International Association Of Certified Practicing Engineers	**INTERNATIONAL ASSOCIATION OF CERTIFIED PRACTICING ENGINEERS** **www.iacpe.com** **Knowledge, Certification, Networking**	**Rev: 01** **Rev. 01 – Feb 2015**
IACPE No 19, Jalan Bilal Mahmood 80100 Johor Bahru Malaysia	**ELECTRICAL THEORY AND APPLICATION** **LEVEL TWO** **TRAINING MODULE**	

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INTRODUCTION

Scope

Electrical Theory and their applications is one of the fastest growing fields that involves the study and application of electricity and electronics. A basic understanding of electricity and electrical systems is necessary for all engineers, operators, maintenance personnel, and technical staff to safely design, operate and maintain the facility and facility support system.

This training module provides an overview of the basic electrical concepts and introduction to electrical terminology. The knowledge of the electrical theory and application is essential to understand electrical and electronic communications. This module will also review the basics of generation, transmission and distribution of electricity.

General Considerations Discussion

A. Fundamental of Electrical Theory

Elements are the basic building blocks of all matter. The atom is the smallest particle of an element. An atom consists of a positively charged nucleus surrounded by negatively charged electrons, so that the atom as a whole is electrically neutral. The nucleus is composed of two kinds of subatomic particles, protons and neutrons. The proton is a single unit positive charge equal in magnitude to the electron charge. The neutron is slightly heavier than the proton and is electrically neutral, as the name implies. These two particles exist in various combinations, depending upon the element involved. The electron is the fundamental negative charge (-) of electricity and revolves around the nucleus, or center, of the atom in concentric orbits, or shells. The proton is the fundamental positive charge (+) of electricity and is located in the nucleus. The number of protons in the nucleus of any atom specifies the atomic number of that atom or of that element.

Electrostatic (Static Electricity)

The electron and the nucleus attract each other and this is called the electrostatic force. It is also the force that holds the electron in orbit. Without this electrostatic force, the electron which is traveling at high speed, could not stay in its orbit. The force that results in an electrostatics field exists around each charged particle or object. This electrostatic field, and the force it creates, can be illustrated with lines called “lines of force” as shown in figure 1.

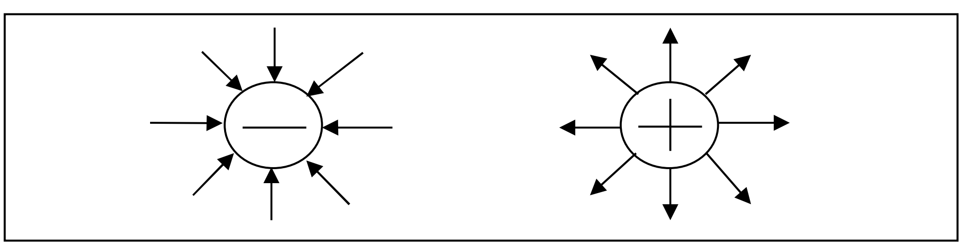

Figure 1. Electrostatic Field

Electrodynamics (Electricity in Motion)

Most electricity that we use to do work is in the form of an electric current, which is electricity in motion. Electrons move through a conductor by passing from one atom to another. A material that has some electrons that are free to flow in this manner are called conductors; materials that do not have free electrons are insulators.

There are two common types of electric currents, DC (Direct Current) and AC (Alternating Current). DC is a current that always flows in the same direction. Common examples are automobile circuits that are powered by batteries. A battery is a device that uses chemical to create an unbalanced charge between its terminals, and thus causes a direct current to flow from a (+) terminal to a (-) terminal. This DC electricity can be harnessed to perform such tasks as lighting, playing music on a radio, etc.

B. Electrical Power Production

Electrochemistry

Electrical energy can be produce by combined chemicals and certain metals to cause chemical reaction that will transfer electrons. One example of this principle is the voltaic chemical cell, shown in figure below.

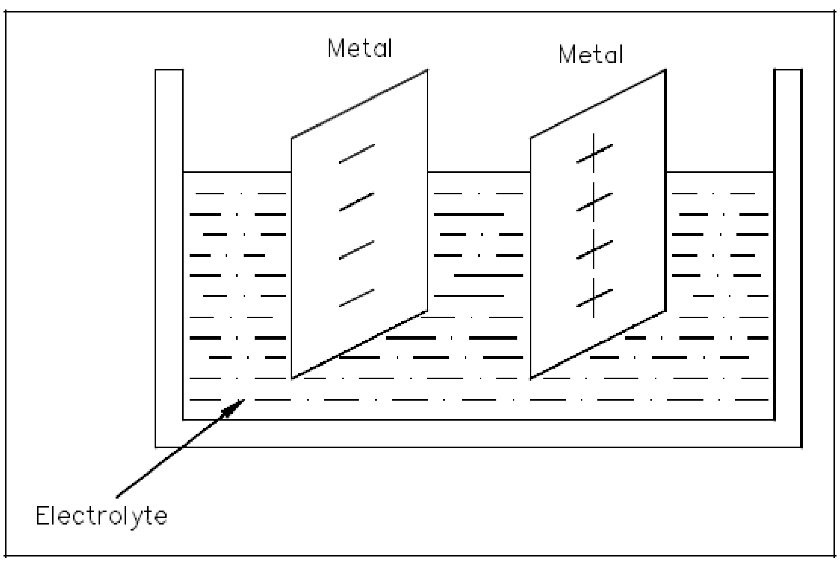

Figure 2. Voltaic chemical cell

A chemical reaction produces and maintains opposite charges on two dissimilar metals that serve as the positive and negative terminals. The metals are in contact with an electrolyte solution. Connecting together more than one of these cell will produce a battery.

Static Electricity (Friction)

Atoms with the proper number of electrons in orbits around them are in a neutral state, or have a "zero charge". A body of matter consisting of these atoms will neither attract nor repel other matter that is in its vicinity. If electrons are removed from the atoms in this body of matter, as happens due to friction when one rubs a glass rod with silk cloth, it will become electrically positive. If this body of matter comes near, but not in contact with, another body having a normal charge, an electric force is exerted between them because of their unequal charges. The existence of this force is referred to as static electricity or electrostatic force.

Magnetic Induction

Magnetism is the central method of producing electrical power in the world today. With our current technology, it is the only technique that can produce enough electrical power to run an entire city. Over 99% of all electrical power is produce by this process. A generator is a machine that converts mechanical energy into electrical energy by using the principle of magnetic induction. Magnetic induction is used to produce a voltage by rotating coils of wire through a stationary magnetic field, as shown in figure 3.

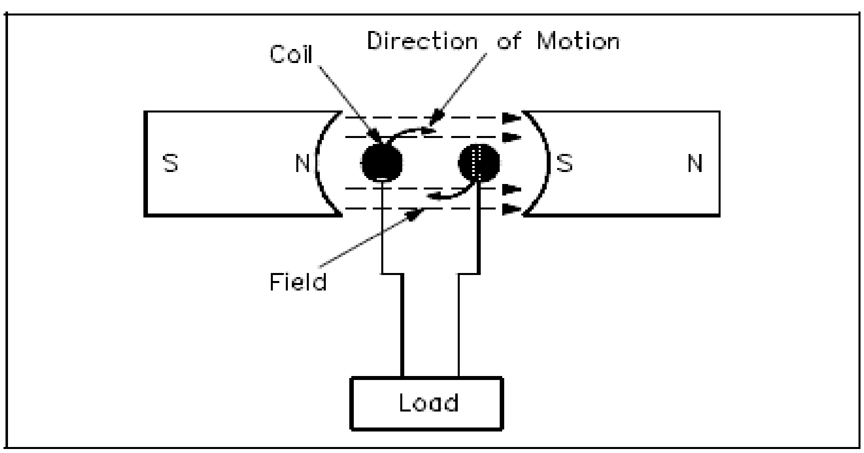

Figure 3. Generator – Electromagnetic Induction

Piezoelectric Effect (Pressure)

By applying pressure to certain crystals (such as quartz or Rochelle salts) or certain ceramics (like varium titanate), electrons can be driven out of orbit in the direction of the force. Electrons leave one side of the material and accumulate on the other side, building up positive and negative charges on opposite sides. When the pressure is released, the electrons return to their orbits. Some materials will react to bending pressure, while others will respond to twisting pressure.

This generation of voltage is known as the piezoelectric effect. If external wires are connected while pressure and voltage are present, electrons will flow and current will be produced. If the pressure is held constant, the current will flow until the potential difference is equalized. When the force is removed, the material is decomposed and immediately causes an electric force in the opposite direction. The power capacity of these materials is extremely small. However, these material are very useful because of their extreme sensitivity to changes of mechanical forces.

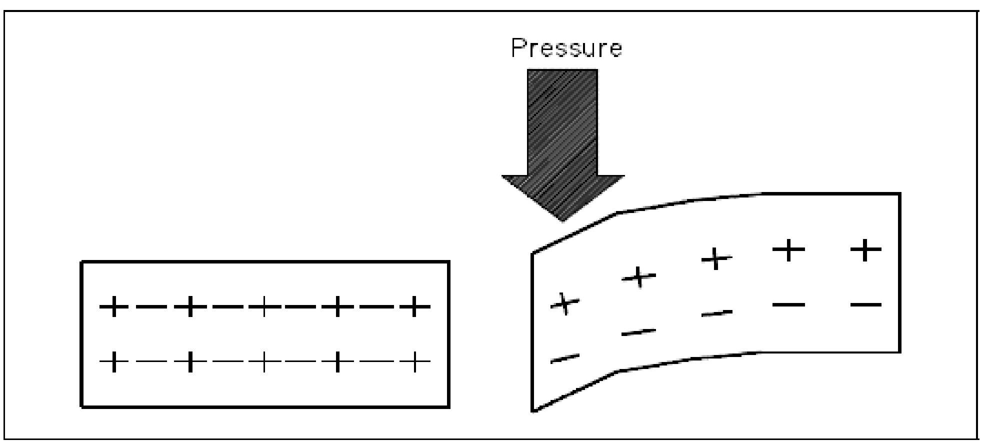

Figure 4. Pressure applied to certain produces an electric change

Thermoelectricity

Some materials readily give up their electrons and others readily accept electrons. For example, when two dissimilar metals like copper and zinc are joined together, a transfer of electrons may take place. Electrons will have the copper atoms and enter the zinc atoms. The zinc gets a surplus of electrons and becomes negatively charged. The copper loses electrons and takes on a positive charge. This creates a voltage potential across the junction of the two metals. The heat energy of normal room temperature is enough to make them release and gain electrons, electrons are released and the voltage potential becomes greater as shown in the figure 8.

When the heat is removed and the junction is cools, the charges will dissipate and the voltage potential will decrease. This process is called thermoelectricity. A device like this generally referred to as “thermocouple”. The thermoelectric voltage in a thermocouple is dependent upon the heat energy applied to the junction of the two dissimilar metals. Thermocouple are widely used to measure temperature and as heat-sensing devices in automatic temperature controlled equipment.

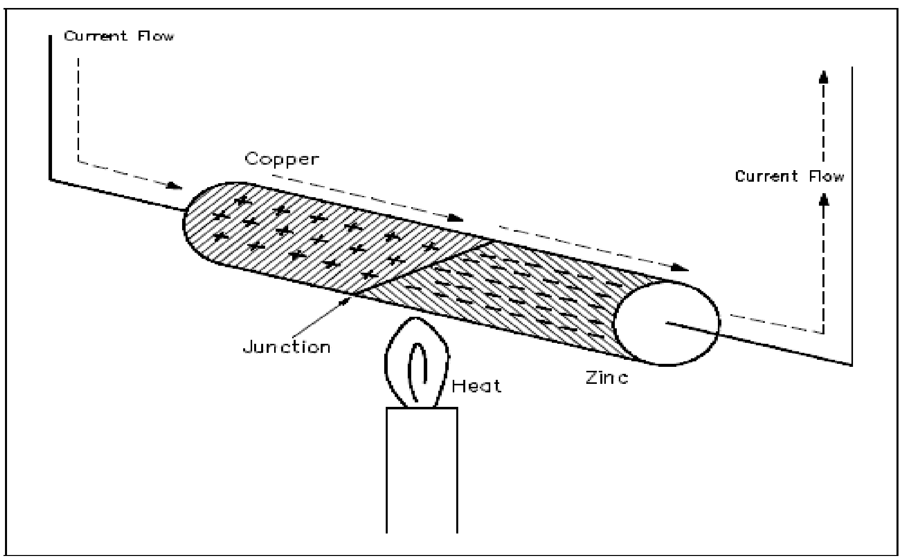

Figure 5. Heat Energy causes to give up electrons to zinc

Thermocouple power capacities are very small compared to some other sources, but are somewhat greater than those of crystals. Generally speaking, a thermocouple can be subjected to higher temperatures than ordinary mercury or alcohol thermocouple.

Photoelectric Effect

Light is a form of energy and is considered by many scientists to consist of small particles of energy called photons. When the photons in a light beam strike the surface of a material, they release their energy and transfer it to the atomic electrons of the material. This energy transfer may dislodge electrons from their orbits around the surface of the substance. Upon losing electrons, the photosensitive (light sensitive) material becomes positively charged and an electric force is created, as shown in figure 6.

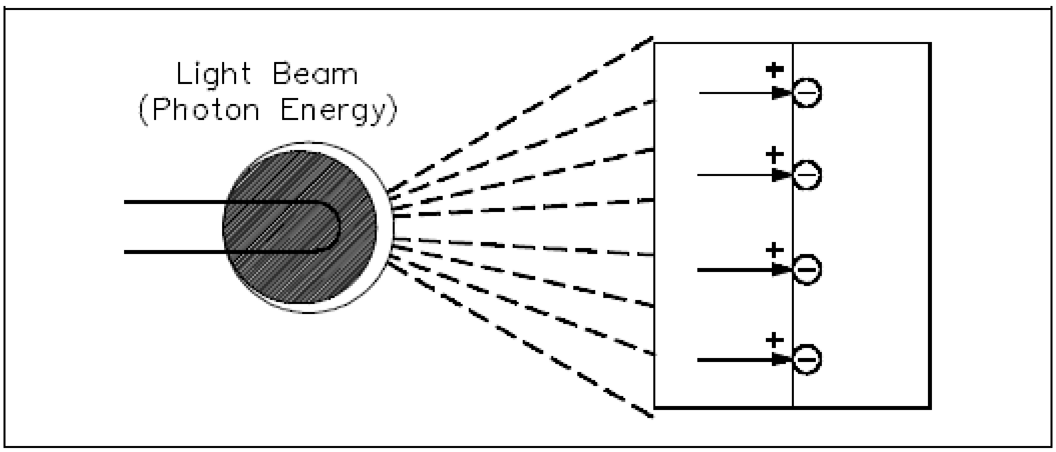

Figure 6. Producing electricity from light using a photovoltaic cell

This phenomenon is called the photoelectric effect and has wide applications in electronics, such as photoelectric cells, photovoltaic cells, optical couplers, and television camera tubes. There uses of the photoelectric effect are described below.

- Photovoltaic : The light in one of two plates that are joined together causes one plate to release electrons to the other. The plates build up opposite charges, like a battery.
- Photoemissions: The photon energy from a beam of light could cause a surface to release electrons in a vacuum tube. A plate would then collect the electrons.
- Photoconduction: The light energy applied to some materials that are normally poor conductors causes free electrons to be produced in the materials so that they become better conductors.

Thermionic Emission

A thermionic energy converter is a device consisting of two electrodes placed near one another in a vacuum. One electrode is normally called the cathode, or emitter, and the other is called the anode, or plate. Ordinally, electrons in the cathode are prevented from escaping from the surface by a potential energy barrier. At ordinary temperatures, almost none of the electrons can acquire enough energy to escape. However, when the cathode is very hot, the electron energies are greatly increased by thermal motion. At high temperatures, a considerable number of electrons are able to escape. The liberation of electrons from a hot surface is called thermionic emission.

The electrons that have escaped from the hot cathode form a cloud of negative charges near it called a space charge. If the plate is maintained positive with respect to the cathode by a battery, the electrons in the cloud are attracted to it. As long as the potential difference between the electrodes between the electrodes is maintained, there will be a steady current flow from the cathode to the plate.

The simple example of a thermionic device is a vacuum tube diode in which the only electrodes are the cathode and plate, or anode, as shown in the figure 7. The diode can be used to convert alternating current (AC) flow to a pulsating direct current (DC) flow.

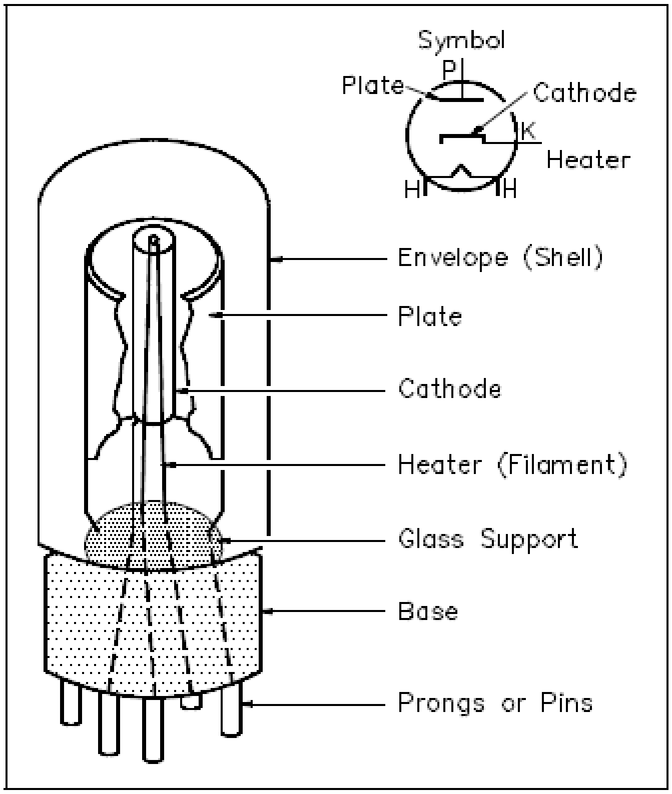

Figure 7. Vacuum Tube Diode

DEFINITIONS

Anode is the positive electrode of a capacitor.

Biomass is general term used for wood, wood wastes, sewage, cultivated herbaceous and other energy crops, and animal wastes.

Cathode is the capacitor's negative electrode.

Coil is a number of turns of wire in the form of a spiral. The spiral may be wrapped around an iron core or an insulating form, or it may be self-supporting. A coil offers considerable opposition to AC current but very little to DC current.

Conductors are materials with electrons that are loosely bound to their atoms, or materials that permit free motion of a large number of electron.

Current is the density of the atoms in copper wire is such that the valence orbits of the individual atoms overlap.

Dielectric is the insulating (non-conducting) medium between the two electrodes (plates) of a capacitor

Fuel Cell is device that converts the chemical energy in a fuel directly and isothermally into electrical energy

Geothermal Energy is thermal energy in the form of hot water and steam in the earth's crust.

Hydropower is conversion of potential energy of water into electricity using generators coupled to impulse or reaction water turbines.

Impedance (Z) is the total opposition offered to the flow of an alternating or pulsating current measured in ohm. (Impedance is the vector sum of the resistance and the capacitive and inductive reactance, i.e, the ratio of voltage to current).

Inductance is the property which opposes any change in the existing current. Inductance is present only when the current is changing.

Inductive reactance (X_L) is the opposition to the flow of alternating or pulsating current by the inductance of a circuit.

Inductor is a conductor used to introduce inductance into a circuit.

Insulators or nonconductors are material with electrons that are tightly bound to their atoms and require large amounts of energy to free them from the influence of the nucleus.

Negative-positive-zero (NPO): An ultra stable temperature coefficient (±30 ppm/°C from –55 to 125°C) temperature compensating capacitor.

Photovoltaics is conversion of insolation into DC electricity by means of solid state junctions diodes.

Power factor (PF): The ratio of effective series resistance to impedance of a capacitor, expressed as a percentage.

Quality factor (*Q*): The ratio of the reactance to its equivalent series resistance.

Reactance (*X*): Opposition to the flow of alternating current. Capacitive reactance (X_c) is the opposition offered by capacitors at a specified frequency and is measured in ohms.

Resistors are made of materials that conduct electricity, but offer opposition to current flow.

Thermionics is direct conversion of thermal energy into electrical energy by using the Edison effect (thermionic emission).

Thermoelectric is direct conversion of thermal energy into electrical energy using the thermoelectric effects in materials, typically semiconductors.

Tidal energy is the energy contained in the varying water level in oceans and estuaries, originated by lunar gravitational force.

Voltage is the basic unit of measure for potential difference is the volt (symbol V), and because the volt unit is used, potential difference is called voltage.

Wind-electric conversion is the generation of electrical energy using electromechanical energy converters driven by aero turbines.

NOMENCLATURE

A	: Area of the cross section, m^2
B	: Magnetic flux density, tesla
C	: Capacitance, F
d	: Distance between the plates, m
E	: Electric field strength, V/m
f	: Frequency, Hz
F	: Force of electrostatic attraction, N
g	: coulombs of charge
I	: Current, Ampere
K	: Constant of proportionality, $Coulumb^2/Nm^2$
L	: Inductance, H
l	: Length, m
M	: Mutual Inductance, H
N	: Number of turns in wire coil
P	: Power rating, W
q	: Charge of particle, Coulombs
r	: Distance between two particles, m
R	: Resistance, Ω
t	: Time, seconds
T	: Temperature, K
v	: velocity, m/s
V	: Voltage, V
X_L	: Inductive Reactance, Ω
X_C	: Inductive capacitance, Ω
Q	: The permeability of the core material
W	: Energy, J
Z	: Impedance, Ω

Greek Letter

α_{Ti} : Temperature coefficient, Ω/°C
β : Flux density
ρ : Resistivity of the material, ohm-meters
θ : Angle
Φ : Magnetic flux in Webers