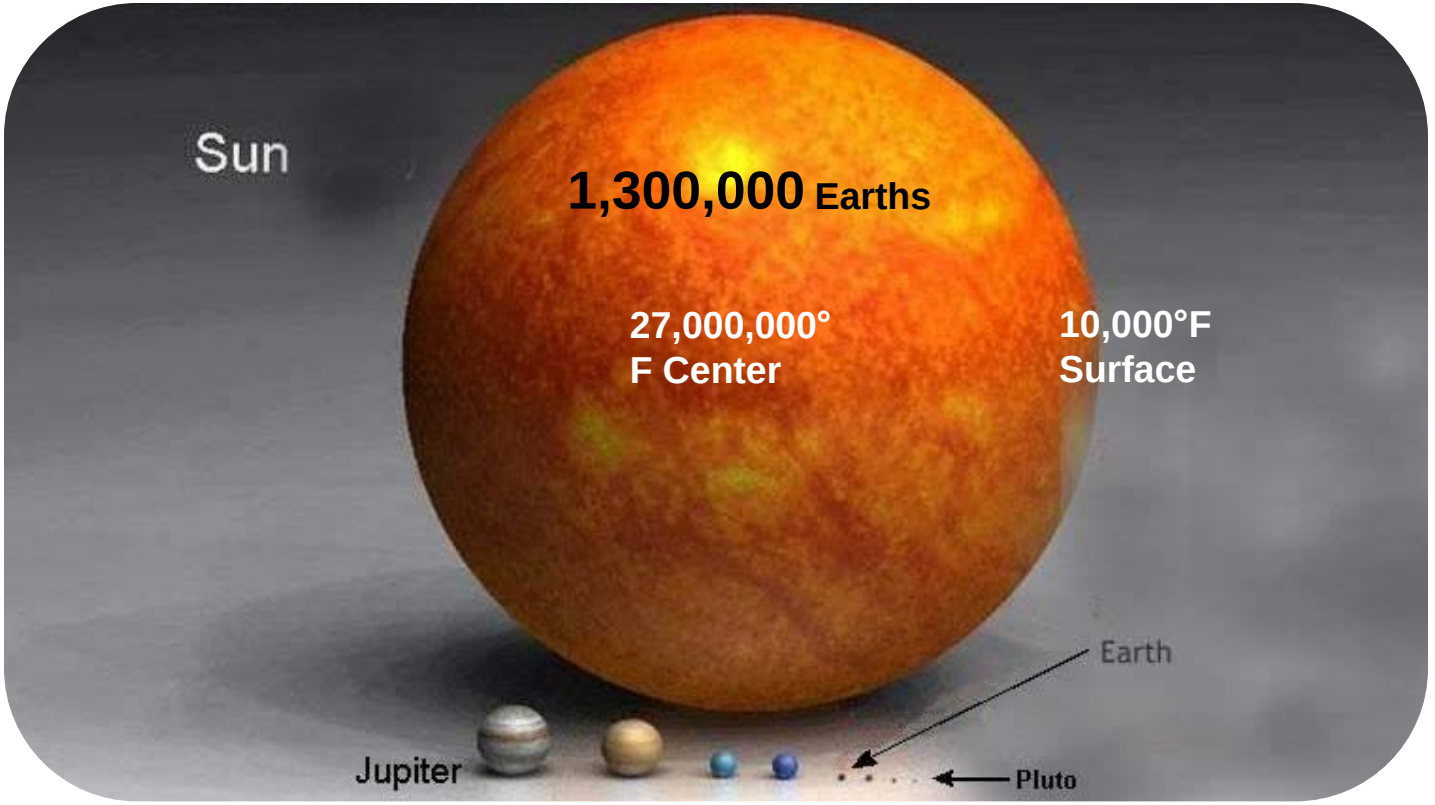

The Sun
Our energy source –
past, present, and future!

What Is The Sun?

The **Sun** is the ***STAR*** at the center of our Solar System

The Sun has a diameter of about 1,392,000 kilometers (865,000 mi).

By itself accounts for about 99.86% of the Solar System's **mass**

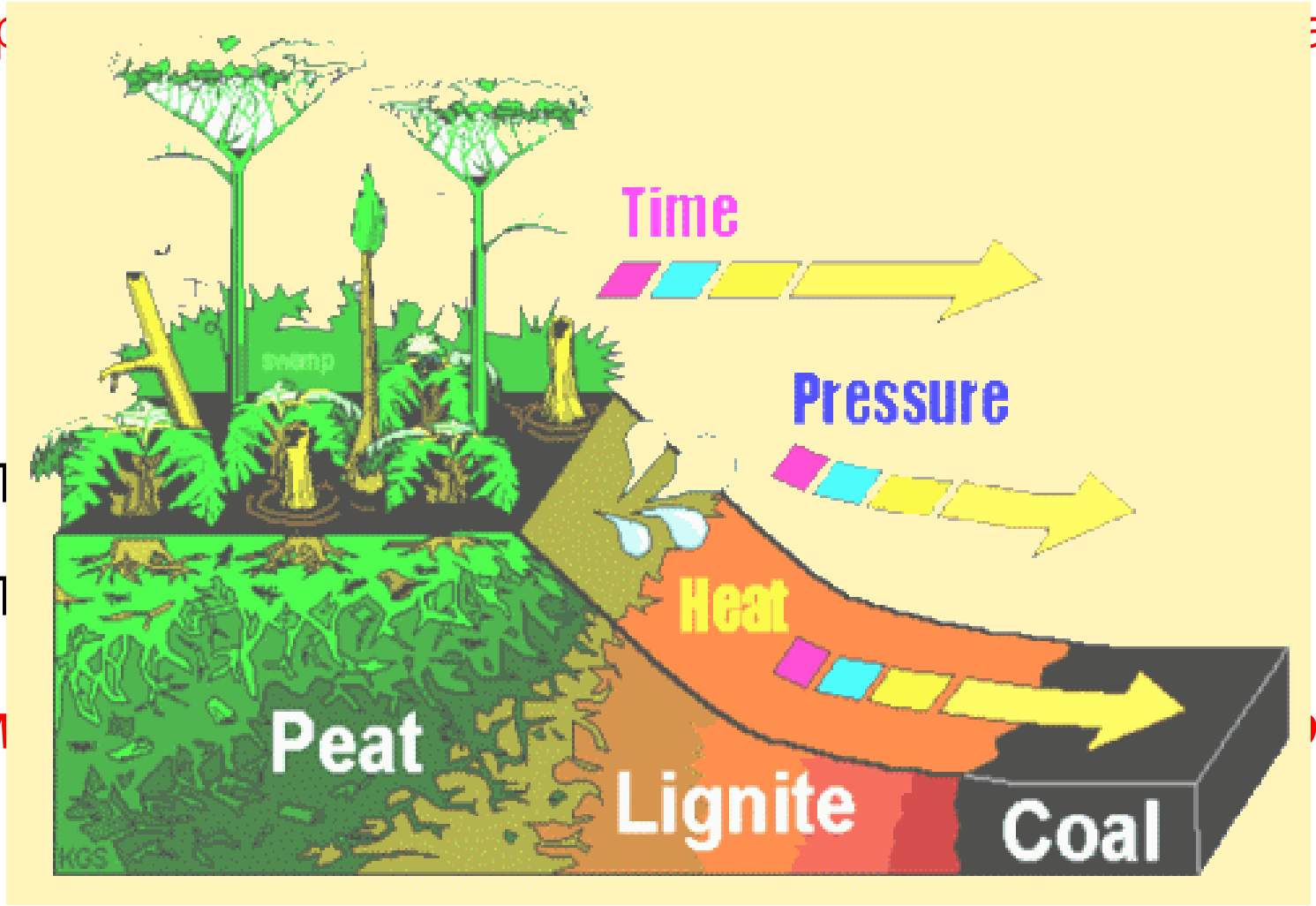


The energy we mostly use today is: oil, coal, and natural gas.

It is non-renewable energy!

To Create More of This Energy Will Take Many Millions of Years – This is Non-Renewable Energy!

Coal, p ant life



How *rk?*

Forms of Renewable Energy

Chemical

Wind

ELECTRICITY

Water

Solar

Electricity: How Do We Make It?

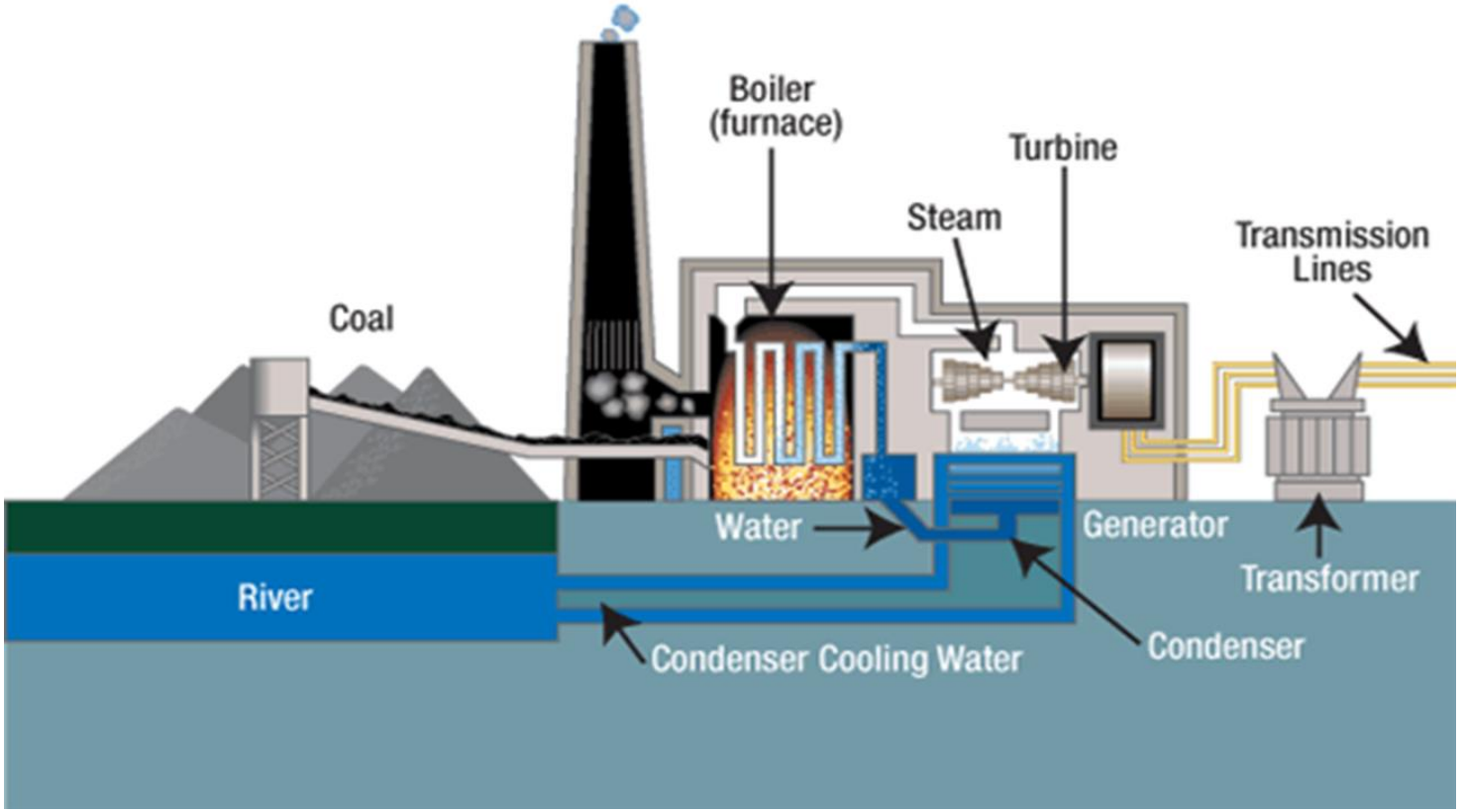
- It is a conversion from other forms of energy:
  - Chemical energy into electricity:

    batteries
  - Mechanical energy into electricity:

    electric generators
  - Light energy into electricity:

    solar panels (photovoltaic effect)

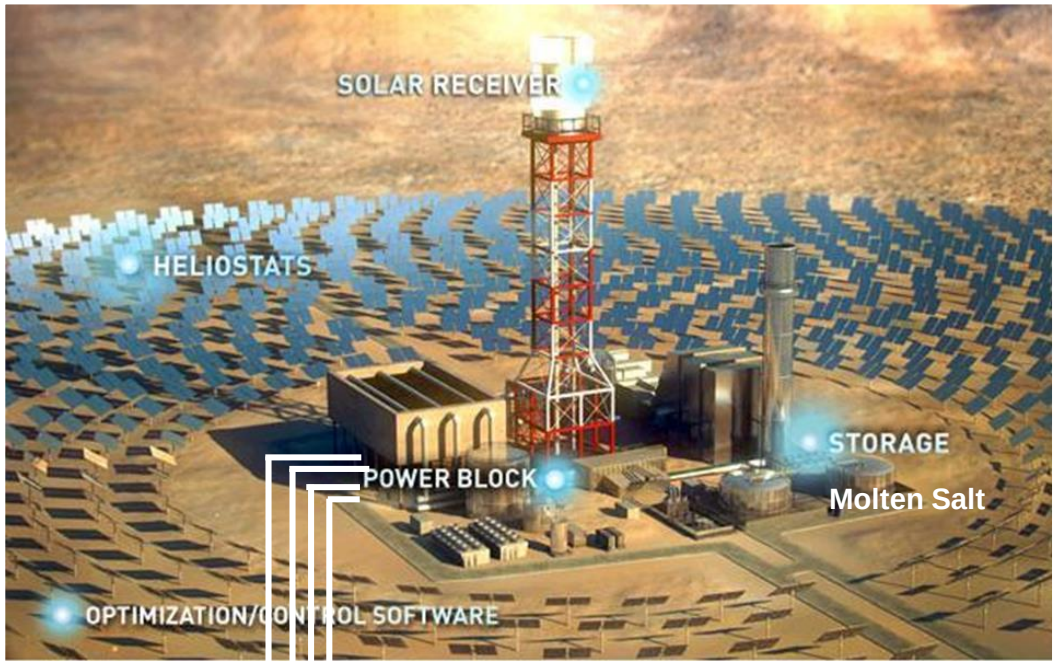
Electricity: How Do We Make It?

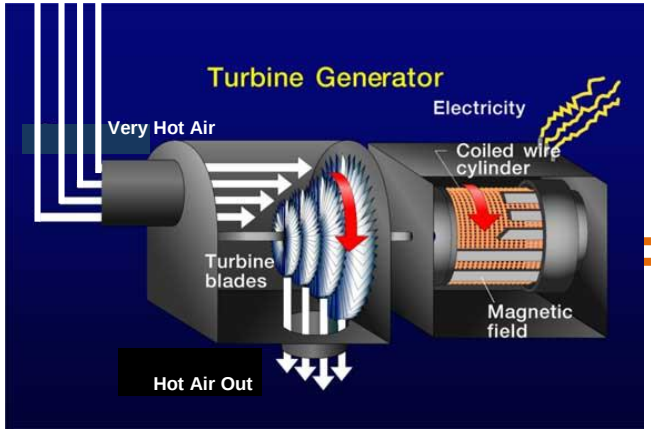


It is a conversion from other forms of energy –

- Chemical energy into heat energy (burn coal, oil, natural gas)
- Heat energy into mechanical energy (turn turbine)
- Mechanical energy into electricity (turn electric generator)

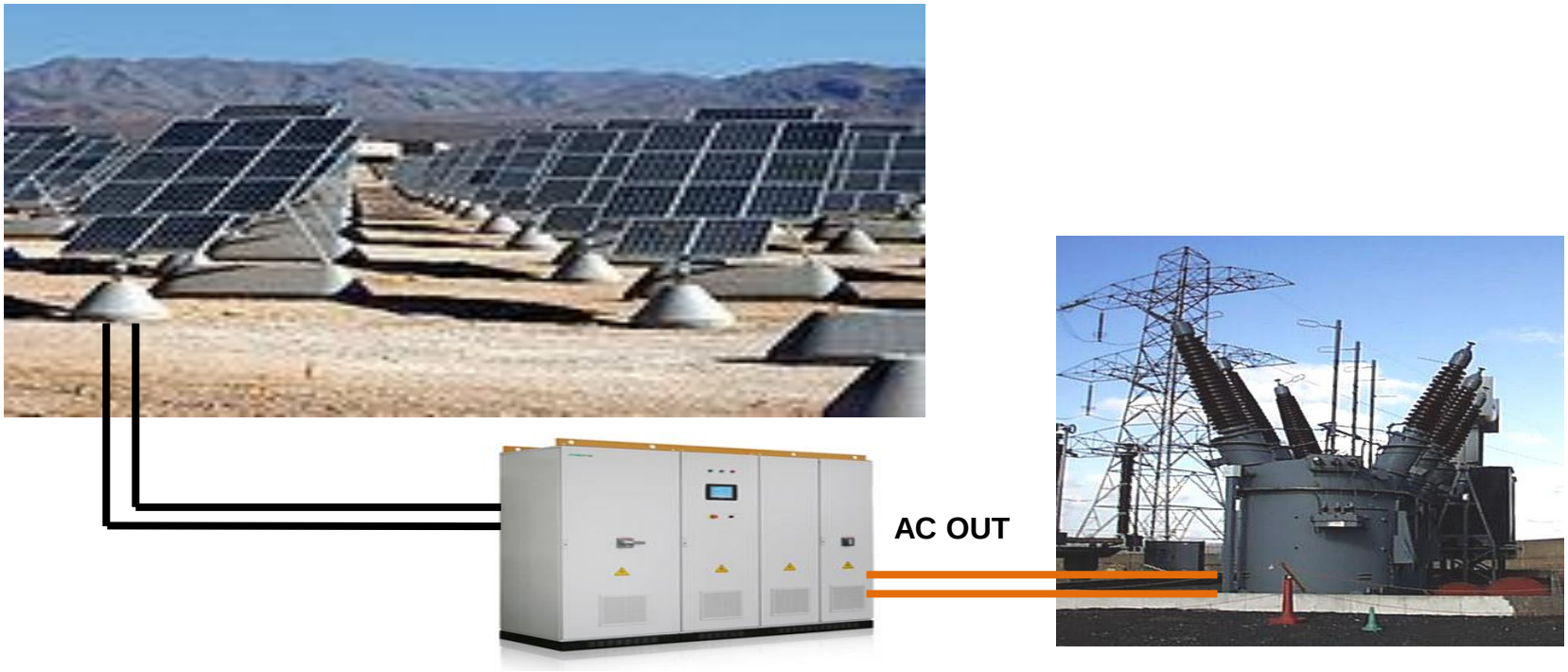
A CLEANER WAY TO PRODUCE ELECTRICITY





AC OUT

A SIMPLE WAY TO PRODUCE ELECTRICITY



No Turbines/Generators!

The Problem with Electricity

Electricity is a form of energy that is very hard to store, but we can convert it to chemical energy in a battery, and then re-convert it back to electricity!

Energy can be neither created nor destroyed, ***but can change form***.

Example: Electric Car

AC Power

Inverter

Battery Pack

DC Power

Electric Cars

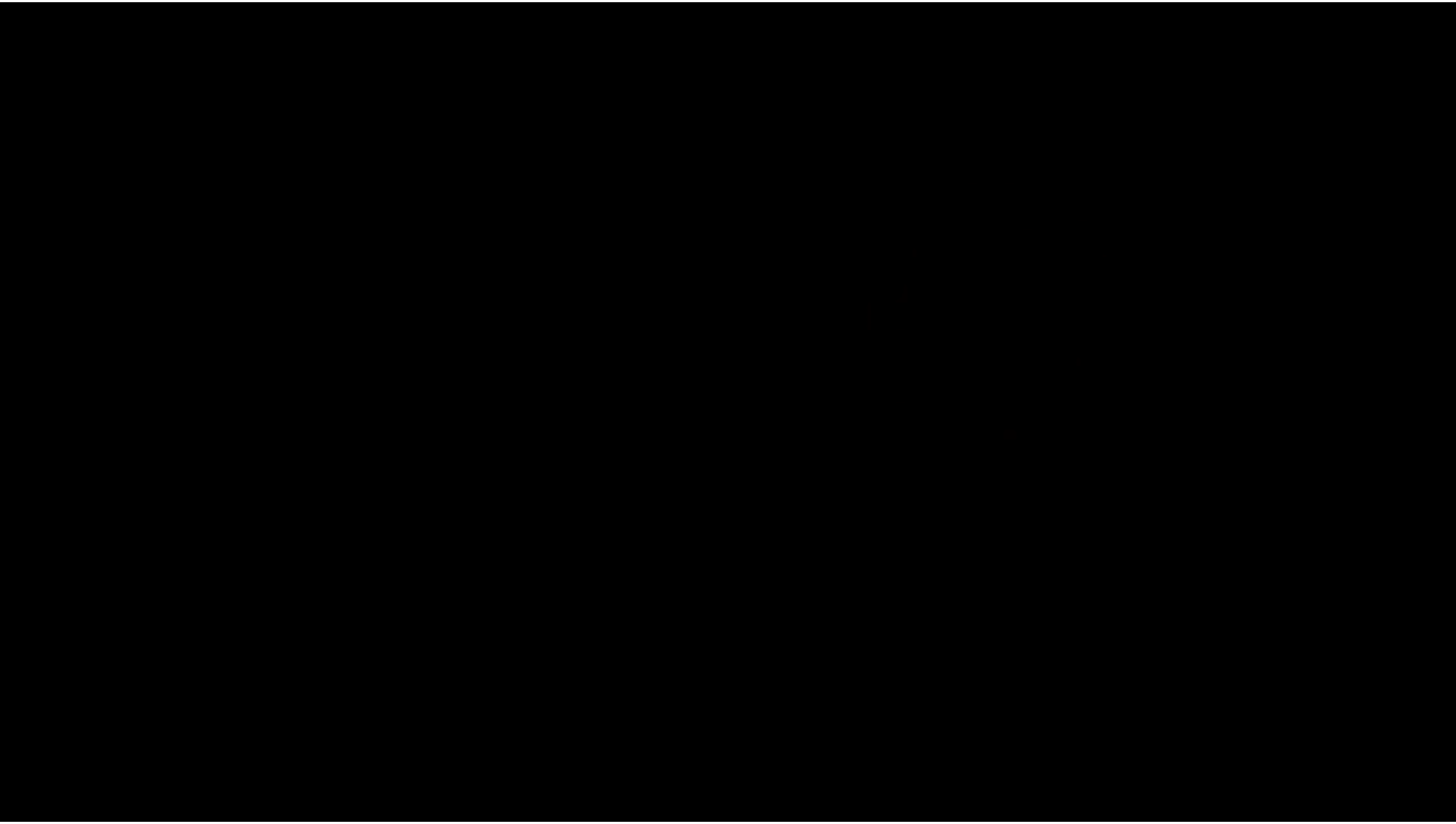
Chevrolet Bolt

Nissan Leaf

Tesla Model S

Solar Power and Houses

Residential Solar System

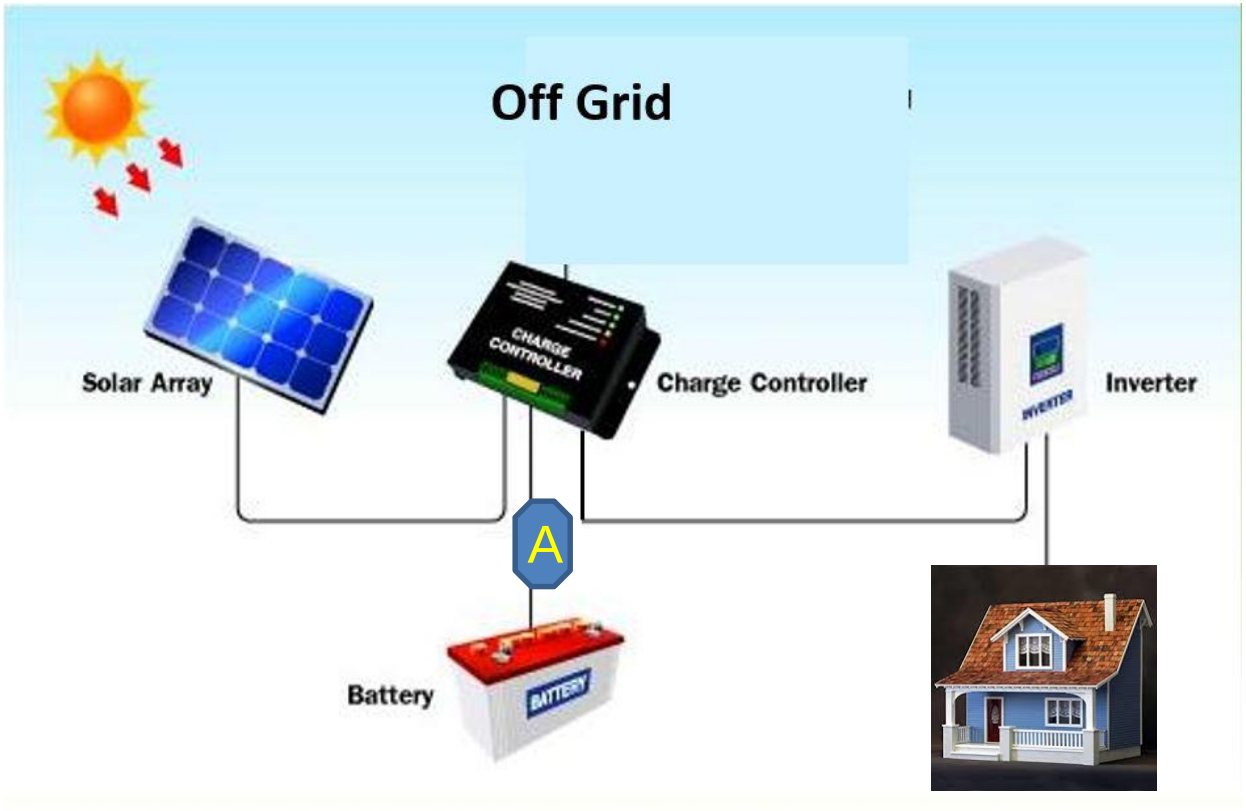


Let’s Look at a Home Solar System!

An Off Grid System

- During the day the **solar array**: charges the battery and provides power for the house.

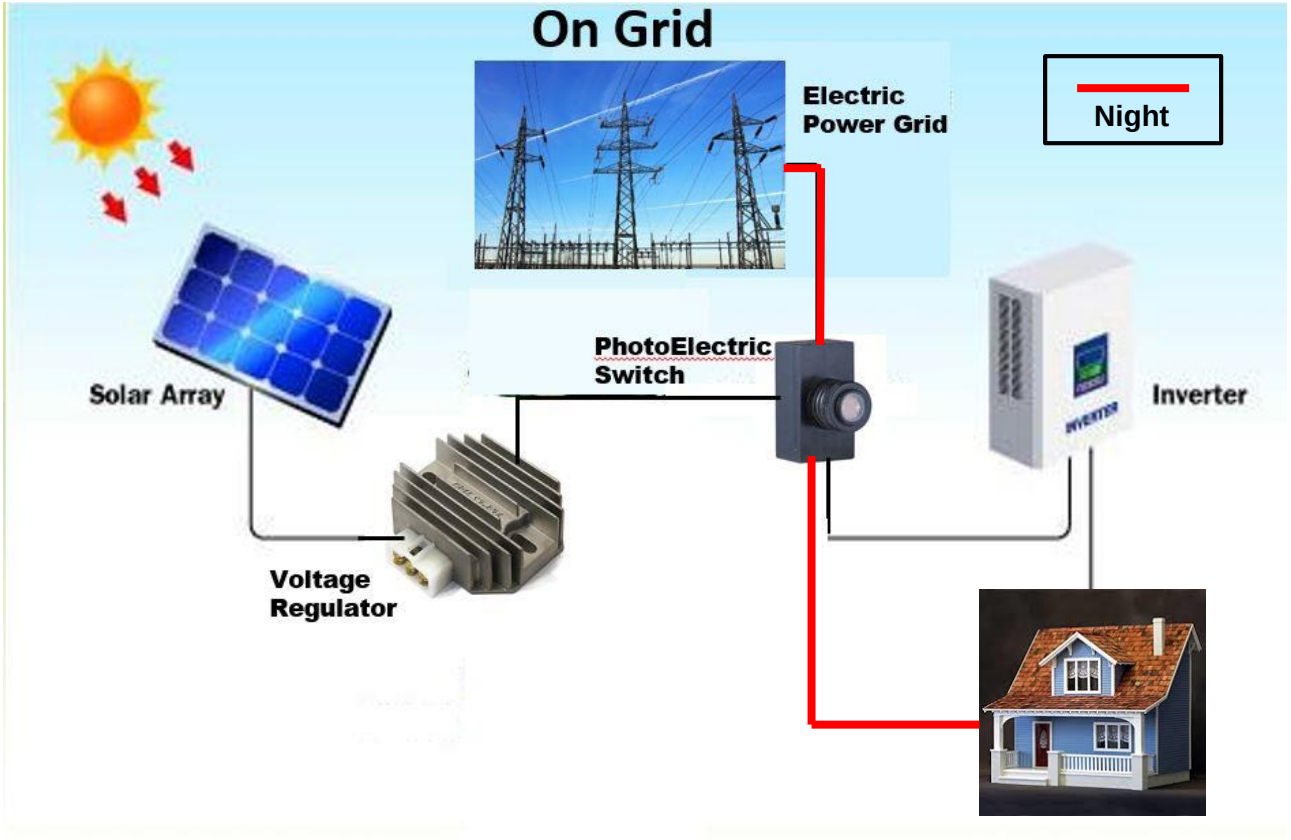
- During the night the **battery**: provides power for the house.



An On Grid System

- During the day **the solar array**: provides power for the house.

- During the night **the grid**: provides power for the house.

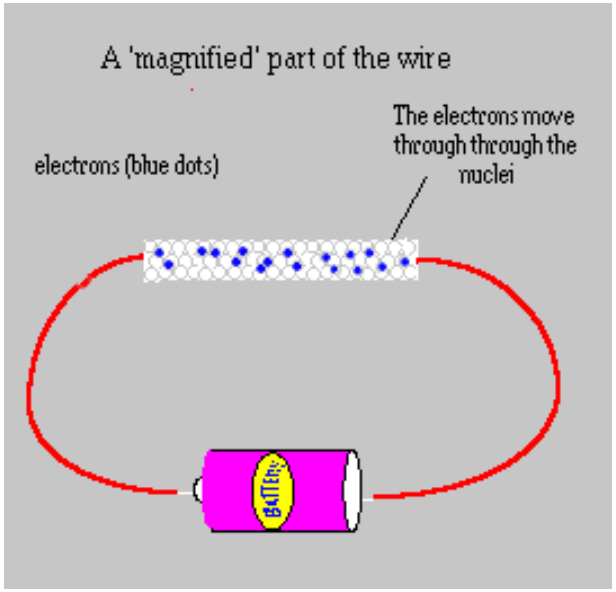


What Is Electricity And What Are It's Properties?

Two Forms:

1. **Static Electricity**

2. **Current Electricity**



What Is Electricity And What Are It's Properties?

Electricity is the flow of *electrons*

The movement of free electrons forms an *electric current*

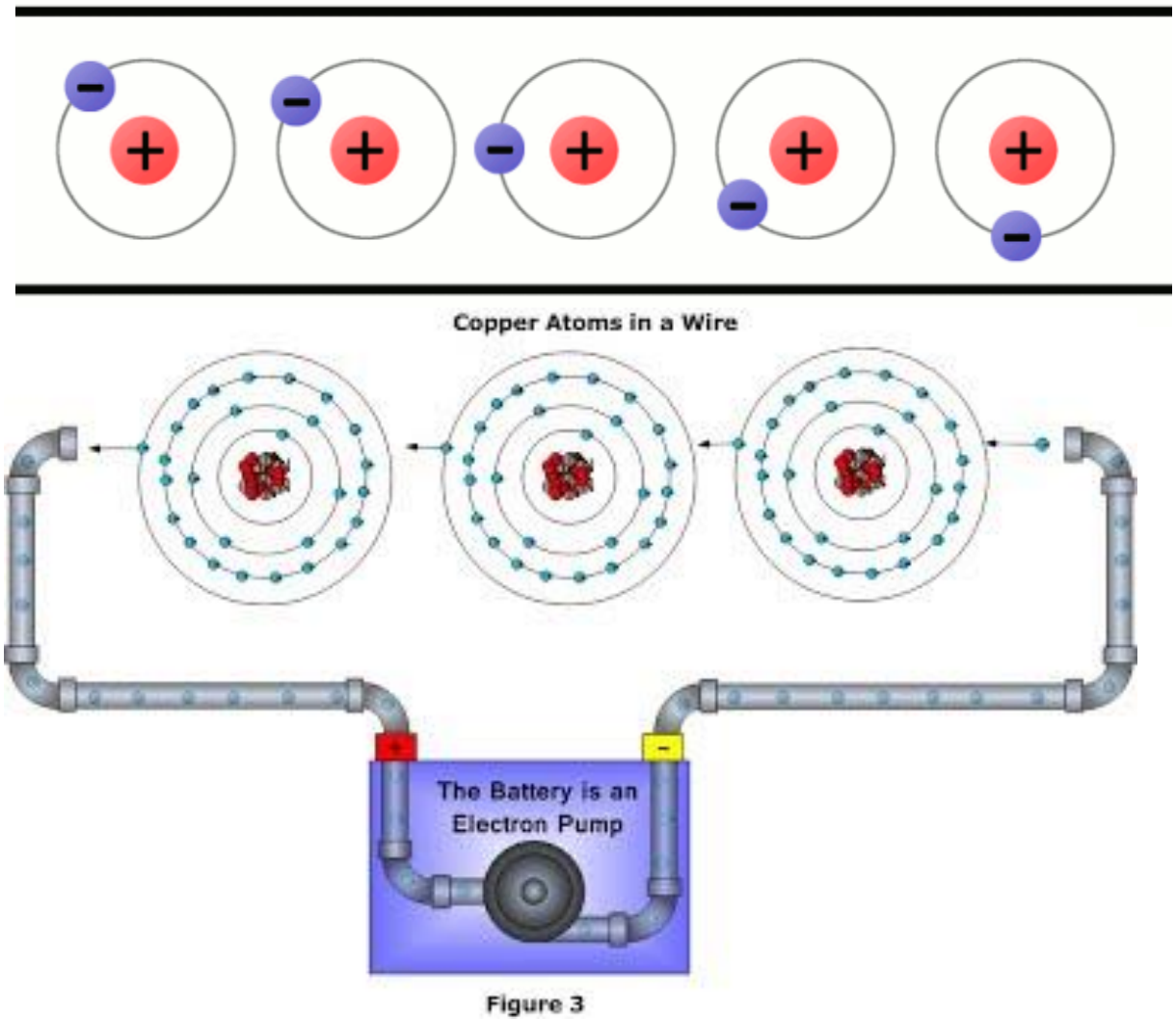
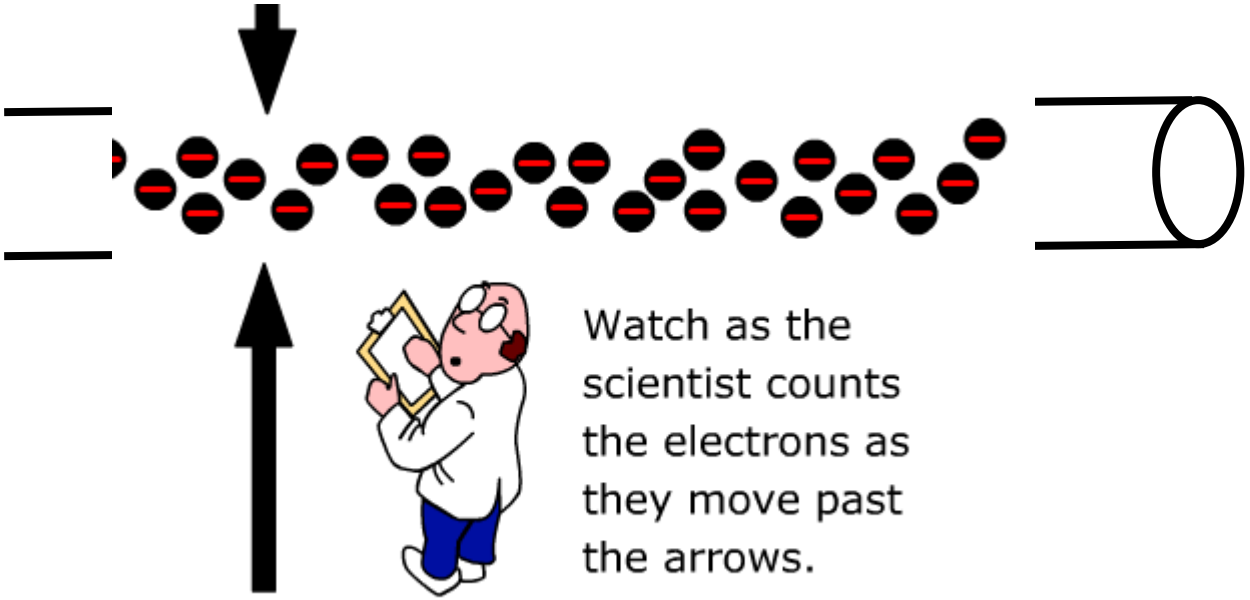


Figure 3

An *Electric Circuit* is a path through which electricity flows

How do we measure electricity?



Billions and billions per second

Characteristics of electric flow:

Amperage – quantity (amount) of electricity flowing

Voltage – pressure (push force) of the electricity

Watts – Power of the electricity: W = A * V

We measure electricity using a calibrated meter

- An electric multimeter (voltmeter, ammeter):

Electrical Nature of Matter

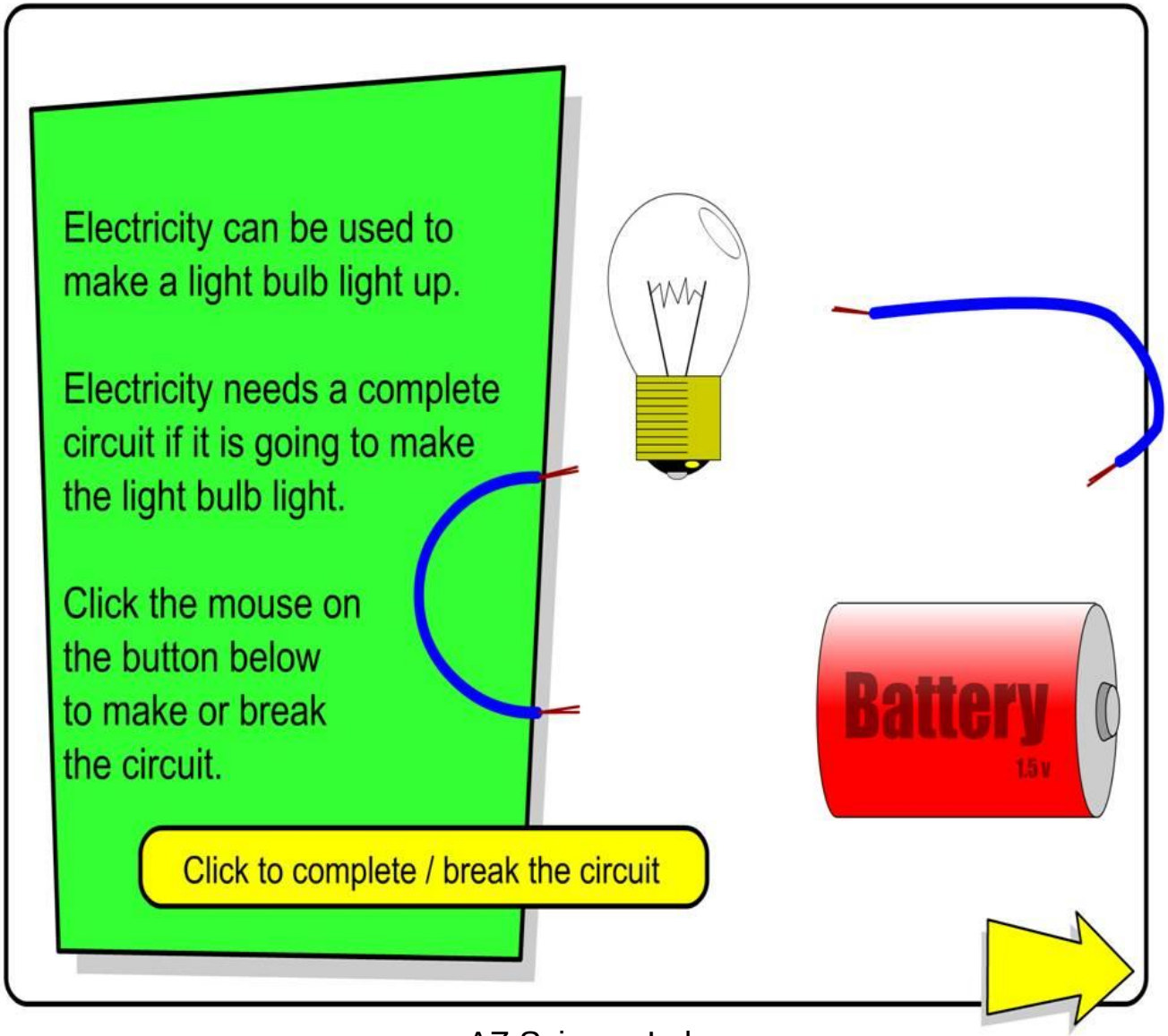
Materials that permit the motion of free electrons are called ***Conductors***.

Materials that oppose the motion of electrons are called ***Insulators***

Conductors are said to have **low resistance** while **insulators** have high **resistance**

CONDUCTORS	***INSULATORS***
Silver	**Dry Air**
Copper	**Glass**
Gold	**Mica**
Aluminum	**Rubber**
Brass	**Asbestos**
Zinc	**Bakelite**
Iron	**PVC**
	Teflon
	Plastics

Non Connected Electrical Circuit

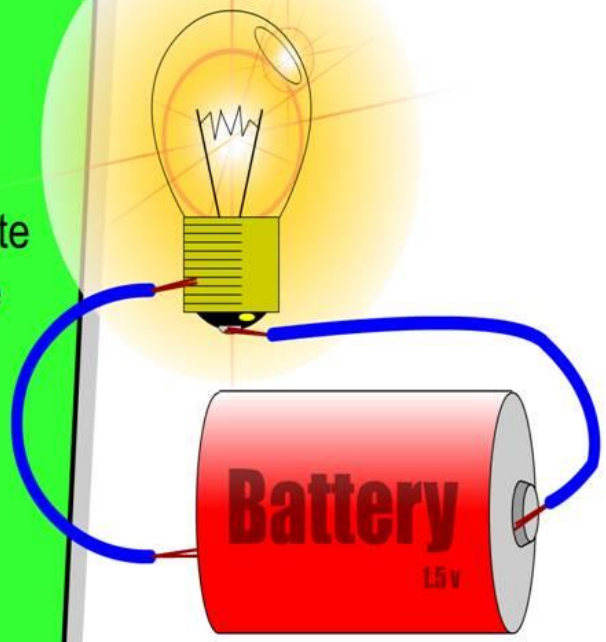


Connected Electrical Circuit

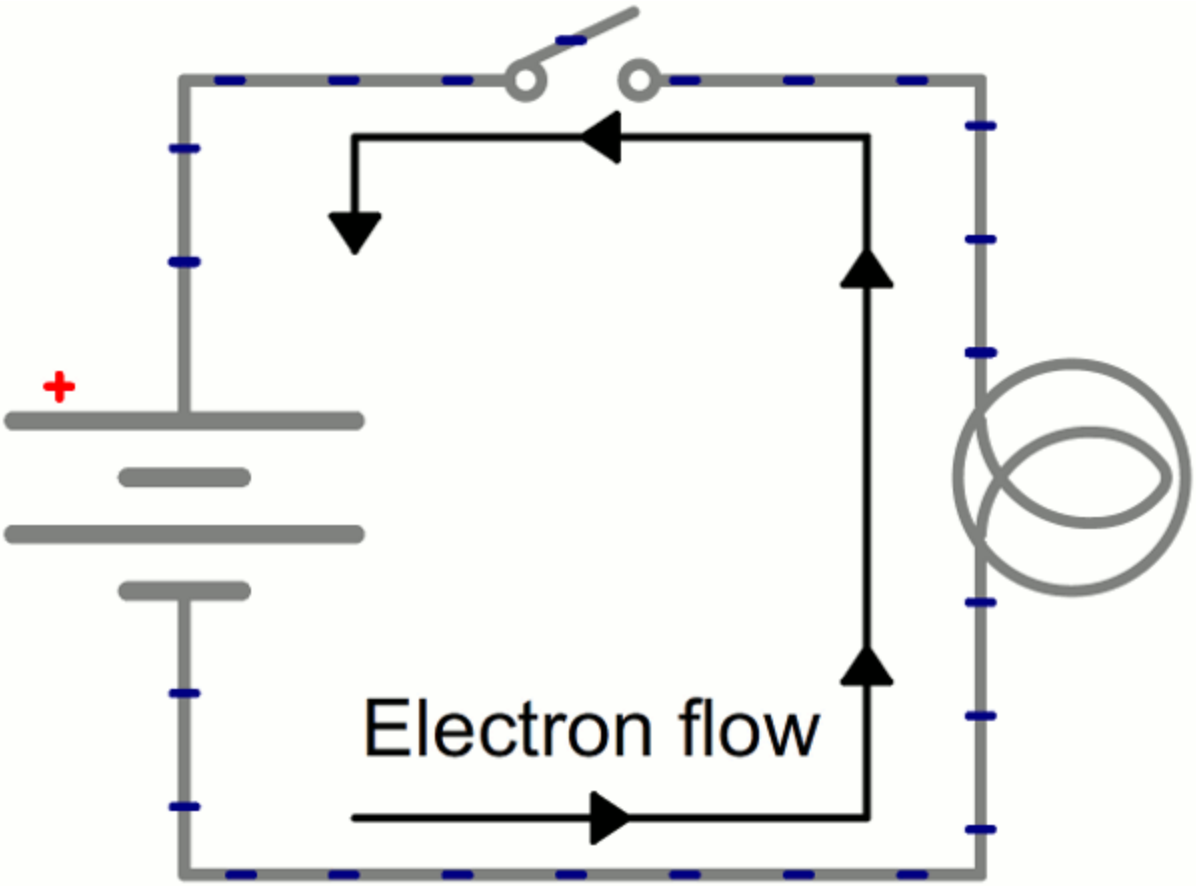
Electricity can be used to make a light bulb light up.

Electricity needs a complete circuit if it is going to make the light bulb light.

Click the mouse on the button below to make or break the circuit.



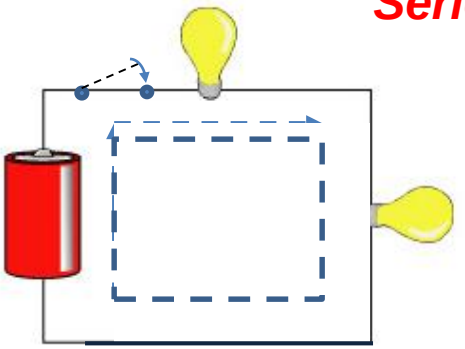
Click to complete / break the circuit

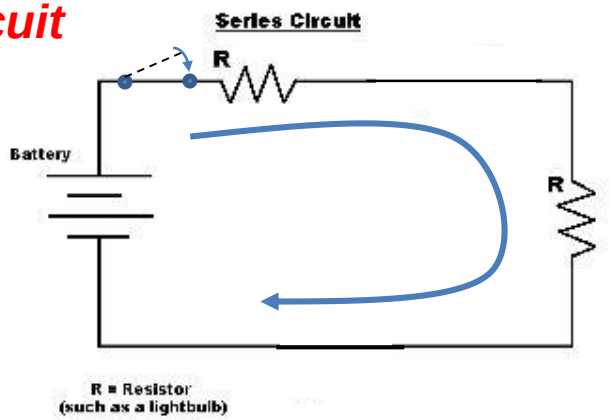

+
Electron flow

How to connect circuits

Connecting *Loads* (*resistors*)

Series Circuit

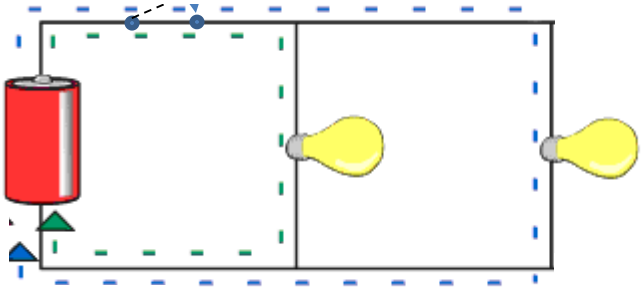


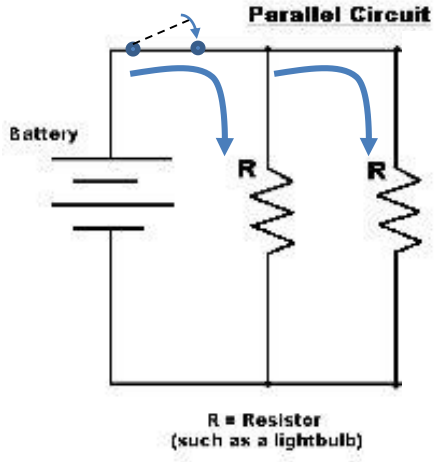


How to connect circuits

Connecting *Loads* (*resistors*)

Parallel Circuit

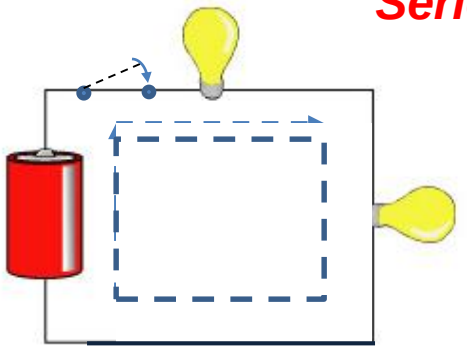


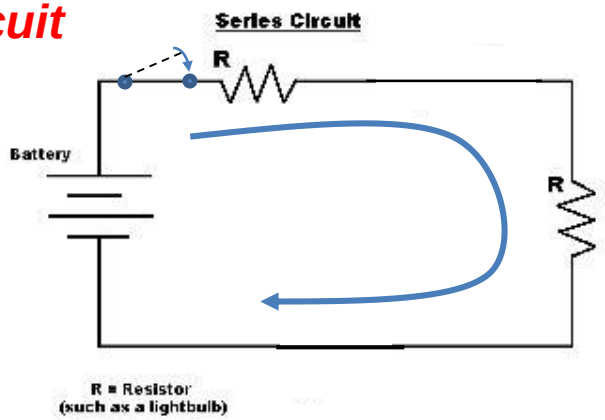


How to connect circuits

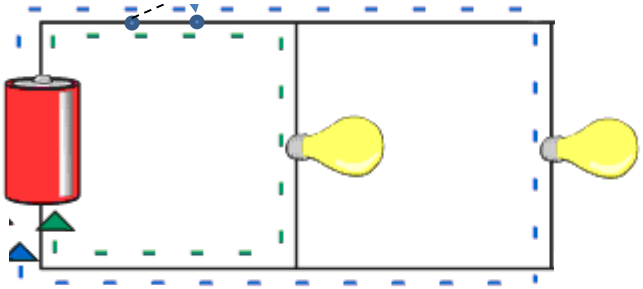
Connecting *Loads* (*resistors*)

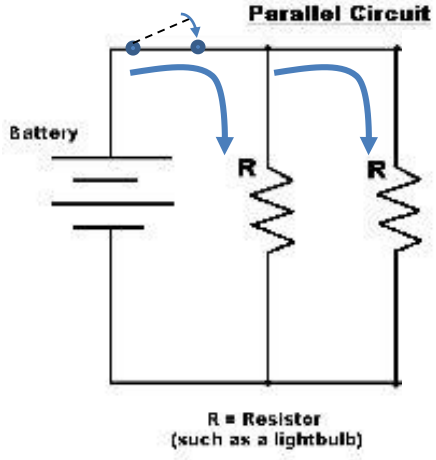
Series Circuit



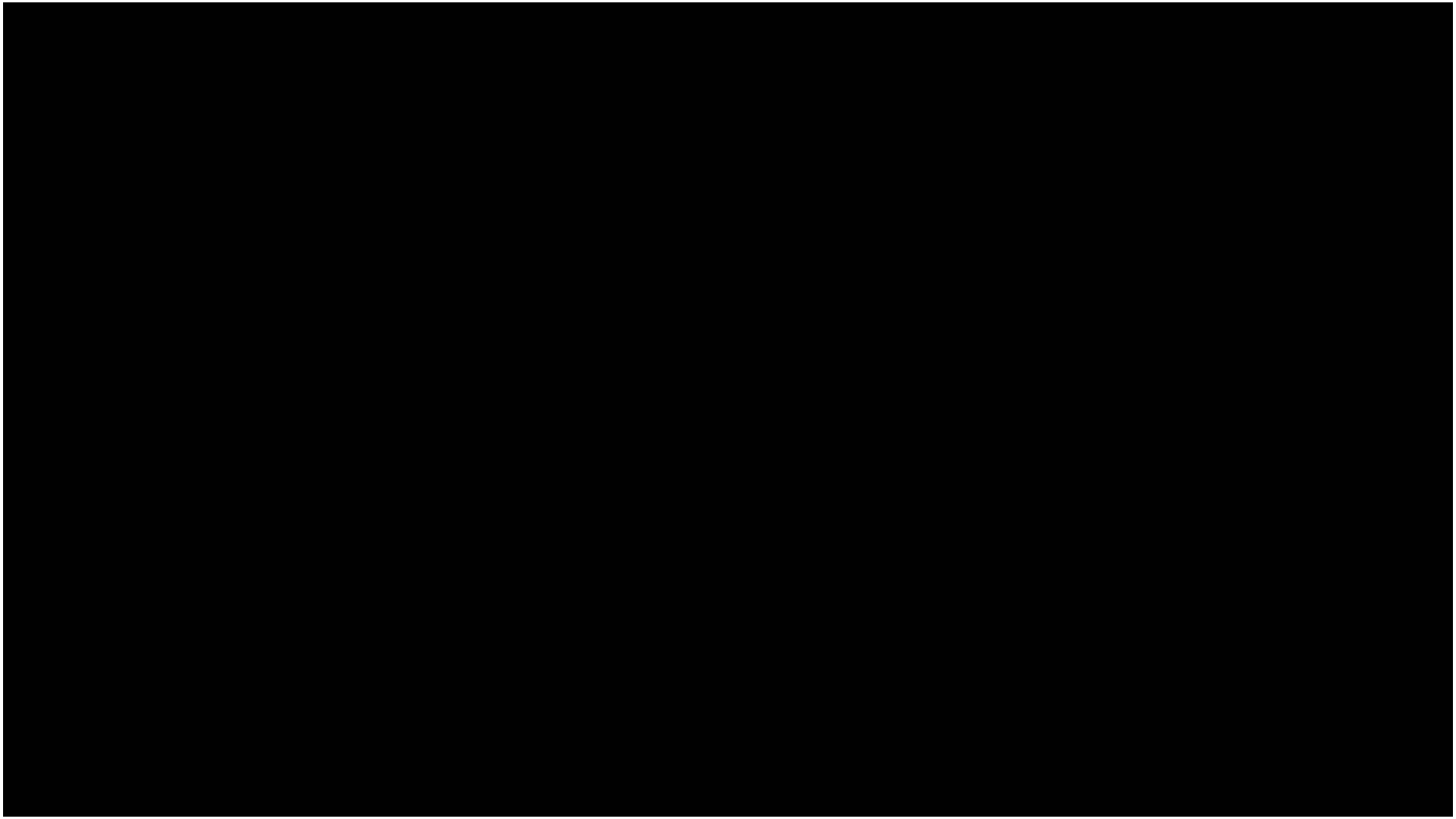


Parallel Circuit



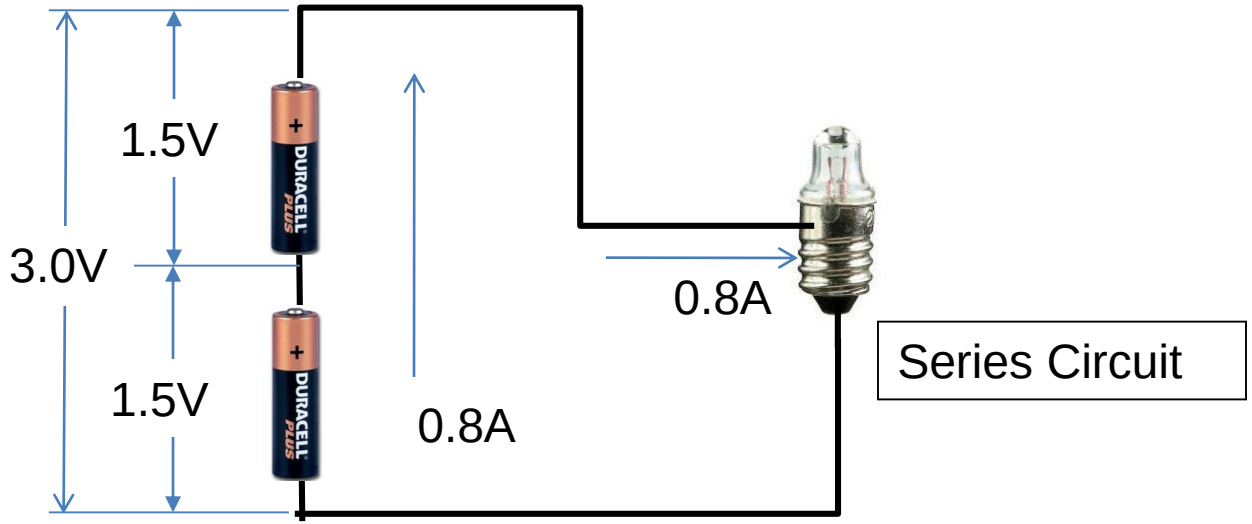


Circuits

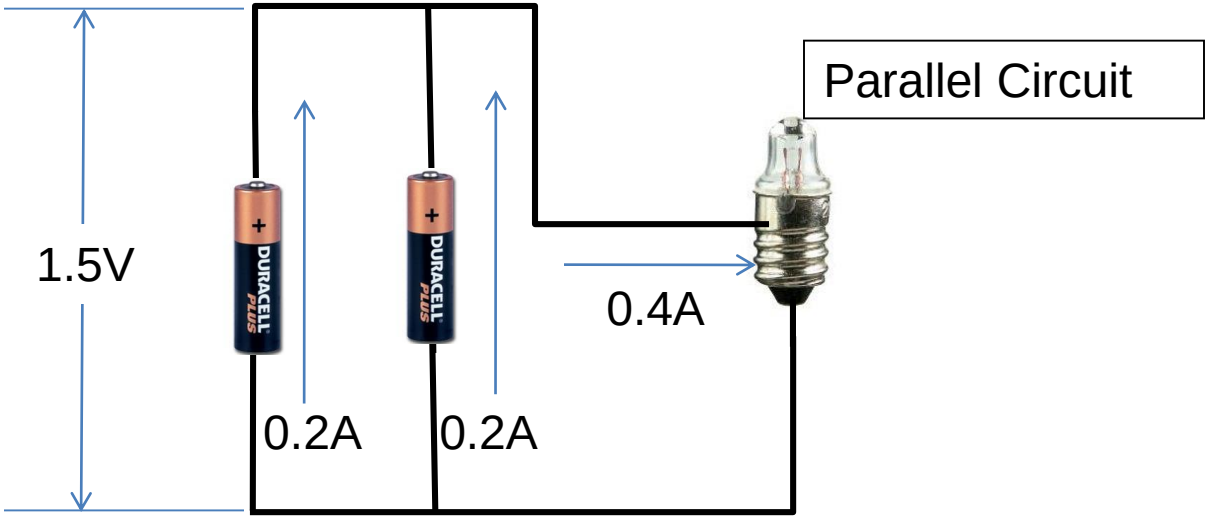


How to connect circuits

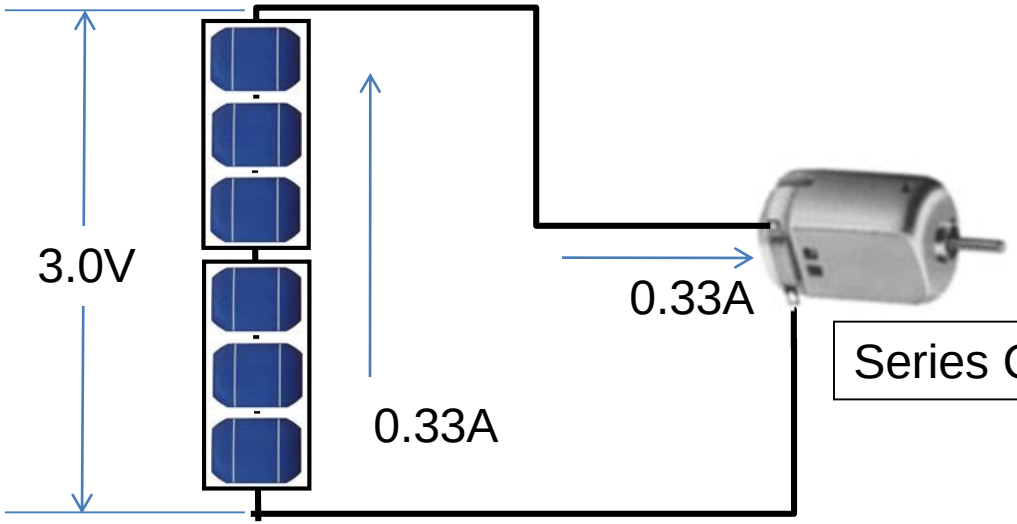
Connecting *Sources* (batteries)



Power = Voltage × Current



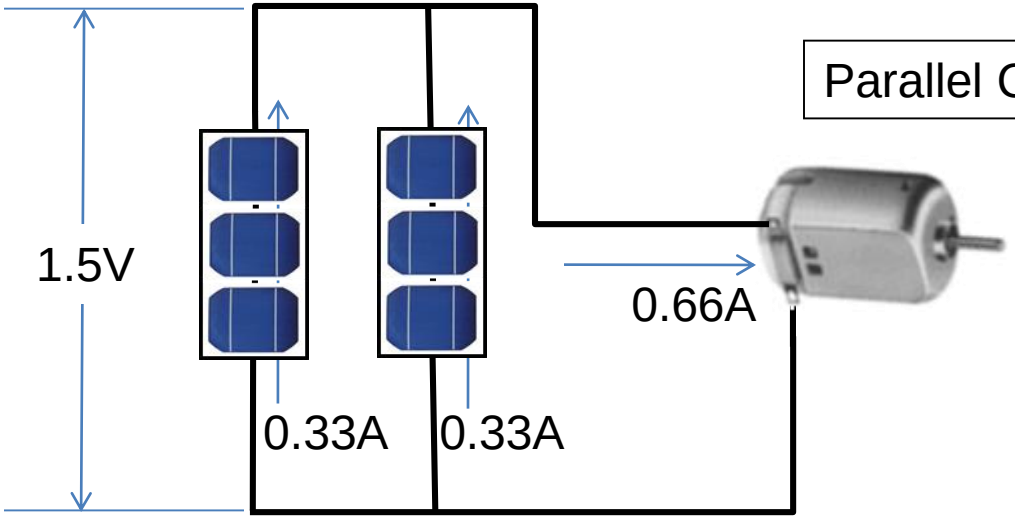
Applying the Series/Parallel Concept to the Solar Car



Speed – 17,629 RPM
Torque – 1.6 gm-cm
Won't Start!

Series Circuit

Power = Voltage × Current



Parallel Circuit

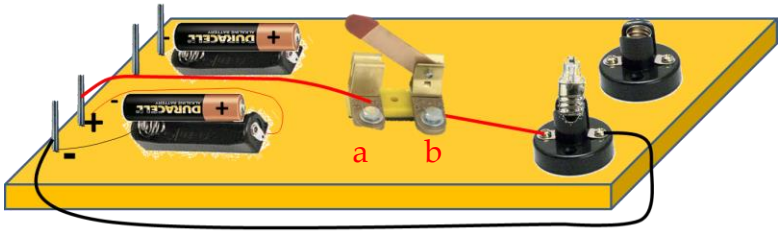
Speed – 6,990 RPM
Torque – 6.0 gm-cm

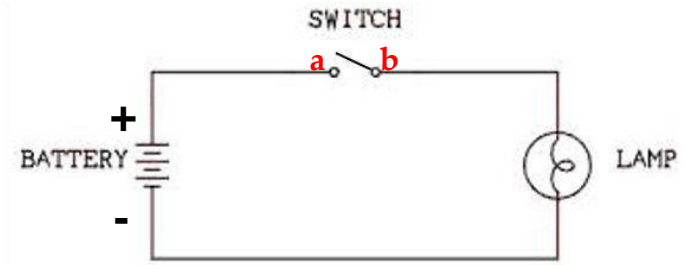
Creating and Connecting Circuits

Using a Breadboard

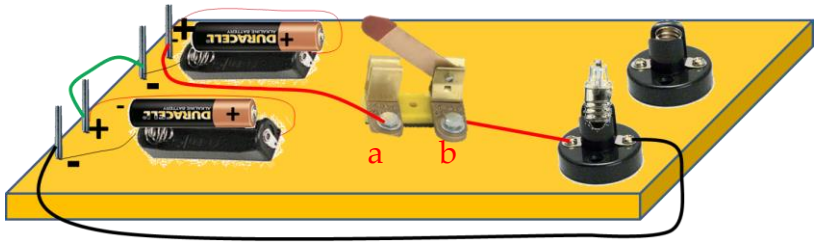
Name:

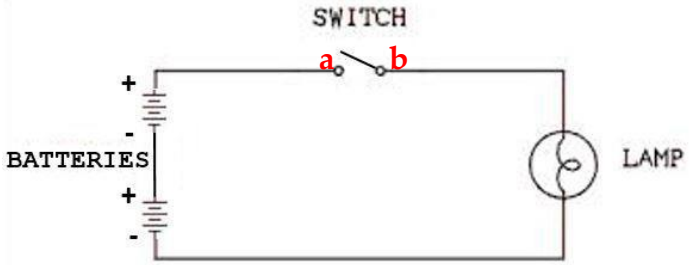
Circuits Worksheet





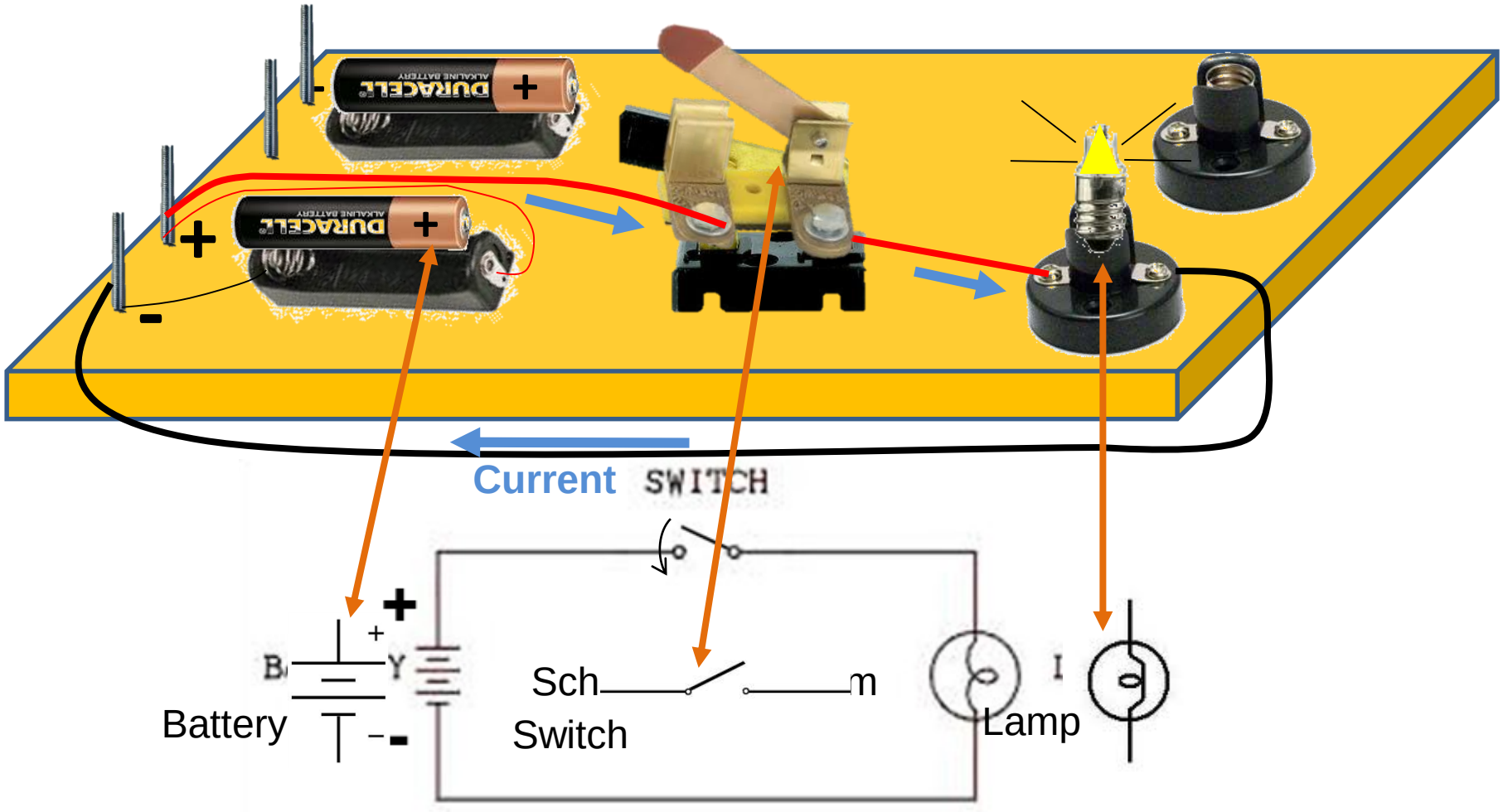
1 Battery,
1 light bulb



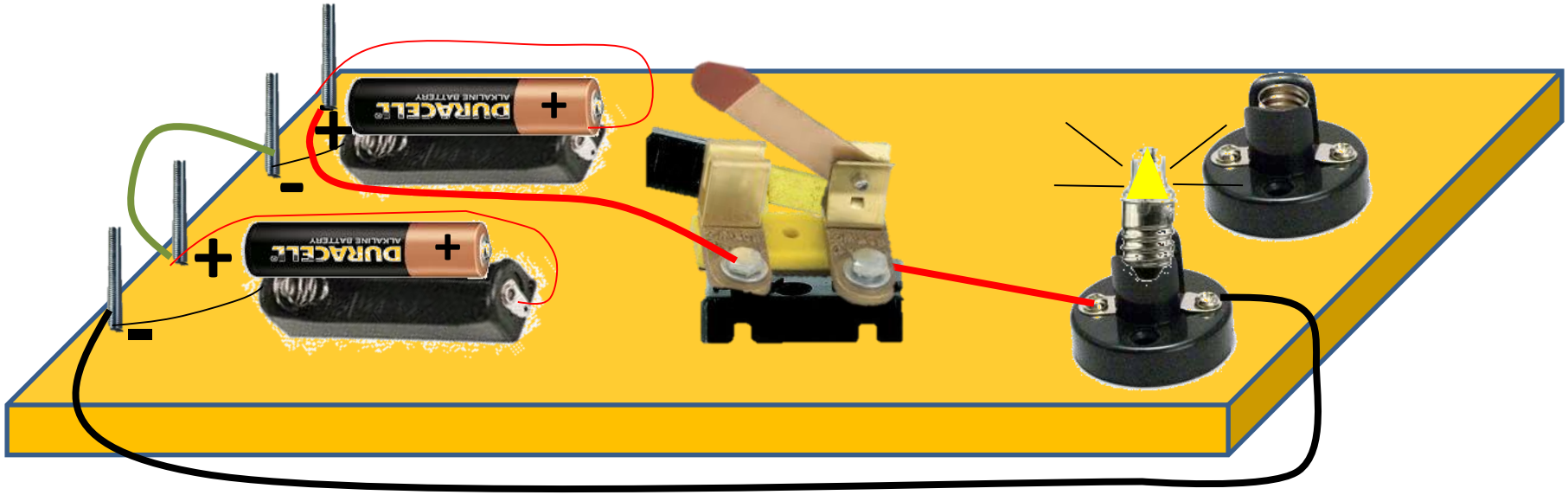


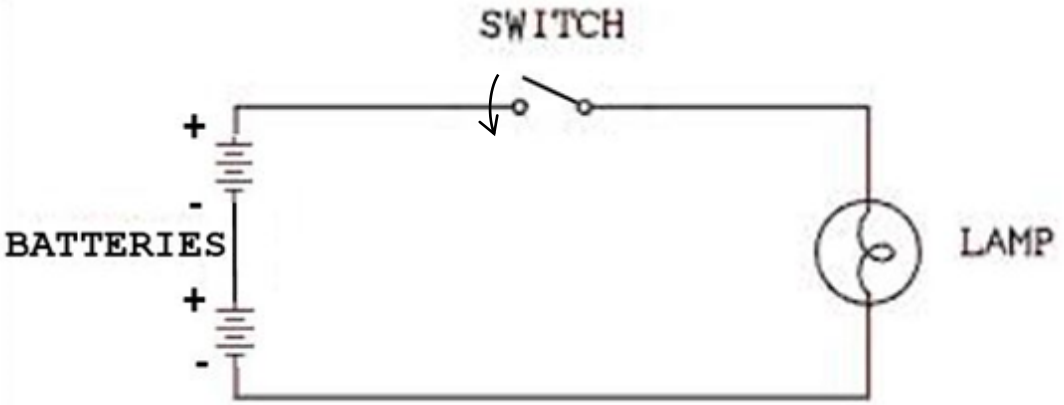
2 Batteries
in series,
1 light bulb

1 Battery, 1 Lightbulb



2 Batteries, 1 Lightbulb



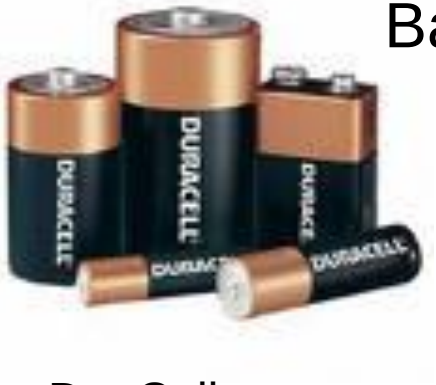


Types of Electricity

Alternating Current - AC

Direct Current - DC

Batteries

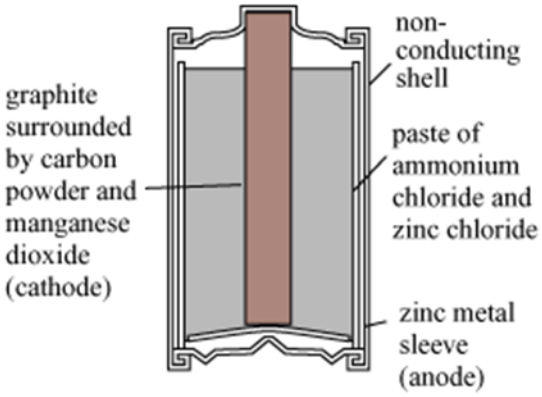


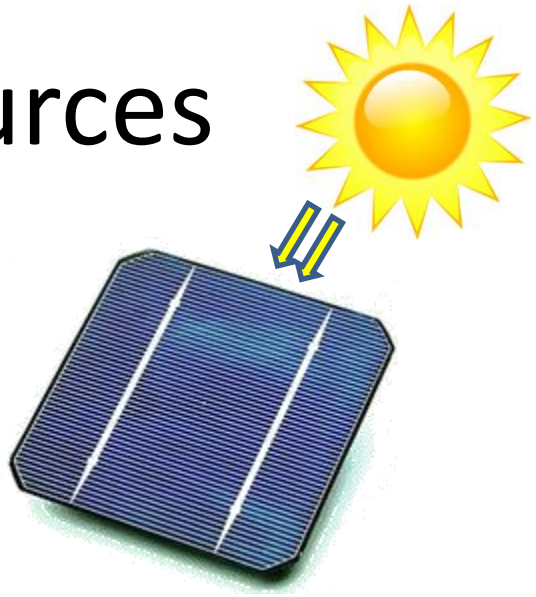
Dry Cells

Wet Cells

Solar Cells

Direct Current Sources





Batteries produce Direct Current (DC)

Batteries produce electricity from a chemical reaction.

Solar Cells produce electricity directly from light!

What Is A Solar Cell?

It converts the energy of sunlight directly into electricity

A Solar Cell is also known as a Photovoltaic (PV) Cell

"***Photovoltaic***" – combination of 2 Greek words

Photo ≡ Light

Voltaic ≡ Electric or Voltage

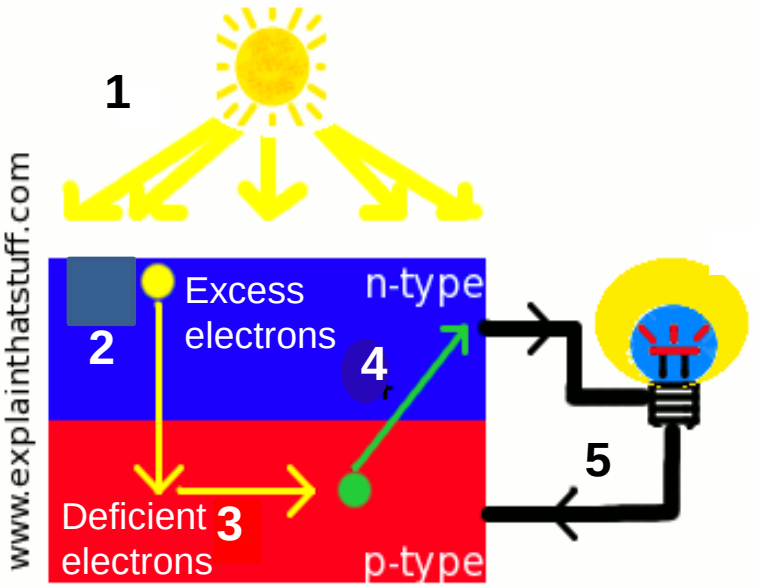
How Do Solar Cells Work?

1. When sunlight shines on the cell, **photons** (light particles) bombard the upper surface.
2. The **photons** carry their energy down through the cell.
3. The photons give up their energy to **electrons** in the lower, ***p-type*** layer.
4. The **electrons** use this energy to jump across the barrier into the upper, ***n-type*** layer and escape out into the circuit.
5. Flowing around the circuit, the electrons make the lamp light up.

Two layers of "doped" silicon material sandwiched together:

Other elements are added to silicon so that:

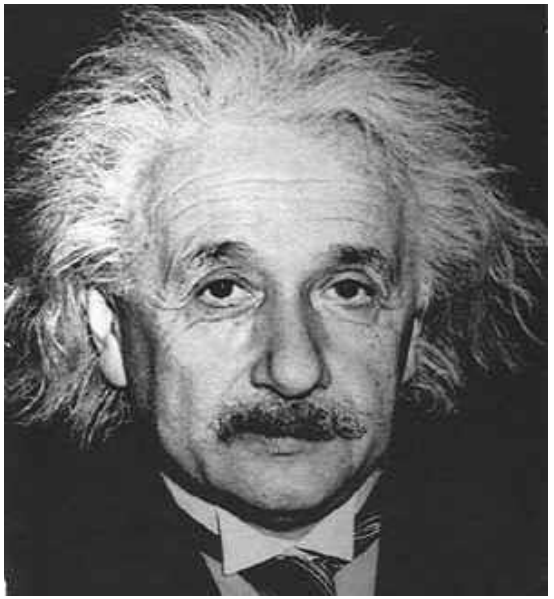
- N-type material has <u>excess</u> of electrons
- P-type material has "holes", <u>deficient</u> in electrons.



Discoverer of the Photoelectric Principle

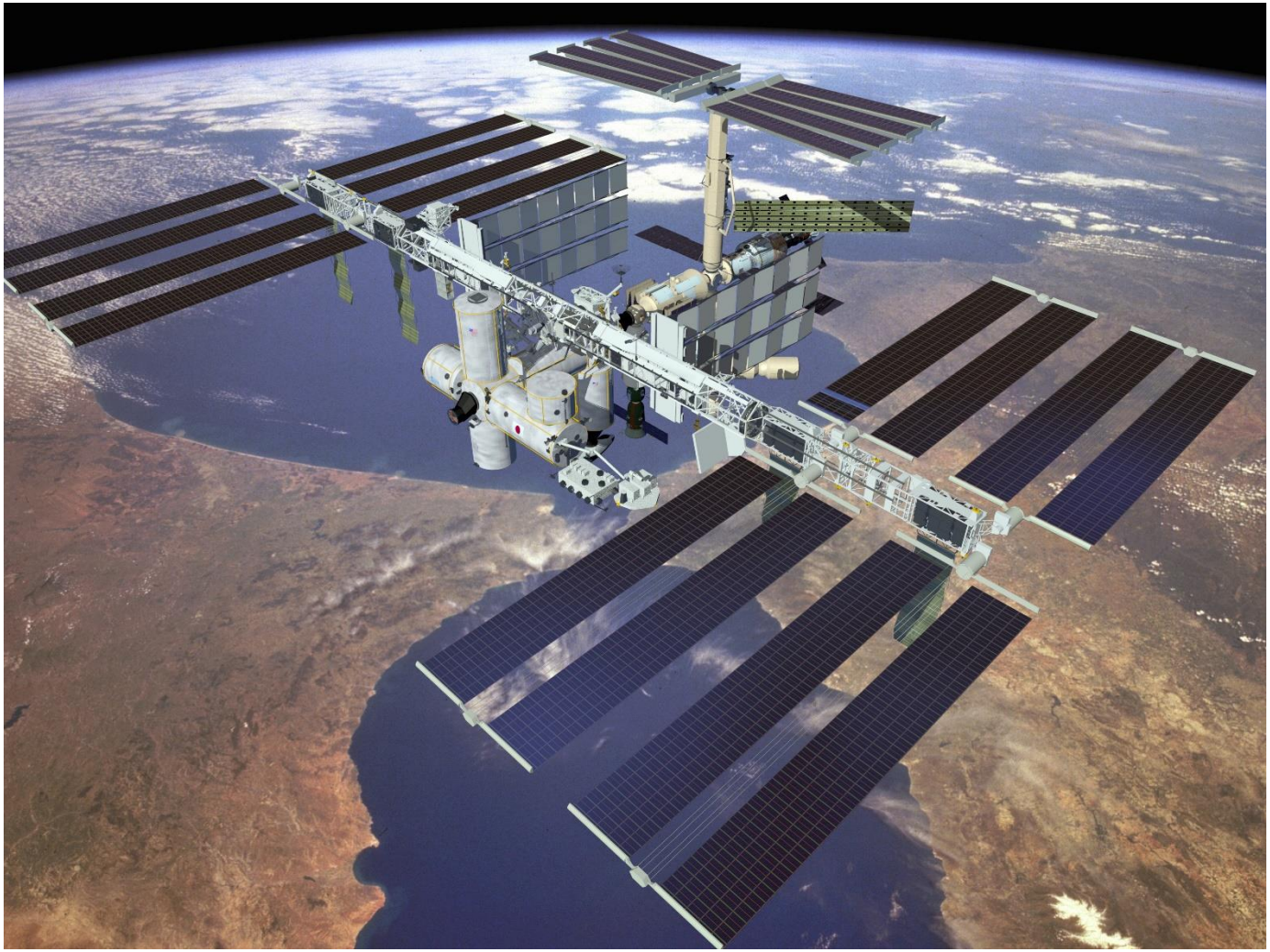
Albert Einstein explained the ***photoelectric*** effect in 1905 for which he received the Nobel prize in Physics in 1921

He was 26 years old!



Albert Einstein
1879-1955

Powering the International Space Station



Solar Powered Airplane!

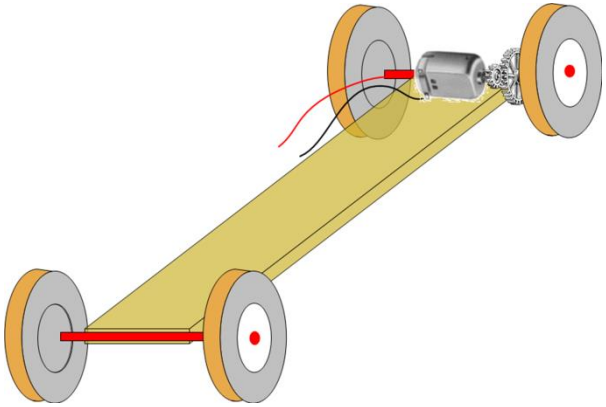
Solar Powered Cars

- A ***solar car*** is an electric car powered by **solar panels**
- Solar vehicles are primarily demonstration vehicles.

Engineering Our Solar Car

- Design Criteria: 5 mph within .5 sec from standing start
- Engineering Design:
    1. Weight of car -> Force required -> Torque required
    2. Motor RPM/Torque -> Gear ratio -> RPM/Torque at axle
    3. RPM of the axle - > Wheel size -> Speed (velocity) of car
    4. Motor -> Electric power required - > Voltage & Current
    5. Voltage & Current - > Number of Solar Panels -> Weight
    6. Back to #1

Let's Build The Chassis



Use foam board or corrugated plastic for the chassis.

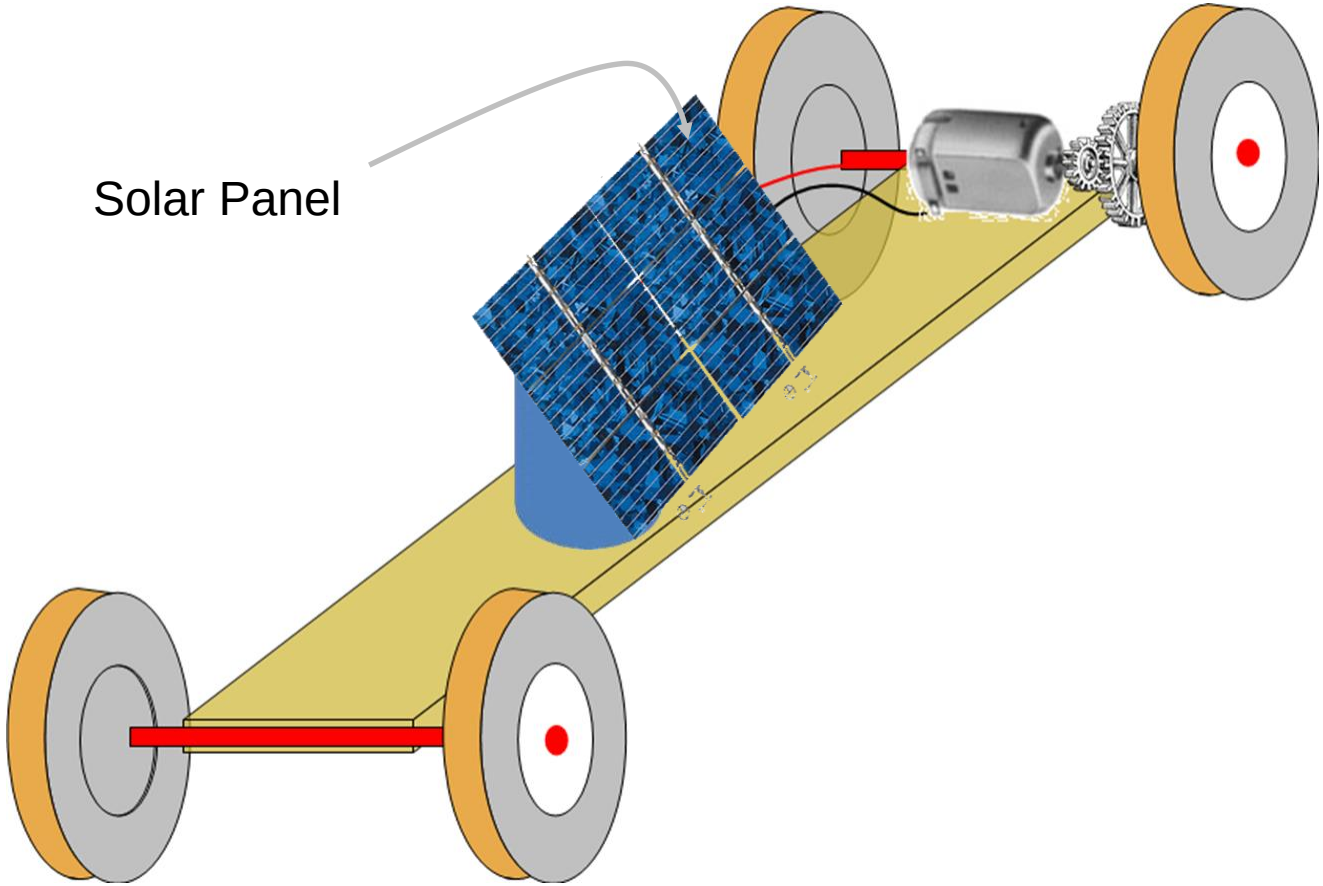
Cut the straw length a little wider than the chassis, but slightly less than the axle length..

Assemble the wheels and gears on the axles with the axles through straws, but leave a little slack between the wheels.
Make sure the axles are parallel.

Tape the straws firmly to the chassis; **Taping the straws to the ends of the chassis is the best way to get parallel wheels.**

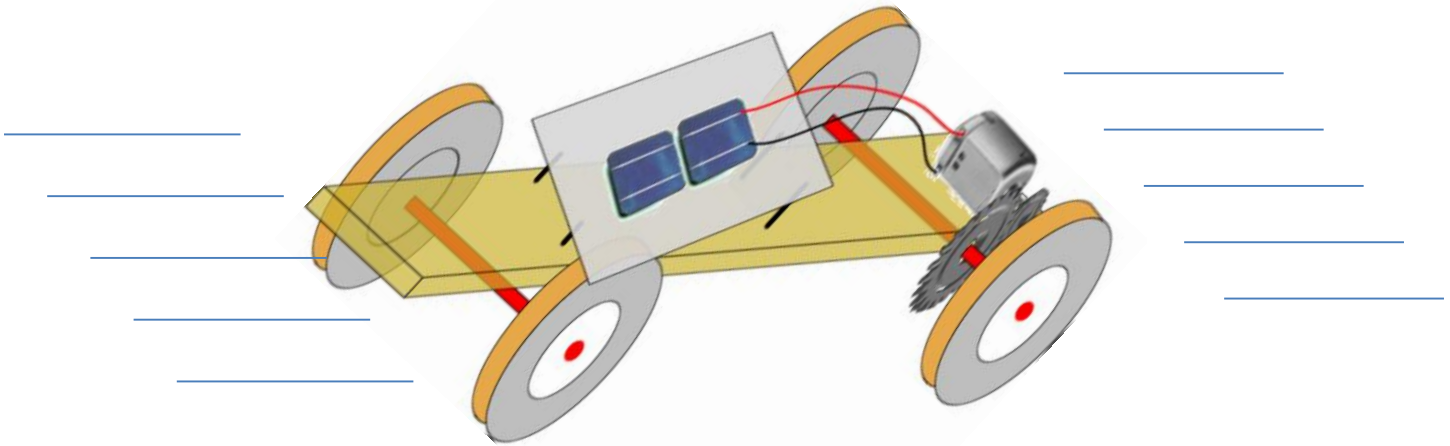
Clip the motor to the chassis on top of the chassis, NOT underneath the chassis (it will rub on the ground otherwise) and align the gears so they mesh, **but not too tightly.**

Let's Add the Solar Power



1. **Handle the solar panels gently; they are fragile! DON'T bend or cut them!**
2. **Keep the car as light weight as possible**
3. **Reverse the wires if the car runs backwards**

Let's Race!



What did we learn today?

- We explored the science, engineering, and technology of Electricity and Solar Energy
- All of the energy on earth comes from the sun*
- How solar cells work
- Electricity is the flow of electrons
- Series and Parallel circuits
- Use math to design machines

*(except nuclear)

Careers in STEM

Careers in Science and Engineering

- You must find your passion
- Financially and socially rewarding
- Continuous learning and training (education)
- Maybe even be another Albert Einstein!

Have Fun Today?

Check out our website: www.azsciencelab.org
click on the “For Students” tab!

Thanks for coming and exploring with us
the world of electricity and solar energy!

Important notes for this presentation:

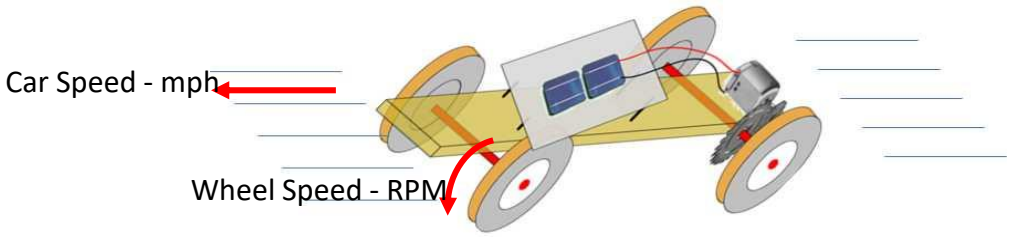
At the end of the presentation are four slides (#’s 63-66)explaining how to use simple math to calculate the speed of the cars, given a few parameters, like the motor speed, wheel diameter, and gear ratio.
The star and circle symbols are hyperlinks to the appropriate slides, Use the blue star (slide 50) to go to the animation, then the red star to return to slide 50. Complete clicking on slide 50, then, when finished, click the green circle to go to slide 52.

APPENDIX

Does the speed of the car depend on the size of the wheels?

Calculate the speed of a solar car with 1 inch diameter wheels, and a 4:1 gear ratio, using a 1.5 volt Mabuchi motor.

Problem: Calculate the speed of a solar car with 1 inch diameter wheels, and a 4:1 gear ratio, using a 1.5 volt Mabuchi motor.



Mabuchi motor Specifications

MODEL		VOLTAGE		NO LOAD		AT MAXIMUM EFFICIENCY					STALL		
		OPERATING RANGE	NOMINAL	SPEED	CURRENT	SPEED	CURRENT	TORQUE		OUTPUT	TORQUE		CURRENT
			V	r/min	A	r/min	A	mN·m	g·cm	W	mN·m	g·cm	A
FA-130RA	2270	1.5 - 3.0	1.5	9100	0.20	6990	0.66	0.59	6.0	0.43	2.55	26	2.20
	18100	1.5 - 3.0	3	12300	0.15	9710	0.56	0.74	7.6	0.76	3.53	36	2.10

Calculate the speed of a solar car with 1 inch diameter wheels, and a 4:1 gear ratio, using a 1.5 volt Mabuchi motor.

From the spec sheet, Motor speed = 6990 RPM, so Wheel speed = 6990/4 = 1747 RPM

Now, for 1 inch dia. Wheels, circumference = π x 1" = π inches

Look at this diagram

So, we see that 1 revolution of a 1" wheel travels 3.14"

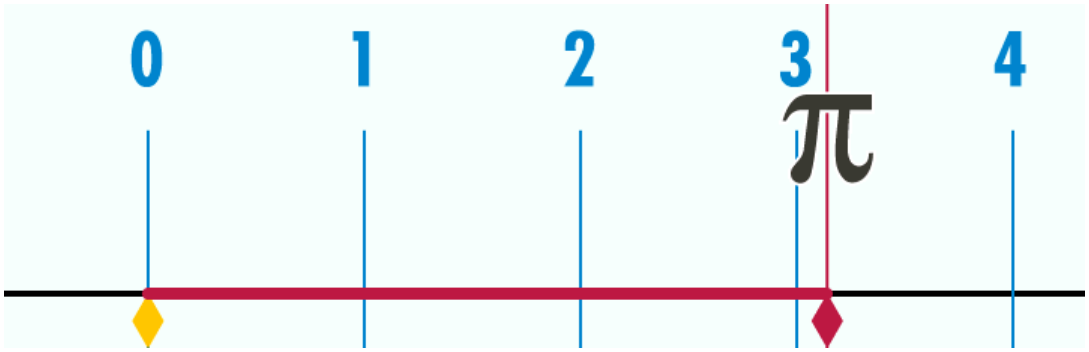
Therefore, 1747rev/min travels 1747 x 3.14" = 5487 inches/min

Now all we have to do is convert inches/min to miles/hours

5487 inches/min x 60 min./1 hour = 329,229 inches/hour

329,229 in/hr x 1 foot/12 in. x 1 mile/5,280 feet = 5.19 miles/hour

Our car will travel at approximately 5.2 mph!


0
1
2
3
π
4

Does the speed of the car depend on the size of the wheels?

Calculate the speed of a solar car with 1 inch diameter wheels, and a 4:1 gear ratio, using a 1.5 volt Mabuchi motor.

Does the speed of the car depend on the size of the wheels?

Calculate the speed of a solar car with 1 inch diameter wheels, and a 4:1 gear ratio, using a 1.5 volt Mabuchi motor.

Motor Speed – 6990 RPM, Wheel Speed – $6990/4 = 1747$ RPM

CIRCUMFERENCE (c) of 1" DIAMETER Wheel $= \pi \times 1" = 3.14"$

So 1 REVOLUTION $= 3.14"$

$1747 \frac{REV}{MIN} \times 3.14 IN = 5487 IN/MIN$

NOW $5487 \frac{IN}{MIN} \times \frac{60 MIN}{1 hr} = 329,229 \frac{IN}{hr}$

So $329,229 \frac{in}{hr} \times \frac{1 ft}{12 in} \times \frac{1 mile}{5280 ft} = 5.19 \frac{miles}{hr}$ or

5.2 mph