202: Principles of electrical science  
**Handout 1: Principles of electricity**

**Learning outcome**

The learner will:

1. Understand the relationship between resistance, resistivity, voltage, current and power.

**Assessment criteria**

The learner can:

4.1 describe the basic principles of electron theory

4.2 identify and distinguish between materials which are good conductors and insulators

4.8 describe the chemical and thermal effects of electric currents

**Learning outcome**

The learner will:

2 Understand standard units of measurement used in electrical installation, maintenance and design work

**Assessment criteria**

The learner can:

2.1 identify and use internationally recognised base and derived **(SI) units of measurement**

2.2 identify and determine values of base and derived SI units which apply specifically to **electrical quantities (SI units)**

**Range**

**(SI) units of measurement**: Length, Area, Volume, Mass, Density, Time, Temperature, Velocity.

**electrical quantities (SI units)**: Resistance, Resistivity, Power, Frequency, Current, Voltage, Energy, Impedance, Inductance and inductive reactance, Capacitance and capacitive reactance, Power factor.

**Principles of electricity**

**Electron theory – structure of matter**

The smallest part of any material is called a **molecule**, yet the latter is made up of one or more **atoms**. For example, water is made up of H2O (two atoms of hydrogen and one atom of oxygen).

Basically, the atom is constructed of a central core containing **protons** surrounded by orbiting **electrons**.

**Electrical nature of atoms**

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| **PROTONS are POSITIVELY CHARGED**  **ELECTRONS are NEGATIVELY CHARGED** |

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| **In an electrically neutral atom the number of PROTONS are equal to the number of ELECTRONS** |

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| * **The simplest atom is hydrogen (1 proton and 1 electron) – see right.** * **The heaviest atom is uranium (92 protons balanced by 92 electrons).** * **Helium atom (two protons and two electrons).** | hydrogen atom.png |

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| **Copper atom – 29 protons and 29 electrons**  An electrically neutral atom has as many **(+ve positive)** **protons** as there are **(‑ve negative) electrons**.  The single electron in the outer orbit of the copper atom is only loosely attached to the atom because:   * it is so far away from the core (nucleus) * inner electrons try to push it off (like charges repel). | copper atom.png |

As a result, this electron may be easily detached. If the balance of protons and electrons is upset and the atom becomes positively charged it will then attract any nearby electron.

This process occurs millions of times every second; at any instant in time the material has a large number of free electrons moving in all directions.

**Random free electron movement**

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| --- | --- |
| **random electron flow.png** |  |

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| **electron flow.png** | If the material is then connected across a battery, the positive plate (or terminal) attracts **electrons**, whilst the negative plate repels them.  The battery provides a source of **electromotive force (EMF)**. |

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| **The resultant electron flow around the circuit is called an ELECTRIC CURRENT** |

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| **circuit.png** | **Note**: even when an appropriate EMF is applied, there must be a complete circuit for the electrons to flow; a break in the circuit will cause the electron flow to stop.  This aspect is useful, as we can use it to control the flow of electricity using, for example, a switch. |

**Conductors and insulators**

A **conductor** is a material that has a loosely attached electron in its outer orbit that can be easily dislodged, as in copper. Any external influence which moves one of them will cause a repulsion of other electrons which spreads, ‘domino fashion’ through the conductor.

Simply stated, most metals are good electrical conductors, most non‑metals are not. Metals are also generally good heat conductors while non‑metals are not. Examples of conductors are:

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| * silver * gold * copper * aluminium * mercury * steel | * sea water * concrete * mercury * platinum * brass | * iron * bronze * graphite * dirty water * lemon juice |

Most solid non‑materials are classified as insulators because they offer very large resistance to the flow of electric current. In an **insulator**, the outermost electrons are so tightly bound that there is essentially zero electron flow through them with ordinary voltages. Examples of insulators are:

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| --- | --- | --- |
| * rubber * glass * pure water * oil * air | * diamond * dry wood * dry cotton * plastic * asphalt | * fiberglass * dry paper * porcelain * ceramic * quartz |

**Effects of an electric current**

When electricity flows, one or more effects occur as follows:

* thermal
* chemical
* magnetic.

**Thermal effect**: When an electric current is passed through a conductor, the conductor becomes hot after some time and produce heat. This happens due to the conversion of some electric energy passing through the conductor into heat energy by the collision of electrons with each other and the atom nuclei. This effect of electric current is called heating effect of current.

The heating effect of current is used in various electrical heating appliances such as electric lamps, electric irons, room heaters, water heaters, electric fuse, etc.

**Chemical effect**: We can use certain chemical reactions which produce electricity as in a battery. But, it is interesting to note that when electric current is passed through certain liquids a chemical reaction takes place. This is called chemical effect of electric current and is referred to as electrolysis. For example, when an electric current is passed through acidified water, it splits up to form hydrogen and oxygen gas.

Electrolysis is used to electroplate objects. This is useful for coating a cheaper metal with a more expensive one, such as copper or silver.

The negative electrode should be the object that is to be electroplated and the positive electrode should be the metal that you want to coat the object with. The electrolyte should be a solution of the coating metal, such as its metal nitrate or sulphate

Two examples are electroplating with silver (silver nitrate electrolyte) and copper (copper sulphate electrolyte.

**Magnetic effect**: Will be covered later in the course.

**Electrical quantities**

Many different quantities are used in electrical systems and therefore need to be standardised. These units are standardised in an international system called the ‘***Système International d’Unités***’ (abbreviated to SI Units). SI Units are based upon a small number of fundamental units from which all other units may be derived.

The table below shows a selection of units appropriate to the electrical industry, including the symbols used in formulae and also their abbreviation.

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| **SI Unit** | **Measure of** | **Symbol** | **Abbreviation** |
| Metre | Length | l | m |
| Square metre | Area | a | m2 |
| Cubic metre | Volume | v | M3 |
| Kilogram | Mass | m | Kg |
| Kilogram/metre3 | Density | ρ | kg/m3 |
| Second | Time | t | s |
| Degrees Celsius | Celsius temperature | t | °C |
| Metres/second | Velocity | v | m/s |
| Ohm | Electrical resistance | R | Ω |
| Rho | Resistivity | ρ | Ohm/m3 |
| Watts | Power | P | W |
| Hertz | Frequency – number of cycles per second | f | Hz |
| Ampere | Electric Current | I | A |
| Volt | Electric potential/Potential difference/Electromotive force | V | V |
| Joule | Energy/Work/Quantity of heat | E | J |
| Ohm | Impedance | Z | Ω |
| Henry | Inductance | L | H |
| Ohm | Inductive reactance | XL | Ω |
| Farad | Capacitance | C | F |
| Ohm | Capacitive reactance | XC | Ω |
| cos θ | Power factor | p.f. | No unit |