Electricity

- Electricity is the flow of electrons. It is a secondary energy source meaning that it is produced from other, primary, energy sources. There are several primary sources from which electricity is produced
- Electromagnetic induction produces electricity by the rotation of a coil through a magnetic field. The energy for this rotation can come from fossil fuel powered generators, steam driven power plants (with the steam produced from burning fossil fuels, the nuclear process, or from renewable sources like spinning hydro and wind turbines).
- Solar panels create electricity from light, by a process known as the photovoltaic effect.
- Batteries store electricity in chemical form –energy is released or absorbed through chemical reactions. Of course the batteries must be charged, so they are not really a source of energy, but rather are a form of energy storage.

Electrical Units

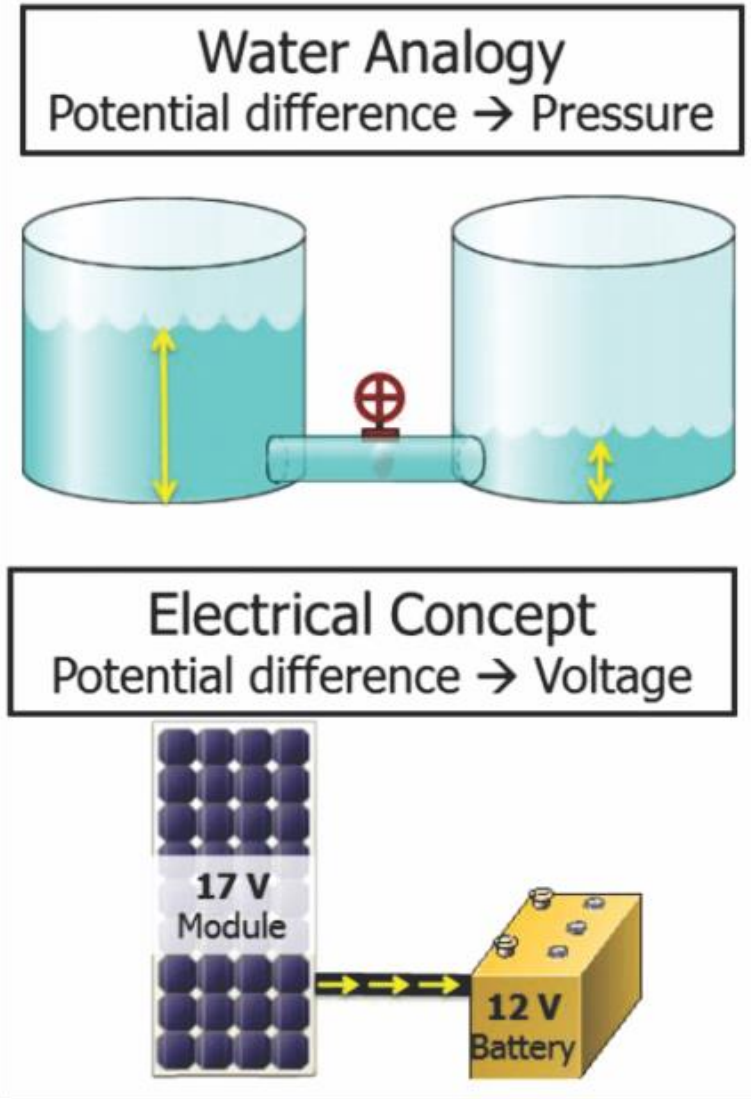
- There are three fundamental terminologies used in electricity:
  - Voltage
  - Current
  - Resistance

Voltage

- It is the quantitative expression of the potential difference in charge between two points in an electric field.
- It is the pressure that pushes electricity through conductors. Voltage is always measured by putting the leads of a multimeter on two points of an electric circuit (there is no need to disconnect the circuit).
- The greater the voltage, the greater the flow of current
- VOLTAGE is like the pressure that pushes water through the hose. It is measured in volts (V).

Voltage

- Volts(E or V)
- Electrical pressure or potential
- Unit for electromotive force

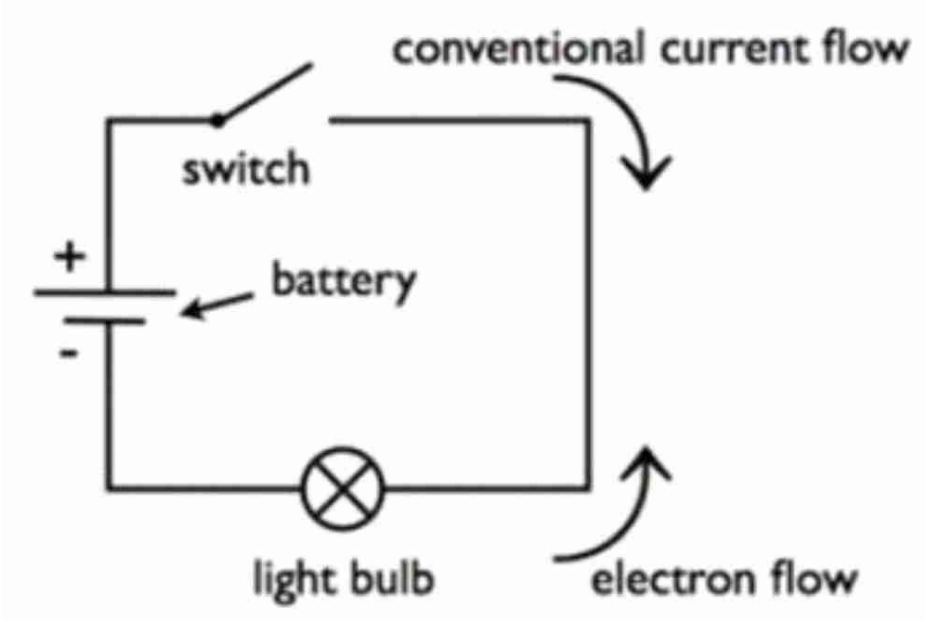


Electric current

- **Electric current is the rate of flow of electric charge** through a predetermined cross-sectional area in a conductor.
- Current is a measure of the ‘intensity’ of electricity flowing in a circuit
- Current flow in wire just like water flow in pipe. It is measured in **ampere**

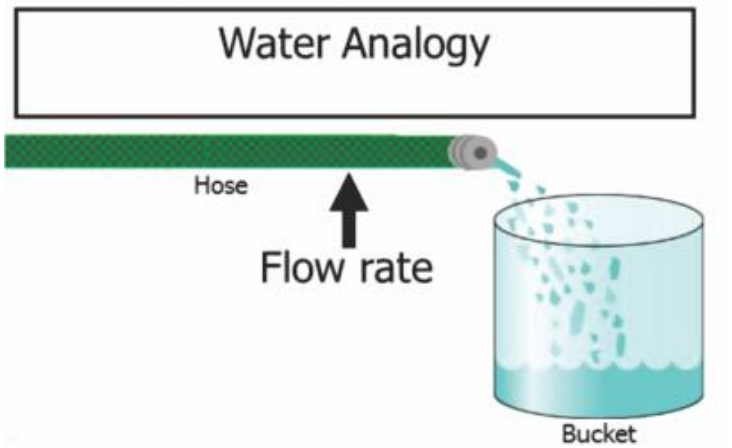
Current and Electron flow

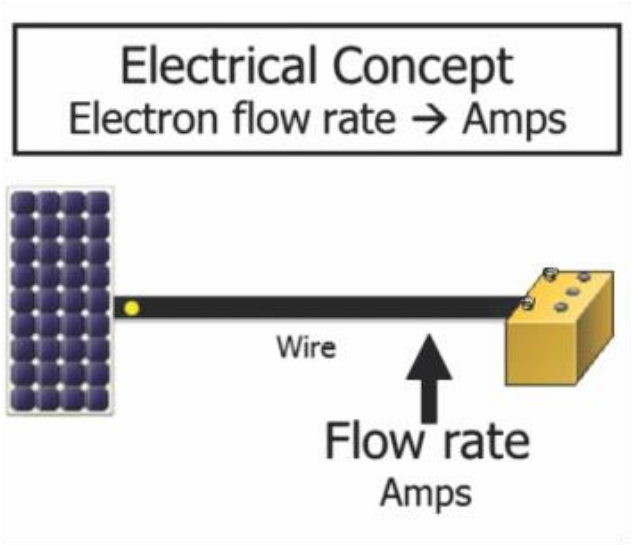
- In electrical circuit, electrons actually flow from the negative terminal to the positive terminal
- In conventional current, we assume they are following from positive to negative



Current or Amperage

- Amps(I or A)
- Rate of flow of electron in a conductor.
- Current and Amperage are interchangeably
- 1 amp = 1 coulomb/second



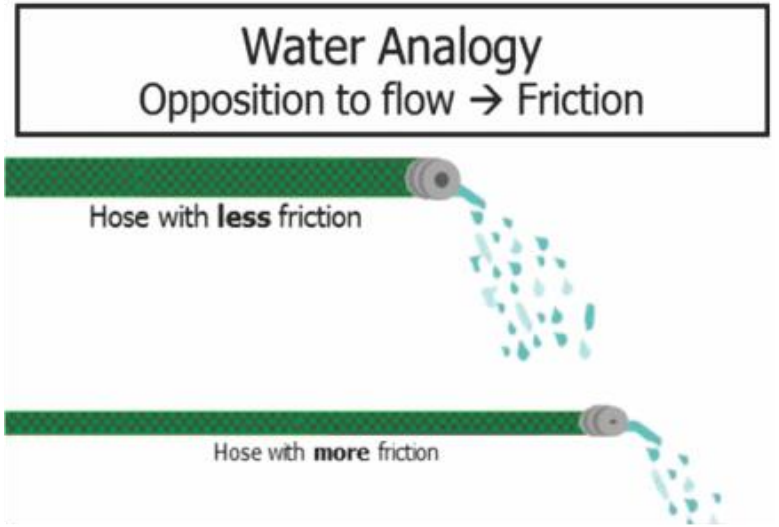


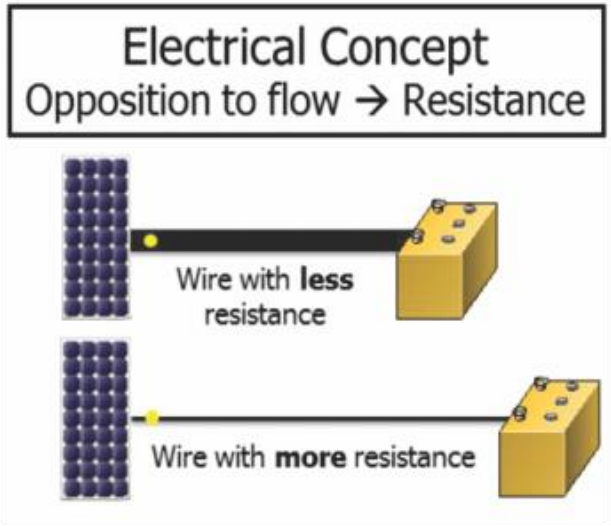
Resistance

- **Resistance (R) is the opposition to the flow** of electrical current in the material through which it is passing measured in ***Ohms. (Electrical friction)***
- The magnitude of resistance is dictated by electric properties of the material and material geometry.
- This behaviour of materials is often used to control/limit electric current flow in circuits. Henceforth, the conductors that exhibit the property of resisting current flow are called resistors.

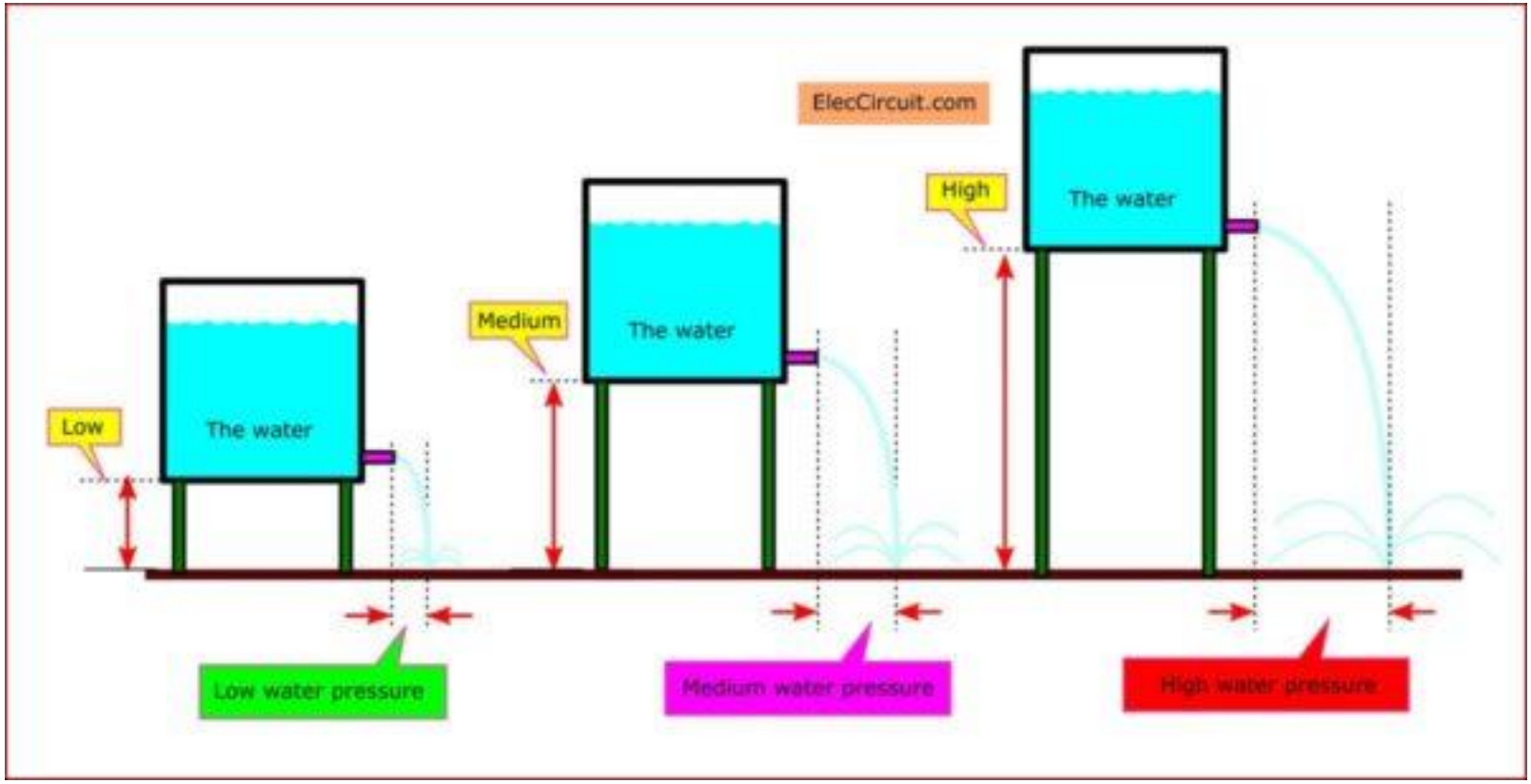
Resistance

- Resistance depends on
  - Material
  - Cross sectional area
  - Length
  - Temperature





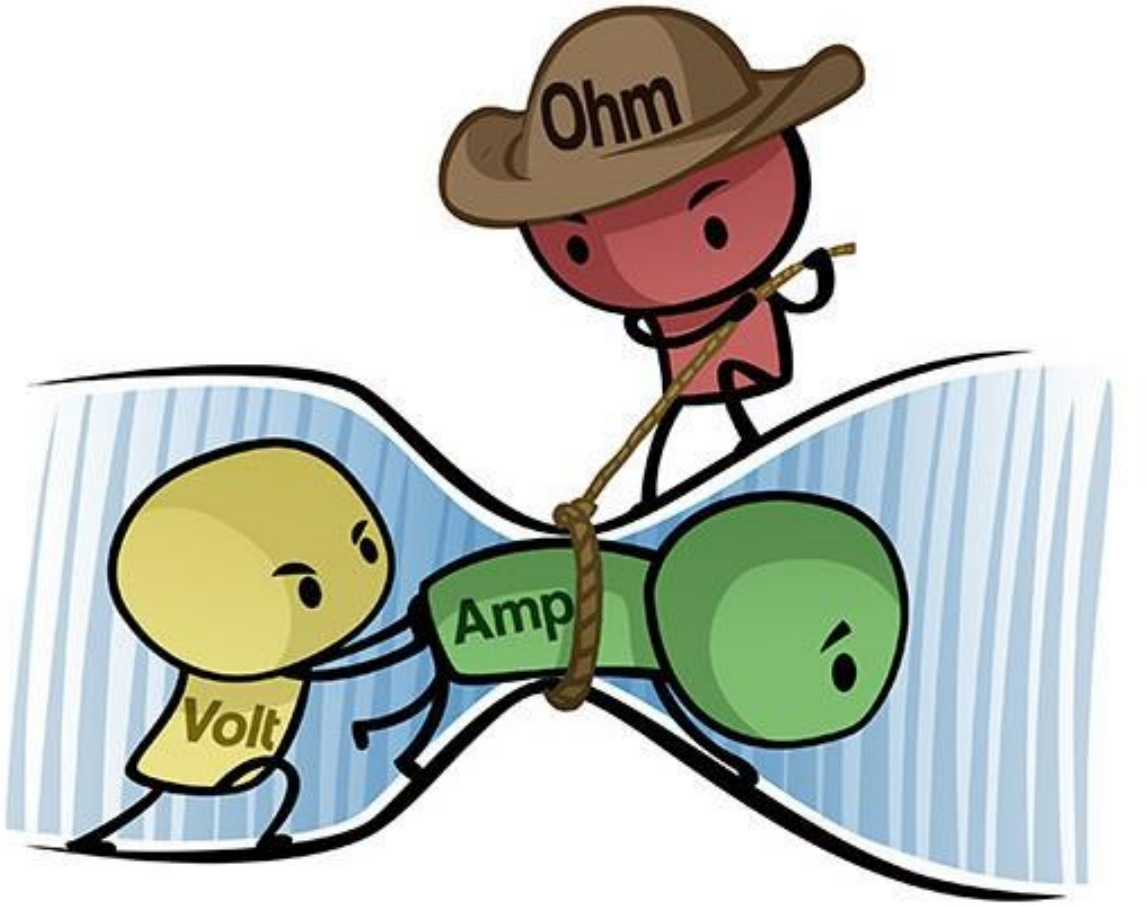
Electricity/Water Analogy



Comparison

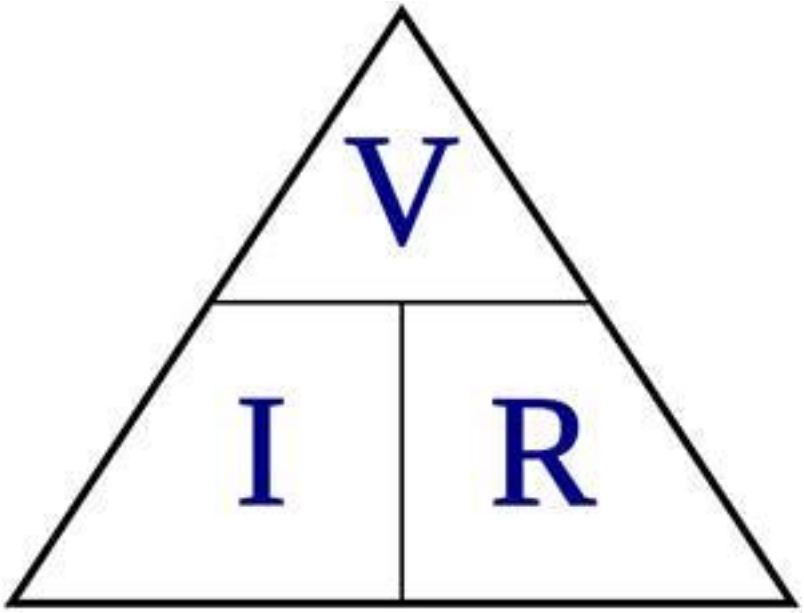
QUANTITY	SYMBOL	METRIC UNIT	ABBREVIATION
CURRENT	I	AMPERE OR AMP	A
VOLTAGE	V	VOLT	V
RESISTANCE	R	OHM	Ω

Relationship between current, voltage and resistance



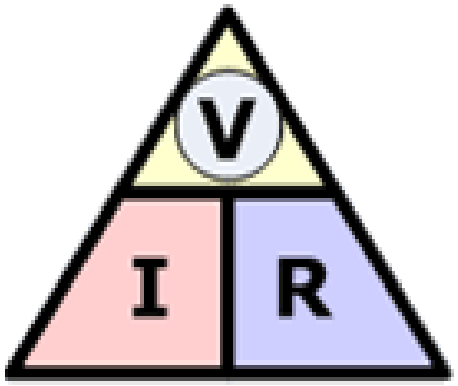
Ohm’s Law

- Ohm's law states that the current in an electrical circuit is directly proportional to the applied potential difference and inversely proportiona to the resistance of the circuit.
- In other words by doubling the voltage across a circuit, the current will also double.
- Ohm’s law describes the way current flows through a material when different levels of voltage is applied.

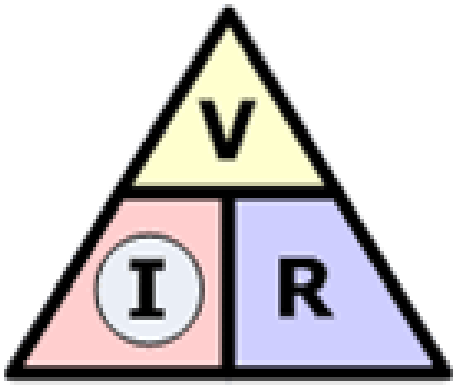


Ohm's Law

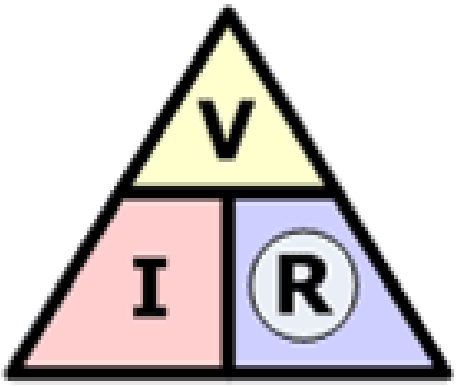
The 3 most common mathematical expressions are:



$$V = I \times R$$



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



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

Power and Energy

- **Power** is the rate of doing work or of transferring heat, i.e. the amount of energy transferred or converted per unit time. Having no direction, it is a scalar quantity. In the International System of Units, the unit of power is the joule per second (J/s), known as the watt (W) in honour of James Watt

- Power is the rate of electrical energy consumption or generation

- **Energy(E)** is the amount of power being produced or consumed, in watts, during a period of time, in hours. Watts times hours equals ***Watt hours***

Wattage = Power

- 1000 Watts = 1kW (Kilowatt)
- 1,000,000 Watts = 1000kW = 1MW (Megawatt)
- 1,000,000,000 Watts = 1,000,000 kW = 1,000 MW = 1 GW(Gigawatt)

Relationship between Watts, Volts and Amps

V x A = W (Volts x Amps = Watts)

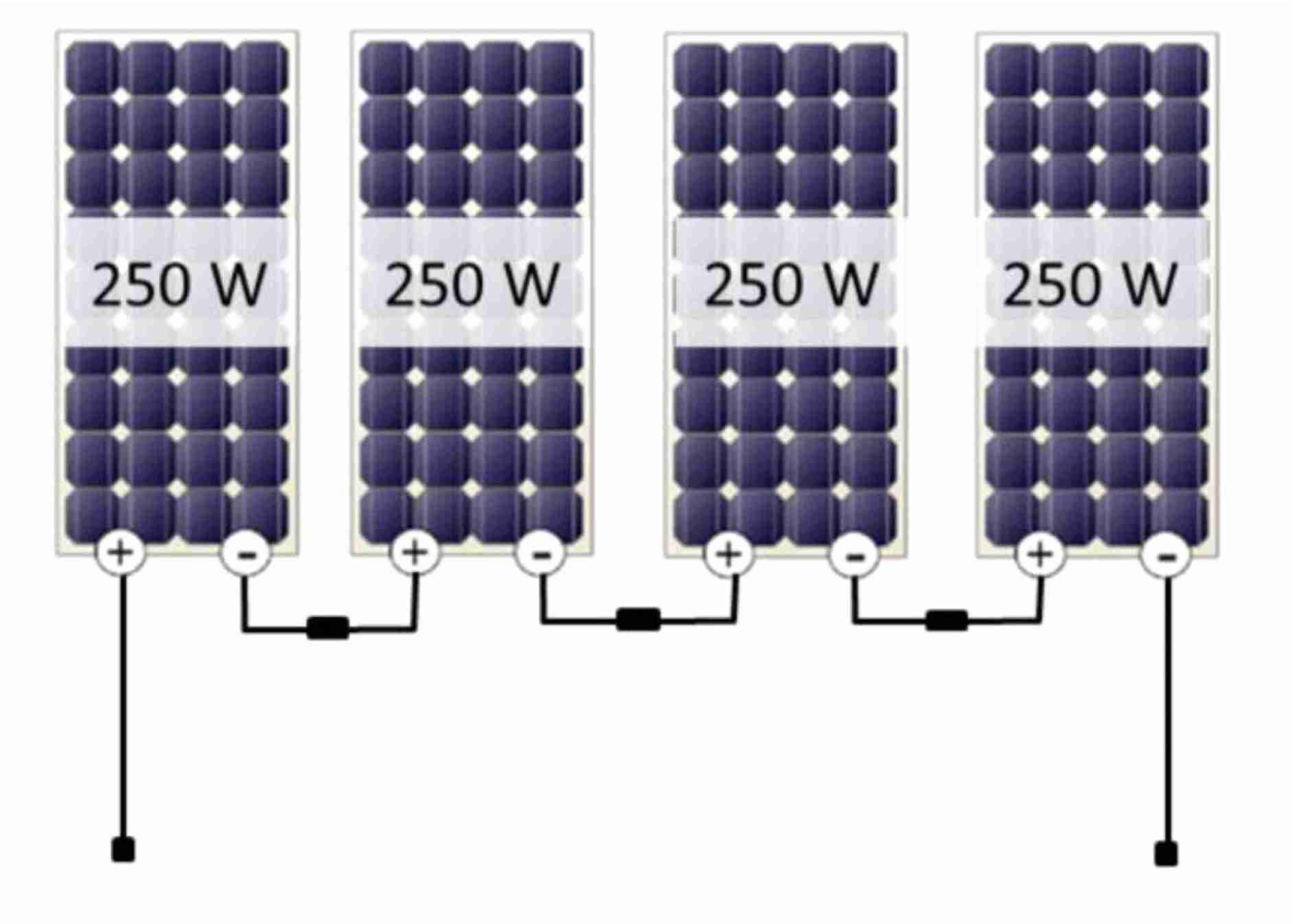
24 V	x	100 A	=	2,400 W
48 V	x	50 A	=	2,400 W
120 V	x	20 A	=	2,400 W
240 V	x	10 A	=	2,400 W
480 V	x	5 A	=	2,400 W

Voltage and current are inversely proportional

Power rating of solar array

- A common way to quantify a PV system is by the DC size of the PV array, either in watts or kilowatts.
- Common phrases include things such as “6 kW grid-direct”, or “4 kilowatt stand-alone, or “200 watt DC.”
- These numbers are sum of the wattage of the individual panels in the array, or the size of an individual module itself.
- In the array pictured there are four 250 watt modules, for a total of 1,000 watts. This could also be called a 1 kilowatt array.

What is the power of this Array?



250 W x 4 modules = 1,000 W = 1kW

Watt-Hours = Energy

Energy = Power(W) for a period of time (h) = Wh

- Watts x hours = Watt-hours(rate x time)
- Total work performed (Production or consumption)

How much energy is used if a 10W light bulb is on for 3 hours? 30 Wh
How much energy is used if a 40W fan runs for5 hours? 200 Wh

1,000 Wh = 1 kilowatt-hour (kWh)
1,000 kWh = 1 megawatt-hour (MWh)
1000 MWh = 1 gigawatt-hour(GWh)

Formulas

- Power = Volts x Current - P = V X I (Watts)
- Volts = Power ÷ Current - V = P ÷ I (Volts)
- Current = Power ÷ Volts - I = P ÷ V (Amperes)
- Resistance = Volts ÷ Current - R = V ÷ I (Ohms)
- Energy = Power x Time - E = P x t (Watt-Hours)

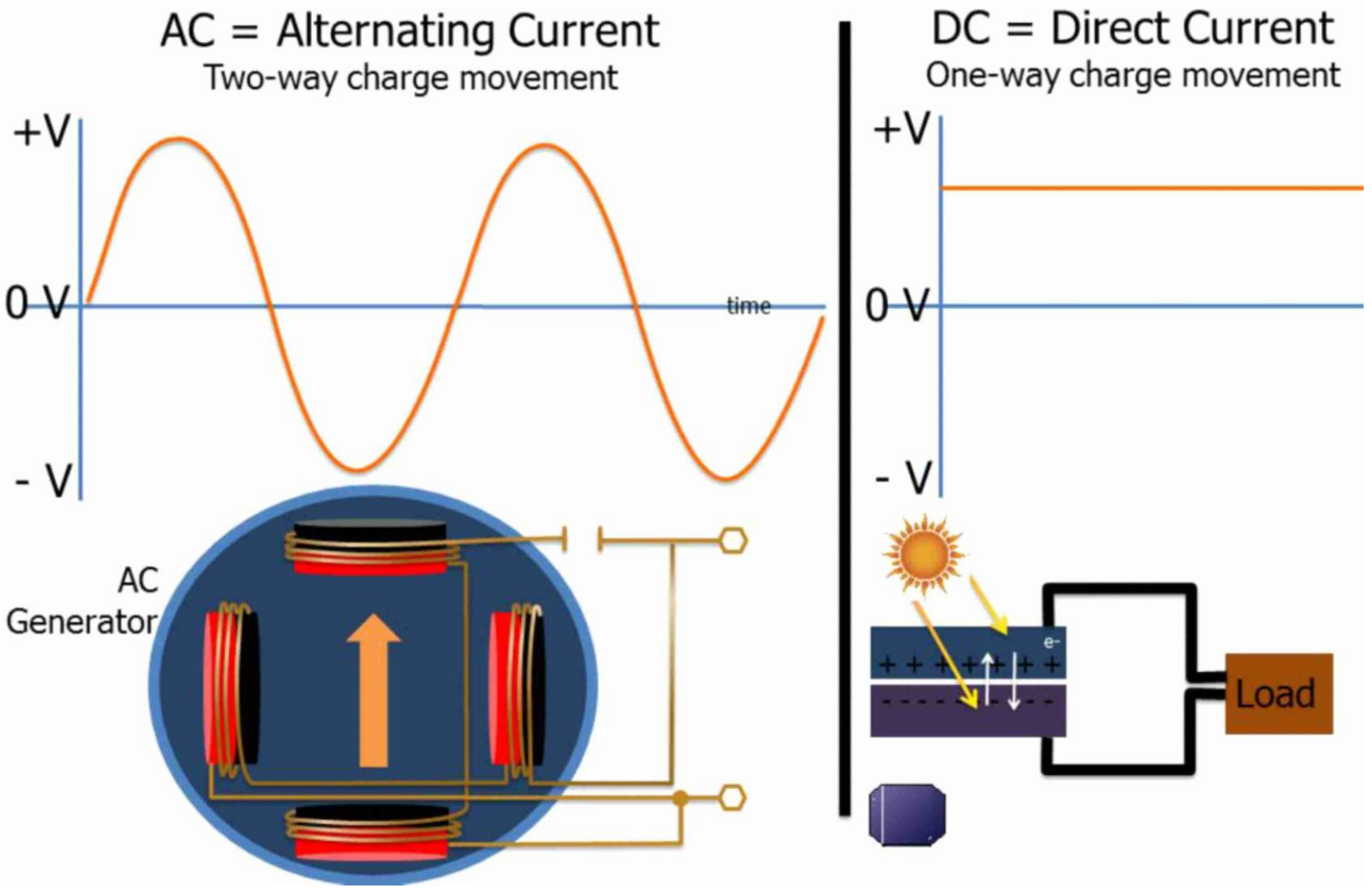
Application in Energy Auditing

- All appliances will have their power consumption in watts listed on a placard or label near the AC cord

The Label on an electric pan indicating a power rating of 1400W

The label on a fan indicating a power rating of 120W

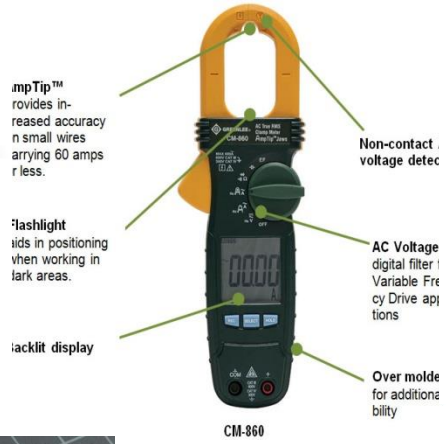
Types of Electrical current

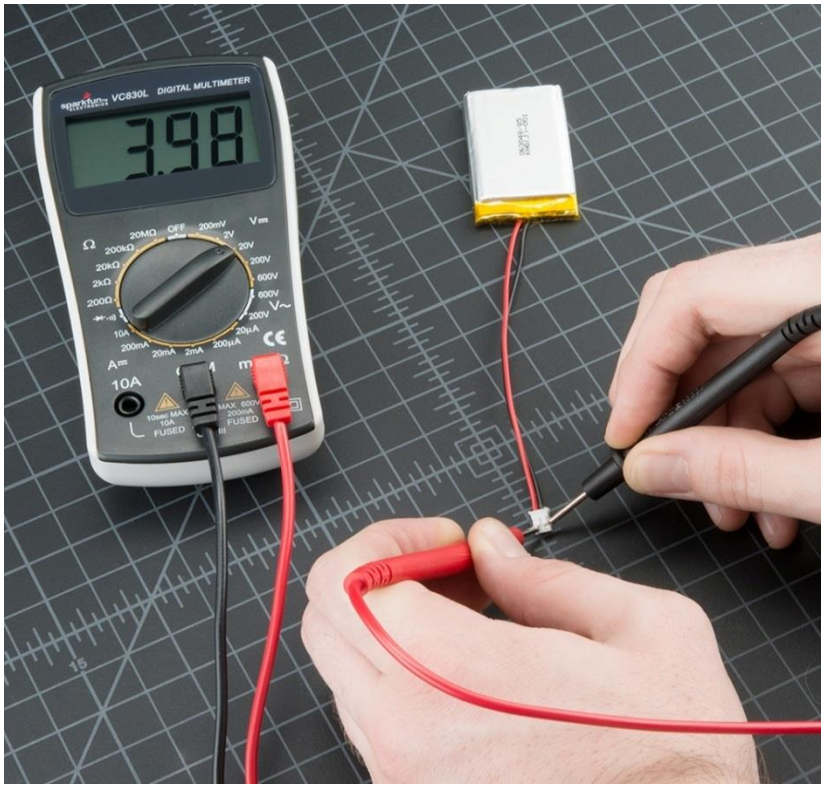


Some key differences between AC and DC

	Alternating Current	Direct Current
Amount of energy that can be carried	Safe to transfer over longer distance and can provide more power.	Cannot travel very far until voltage drop will start to affect it hence there will be loss of energy.
Frequency	The frequency of alternating current is 50Hz or 60Hz, as indicated on most appliances	The frequency is zero.
Direction	Reverses its direction at frequent, regular intervals while flowing in a circuit.	Flows in one direction in a circuit.
Current	It is the current of magnitude varying with time	It is the current of constant magnitude.
Flow of electrons	Electrons keep switching directions - forward and backward.	Electrons move steadily in one direction or 'forward'.
Obtained from	A.C Generator and mains.	Cell or Battery.
Storage	Cannot be stored	Can be stored in batteries.

BASIC MEASURING EQUIPMENTS AND TOOLS





Handling measuring equipment

- Measuring equipment are very important tools that are designed to give the most precise measurement of the various dimension on which they are used to determine.
- The smallest inaccuracy in measurement as a result of a fault from measuring tools can result in the damage of sensitive equipment and loss of life in extreme situations.
- Basically, measuring equipment are useless if they cannot give reliable and accurate results. Therefore it is important they are kept in good condition at all time.

Ways of maintaining measuring equipment

- Have dedicated space for them.
- Avoid putting them on wet places or under extreme temperature.
- Carry out regular professional maintenance for them.
- Ensure that they are properly handled, cleaned and lubricated.
- Ensure that each equipment is used according to the manufacturers Manuel.

Using a multimeter

- A **multimeter** is also known as an AVO, current-volt-ohm meter, or a multitester. These can be used to test many types of electrical devices for problems such as shorts or a broken circuit. The best wire tester is a multimeter that provides both voltage and continuity testing

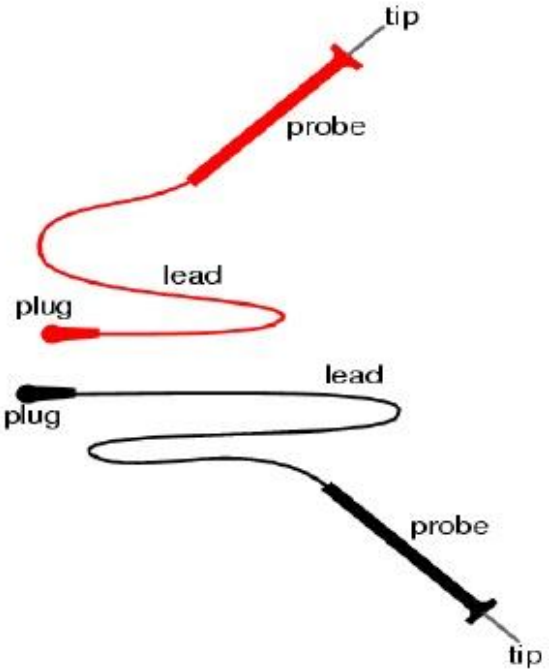
Multimeter

Meter leads

•**Red** meter lead
Is connected to Voltage/Resistance or amperage port
Is considered the positive connection

•**Probes**
Are the handles used to hold tip on the tested connection

•**Tips**
Are at the end of the probe and provides a connection point



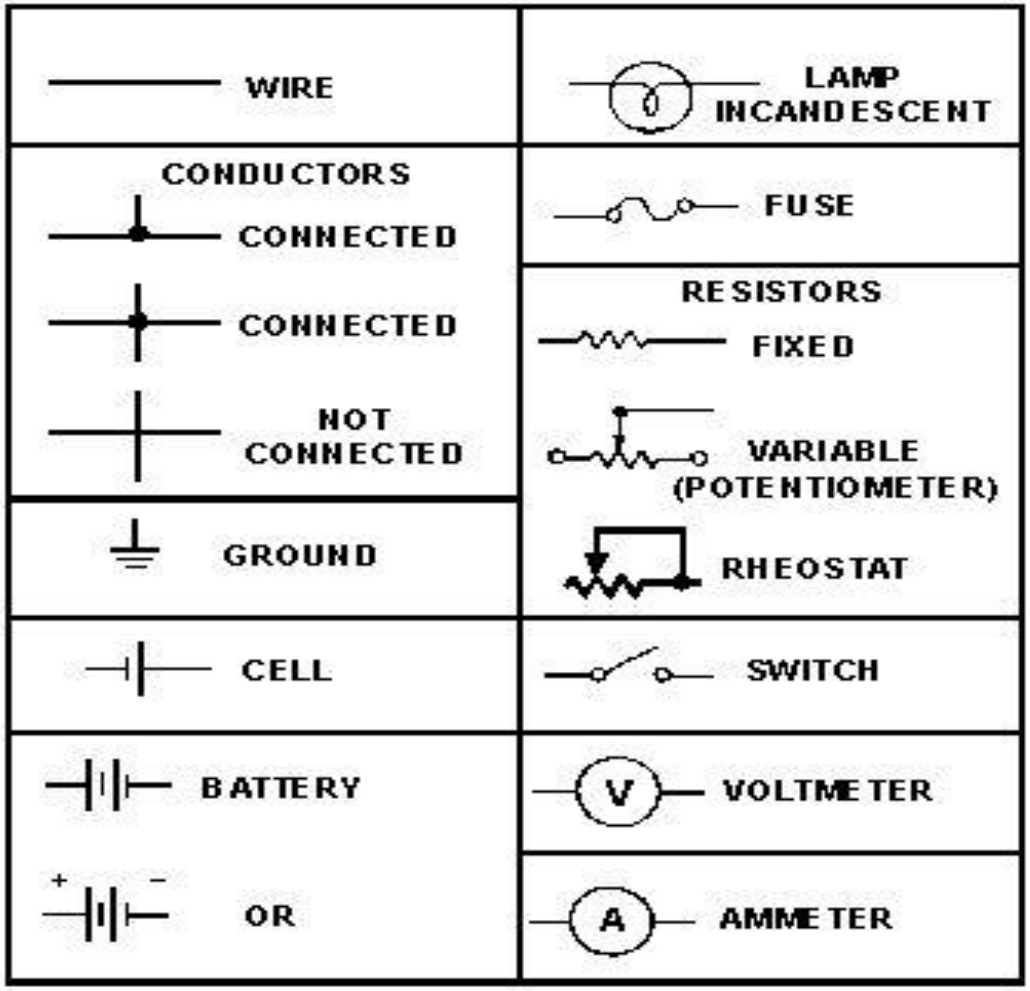
•**Black meter lead**
Is always connected to the common port
Is considered the negative connection

Multimeter symbols

Front Panel Symbols

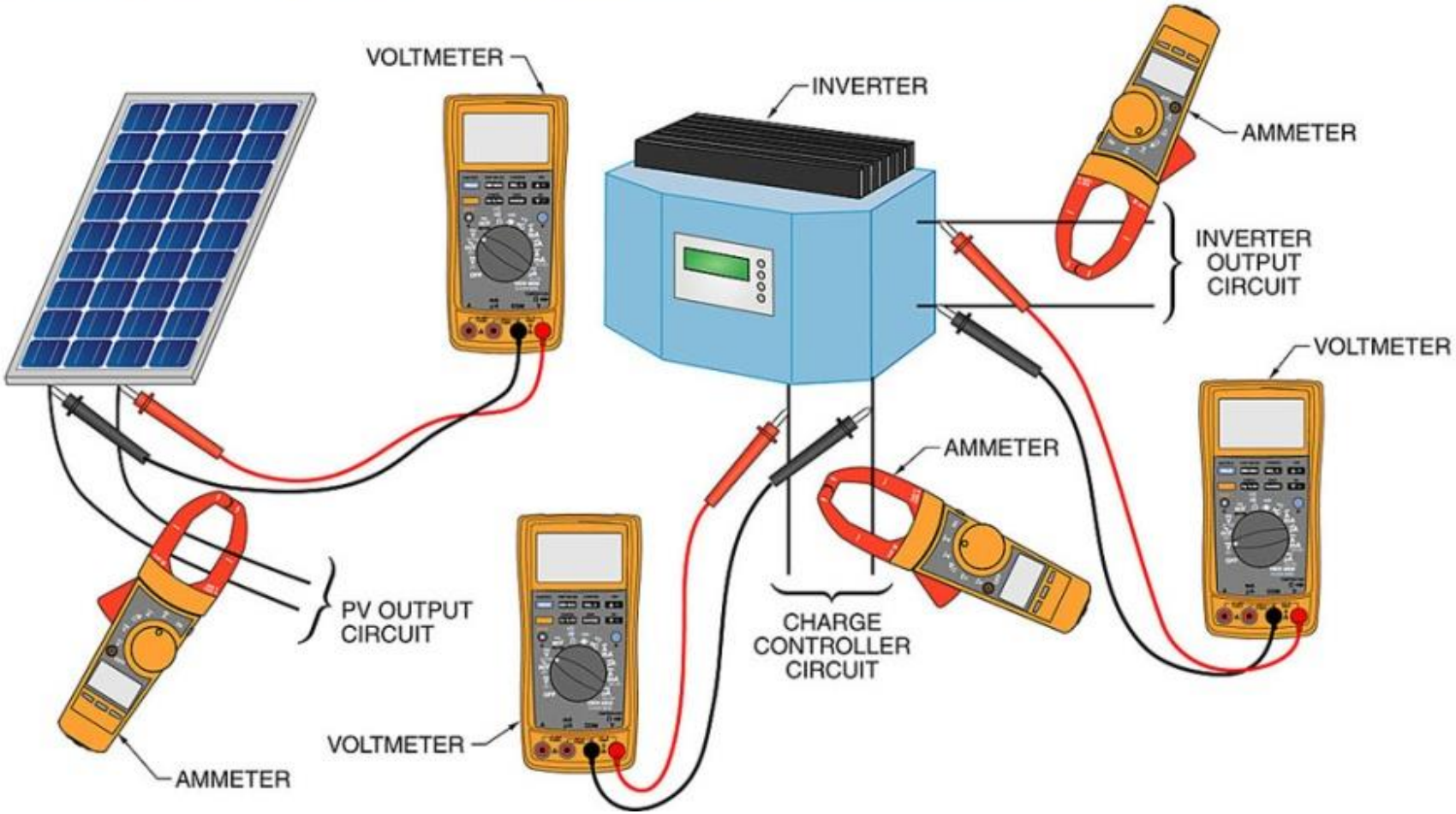
Symbol	Meaning
V ⎓	V DC
V ∿	V AC
mV	millivolts (.001V or 1/1,000V)
A	Amps
mA	milliamps (.001A or 1/1000A)
µA	microA (.000001A or 1/1,000,000A)
Ω	Resistance (Ohms)
k Ω , M Ω	kilo-Ohms, Megohms
))))	Continuity beeper

Electrical Symbols

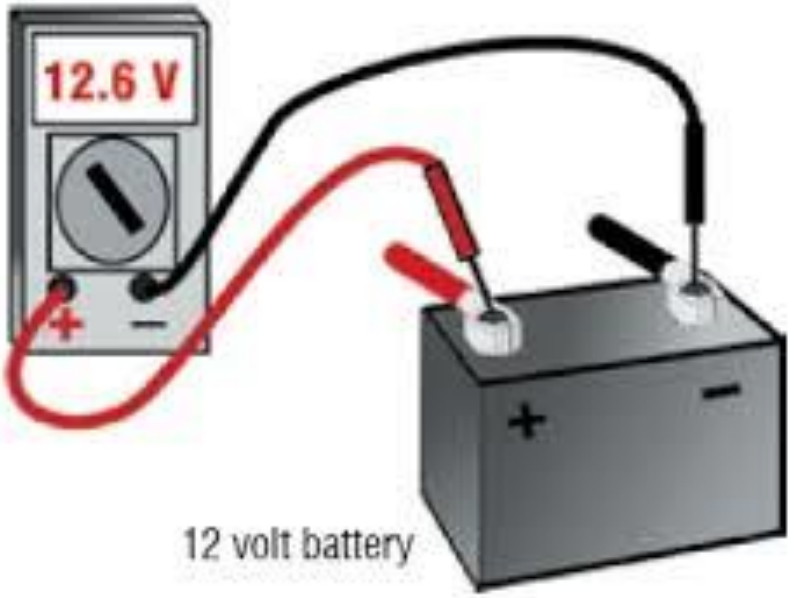


How to measure PV

Primary Monitoring Points



How to measure battery voltage



Thank you for your attention

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