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ESCI-61
Introduction to Photovoltaic Technology

Ridha Hamidi, Ph. D.

Basics of Electricity for PV

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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

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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

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Electric Current

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

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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)

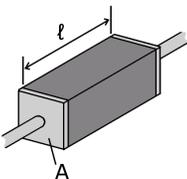
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Electric Resistance

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

R : resistance (Ω , Ohm)
 ρ : resistivity (Ωm)
l : wire length (m)
A : wire section area (m^2)



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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

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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.

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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

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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

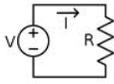
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Ohm's Law

- 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

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



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Ohm's Law Triangle



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More Triangles!

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Solving Ohm's Law

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Mistakes can be disastrous!

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Voltage Sources

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Current Sources

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Basic Electrical Model of a Photovoltaic Cell

Photovoltaic I V Characteristics

Decreasing Light Intensity → Decreasing R_{sh}

Increasing Temperature → Increasing R_s

Photovoltaic Cell DC Equivalent Circuit Illuminated

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