

ESCI-61

Introduction to Photovoltaic Technology

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Basics of Electricity for PV



Electrons

- Matter is made of atoms
- An atom is made of a nucleus and several electrons (negatively charged) orbiting around the nucleus
- The nucleus is made of protons (positively charged) and neutrons (electrically neutral)
- Electrons and protons attract one another because they have opposite electric charges
- The atom is electrically balanced because the number of positive and negative charges are the same



Electricity

- Under certain conditions, electrons may be knocked out of their orbits and become free electrons that can move to another nucleus
- Electricity is the continuous movement of free electrons from atom to atom



Electric Current

- Current is a measure of the flow of electrons through matter
- Current is measured in Amperes (Amps)
 - $1 \text{ A} = 6.28 \times 10^{18}$ electrons per second



Electric Resistance

- Every conductor offers some resistance to current flow
- Electric resistance causes conductors to heat up when traversed by electric current
- Conductor resistance depends on conductor type and size (length and section area)



Electric Resistance

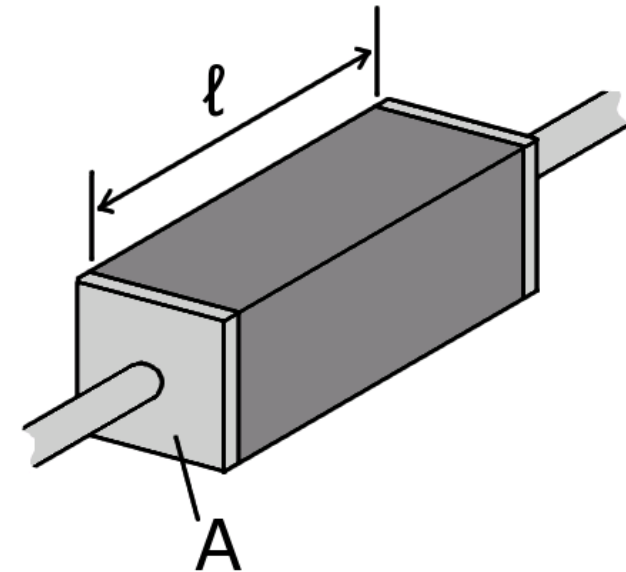
$$R = \rho \frac{l}{A}$$

R : resistance (Ω , Ohm)

ρ : resistivity (Ωm)

l : wire length (m)

A : wire section area (m^2)



Resistivity of Various Materials

Material	ρ ($\Omega\cdot\text{m}$) at 20 °C
Silver	1.59×10^{-8}
Copper	1.68×10^{-8}
Gold	2.44×10^{-8}
Aluminum	2.82×10^{-8}
Calcium	3.36×10^{-8}
Tungsten	5.60×10^{-8}
Zinc	5.90×10^{-8}
Nickel	6.99×10^{-8}
Iron	1.0×10^{-7}
Platinum	1.06×10^{-7}

Material	ρ ($\Omega\cdot\text{m}$) at 20 °C
Carbon	3.5×10^{-5}
Sea Water	2×10^{-1}
Germanium	4.6×10^{-1}
Silicon	6.40×10^2
Hard Rubber	$\sim 10^{13}$
Glass	10^{10} to 10^{14}
Sulfur	10^{15}
Paraffin	10^{17}
Quartz	7.5×10^{17}
Teflon	10^{22} to 10^{24}



Voltage

- Voltage is the electric pressure that causes electrons to move from one atom to another
- Voltage is a measure of a potential difference between two points along a conductor



Electricity-Water Analogies

Electricity

Current



Voltage



Battery



Generator



Wire



Water

Flow

Pressure

Water Tower

Pump

Pipe



Conductors

- Materials made of atoms whose electrons are easily freed
- most metals are good conductors of electricity
- Silver, Copper, Gold, and Aluminum are examples of very good Conductors of electricity
 - Copper and Aluminum are conductors that have a good performance/cost ratio
 - Silver, Gold, Platinum and others are commonly used microelectronics, high quality audio components, computer chips, and telecommunications satellites because they react/corrode less than some of the other conductive materials



Insulators

- Insulators are materials that have structural properties exactly opposite of conductors. These materials are made up of atoms whose electrons are not easily "freed". These electrons are said to be tightly bound to the nucleus, and are very stable.
- Insulators are used to prevent the flow of electrical current. The rubberized power cord and plastic coverings on appliances are typical examples of insulators. Glass, rubber, porcelain, and most plastics are good insulators.



Electric Power

- Power is a measure of the amount of work an electric current can accomplish in a specified period of time
- Power is the rate at which electrical energy is converted into some other form of energy such as light, heat or mechanical work
- the most common unit of electrical power measurement is the watt, or kilowatt, but motor manufacturers still rate motors in units of horsepower
 - one horsepower equals 746 watts



Electric Energy

- Electrical energy is the average amount of power used over a given period of time
- Energy is generally measured in Joules, but electric utilities usually measure their customers' electricity usage in kilowatt-hour



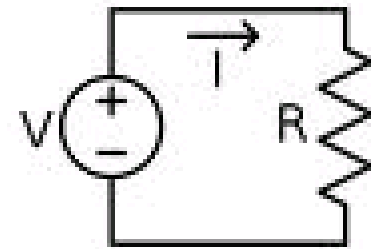
Ohm's Law

- Current (I) through a conductor between two points is directly proportional to the Voltage (V) across the two points, and inversely proportional to the Resistance (R) between them

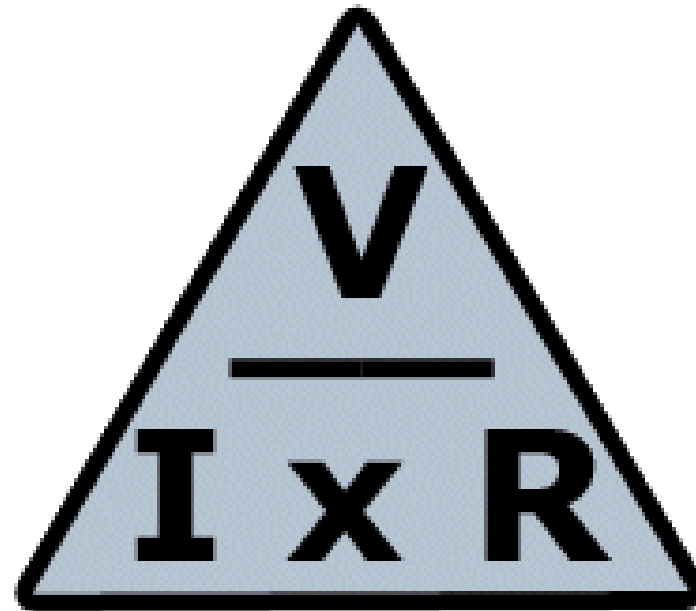
$$I = \frac{V}{R}$$

$$V = RI$$

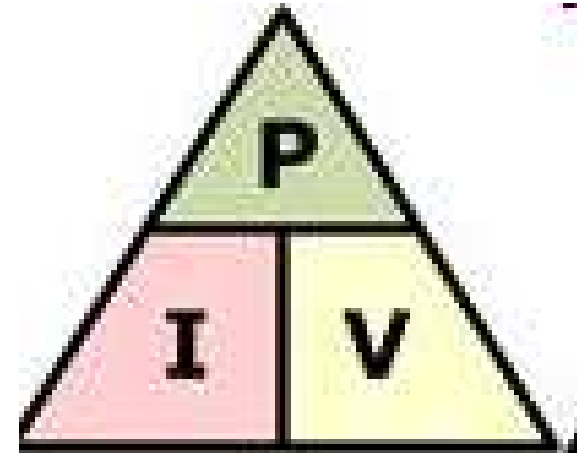
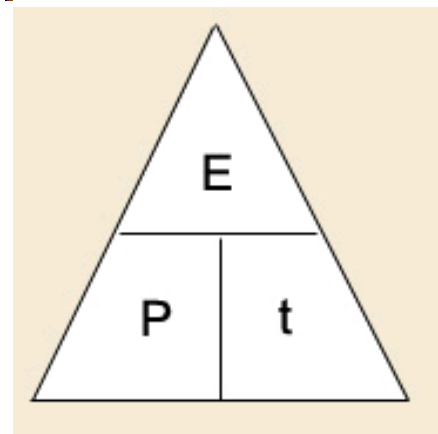
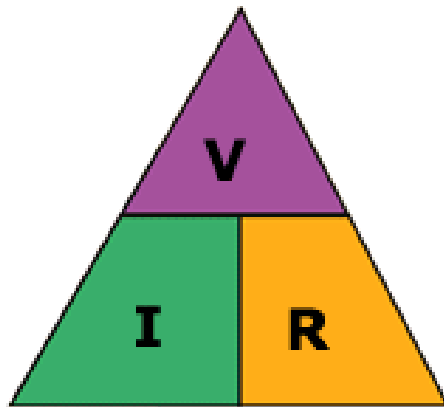
$$R = \frac{V}{I}$$



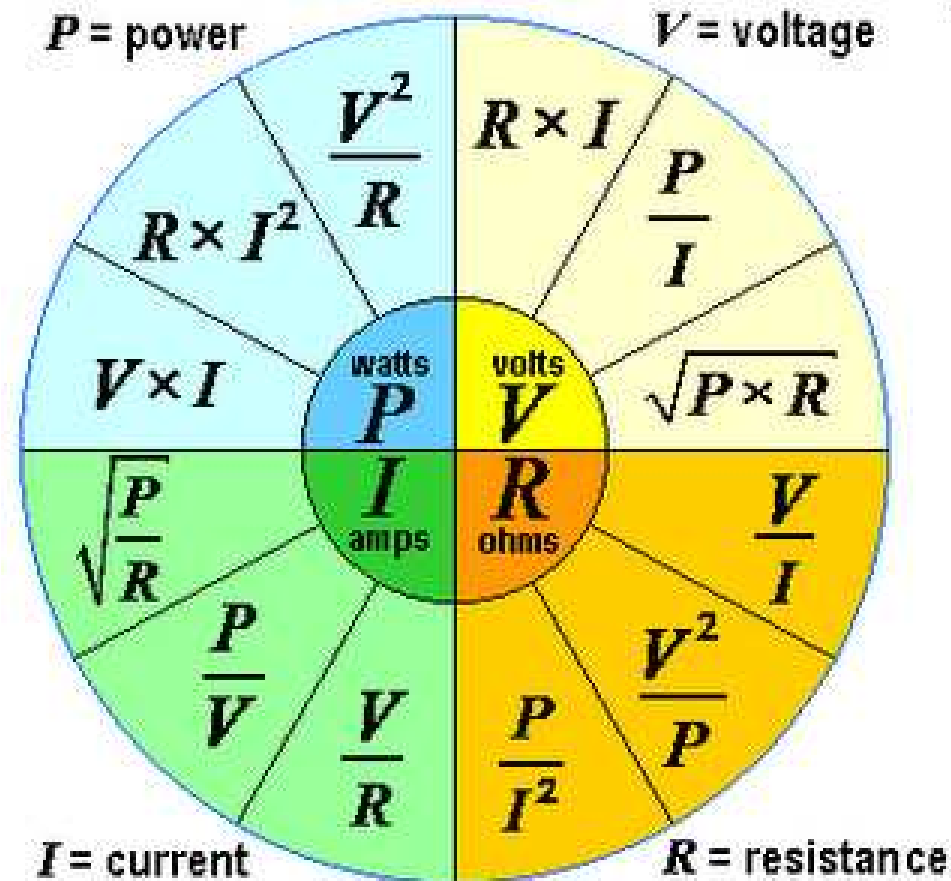
Ohm's Law Triangle



More Triangles!



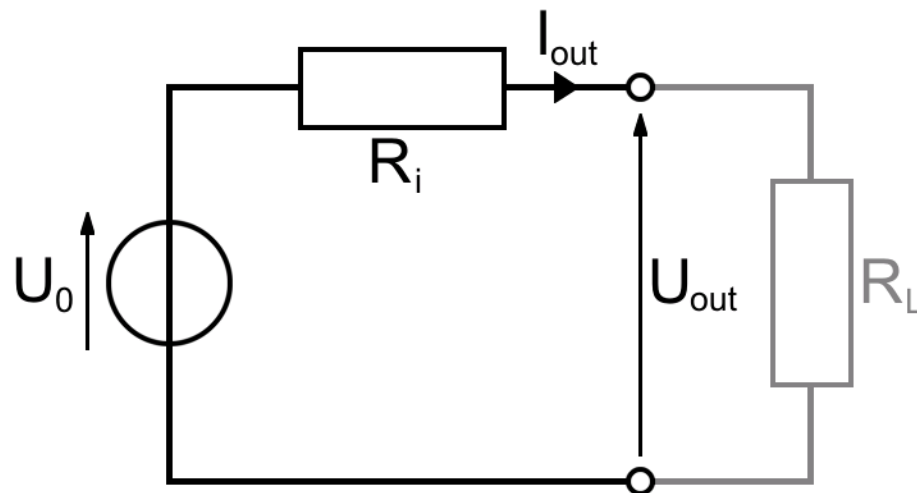
Solving Ohm's Law



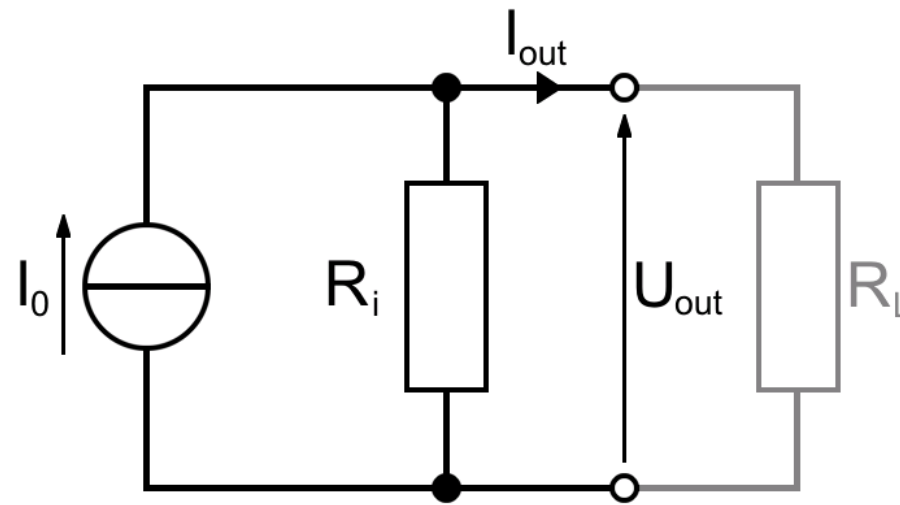
Mistakes can be disastrous!



Voltage Sources



Current Sources



Basic Electrical Model of a Photovoltaic Cell

