Electricity principles

Objectives: At the end of this lesson you shall be able to
- **describe an atom**
- **describe electricity**
- **describe electron flow**
- **describe conductors**
- **describe insulators**
- **describe semlconductors**
- **describe shielding.**

Introduction

Electricity is one of today's most useful sources of energy. Electricity is of utmost necessity in the modern world of sophisticated equipment and machinery.

Electricity in motion is called electric current. Whereas the electricity that does not move is called static electricity.

Examples of Electric current

- Domestic electric supply, industrial electric supply.

Examples of static electricity

Shock received from door knobs of a carpeted room. Attraction of paper of the comb.

Structure of matter

To understand electricity, one must understand the structure of matter. Electricity is related to some of the most basic building blocks of matter that are atoms. All matter is made of these electrical building blocks, and, therefore, all matter is said to be 'electrical'.

Matter is defined as anything that has mass and occupies space. A matter is made of tiny, invisible particles called molecules. A molecule is the smallest particle of a substance that has the properties of the substance. Each molecule can be divided into simpler parts by chemical means. The simplest parts of a molecule are called atoms.

Basically, an atom contains three types of sub-atomic particles that are of relevance to electricity. They are the electrons, protons and neutrons. The protons and neutrons are located in the centre, or nucleus, of the atom, and the electrons travel around the necleus in orbits.

Atomic Structure

The Nucleus

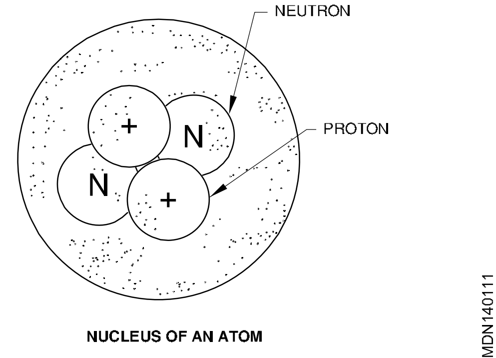
The nucleus is the central part of the atom. It contains the protons and neutrons of an atom as shown in Fig 1

Protons

The proton has a positive electrical charge. (Fig 1) It is almost 1840 times heavier than the electron and it is the permanent part of the nucleus; protons do not take an active part in the flow or transfer of electrical energy.

Electron

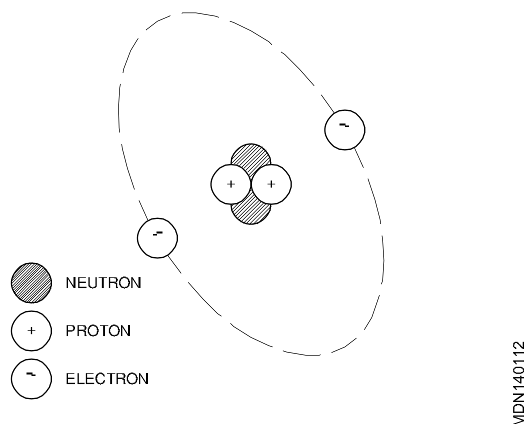
Fig 1



It is a small particle revolving round the nucleus of an atom as shown in (Fig 2). It has a negative electriccharge. The electron is three times larger in diameter than the proton. In an atom the number of protons is equal to the number of electrons.

Neutron

Fig 2

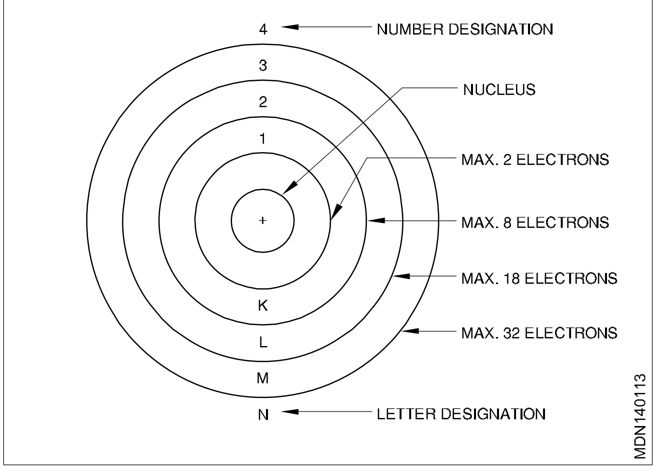


A neutron is actually a particle by itself, and is electrically neutral. Since neurtons are electrically neutral, they are not too important to the electrical nature of atoms.

Energy Shells

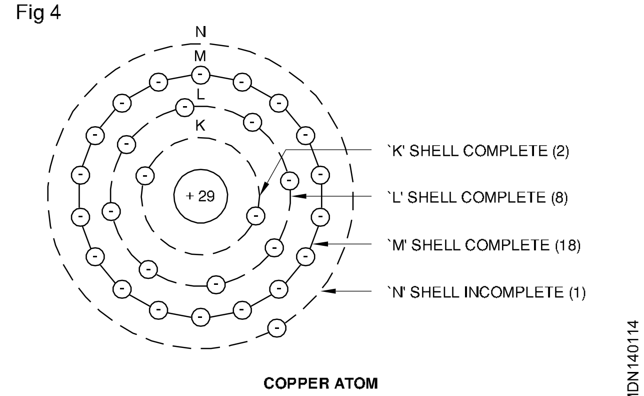
In an atom, electrons are aranged in shells around the nucleus. A shell is an orbiting layer or energy level of one or more lectrons. The major sheel layers are identified by numbers of by letters starting with 'K' nearest the nuclues and continuing alphabetically outwards. There is a maximum number of electrons that can be contained in each sheel. (Fig 3) illustrates the relationship between the energy shell level and the maximum number of electrons it can contain.

Fig 3



If the total number of electrons for a given atom is known, the placement of electrons in each shell can be easily determined. Each shell layer, beginning with the first, is filled with the maximum number of electrons in sequence. For example, a copper atom which has 29 electrons would have four sheels with a number of electrons in each shell as shown in (Fig 4).

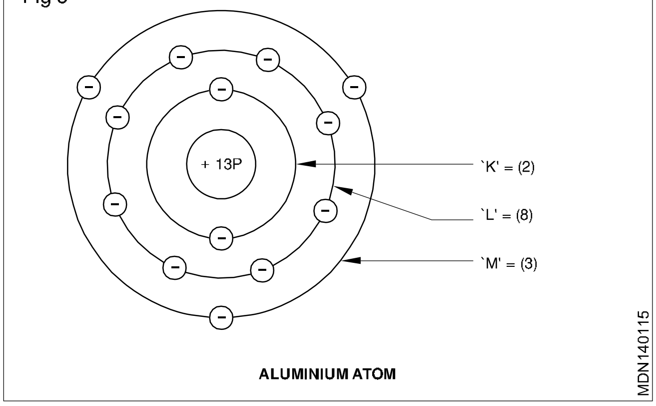
Fig 4



COPPER ATOM

Similarly an aluminium atom which has 13 electrons has 3 shell as shown in (Fig 5).

Fig 5



ALUMINIUM ATOM

Electron distribution

The chemical and electrical behaviour of atoms depends on how completely the various shell and sub-shells are filled.

Atoms that are chemically active have one electron more or one less than a completely filled shell. Atoms that have the outer shell exactly filled are chemically inactive. They are called inert elements. All inert elements are gases and do not combine chemically with other elements.

Metals possess the following characteristics

- They are good electric conductors.
- Electrons in the outer shell and sub-shells can move more easily from one atom to another.
- They carry charge through the material.

The outer shell of the atom is called the valence shell and its electrons are called valence electrons. Because of their greater distance from the nucleus, and because of the partial blocking of the electric field by electrons in the inner shells, the atrracting force exerted by nuclues on the valence electrons is less. Therefore, valence electrons can be set free most easily. Whenever a valence electron is removed from its orbit it becomes a free electron. Electricity is commonly defined as the flow of these free electrons through a conductor. Though electrons flow from negative terminal to positive terminal, the conventional current flow is assumed as from positive to negative.

Conductors Insulators and Semicondutors

Conductors

A conductor is a material that has many free electrons permitting electrons to move through it easily. Generally, conductors have incomplete valence shells of one, two or three electrons. Most metals are good conductors.

Some common good conductors are Copper, Aluminium, Zinc, Lead, Tin, Eureka, Nichrome, Silver and Gold.

Insulators

An insulator is a material that has few, if any, free electrons and resists the flow of electrons. Generally, insulators have full valence shells of five, six or seven electrons. Some common insulators are air, glass, rubber, plastic, paper, porcelain, PVC, fibre, mica etc.

Semiconductors

A semiconductor is a material that has some of the characteristics of both the conductor and insulator. Semiconductor have valence shells containing four electrons.

Common examples of pure semiconductor materials are silicon and germanium. Specially treated semiconductors are used to produce modern electronic components such as diodes, transistors and integrated circuit chips.

Earthing and its importance

Objectives : At the end of this lesson you shall be able to
- **describe the necessity of earthing**
- **describe the reasons for system and equipment earthing**.
- **describe shielding**

Necessity of earthing

While working in electrical circuits, the most important consideration for an Electrician is the safety factor - safety not only for himself but also for the consumer who uses the electricity.

Earthing the metal frames/ casing of the electrical equipment is done to ensure that the surface of the equipment under faulty conditions does not hold dangerous potential which may lead to shock hazards. However, earthing the electrical equipment needs further consideration as to ensure that the earth electrode resistance is reasonably low to activate the safety devices like earth circuit leakage breaker, fuses and circuit breakers to open the faulty circuit, and thereby, protect men and material.

Earthing of an electrical installation can be brought under the following three categories.

System earthing

Equipment earthing

Special requirement earthing

System earthing

Earthing associated with current - carrying conductors is normally essential to the safety of the system and it is generally known as system earthing.

System earthing is done at generating stations and substations.

Equipment earthing

This is a permanent and continuous bonding together (i.e. connecting together) of all non-current carrying metal parts of the electrical equipment to the system earthing electrode.

'Equipment earthing' is provided to ensure that the exposed metallic parts in the installation do not become dangerous by attaining a high touch potential under conditions of faults. It is also carry the earth fault currents, till clearance by protective devices, without creating a fire hazard.

Special requirements for earthing

'Static earthing' is provided to prevent building up of static charges, by connections to earth at appropriate locations. Example, operation theatres in hospitals.

'Clean earth' may be needed for some of the computer data processing equipments. These are to be independent of any other earthing in the building.

Earthing is essentially required for the protection of buildings against lightning.

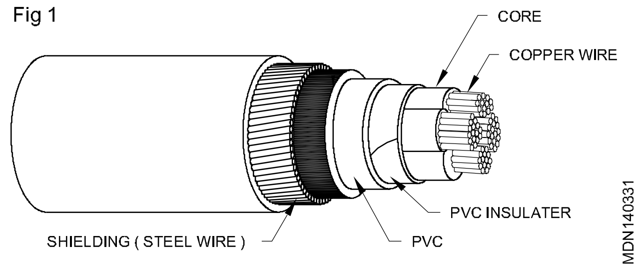
Reasons for earthing

An electric shock is dangerous only when the current flow through the body exceeds beyond certain milliampere value. In general any current flowing through the body beyond 5 milliamperes is considered as dangerous.

Shielding

Shielding is the (Fig 1) protective device layer over the insulated cable.

Fig 1



Uses

- It act as earth/ground for the electrical appliances.
- It protect the cables from moisture entering as well as flexible.
- It also act as mechanical strength as well as flex ible to the cables.
- It protect the cable from all whether condition like water, oil, grease and heat.

Neutron

A neutron is actually a particle by itself, and is electrically neutral. Since neutrons are electrically neutral, they are not too important to the electrical nature of atoms.

Ohm's Law

Objectives: At the end of the lesson you shall be able to
- **describe an atom**
- **describe electricity**
- **describe electron flow**
- **describe conductors**
- **describe insulators**
- **describe semiconductors.**

Electrical terms and definitions EMF and Pd

The force tending to make electrons to move along a conductor is called the potential difference (pd) in the conductor and is expressed in volts. This is also called the electric pressure or voltage.

The voltage developed by a source such as a generator is called as electromotive force. (emf)

When one ampere current flows through one ohm resistance the p.d. across the resistance is said to be one "Volt". Voltmeter is used to measure the voltage of a supply and is connected in parallel to the supply. EMF/Pd is denoted by letter "V".

Current

The flow of electrons is called current. Its unit is ampere. When one volt is applied across a resistance of one ohm the amount of current passess through the resistance is said to be one "Ampere". It is denoted by "A". Smaller units are milliampere and microampere. Ammeter should be connected in series with the load.

Resistance

It is the property of a substance which opposes the flow of electricity. Its unit is ohm. The resistance of a conductor, in which a current of one ampere flows when potential difference of one volt is applied across its terminals, is said to be one ohm.

An ohmmeter is used to measure the resistance of an electric circuit. It is denoted by "Ω" Bigger units are Kilo ohms and Mega ohms.

1 K $\Omega = 10^3$ ohms

1 Mega $\Omega = 10^6$ ohms

Ohmmeter should be connected in parallel with the load and should not be connected when there is a supply.

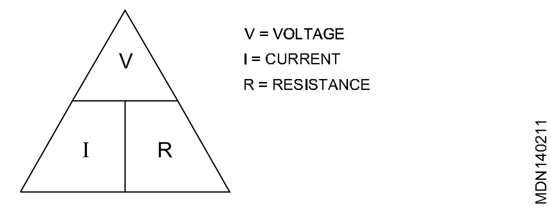
There is a definite relationship between the three electrical quantities of Voltage, Current and Resistance.

Ohm's Law states

`The current is directly proportional to the voltage and inversely proportional to the resistance' when the temperature remains constant.

An aid to remember the Ohm's law relationship is shown in the divided triangle.(Fig 1)

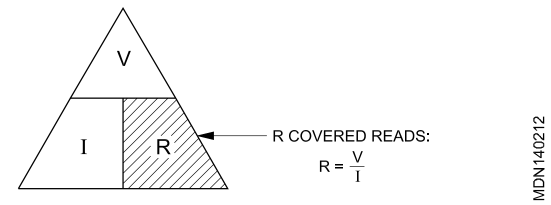
Fig 1



Written as a mathematical expression, Ohm's Law is -

$$\text{Current } (I) = \frac{\text{Voltage (V)}}{\text{Resistance (R)}}$$

Fig 2



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

Of course, the above equation can be rearranged as:

$$\text{Resistance(R)} = \frac{\text{Voltage (V)}}{\text{Current (I)}}$$

$$\text{or } R = \frac{V}{I}$$ (Refer Fig 2)

Example

How much current(I) flows in the circuit shown in (Fig 3)

Given:

Voltage(V)	=	1.5 volts
Resistance(R)	=	1 k ohm
	=	1000 ohms.

Find:

Current(I)

Known:

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

Solution:

$$I = \frac{1.5\ V}{1000\ ohms} = 0.0015\ amp$$

Answer:

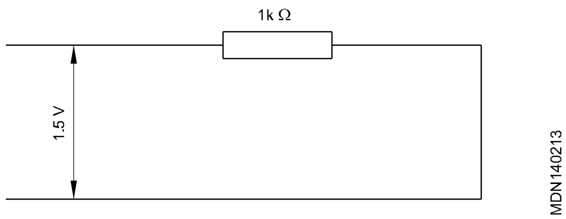
The current in the circuit is 0.0015 A

or

the current in the circuit is 1.5 milliampere (mA).

(1000 milliamps = 1 ampere)

Fig 3



Electrical power (Fig 4)

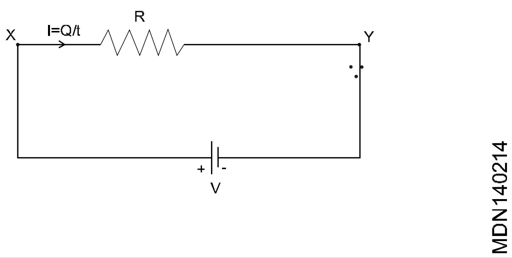
The rate which work is done in an electric circuit is called electrical power.

When voltage is applied to a circuit, it causes current to flow through it or in other words it causes electrons or charge through it, clearly certain amount of work is being done in moving these electrons in the circuit. This work done in moving the electrons in unit time is called as electrical power, From Fig 4.

V	=	P.D. across xy in colts,
I	=	Current in amps.
R	=	resistance between xy in
t	=	time in sec for which current flows.

The total charge flows in t secs is Q = I X T coulombs

Fig 4



As per earlier definition the P.d, $V = \frac{work}{charge} = \frac{work}{Q}$

$\therefore$ Work = VQ.

= VIt (Q = IT).

$\therefore$ Electrical power $P = \frac{Workdone}{time} = \frac{Vit}{t}$

W = VI joules/secs. (or) watts.

Wattmeter is used to measure the electrical power.

Electrical power in watts = Voltage in volts X current in ampere

The digger units of electric power are kilowatts (KW) and Megawatts (MW).

1 KW = 1000 watts(or) 10^3 watts

1 MW = 1000000 watts (or) 10^6 watts

Electrical Energy: (E)

The total work done in an Electric circuit is called as Electrical Energy.

Electrical Energy = Electrical power X time

= VI X t = VIT

i.e. Electrical power multiplied by the time for which the current flows in the circuit is known as Electrical energy. The meter used to measure electrical energy is energy meter. The symbol for electrical energy is E.

The unit of electrical energy will depend upon the units of electric power and time.

(a) If power is in watts and time is in seconds then the unit of Electrical energy will be watt-sec.

i.e. Electrical energy in watt - secs. = Power in watts Time In secs.

(b) If power is in watts and time is in hours then the unit of Electrical Energy will be watt-hours.

i.e. Electrical energy in watt - hours = power in watts time in hours

(C) If Power is in kilowatts (10 watts (or)1000 watts) and time is in hours then the unit of electrical energy will be kilowatt - hour (Kwh).

i.e. Electrical energy in kwh = power in kilowatt time in hours

In practice the electrical energy is measured in kilowatt-hours (KWh). The electricity bils are made on the basis of total electrical energy consumed by the consumer. 1KWh of electrical energy is called as Board of Trade (B.O.T.) Unit or simply 1 unit. i.e. 1KWh = 1Unit.

Thu when we say a consumer has consumed 75 units of electricity means the electrical energy consumed by the consumer is 75 KWh.

In and Electrical circuit if 100 watts (or) 1Kw of power is supplied for 1 hour then the electrical energy expended is one kilowatt-hour (1KWH) or 1 electrical unit (Or) 1 unit.

1Kwh = 1 Unit	=	power in watts time in sece
	=	Watts, secs (or) joules.
	=	1000 60 60 joules
	=	36 105 joules (or) watt-sec.
1 calorie	=	4. 186 joules (or)
1 kilo calorie	=	4186 joules.
1kwh = calories	=	860009.557
	=	860000 calories = 860 10^3 calories
	=	860 kilo calories.
∴1 kwh	=	860 Kcal.

Identification of AC and DC Meters

AC and DC meters can be identified as follows

1 By the symbol available on the dial / scale.

(a) Direct current

(b) Alternating current

2 By seeing the graduation on the dial / scale

a) If the graduation of dial is uniform throughout, it is a D C meter.

(b) If the graduation of dial is cramped at the beginning and at the end, it is an A.C. meter

3 By seeing the terminals

(a) In the d C meter the terminals are marked with + and– The positive (+) terminal is Red in colour and the negative (–) terminal is Black in colour.

(b) In the A.C. meter there is no marking on the terminals and no difference in colour.

(iii) current :

$I = V / R$

$= P / V$

$= \sqrt{P / R}$

(iv) Voltage :

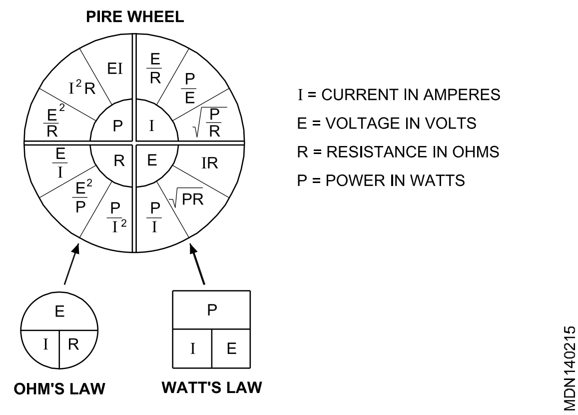
$V = IR$

$= P / I$

$= \sqrt{PR}$

The formulae (or equations) to solve for unkown voltage, current, resistance or power can be obained by combining Ohm's law and Power law. This is shown in (Fig 5).

Fig 5



Basic types of electrical meters

Objectives: At the end of this lesson you shall be able to
- **describe the connection of an ammeter in the circuit**
- **describe resistance symbols used in wiring diagram**
- **state the use of an ammeter**
- **describe the care to be taken of an ammeter**
- **describe the connection of a voltmeter**
- **describe the use of a voltmeter**
- **describe the care to be taken of voltmeters**
- **describe the connection of an ohmmeter**
- **state the use of an ohmmeter**
- **describe the care to be taken of ohmmeters**
- **describe the maintenance of meters**
- **state the simple electric circuit**
- **state the open electric circuit**
- **state the short electric circuit**
- **state the series circuits & parallel circuits**

There are three basic types of meters used to test the electric circuit and accessories. The following meters are used in automobiles.

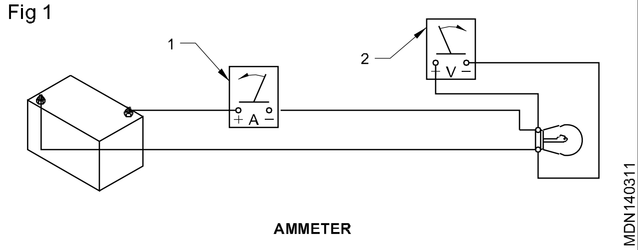
– Ammeter

– Voltmeter

– Ohmmeter

Ammeter (Fig 1)

Fig 1



AMMETER

The ammeter (1) is fitted on the vehicle panel board/ dashboard.

It is connected in series in the circuit as shown in the fig.1.

Uses of ammeter

An ammeter is used to measure the amount of current flowing in the circuit.

This is connected in series with the load.

It is used to indicate the rate at which the battery is being charged or discharged.

Care

Do not connect an ammeter in parallel in the circuit.

Take care of "+" and "-" mark on terminals.

Use DC meter for automobile charging system.

Select and use an ammeter as per the required range.

Voltmeter

A voltmeter (2) is used to measure electrical voltage. It is not fitted permanently on the vehicle but used separately whenever required. It is connected in parallel with the circuit. Use DC voltmeter for automobiles.

Uses of a voltmeter

To measure the voltage at any point of circuit.

To measure the voltage drop in the circuit.

To check the condition of the battery.

Care

Select the voltmeter as per the required range.

Do not connect the voltmeter in series in the circuit.

Ohmmeter (Fig 2)

An ohmmeter (1) is also known as resistance meter.

It is not fitted permanently on the vehicle but is used separately whenever required.

It has its own built-in power source. Hence the device/ circuit being checked with the ohmmeter should be disconnected from the power supply as shown in the figure, to prevent damage to the ohmmeter.

The unit of resistance is an ohm.

Uses of ohmmeter

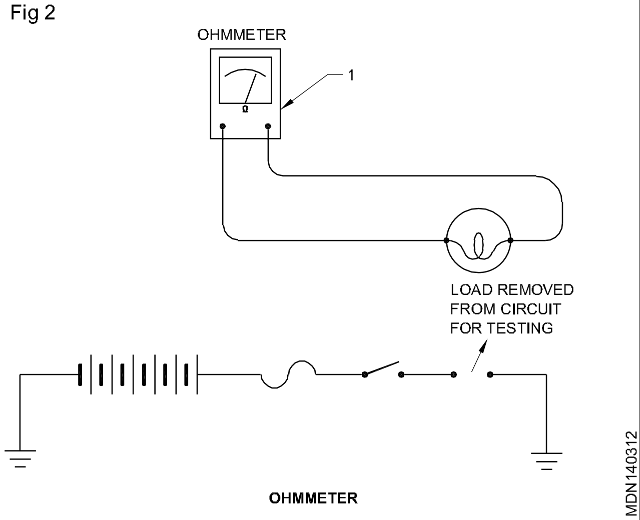
An ohmmeter is used:

– to measure the resistance of any conductor

– to measure the resistance of any load

– to check the continuity of the field coils.

Fig 2



Care

Do not connect an ohmmeter to any part of a live circuit.

Do not connect an ohmmeter across the terminals of a battery.

Maintenance of meters

Handle the meters with care.

Keep the connections tight while the meters are in use.

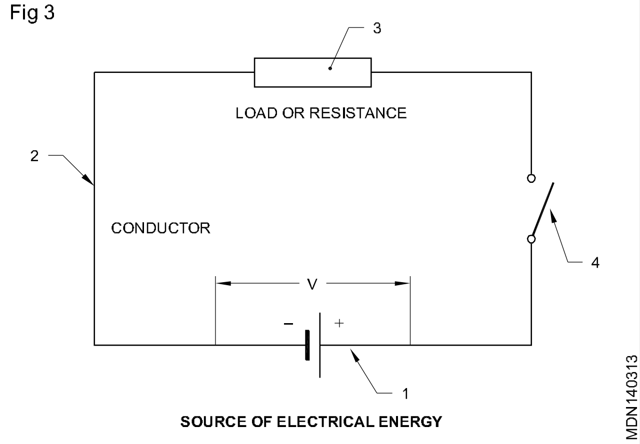
Use the meters within specified loads.

After use, keep the meters in a separate place.

Electrical circuits

Simple electrical circuit (Fig 3)

Fig 3

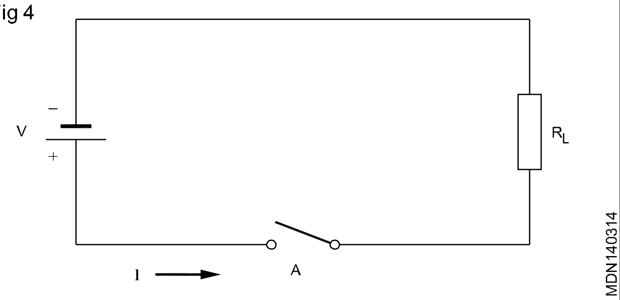


A simple electric circuit is a complete pathway of the current flow from the battery via the switch and load and back to the battery. An electric circuit consists of :

– a voltage source (1)
– connecting wires (conductors) (2)
– a load (lamp or motor) (3)
– switch (4).

Open circuit (Fig 4)**:** In an open circuit, an infinite resistance is provided, most of the time by the open switch (A). Therefore no current can flow.

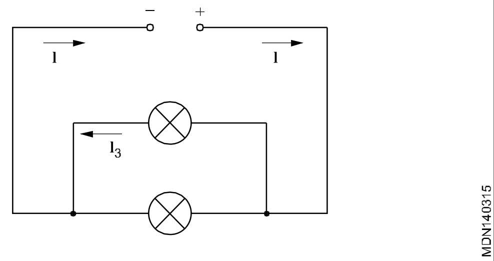
Fig 4



Short circuit : A short circuit will occur when two terminals of the same circuit touch each other. A short circuit may also occur if the insulation between the two cores of the cable are defective. This results in a lower resistance. This causes a large current to flow which can become a hazard.

Parallel circuit (Fig 5)**:** In this circuit two or more loads are connected. Each load is provided with its own path to the source of supply.

Fig 5



Example

A pair of head lights is connected in parallel circuit. When wired in parallel the failure of one bulb will not effect the operation of the other bulb. Each load receives full system voltage.

The formula to calculate resistance in a parallel circuit is:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

where

I	= current
R	= resultant resistance
R_1, R_2, R_3	= resistance of each load.

Series circuit : This circuit consists of only one load and one source of supply. It has one continuous path for the flow of current. Hence the current flows through all the load in a sequence in circuit. If any of the parts fails the circuit breaks and the current stops flowing.

$$Resistance(R) = \frac{Voltage(V)}{Current(I)}$$

$$Current(I) = \frac{Voltage(V)}{Resistance\ (R)}$$

Voltage = Current (I) x Resistance (R)

Types of resistance

Based on the ohmic value of resistance it is grouped as low, medium and high resistance.

Low resistance

Range : 1 Ohm and below.
Uses : Armature winding, ammeter.

Medium resistance

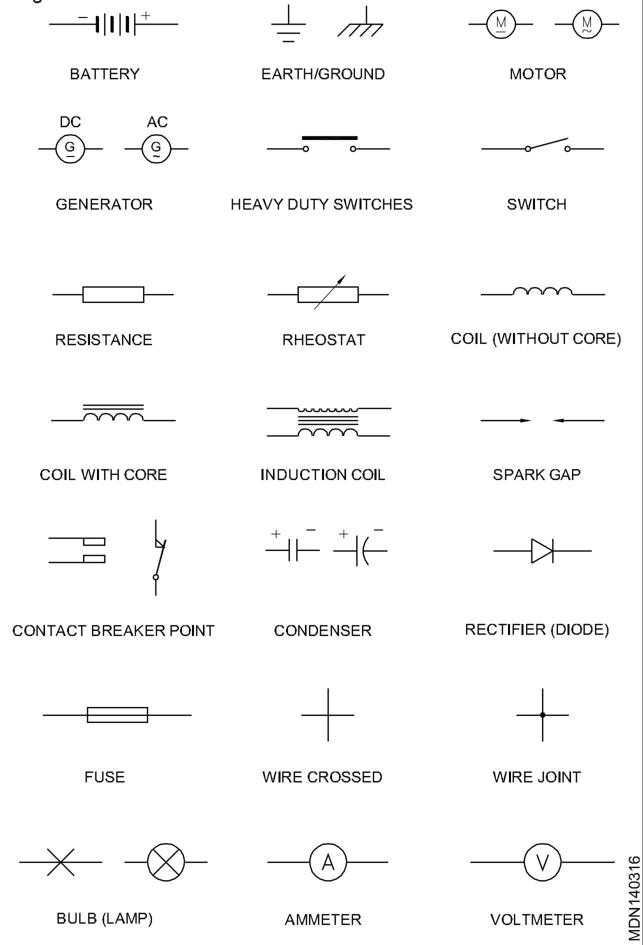
Range : Above 1 Ohm up to 1,00,000 Ohm.
Uses : Bulbs, heaters, relay starters.

High resistance

Range : Above 1,00,000 Ohm (100 k.Ohms).
Use : Lamps.

Electrical symbols used in a wiring diagram (Fig 6)**:** Automotive circuits are generally shown by wiring diagrams. The parts in those diagrams are represented by symbols. Symbols are codes or signs that have been adopted by various automobile manufacturers as a convention.

Fig 6



Multimeter

Objectives: At the end of this lesson you shall be able to
- **state the function of multimeter controls**
- **explain about the dial (scale) of the multimeter**
- **explain about zero adjustment during ohmmeter function**
- **state the function of digital multimeter**
- **state the application of the multimeter**
- **state the precautions to be followed while using a multimeter.**

A multimeter is an instrument in which the functions of an ammeter, voltmeter and ohmmeter are incorporated for measurement of current, voltage and resistance respectively. Some manufacturers call this a VOM meter as this meter is used as volt, ohm and milli ammeter, Multimeters use the basic d'Arsonval (PMMC) movement for all these measurements. This meter has facilities through various switches to change the internal circuit to convert the meter as voltmeter, ammeter or ohmmeter.

There are two major types of multimeters

1 Ordinary multimeters having passive components.

2 Electronic multimeters having active and passive com ponents. An electronic multimeter may be of the analog type or digital type.

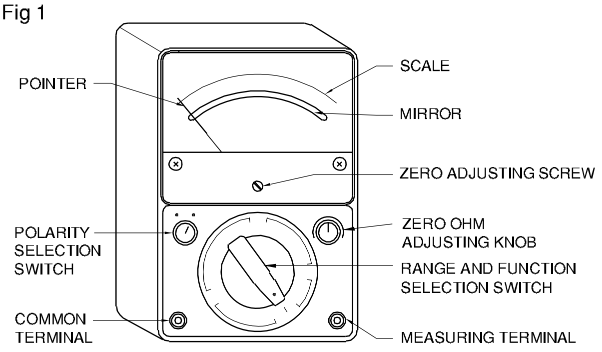
Most of the ordinary multimeters will have a sensitivity of 20k ohms per volt in the voltmeter mode whereas electronic multimeters have internal resistances to the tune of 5 to 10 megohms, irrespective of the selected voltage range.

There are several types of multimeters available in the market, manufactured by various manufactures. Each model differs from the others by the extra facilities available. It is a versatile tool for all automobile. With proper usage and care, it could give service for many years.
Rectifiers are provided inside the meter to convert AC to DC in the AC measurement circuit.

Parts of a multimeter

A standard multimeter consists of these main parts and controls as shown in (Fig 1).

Fig 1



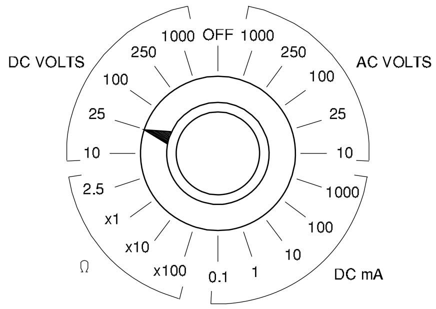
MULTIMETER

MDN140321

Controls

The meter is set to the required current, voltage or resistance range - by means of the range selector switch. in (Fig 2), the switch is set to DC, 25 volts.

Fig 2



FUNCTION AND RANGE SWITCH

MDN140322

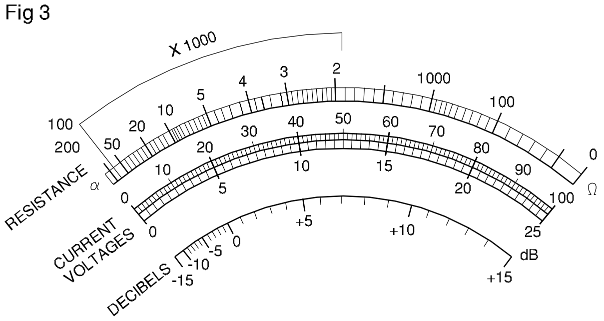
Scale of multimeter

Separate scales are provided for :

- resistance
- voltage and current.

The scale of current and voltage as uniformly graduated (Fig 3)

Fig 3



MDN140323

The scale for resistance measurement is non-linear. That is, the divisions between zero and infinity (α) are not equally spaced. As you move from zero to the left across the scale, the division become closer together.

The scale is usually 'backward', with zero at the right.

Zero adjustment

When the selector switch is in the resistance range and the leads are open, the pointer is at left side of scale, indicating infinite (α) resistance (open circuit). When the leads are shorted, the pointer is at right side of the scale,indicating zero resistance.

The purpose of the zero ohm adjusting knob is to vary the variable resistor and adjust the current so that the pointer is at exactly aero when the leads are shorted. It is used to compensate for changes in the internal battery voltage due to aging.

Multiple range

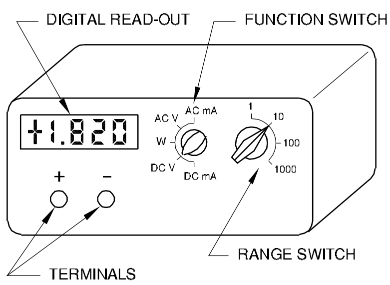
Shunt (parallel) resistors are used to provide multiple ranges so that the meter can measure resistance values from very small to very large values. For each range, a different value of shunt resistance is switched on. The shunt resistance increases for the higher ohm ranges and is always equal to the centre scale reading on any range. These range settings are interpreted differently from those of the ammeter or voltmeter. The reading on the ohmmeter scale is multiplied by the factor indicated by the range setting.

Remember, when a multimeter is set for the ohmmeter function, the multimeter must not be connected to the circuit with the circuit's power is on.

Digital multimeter (DMM)

In a digital multimeter the meter movements is replaced by a digital read - out. (Fig 4) this read-out is similar to that used in electronic calculators. The internal circuitry of the digital multimeter is made up of digital integrated circuits. Like the analog-type multimeter, the digital multimeter has also a front panel switching arrangement. The quantity measured is displayed in the form of a four digit number with a properly placed decimal point. When d quantities are measured, the polarity is identified be means of a + or - sign displayed to the left of the number.

Fig 4



DIGITAL MULTIMETER

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