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

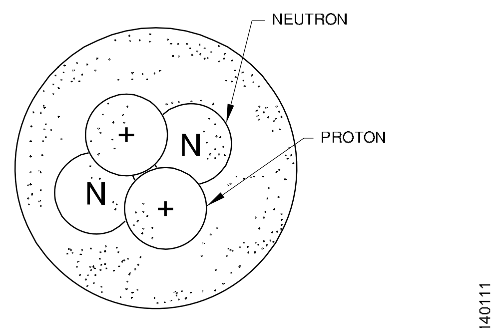
The nucleus is the central part of the atom. It contains the protons and neutrons of an atom as shown in Fig 1

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

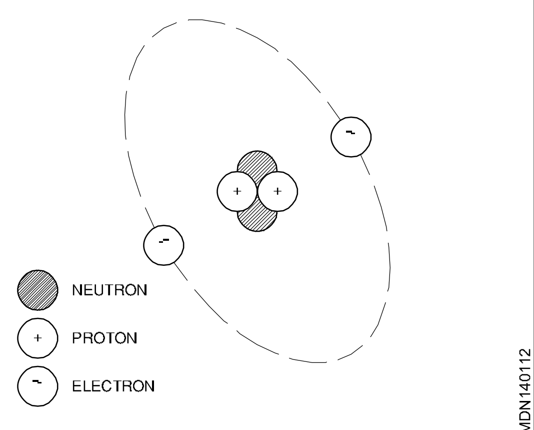


NUCLEUS OF AN ATOM

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

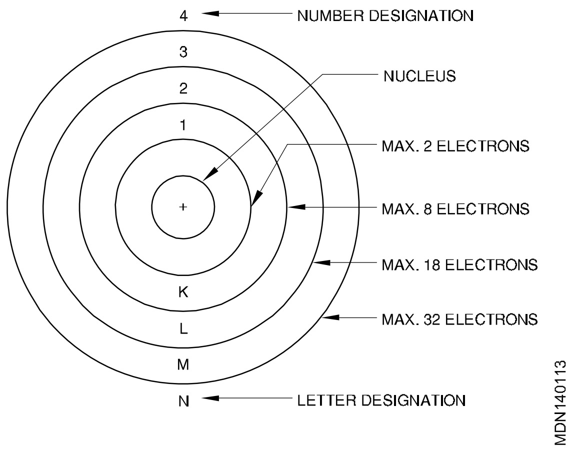


A neutron is actually a particle by itself, and is electrically neutral. Since neurtons are electrically neutral, they are not too important to the electrical nature of atoms.

Energy Shells

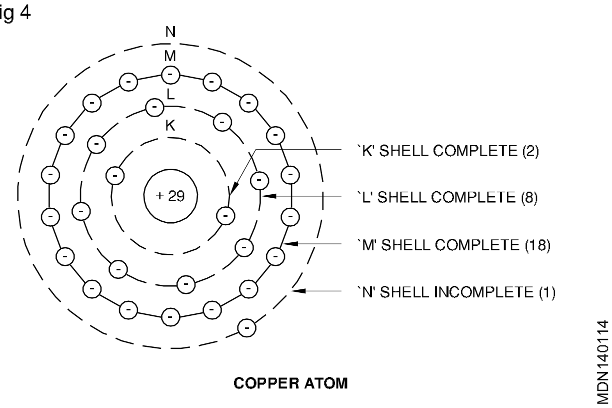
In an atom, electrons are aranged in shells around the nucleus. A shell is an orbiting layer or energy level of one or more lectrons. The major sheel layers are identified by numbers of by letters starting with 'K' nearest the nuclues and continuing alphabetically outwards. There is a maximum number 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).

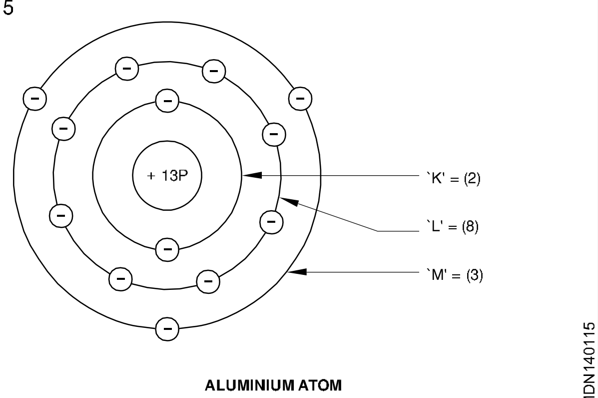
Fig 4



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.

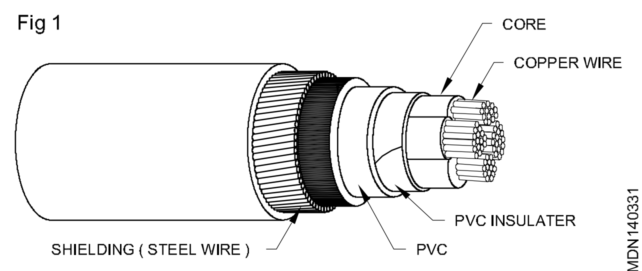
Reasons for earthing

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.

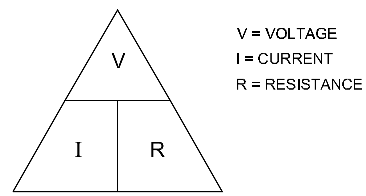
There is a definite relationship between the three electrical quantities of Voltage, Current and Resistance.

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



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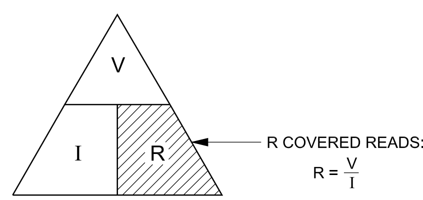
Written as a mathematical expression, Ohm's Law is -

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

Fig 2



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

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:

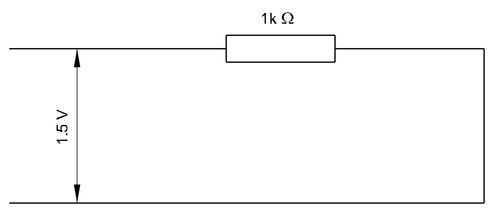
The current in the circuit is 0.0015 A

or

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

(1000 milliamps = 1 ampere)

Fig 3



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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,

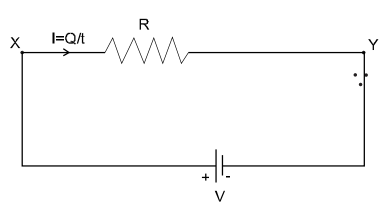
I = Current in amps.

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



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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.
$\therefore$ 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 :

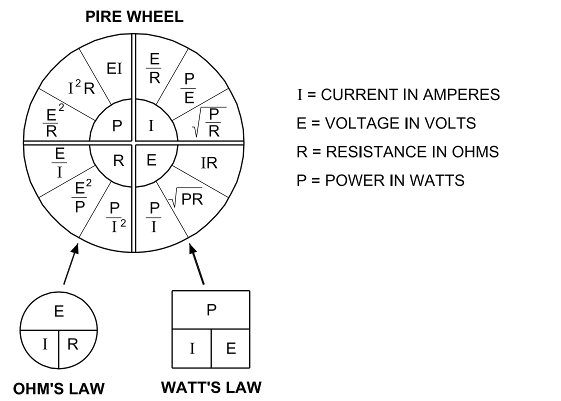
V = I R

= 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

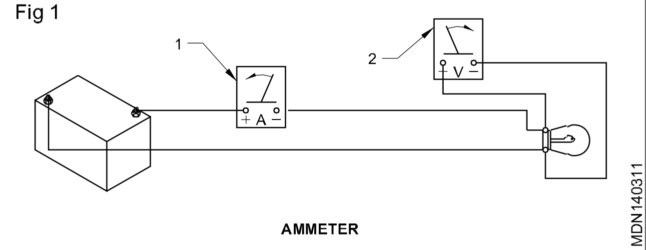
Objectives: At the end of this lesson you shall be able to
- **describe the connection of an ammeter in the circuit**
- **describe resistance symbols used in wiring diagram**
- **state the use of an ammeter**
- **describe the care to be taken of an ammeter**
- **describe the connection of a voltmeter**
- **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.

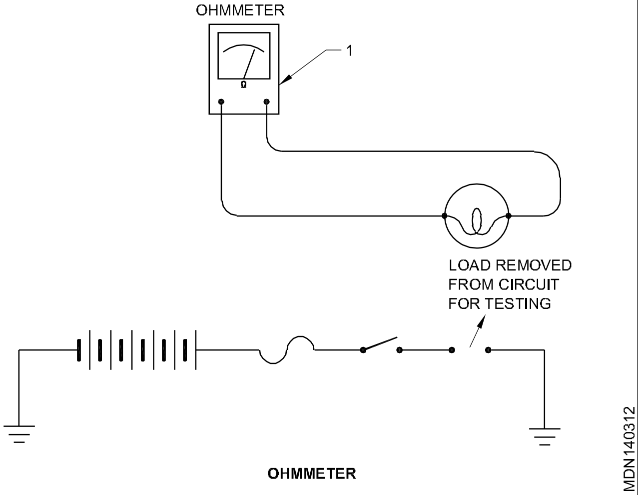
The unit of resistance is an ohm.

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.

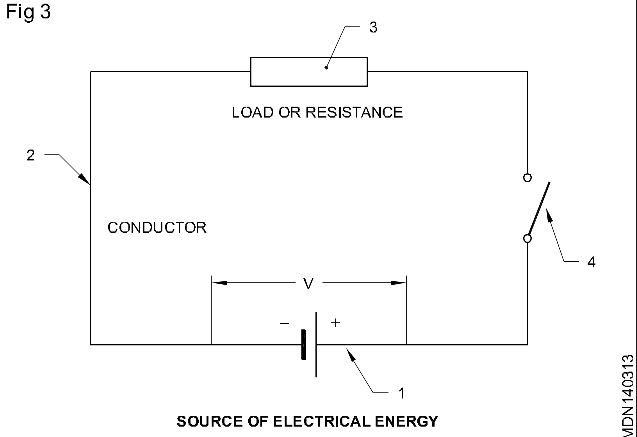
Use the meters within specified loads.

After use, keep the meters in a separate place.

Electrical circuits

Simple electrical circuit (Fig 3)

Fig 3

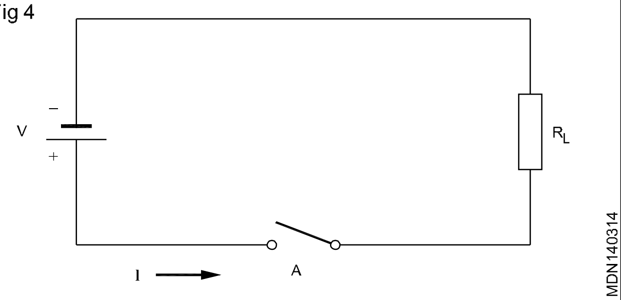


A simple electric circuit is a complete pathway of the current flow from the battery via the switch and load and back to the battery. An electric circuit consists of :

– 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.

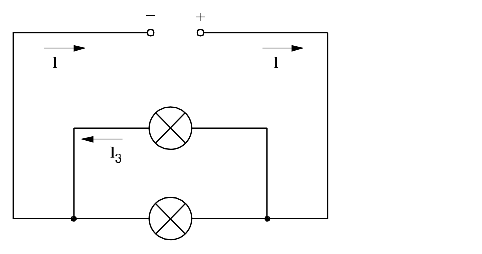
Fig 4



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.

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

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

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

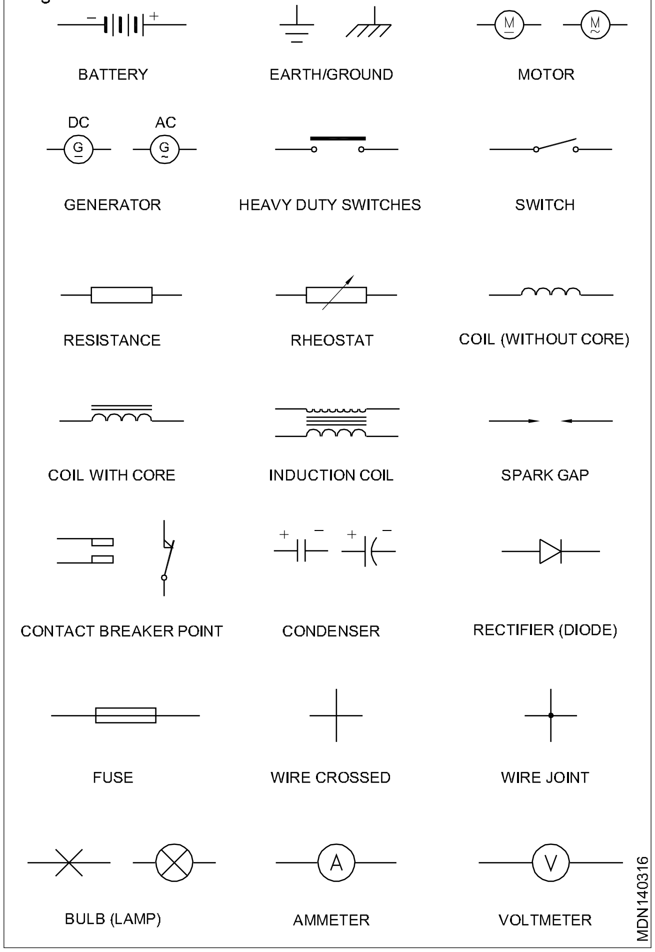
Range : Above 1 Ohm up to 1,00,000 Ohm.
Uses : Bulbs, heaters, relay starters.

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.

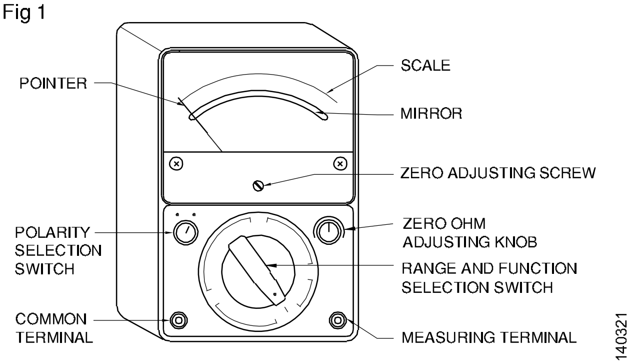
Most of the ordinary multimeters will have a sensitivity of 20k ohms per volt in the voltmeter mode whereas electronic multimeters have internal resistances to the tune of 5 to 10 megohms, irrespective of the selected voltage range.

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

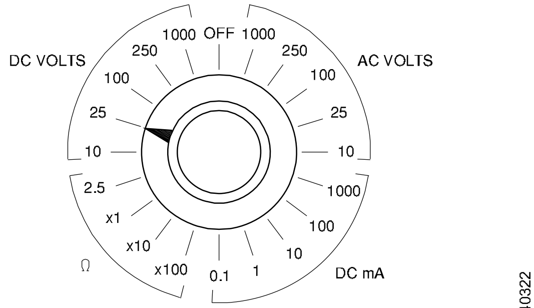


MULTIMETER

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

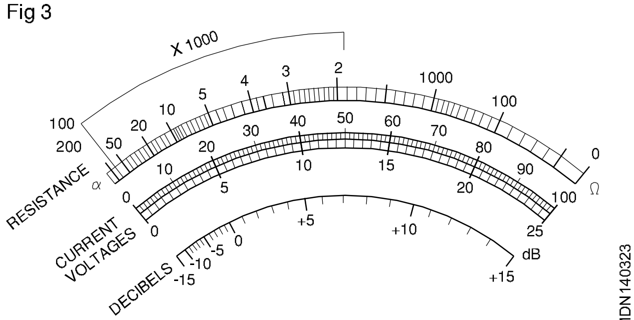
Scale of multimeter

Separate scales are provided for :

- resistance
- voltage and current.

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

Fig 3



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

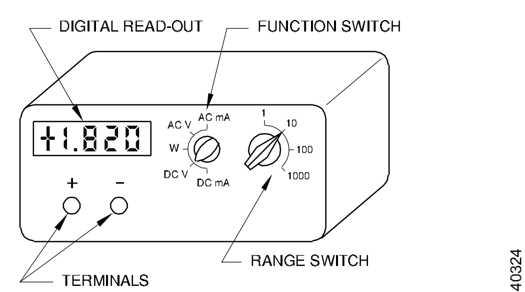
Shunt (parallel) resistors are used to provide multiple ranges so that the meter can measure resistance values from very small to very large values. For each range, a different value of shunt resistance is switched on. The shunt resistance increases for the higher ohm ranges and is always equal to the 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

Fuse

Objectives: At the end of this lesson you shall be able to
- **state the need of a fuse in the circuit**
- **state the construction of a fuse**
- **list out the types of fuses**
- **describe the working of fuses**
- **describe the circuit with and without a fuse**
- **describe the circuit breakers.**

Introduction

A fuse is a protective device. It is a weakest portion in the electrical circuit.

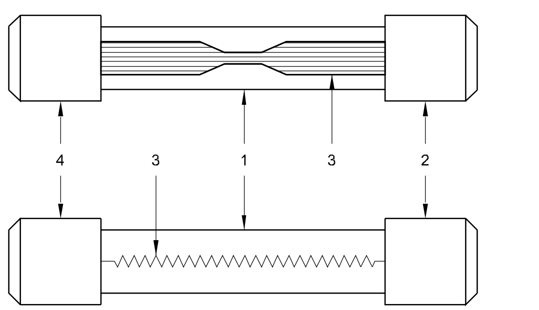
An electric current heats the wire when the current passes through it. The amount of heat depends upon the current and resistance in the wire.

In automobiles, this heating effect is utilized in heaters, bulbs and gauges etc,

The heating effect in the circuit is limited by the fuse. If this limit is not controlled, the circuit of accessories will be overloaded causing severe damage to them.

Purpose of fuse (Fig 1)

Fig 1



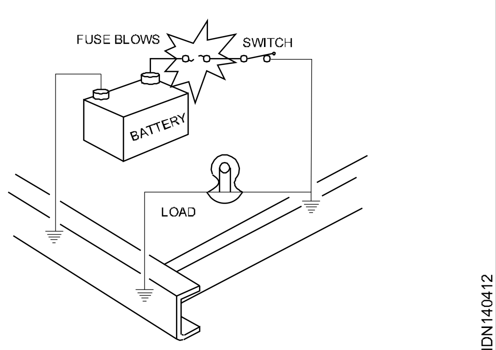
A fuse opens the circuit by blowing out when current (overload) flows in the circuit to prevent severe damage to the accessories.

The flow of excess current in a circuit may be caused by a short circuit.

Construction

Fuse elements are of lead-tin or tin-copper alloy wire in strip of correct amperage for each circuit.

Fig 2



The fuse is assembled in a fuse carrier of glass or ceramic material.

Nowadays fuse elements assembled in glass tubes, called cartridges, are widely used in automobiles.

It consists of a glass tube (1) with metal end caps (2) & (4).

A soft fine wire or strip (3) carries the current from one cap to another (4).

The conductor (3) is designed to carry a specific maximum current.

Working

The current flows through the conductor (3) between two metal caps (2) & (4) and then to the equipment.

If the current value exceeds the limit prescribed on the fuse, the fuse element (3) melts and opens the circuit and prevents the equipment from damage.

Identification of blown fuse

If you look at the burnt fuse and if the element is broken the fuse is burnt due to overloading (Fig 2).

The glass is foggy white or black the fuse is blown out due to short circuit.

Circuits protected with fuse

- Headlight circuit
- Tail - light circuit
- Number -plate circuit
- Panel lamp circuit
- Interior lamp circuit
- Side indicator circuit
- Horn circuit
- Wiper circuit
- Dashboard / panel instruments circuit
- Heater and air conditioner circuit
- Charging circuit
- Radio / Audio / Video circuit

- Cigarette lighter
- Reverse lamp

Circuits without fuse

- Starting circuit
- Ignition circuit
- Fuel pump circuit
- Stop - light circuit
- Oil pressure lamp circuit
- Ignition warning lamp circuit.

Fuse rating and colour

Rating	Colour
3 Amp	Violet
5 Amp	Tan
10 Amp	Red
20 Amp	Yellow
25 Amp	White
30 Amp	Light green

Fusible link and circuit breakers:

Fusible link (Fig 3)

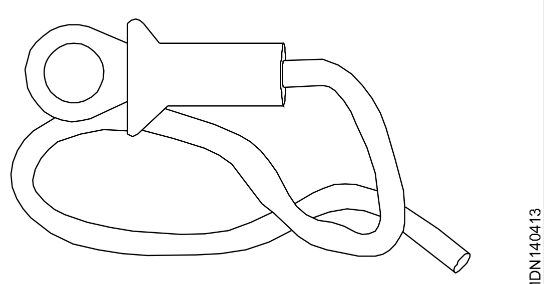
An electrical fusible link is a type of electrical fuse that is constructed simply with a short piece of wire typically four standard wire gauge sizes smaller than the wiring harness that is being protected.

Electrical fusible links are common in high -current automotive applications. The wire in an electrical fusible link is covered with high-temperature fire-resistant insulation to reduce hazards when the wire melts and also encased in special materials that are designed to not catch on fire when exposed to high temperatures.

Fusible links can be found in a variety of places in cars and truck, but they are commonly used in high-amperage applications. Such as starter motors, alternator where load exceeds rated amps.

When this type of fusible link blows, the vehicle will no longer start, but the risks of fire are eliminated.

Fig 3



Circuit Breakers - Automotive

Automotive circuit breakers provide a resettable and reusable alternative over standard fuses for circuit protection, and can altogether replace fuses and fusible links in most applications.

Circuit breakers come in 3 types:

Type 1

This type are auto resettable, and once tripped, will attempt to reset the circuit, as the internal elements of the breaker cool down.

Type 2 (trip and hold)

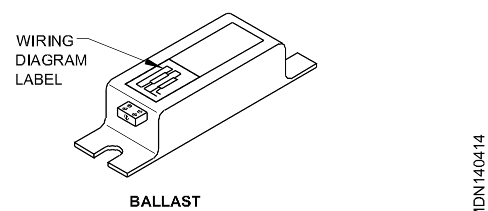
This type are called modified reset, and will remain tripped until the power is removed from the breaker.

T**ype 3 (circuit breakers)**

This type are manual resettable, and require that a button or lever be pushed in order to reset breaker.

Ballast (Choke): The ballast is basically a coil of many turns wound on a laminated iron core (Fig 4). It steps up the supply voltage to start the fluorescent tube conducting. Once the tube is conducting, it regulates the flow of current to the tube cathodes to keep them from burning out.

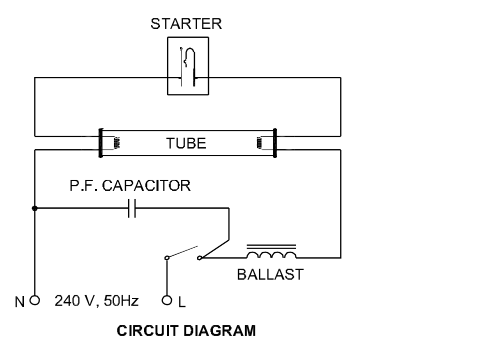
Fig 4



Circuit diagram: The method of connecting the starter, ballast and the tube's electrodes at its either end is shown in Fig 5.

Function of the various parts in a fluorescent light circuit.

Fig 5



Cable colour codes and size

Objectives: At the end of the lesson you shall be able to
- **describe automobile cables**
- **state the needs of colour coding in wiring**
- **state the use of colours in various circuits.**

Description of cables

The cable consists of multi - strand copper conductor covered with good quality PVC insulation.

The current to the various electrical accessories is carried through cables.

The various cables used in wiring are :

- Starting system cable
- General purpose cable
- High tension cable

The specification of the cable refers to the number of stands and diameter of each strand. Eg. 25/012 indicates, the cable consists of 25 strands of 0.012" gauge diameter of each strand.

The size of the cable depends upon the current rating of the accessories connected in that circuit. A thick cable can carry more current and is used in the starting system.

Colour code in cables

In automobiles a number of electric circuits are connnected to the battery which is quite complicated.

The large number of cables are braided into a single har ness assembly.

The automobile manufactures use cables of different colours and usually follow the Lucas colour code system. It consists of basic colours (main colours) and combination of colours to identity individual circuits. (Refer of Fig 1).

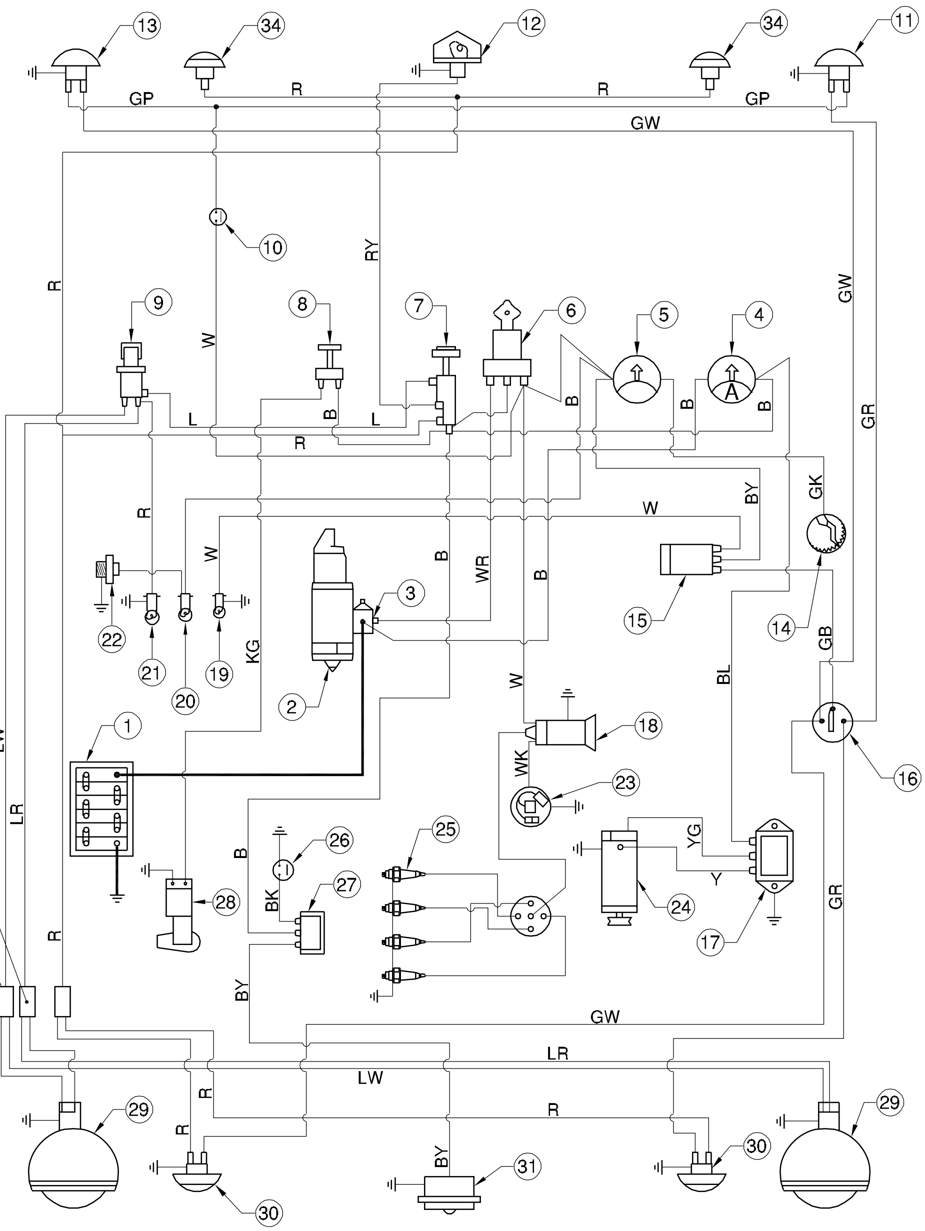
The distinction between wires in a group is done by the use of a coloured bracer on the main colours of the insulator of each wire.

Purpose of colour code

For easy identification of each circuit.

To help to locate the defect easily in a particular circuit and to rectify the same quickly.

Fig 1



NO.	INDEX	NO.	INDEX	COLOUR CODE			
1	BATTERY	18	IGNITION COIL	B	BROWN	GK	GREEN BLACK
2	STARTER MOTOR	19	INDICATOR WARNING LAMP	Y	YELLOW	GP	GREEN PURPLE
3	SOLENOID SWITCH	20	OIL PRESSURE WARNING LAMP	W	WHITE	LR	BLUE RED
4	AMMETER	21	HEAD LIGHT WARNING LAMP	G	GREEN	LW	BLUE WHITE
5	FUEL GUAGE	22	OIL PRESSURE SWITCH	L	BLUE	RG	RED GREEN
6	IGNITION SWITCH	23	DISTRIBUTOR	R	RED	RW	RED WHITE
7	HEADLIGHT SWITCH	24	DYNAMO	K	BLACK	RY	RED YELLOW
8	WIPER SWITCH	25	SPARK PLUG	BL	BROWN BLUE	KG	BLACK GREEN
9	DIM-DIP SWITCH	26	HORN SWITCH	BK	BROWN BLACK		
10	STOP LIGHT SWITCH	27	HORN RELAY	BY	BROWN YELLOW		
11	STOP CUM INDICATOR LAMP	28	WIPER UNIT	BG	BROWN GREEN		
12	NUMBER-PLATE LAMP	29	HEAD LIGHT	YG	YELLOW GREEN		
13	STOP CUM INDICATOR LAMP	30	FRONT PARKING CUM I-LAMP	WR	WHITE RED		
14	FUEL TANK UNIT	31	HORN	WK	WHITE BLACK		
15	FLASHER UNIT	32	DIM SOCKET	GB	GREEN BROWN		
16	INDICATOR SWITCH	33	DIP SOCKET	GW	GREEN WHITE		
17	CONTROL BOX	34	TAIL-LAMP	GR	GREEN RED		

Law of Resistances

Objectives: At the end of this lesson you shall be able to
- **state the Laws of Resistance, compare resistances of different materials**
- **state the formula giving the relationship between the resistance and dimemsions of a conductor**
- **state the effect of temperature on resistance and describe the temperature cofficient of resistance**
- **calculate the resistance of a conductor.**

Laws of resistance (Fig. 1): The resistance R offered by a conductor depends on the following factors.

– The resistance of the conductor varies directly with its length.

– The resistance of the conductor is inversely proportional to its cross-sectional area.

– The resistance of the conductor depends on the material with which it is made of.

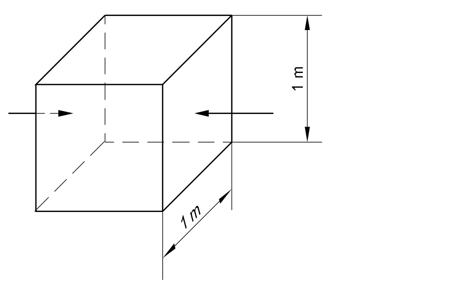
– It also depends on the temperature of the conductor.

Ignoring the last factor for the time being,we can say that

$$R = \frac{PL}{a}$$

where r is a constant depending on the nature of the material of the conductor, and is known as its specific resistance or resistivity.

Fig 1



If the length is one metre and the area, 'a' = 1 m^2, then R = r.

Hence, specific resistance of a material may be defined as `the resistance between the opposite faces of a metre cube of that material'. (sometimes, the unit cube is taken in centimetre cube of that material).

We have $\rho = \frac{aR}{L}$

In the SI system of units

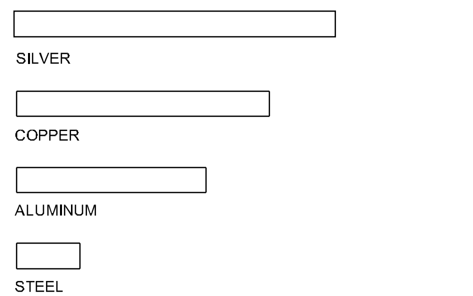
$$\rho = \frac{a\ \text{metre}^2 \times R\ \text{ohm}}{L\ \text{metre}}$$

$$= \frac{aR}{L}\ \text{ohm-metre}$$

Hence the unit of specific resistance is ohm metre (Wm).

Comparison of the resistance of different materials: (Fig 2) gives some relative idea of the more important materials as conductors of electricity. All the conductors have the same cross-sectional area and the same amount of resistance. The silver wire is the longest while that of copper is slightly short and that of aluminium is shorter still. The silver wire is more than 5 times longer than the steel wire.

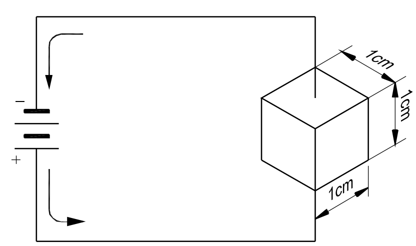
Fig 2



THE CONDUCTANCE OF DIFFERENT MATERIALS

Since different metals have different conductance ratings, they must also have different resistance ratings. The resistance ratings of the different metals can be found by experimenting with a standard piece of each metal in an electric circuit. If you cut a piece of each of the more common metals to a standard size, and then connect the pieces to a battery, one at a time, you would find that different amounts of current would flow. (Fig 3)

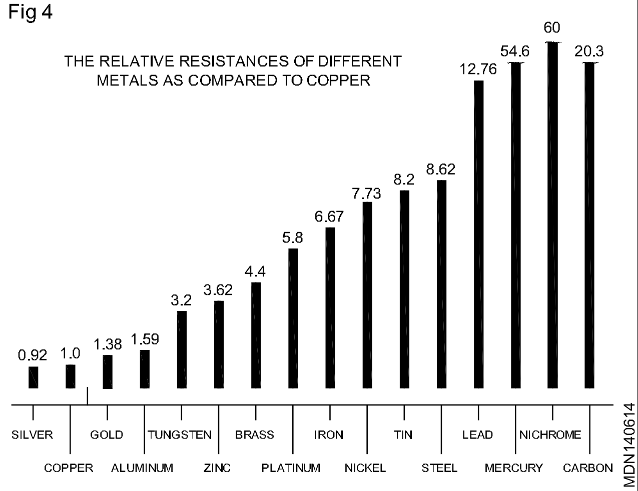
Fig 3



THE MORE RESISTANCE A MATERIAL HAS, THE LESS CURRENT THE MATERIAL WILL CONDUCT. GOOD INSULATORS, SUCH AS GLASS, RUBBER, MICA, POLYSTYRENE, ETC., HAVE CONSIDERABLY MORE THAN A MILLION TIMES THE RESISTANCE OF ANY GOOD CONDUCTOR

The bar graph (Fig 4) shows the resistance of some common metals as compared to copper. Silver is a better conductor than copper because it has less resistance. Nichrome has 60 times more resistance than copper, and copper will conduct 60 times as much current as Nichrome, if they were connected to the same battery, one at a time.

Fig 4



Resistors :

These are the most common passive component used in electronic circuits. A resistor is manufacture with a specific value of ohms resistance. The purpose using a resistor in circuit is either to limit the current to speciifc value or to provide desired voltage drop (IR) The power rating of resistors may be from O.1.W. to hundred of Watts.

Wire - wound resistors

Wire-wound resistors are manufactured by using resistance wire (nickel - chrome alloy called Nichrome) wrapped around an insulating core, such as cerami porcelain bakelite pressed paper etc (Fig 4). The bare wire used in the unit is generally enclosed in insulating material. Wire wound resistors are used for high current application. They are avilable in wattage ratings from one watt to 100 watts or more. The resistance can be less than 1 ohm and go up to several thousand ohms. They are also used where accurate resistance values are required.

One type of Wire-wound resistor is called as fusible resistor enclosed in a porcelain case. The resistance is designed to open the circuit when the current through it exceeds certain limit.

This type of ballast resistor is used in the automobile vechile flasher unit. Due to which the the indicator lamp flash at the regulation of 70-100 times / min.

Resistors and Capacitors

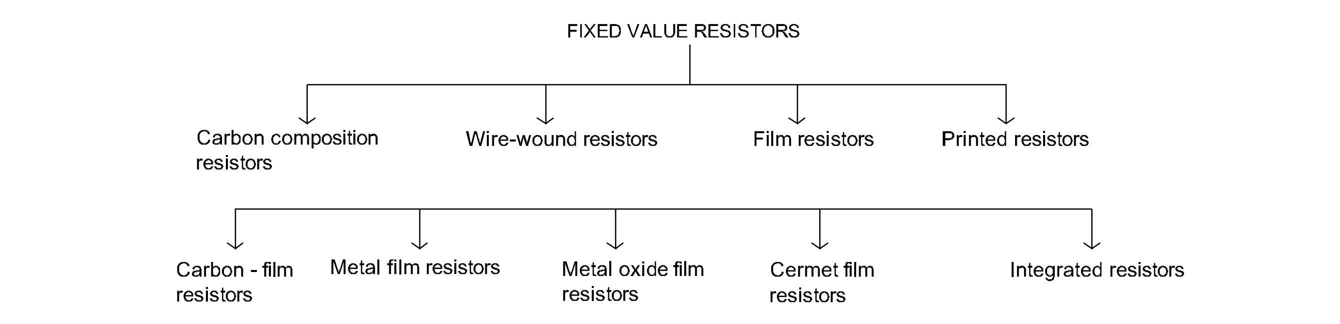
Objectives: At the end of this lesson you shall be able to
- **name the types of resistors**
- **state the meaning of tolerance in resistor**
- **give examples to find the value of a resistor**

Fixed value resistors

Its ohmic value is fixed. This value cannot be changed by the user. Resistors of standard fixed values are manufactured for use in majority of applications.

Fixed resistors are manufactured using different materials and by different methods. Based on the material used and their manufacturing method/process, resistors carry different names.

Fixed value resistors can be classified based on the type of material used and the process of making as follows.

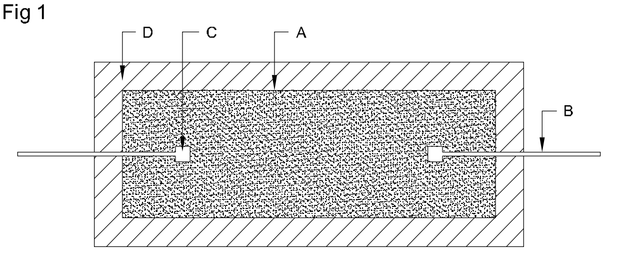


Carbon composition resistors

Construction

These are the simplest and most economical of all other types. Brief constructional detail of the simplest type of carbon composition resistors commonly called carbon resistor is shown in (Fig 1).

Fig 1

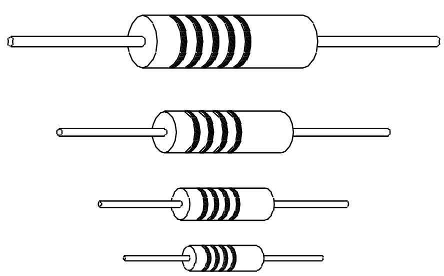


A mixture of finely powdered carbon or graphite(A), filler and binder is made into rods or extruded into desired shapes. Leads(B) made of tinned copper are then attached to the body either by soldering or embedding(C) in the body. A protective layer/tube(D) of phenolic or Bakelite is moulded around the assembly. Finally its resistance value is marked on the body.

Power rating

As already discussed, when current flows through a resistor, heat is generated. The heat generated in a resistor will be proportional to the product of applied voltage (V) across the resistor and the resultant current (I) through the resistor. This product VI is known as *power*. The unit of measurement of power is watts.

Fig 2



The physical size of a resistor should be sufficiently large to dissipate the heat generated. The higher the physical size, the higher is the heat that a resistor can dissipate. This is referred to as the power rating or wattage of resistors. Resistors are manufactured to withstand different power ratings.

(Fig 2) illustrates comparative physical sizes of different wattage resistors. If the product of V and I exceeds the maximum wattage a resistor can dissipate, the resistor gets charred and loses all its property. For instance, if the applied voltage across a 1 watt resistor is 10 volts resulting in 0.5 Amps of current through the resistor, the power dissipated (VI) by the resistor will be 5 watts. But, the maximum power that can be dissipated by the IW resistor is much less. Therefore, the resistor will get overheated and gets charred due to overheat.

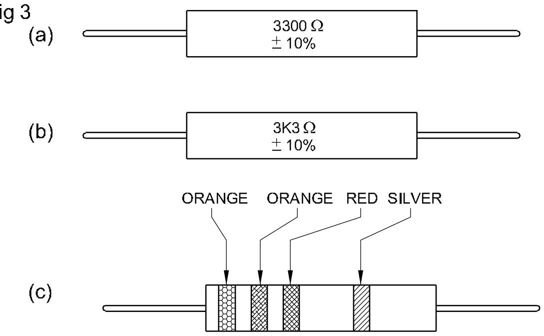
Hence, before using a resistor, in addition to its ohmic value, it is important to choose the correct wattage rating. If in doubt, choose a higher wattage resistor but never on the lower side. The power rating of resistors are generally printed on the body of the resistor.

Resistor values - coding schemes

For using resistors in circuits, depending upon the type of circuit in which it is to be used, a particular type, value and wattage of resistor is to be chosen. Hence before using a resistor in any circuit, it is absolutely necessary to identify the resistor's type, value and power rating.

Selection of a particular type of resistor is possible based on its physical appearance. The resistance value of a resistor will generally be printed on the body of the resistor either directly in ohms as shown in (Fig 3a) or using a typographic code as shown in (Fig 3b) or using a colour code as shown in (Fig 3c).

Fig 3



Colour band coding of resistors

Colour band coding as shown in (Fig 3c) is most commonly used for carbon composition resistors. This is because the physical size of carbon composition resistor is generally small, and hence, printing resistance values directly on the resistor body is difficult. Refer Table 1.

Tolerance

In bulk production/ manufacturing of resistors, it is difficult and expensive to manufacture resistors of particular exact values. Hence the manufacturer indicates a possible variation from the standard value for which it is manufactured. This variation will be specified in percentage tolerance. Tolerance is the range(max -to- min) within which the resistance value of the resistor will exist.

Typographical coding of resistors

In the typographical coding scheme of indicating resistance values, the ohmic value of the resistor is printed on the body of the resistor using an alpha-numeric coding scheme.

> **Some resistance manufacturers use a coding scheme of their own. In such cases it will be necessary to refer to the manufacturer's guide.**

Applications

Carbon composition, fixed value resistors are the most widely used resistors in general purpose electronic circuits such as radio, tape recorder, television etc. More than 50% of the resistors used in electronic industry are carbon resistors.

TABLE 1

Resistor Colour Code

Colour	Significant figures	Multiplier	Tolerance
Silver	-	10^{-2}	± 10%
Gold	-	10^{-1}	± 5%
Black	0	1	-
Brown	1	10	± 1%
Red	2	10^{2}	± 2%
Orange	3	10^{3}	± 3%
Yellow	4	10^{4}	± 4%
Green	5	10^{5}	± 0.5%
Blue	6	10^{6}	-
Violet	7	-	-
Grey	8	-	-
White	9	-	-
(None)	-	-	± 20%

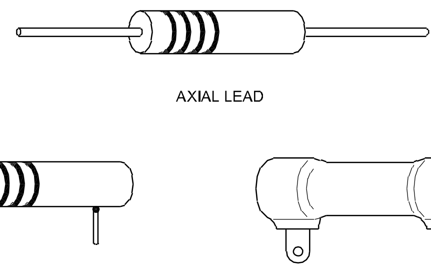
1, 2 and 3: 1st, 2nd and 3rd significant figures ;

M : Multiplier ; T : Tolerance ; T_c : Temperature co-efficient

Types of resistor leads

Resistors are available with different types of lead attachment as shown in Fig 4. This make it easy for the user to mount the resistors in different ways on lug boards, PCBs and other types of circuit boards.

Fig 4



Capacitors

Objectives: At the end of this lesson you shall be able to
- **state and describe a capacitor**
- **state and explain charging of a capacitor**
- **state and explain capacitance and unit of capacitance**
- **state and describe the factors determining the capitance**
- **state and describe the different types of capacitors**
- **explain the defects in capacitors**
- **state and describe the testing of capacitors.**

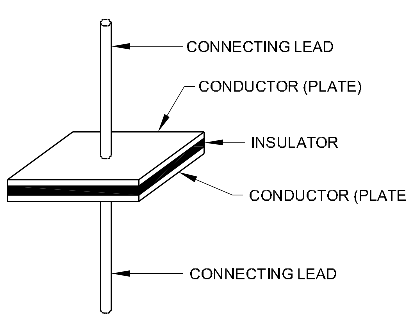
Capacitors

A device designed to posses capacitance is called a capacitor.

Construction

A capacitor is an electrical device consisting of two parallel conductive plates, separated by an insulating material called the dielectric. Connecting leads are attached to the parallel plates. (Fig 1)

Fig 1



SIMPLE CAPACITOR. THE PLATES OF A CAPACITOR ARE ALWAYS INSULATED FROM EACH OTHER

Function

In a capacitor the electric charge is stored in the form of an electrostatic field between the two conductors or plates, due to the ability of dielectric material to distort and store energy while it is charged and keep that charge for a long period or till it is discharged through a resistor or wire. The unit of charge is coulomb and it is denoted by the letter `C'.

How a capacitor stores charge?

In the neutral state, both plates of a capacitor have an equal number of free electrons, as indicated in (Fig 2a). When the capacitor is connected to a voltage source through a resistor, the electrons (negative charge) are removed from plate A, and an equal number are deposited on plate `B'. Plate A becomes positive with respect to plate B as shown in (Fig 2b).

The current enters and leaves the capacitor, but the insulation between the capacitor plates prevents the current from flowing through the capacitor.

As electrons flowing into the negative plate of a capacitor have a polarity opposite to that of the battery supplying the current, the voltage across the capacitor opposes the battery voltage. The total circuit voltage, therefore, consists of two series-opposing voltages.

As the voltage across the capacitor increases, the effective circuit voltage, which is the difference between the battery voltage and the capacitor voltage, decreases. This, in turn, causes a decrease in the circuit current. When the voltage across the capacitor equals the battery voltage, the effective voltage in the circuit is zero, and so the current flow stops. At this point, the capacitor is fully charged, and no further current can flow in the circuit.

Capacitance (Fig 2c)

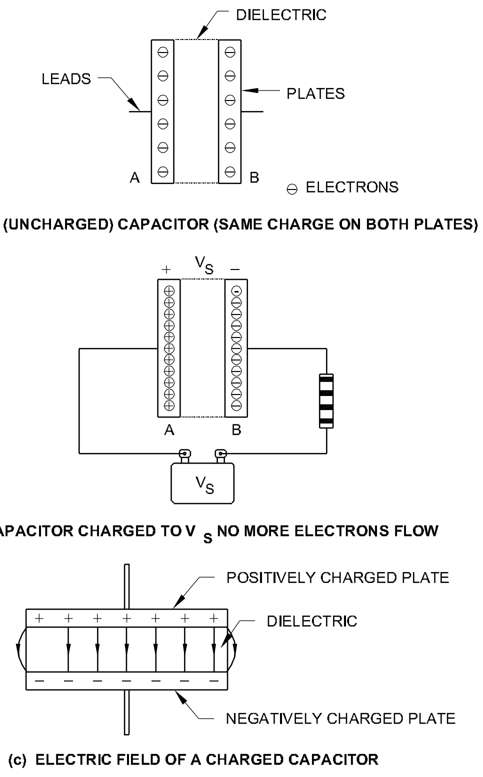
The ability to store energy in the form of electric charge is called capacitance. The symbol used to represent capacitance is C.

Unit of capacitance

The base unit of capacitance is farad. The abbreviation for farad is F. One farad is that amount of capacitance which stores 1 coulomb of charge when the capacitor is charged to 1 V. In other words, a farad is a coulomb per volt (C/V).

A farad is the unit of capacitance (C), and a coulomb is the unit of charge(Q), and a volt is the unit of voltage(V).

Fig 2



Grouping of capacitors

Objectives : At the end of this lesson you shall be able to
- **state the necessity of grouping of capacitors**
- **list the conditions for connecting capacitors in parallel**
- **determine the values of capacitance and voltage in parallel combination**
- **list the conditions for connecting capacitors in series**
- **determine the values of capacitance and voltage in series combination.**

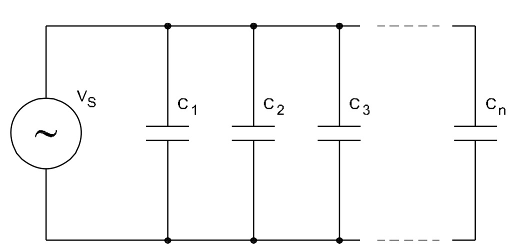
Necessity of grouping of capacitors

In certain instances, we may not be able to get a required value of capacitance and a required voltage rating. In such instances, to get the required capacitances from the available capacitors and to give only the safe voltage across capacitor, the capacitors have to be grouped in different fashions. Such grouping of capacitors is very essential.

Necessity of parallel grouping

Capacitors are connected in parallel to achieve a higher capacitance than what is available in one unit.

Fig 1



CAPACITORS IN PARALLEL

Connection of parallel grouping

Parallel grouping of capacitors is shown in (Fig 1) and is analogous to the connection of resistance in parallel or cells in parallel.

Total capacitance

When capacitors are connected in parallel, the total capacitance is the sum of the individual capacitances, because the effective plate area increases. The calculation of total parallel capacitance is analogous to the calculation of total resistance of a series circuit.

By comparing (Fig 2a and 2b), you can understand that connecting capacitors in parallel effectively increases the plate area.

General formula for parallel capacitance

The total capacitance of parallel capacitors is found by adding the individual capacitances.

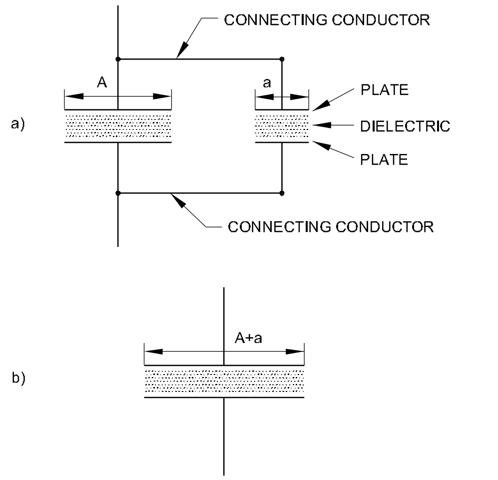
$C_T = C_1 + C_2 + C_3 + ... + C_n$

where C_T is the total capacitance,

C_1, C_2, C_3 etc. are the parallel capacitors.

The voltage applied to a parallel group must not exceed the lowest breakdown voltage for all the capacitors in the parallel group.

Fig 2



CAPACITORS IN PARALLEL. THE EQUIVALENT CAPACITANCE IN (b) IS EQUAL TO THE SUM OF THE CAPACITANCES IN (a).

MDN140642

Example: Suppose three capacitors are connected in parallel, where two have a breakdown voltage of 250 V and one has a breakdown voltage of 200 V, then the maximum voltage that can be applied to the parallel group without damaging any capacitor is 200 volts.

The voltage across each capacitor will be equal to the applied voltage.

Charge stored in parallel grouping

Since the voltage across parallel-grouped capacitors is the same, the larger capacitor stores more charge. If the capacitors are equal in value, they store an equal amount of charge. The charge stored by the capacitors together equals the total charge that was delivered from the source.

$Q_T = Q_1 + Q_2 + Q_3 + ... + Q_n$

where Q_T is the total charge

Q_1, Q_2, Q_3.....etc. are the individual

charges of the capacitors in parallel.

Using the equation Q = CV,

the total charge $Q_T = C_T V_S$

where V_S is the supply voltage.

Again $C_T V_S = C_1 V_S + C_2 V_S + C_3 V_S$

Because all the V_S terms are equal, they can be cancelled.

Therefore, $C_T = C_1 + C_2 + C_3$

Series grouping

Necessity of grouping of capacitors in series

The necessity of grouping capacitors in series is to reduce the total capacitance in the circuit. Another reason is that two or more capacitors in series can withstand a higher potential difference than an individual capacitor. But, the voltage drop across each capacitor depends upon the individual capacitance. If the capacitances are unequal, you must be careful not to exceed the breakdown voltage of any capacitor.

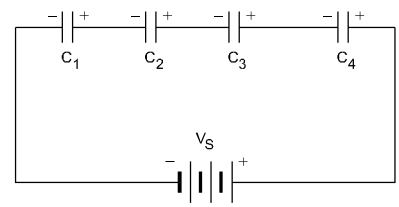
Conditions for series grouping

- If different voltage rating capacitors have to be connected in series, take care to see that the voltage drop across each capacitor is less than its voltage rating.
- Polarity should be maintained in the case of polarised capacitors.

Connection in series grouping

Series grouping of capacitors, as shown in (Fig 3) is analogous to the connection of resistances in series or cells in series.

Fig 3



SERIES CONNECTION OF CAPACITORS

MDN140643

Total capacitance

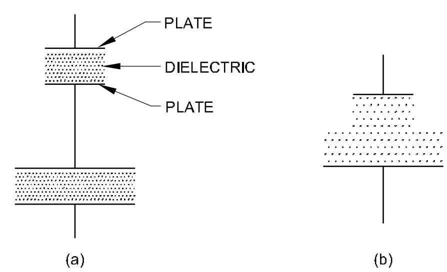
When capacitors are connected in series, the total capacitance is less than the smallest capacitance value, because

- the effective plate separation thickness increases
- and the effective plate area is limited by the smaller plate.

The calcualtion of total series capacitance is analogous to the calculation of total resistance of parallel resistors.

By comparing (Fig 4a and 4b) you can understand that connecting capacitors in series increases the plate separation thickness, and also limits the effective area so as to equal that of the smaller plate capacitor.

Fig 4



THE EQUIVALENT CAPACITANCE IN (b) IS LESS THAN THE LOWER OF THE TWO CAPACITANCES IN (a).

MDN140644

General formula for series capacitance

The total capacitance of the series capacitors can be calculated by using the formula

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_n}}$$

or

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_n}$$

If there are two capacitors in series

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

If there are three capacitors in series

$$C_T = \frac{C_1 C_2 C_3}{(C_1 C_2) + (C_2 C_3) + (C_3 C_1)}$$

If there are `n' equal capacitors in series

$$C_T = \frac{C}{n}$$

Maximum voltage across each capacitor

In series grouping, the division of the applied voltage among the capacitors depends on the individual capacitance value according to the formula

$$V = \frac{Q}{C}$$

The largest value capacitor will have the smallest voltage because of the reciprocal relationship.

Likewise, the smallest capacitance value will have the largest voltage.

The voltage across any individual capacitor in a series connection can be determined using the following formula.

$$V_x = \frac{C_T}{C_x} \times V_s$$

where

V_x - individual voltage of each capacitor

C_x - individual capacitance of each capacitor

V_s - supply voltage.

The potential difference does not divide equally if the capacitances are unequal. If the capacitances are unequal you must be careful not to exceed the breakdown voltage of any capacitor.

Example: Find the voltage across each capacitor in Fig 6.

DC series - parallel - series and parallel combination circuits

Objectives: At the end of this lesson you shall be able to
- **identify the series connection and determine the current in the series circuit**
- **determine the voltage across elements in a series circuit**
- **determine the total voltage in a circuit when the voltage sources are in series**
- **state the uses of a series connection.**

The series circuit

It is possible to connect two incandescent lamps in the way shown in (Fig 1). This connection is called a series connection, in which the same current flows in the two lamps.

Fig 1

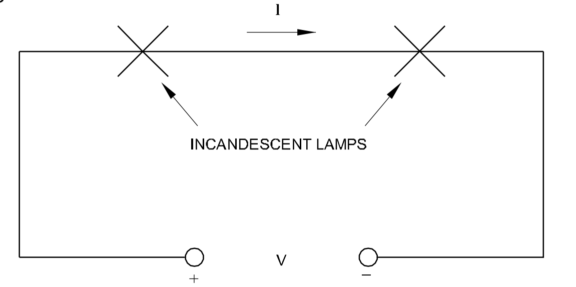
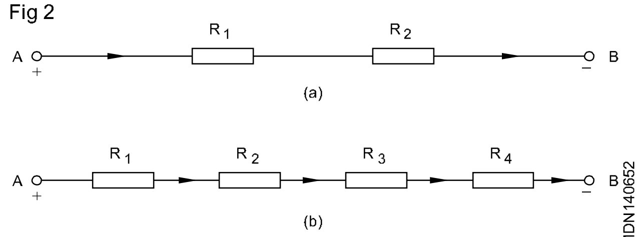


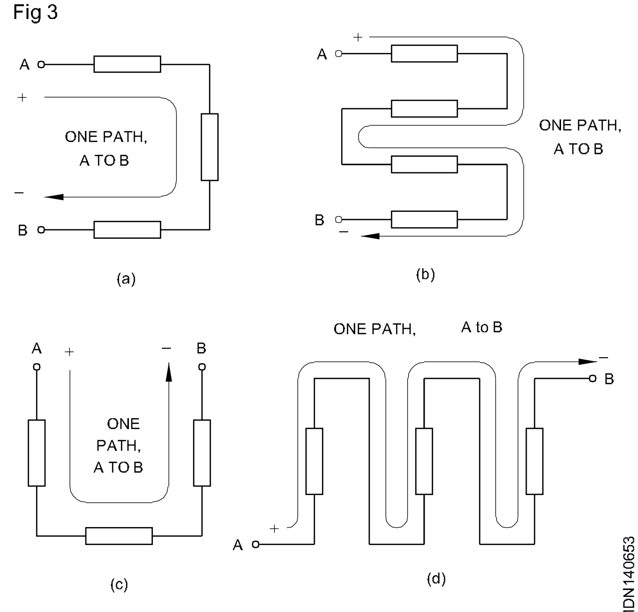
Fig 2



The lamps are replaced by resistors in Fig 2. Fig 2 (a) shows two resistors are connected in series between point A and point B. Fig 2(b) shows four resistors are in series. Of course, there can be any number of resistors in a series connection. Such connection provides only one path for the current to flow.

Identifying series connections

Fig 3



In an actual circuit diagram, a series connection may not always be as easy to identify as those in the figure. For example, (Fig 3(a), 3(b), 3(c) & 3(d)) shows series resistors drawn in different ways. In all the above circuits we find there is only one path for the current to flow.

Current in series circuits

The current will be the same at any point of the series circuit. This can be verified by measuring the current in any two points of a given circuit as shown in (Fig 4 (a) and 4(b)). The ammeters will show the same reading.

The current relationship in a series circuit is

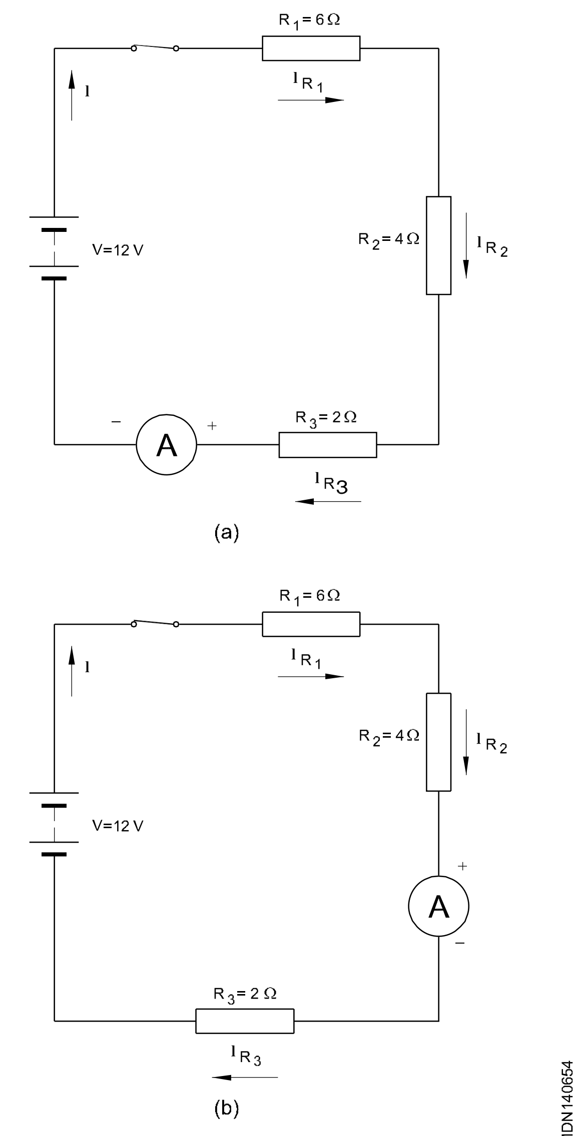
$I = I_{R1} = I_{R2} = I_{R3}$. (Refer Fig 4)

We can conclude that there is only one path for the current to flow in a series circuit. Hence, the current is the same throughout the circuit.

Total resistance in series circuit

You know how to calculate the current in a circuit, by Ohm's law, if resistance and voltage are known. In a circuit consisting of two resistors R_1 and R_2 we know that the resistor R_1 offers some opposition to the current flow. As the same current should flow through R_2 in series it has to overcome the opposition offered by R_2 also.

Fig 4



If there are a number of resistances is series, they all oppose the flow of current through them.

The 2nd characteristic of a DC series circuit could be written as follows.

The total resistance in a series circuit is equal to the sum of the individual resistances around the series circuit. This statement can be written as

$R = R_1 + R_2 + R_3 + ...R_n$

where R is the total resistance

$R_1, R_2, R_3, ...R_n$ are the resistances connected in series.

When a circuit has more than one resistor of the same value in series, the total resistance is $R = r \times N$

where 'r' is the value of each resistor and N is the number of resistors in series.

Voltage in series circuits

In DC circuit voltage divides up across the load resistors, depending upon the value of the resistor so that the sum of the individual load voltages equals the source voltage.

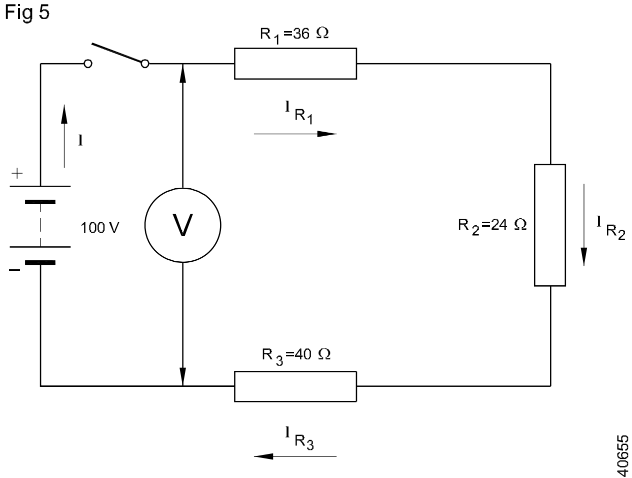
The 3rd characteristic of a DC circuit can be written as follows.

As the source voltage divides/drops across the series resistance depending upon the value of the resistances

$V = V_{R1} + V_{R2} + V_{R3} + ...$

the total voltage of a series circuit must be measured across the voltage source, as shown in (Fig 5).

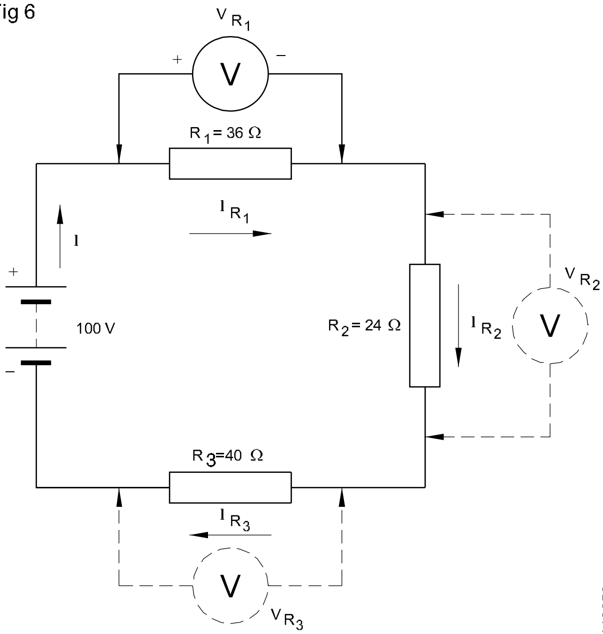
Fig 5



MEASURIING THE TOTAL VOLTAGE OF SERIES CIRCUIT

Voltages across the series resistors could be measured using one voltmeter at different positions as illustrated in (Fig 6).

Fig 6



VOLTAGE DROP IN A SERIES CIRCUIT

When Ohm's law is applied to the complete circuit having an applied voltage V, and total resistance R, we have the current in the circuit as

$I = V/R$

Application of Ohm's law to DC series circuits

Applying to Ohm's law to the series circuit, the relation between various currents could be stated as below

Potential difference and polarity of I R voltage drops

Objectives: At the end of this lesson you shall be able to

- **state the relation between the emf, potential difference and terminal voltage**
- **define I.R. drop (voltage drop) in a DC series circuit**
- **identify polarity of voltage drops**
- **identify positive and negative grounds**
- **mark the polarity of the voltage drop with respect to ground to determine the terminals of the voltmeter.**

Definitions

Electromotive force (emf)

We have seen in Related Theory of Exercise 1.07, the electromotive force (emf) of a cell is the open circuit voltage, and the potential difference (PD) is the voltage across the cell when it delivers a current. The potential difference is always less than the emf.

Potential difference

PD = emf – voltage drop in the cell

Potential difference can also be called by another term, the terminal voltage, as explained below.

Terminal voltage

It is the voltage available at the terminal of the source of supply. Its symbol is V_T. Its unit is also the volt. It is given by the emf minus the voltage drop in the source of supply,

i.e. $V_T = \text{emf} - IR$

where I is the current and R the resistance of the source.

Voltage drop (IR drop)

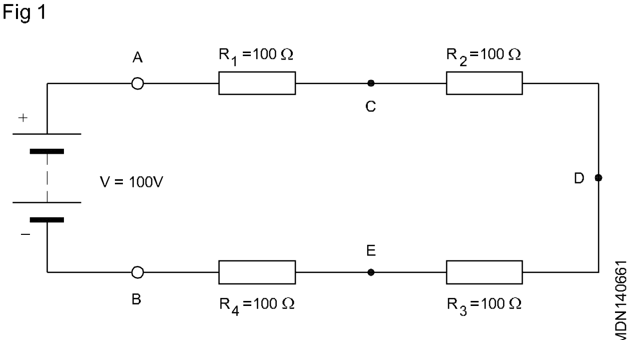
The voltage lost by resistance in a circuit is called the Voltage drop or IR drop.

Example 1

The resistances and applied voltage are known. (Fig 1)

What are the voltage drops across the resistors

Fig 1



The total resistance of the circuit in (Fig 1) would be equal to $R_T = 100 + 100 + 100 + 100 = 400$ ohms.

The current flowing through the circuit would be

$I = (100/400) = 0.25$ amps.

But point A has a potential of 100 volts and point B has zero. Somewhere along the circuit between A and B, the 100 volts have been lost.

To find the voltage drop for each resistor is easy. First find the current, which we have calculated as 0.25 amps, then

$V_{R1} = 0.25 \times 100 = 25$ V

$V_{R2} = 0.25 \times 100 = 25$ V

$V_{R3} = 0.25 \times 100 = 25$ V

$V_{R4} = 0.25 \times 100 = 25$ V.

Add up all the voltage drops and they will total 100 volts which is the applied voltage of the circuit.

25 + 25 + 25 + 25 = 100 volts.

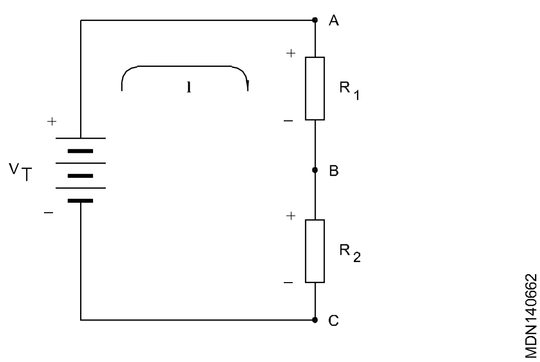
The sum of the voltage drops in a circuit must be equal to the applied voltage.

$V_{Total} = V_{R1} + V_{R2} + V_{R3} + V_{R4}$.

Polarity of voltage drops

When there is a voltage drop across a resistance, one end must be more positive or more negative than the other end. The polarity of the voltage drop is determined by the direction of conventional current. In (Fig 2), the current direction is through R_1 from point A to B.

Fig 2



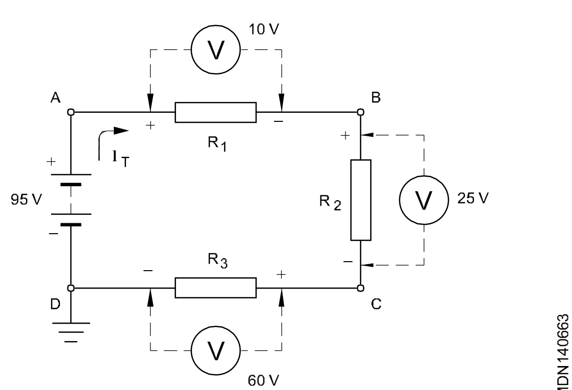
Therefore, the terminal of R_1 connected to point A has a more positive potential than point B. We say that the voltage across R_1 is such that point A is more positive than point B. Similarly the voltage of point B is more positive than point C. Another way to look at polarity between any two points is that the one nearer to the positive terminal of the voltage source is more positive; also, the point nearer to the negative terminal of the applied voltage is more negative. Therefore, point A is more positive than B, while C is more negative than B. (Fig 2)

Example 2

Find the voltage at the points A,B, C and D with respect to ground.

Mark the polarity of voltage drops in the circuit (Fig 3) and find the voltage values at points A, B, C and D with respect to ground.

Fig 3



Trace the complete circuit in the direction of current from the + terminal of the battery to A, A to B, B to C, C to D, and D to the negative terminal. Mark plus (+) where the current enters each resistor and minus (–) where the current leaves each resistor.

The voltage drops indicate (Fig 3) Point A is the nearest point to the positive side of the terminal; so voltage at A with respect to ground is

V_A = +95 V.

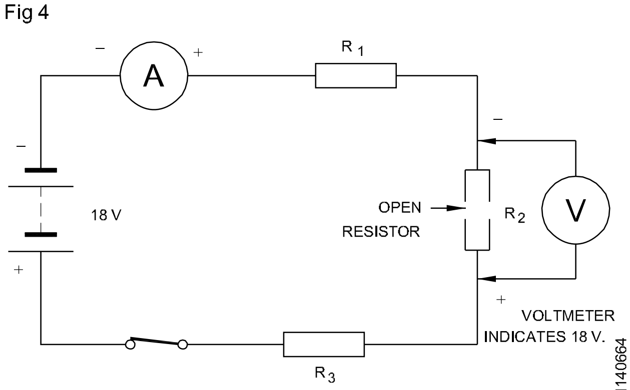
There is a voltage drop of 10 V across R_1; so voltage at B is

V_B = +85 V.

An open circuit results whenever a circuit is broken or is incomplete, and there is no continuity in the circuit.

In a series circuit, open circuit means that there is no path for the current, and no current flows through the circuit. Any ammeter in the circuit will indicate no current as shown in (Fig 4).

Fig 4



OPEN CIRCUIT DUE TO OPEN RESISTOR R_2

Causes for open circuit in series circuit

Open circuits, normally, happen due to improper contacts of switches, burnt out fuses, breakage in connection wires and burnt out resistors etc.

Effect of open in series circuit

a No current flows in the circuit.

b No device in the circuit will function.

c Total supply voltage/ source voltage appear across the open.

How can we determine where a break in the circuit has occurred?

Use a voltmeter on a range that can accommodate the supply voltage; connect it across each connecting wire in turn. If one of the wire is open as shown in (Fig 4), the full supply voltage is indicated on the voltmeter. In the absence of a current, there is no voltage drop across any of the resistors. Therefore, the voltmeter must be reading full supply voltage across the open. That is

Voltmeter reading

$= 18\ V - V_{R1} - V_{R2} - V_{R3}$

$= 18\ V - O\ V - O\ V - O\ V = 18\ V.$

If the circuit was open due to a defective resistor, as shown in (Fig 5) (resistors usually open when they burn out), the voltmeter would indicate 18 V when connected across this resistor, R_2.

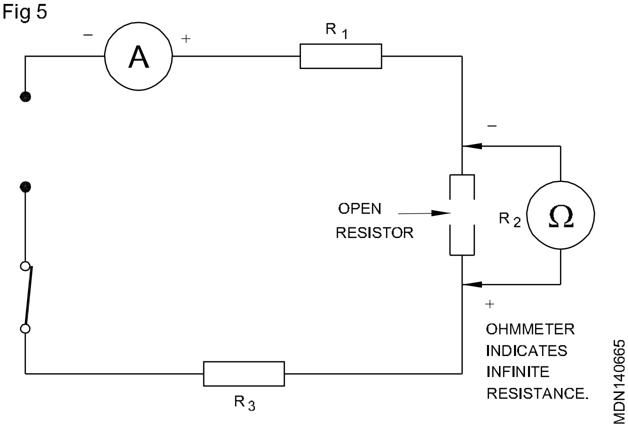
Alternatively, the open circuit may be found using an ohmmeter. With the voltage removed, the ohmmeter will show no continuity (infinite resistance), when connected across the broken wire or open resistor. (Fig 5)

Practical application

With the knowledge gained from this lesson:

- locate open and short circuit faults in a series circuit
- repair series-connected decoration bulb sets.

Fig 5



DC parallel circuit

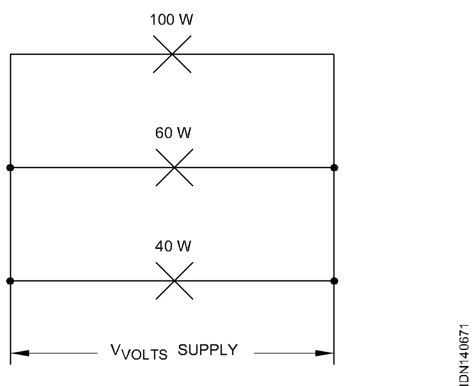
Objectives: At the end of this lesson you shall be able to

- **explain a parallel connection**
- **determine the voltages in a parallel circuit**
- **determine the current in a parallel circuit**
- **determine the total resistances in a parallel circuit**
- **state the application of a parallel circuit.**

Parallel circuit

It is possible to connect three incandescent lamps as shown in (Fig 1). This connection is called parallel connection in which, the same source voltage is applied across all the three lamps.

Fig 1



Voltage in parallel circuit

The lamps in (Fig 1) are replaced by resistors in (Fig 2). Again the voltage applied across the resistors is the same and also equal to the supply voltage.

We can conclude that the voltage across the parallel circuit is the same as the supply voltage.

(Fig 2) could also be drawn as shown in (Fig 3).

Mathematically it could be expressed as $V = V_1 = V_2 = V_3$.

Fig 2

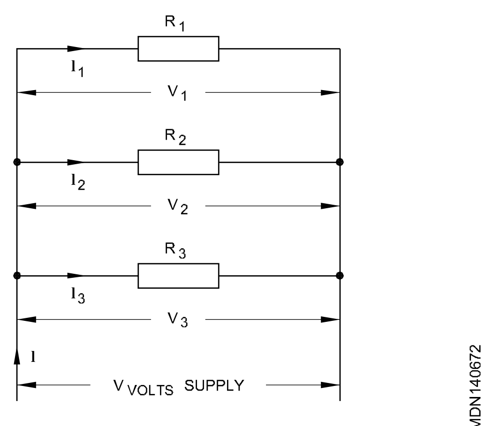
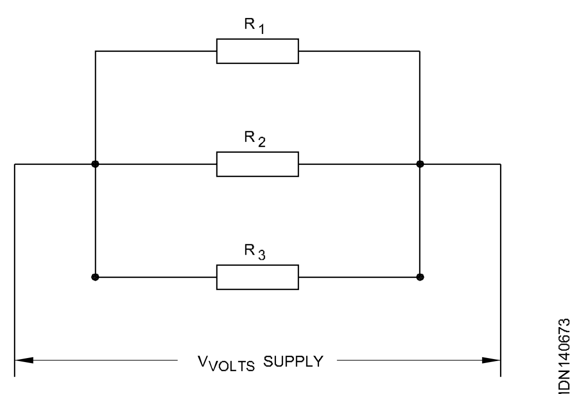


Fig 3



Current in parallel circuit

Again referring to (Fig 2) and applying Ohm's law, the individual branch currents in the parallel circuit could be determined.

Current in resistor $R_1 = I_1 = \quad = \quad .$

Current in resistor $R_2 = I_2 = \quad = \quad .$

Current in resistor $R_3 = I_3 = \quad =$

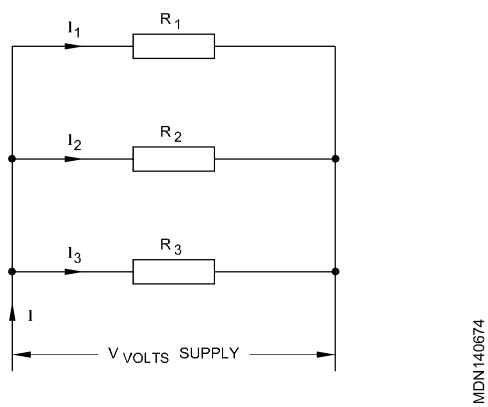
as $V_1 = V_2 = V_3$.

Refer to (Fig 4) in which the branch currents I_1, I_2 and I_3 are shown to flow into resistance branches R_1, R_2 and R_3 respectively.

The total current I in the parallel circuit is the sum of the individual branch currents.
Mathematically it could be expressed as $I = I_1 + I_2 + I_3 + ... I_n$.

Resistance in parallel circuit (Fig 4)

Fig 4



In a parallel circuit, individual branch resistances offer opposition to the current flow though the voltage across the branches will be same.

Let the total resistance in the parallel circuit be R ohms.

By the application of Ohm's law

we can write

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

where

R is the total resistance of the parallel circuit in ohms

V is the applied source voltage in volts, and

I is the total current in the parallel circuit in amperes.

We have also seen

$$I = I_1 + I_2 + I_3$$

$$\text{or } R = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_2}$$

As V is the same throughout the equation and dividing the above equation by V, we can write

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

The above equation reveals that in a parallel circuit, the reciprocal of the total resistance is equal to the sum of the reciprocals of the individual branch resistances.

Special case: Equal resistances in parallel

Total resistance R, of equal resistors in parallel (Fig 5) is equal to the resistance of one resistor, r divided by the number of resistors, N.

$$R = \frac{r}{N}$$

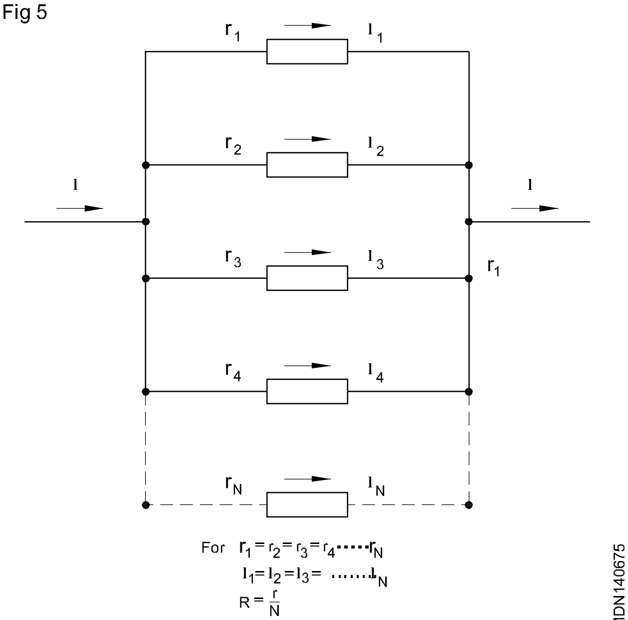
Applications of parallel circuits

An electric system in which section can fail and other sections continue to operate in parallel circuits. As previously mentioned, the electric system used in homes consists of many parallel circuits.

An automobile electric system uses parallel circuits for lights, horn, motor, radio etc. Each of these devices operates independently.

Individual television circuits are quite complex. However, the complex circuits are connected in parallel to the main power source. That is why the audio section of television receivers can still work when the video (picture) is inoperative.

Fig 5



Series parallel combination

Objectives: At the end of this lesson you shall be able to
- **compare the characteristics of series and parallel circuits**
- **solve the series-parallel circuit problems**
- **calculate the current in series-parallel circuits.**

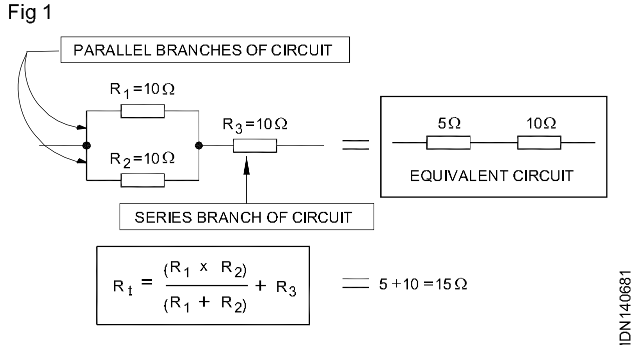
Comparison of characteristics of DC series and parallel ciruits

Series circuit	Parallel circuit
1 The sum of voltage drops across the individual resistances equals the applied voltage.	The applied voltage is the same across each branch.
2 The total resistance is equal to the sum of the individual resistances that make up the circuit. $R_t = R_1+R_2+R_3+...$ etc	The reciprocal of the total resistance equals the sum of the reciprocal of the resistances. The resultant resistance is less than the smallest resistance of the parallel combination.
3 Current is the same in all parts of the circuit.	The current divides in each branch according to the resistance of each branch.
4 Total power is equal to the sum of the power dissipated by the individual resistances.	(Same as series circuit) Total power is equal to the sum of the power dissipated by the individual resistances.

Formation of series parallel circuit

Apart from the series circuit and parallel circuits, the third type of circuit arrangement is the series-parallel circuit. In this circuit, there is at least one resistance connected in series and two connected in parallel. The two basic arrangements of the series-parallel circuit are shown here. In one, resistor R_1 and R_2 are connected in parallel and this parallel connection, in turn, is connected in series with resistance R_3.(Fig 1)

Fig 1

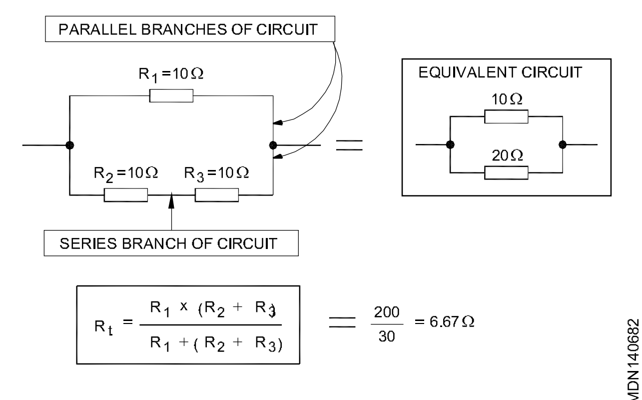


Thus, R_1 and R_2 form the parallel component, and R_3 the series component of a series-parallel circuit. The total resistance of any series-parallel circuit can be found by merely reducing it into a simple series circuit. For example, the parallel portion of R_1 and R_2 can be reduced to an equivalent 5-ohm resistor(two 10-ohm resistors in parallel).

Then it has an equivalent circuit of a 5-ohm resistor in series with the 10-ohm resistor(R_3), giving a total resistance of 15 ohms for the series-parallel combination.

A second basic series-parallel arrangement is shown in (Fig 2) where basically it has two branches of a parallel circuit. However, in one of the branches it has two resistances in series R_2 and R_3. To find the total resistance of this series -parallel circuit, first combine R_2 and R_3 into an equivalent 20-ohm resistance. The total resistance is then 20 ohms in parallel with 10 ohms, or 6.67 ohms.

Fig 2



Combination circuits

A series-parallel combination appears to be very complex.

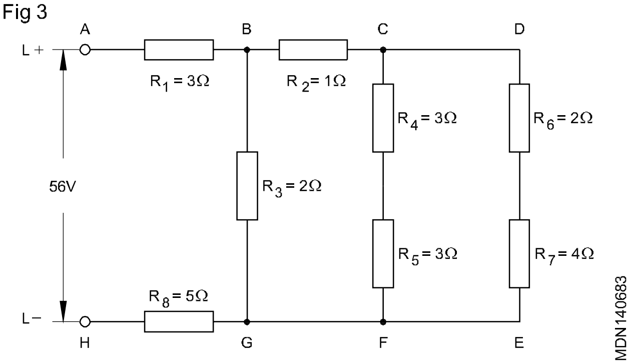
However, a simple solution is to break down the circuit into series/or parallel groups, and while solving problems, each may be dealt with individually. Each group may be replaced by one resistance, having the value equal to the sum of all resistances.

Each parallel group may be replaced by one resistance value equivalent to the combined resistance of that group. Equivalent circuits are to be prepared for determining the current, voltage and resistance for each component.

Example

Determine the combined resistance of the circuit shown in (Fig 3).

Fig 3



PROCEDURE

1) Combine R_6 and R_7.

$R_a = R_6 + R_7$

$R_a = 2 + 4$

$R_a = 6$ ohms.

2) Draw an equivalent circuit with resistance Ra. (Fig 4)

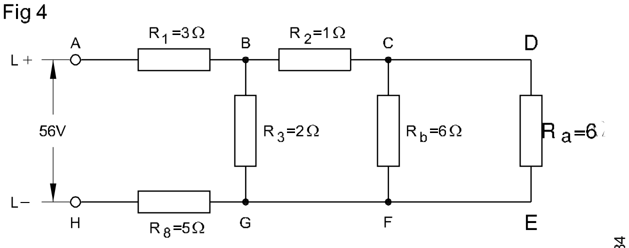
3) Combine R_4 and R_5 of Fig 4.

$R_b = R_4 + R_5$

$R_b = 3 + 3$

$R_b = 6$ ohms.

Fig 4

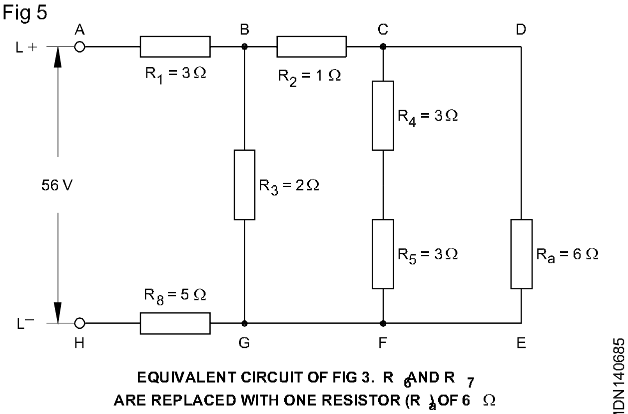


EQUIVALENT CIRCUIT TO FIG 3. R_4 AND R_5 ARE REPLACED WITH ONE RESISTOR (R_b) OF 6 Ω

4) Draw an equivalent circuit as per Figure 5.

5) Combine R_a and R_b and call the equivalent resistance value as R_C. (Fig 5)

Fig 5



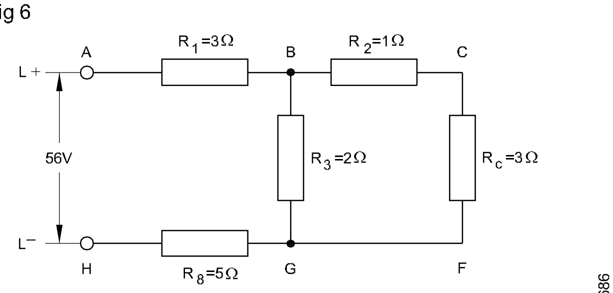
EQUIVALENT CIRCUIT OF FIG 3. R_6 AND R_7 ARE REPLACED WITH ONE RESISTOR (R_a) OF 6 Ω

$$\frac{36}{12} R_c = \frac{R_a \times R_b}{R_a + R_b} = \frac{6 \times 6}{6 + 6}$$

$$= \frac{36}{12} \text{ 3 ohms.}$$

6) Draw the equivalent circuit. (Fig 6)

Fig 6



EQUIVALENT CIRCUIT TO FIG 3, R_4, R_5, R_6, R_7 ARE REPLACED WITH ONE RESISTANCE (R_c) OF 3 Ω.

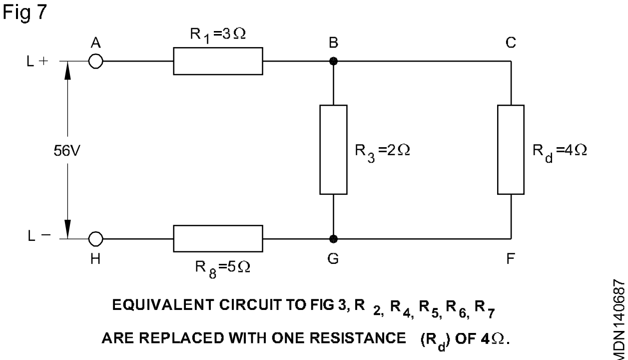
7) Combine R_2 and R_c and call the equivalent resistance R_d.

$R_d = R_2 + R_c$

$R_d = 1 + 3$ $R_d = 4$ ohms.

8) Draw an equivalent circuit. (Fig 7)

Fig 7



EQUIVALENT CIRCUIT TO FIG 3, R_2, R_4, R_5, R_6, R_7 ARE REPLACED WITH ONE RESISTANCE (R_d) OF 4Ω.

9) Now combine R_3 and R_d and call it R_e

$$R_e = \frac{R_3 \times R_d}{R_3 + R_d} = \frac{2 \times 4}{2 + 4}$$

$$= \frac{8}{6} = \frac{4}{3} = 11/3 \text{ ohms.}$$

10) Draw an equivalent circuit. (Fig 8)

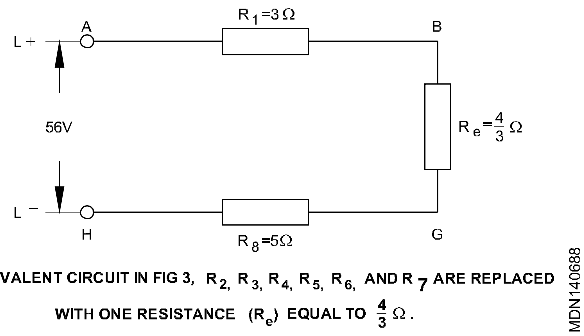
11) Combine R_1, R_e, and R_8.

$R_t = R_1 + R_e + R_8$

$$R_t = 1\frac{1}{3} + 5 + 5$$

$$R_t = 9 = \frac{1}{3}\text{ ohms.}$$

Fig 8



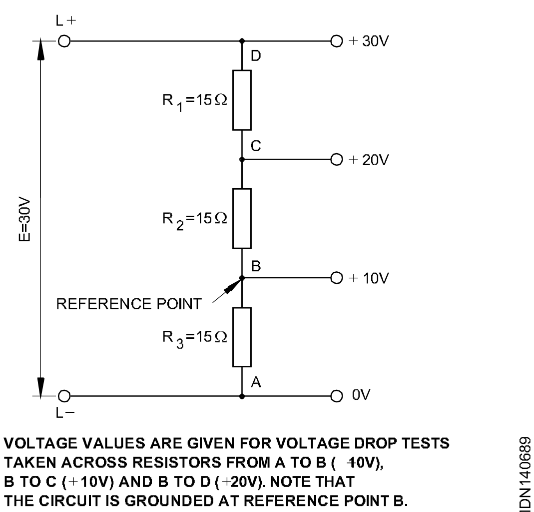
EQUIVALENT CIRCUIT IN FIG 3, R_2, R_3, R_4, R_5, R_6, AND R_7 ARE REPLACED WITH ONE RESISTANCE (R_e) EQUAL TO $\frac{4}{3}\,\Omega$.

The total combined resistance of the circuit is $9\frac{1}{3}$ ohms.

Application

Series-parallel circuits can be used to form a specific resistance value which is not available in the market and can be used in the voltage divider circuits (Fig 9).

Fig 9



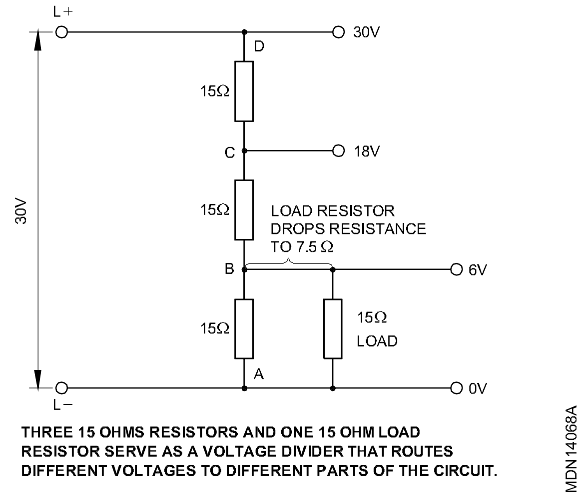
VOLTAGE VALUES ARE GIVEN FOR VOLTAGE DROP TESTS TAKEN ACROSS RESISTORS FROM A TO B (−10V), B TO C (+10V) AND B TO D (+20V). NOTE THAT THE CIRCUIT IS GROUNDED AT REFERENCE POINT B.

Voltage divider

To have different voltages for different parts of a circuit, construct a voltage divider. In effect, a voltage divider is nothing more than a series-parallel circuit.

A good voltage divider cannot be designed without first looking at the load resistance. Note in (Fig 9) that a voltage divider is made with three 15 ohm resistors to get 10 volts drop across each one.

Fig 10



THREE 15 OHMS RESISTORS AND ONE 15 OHM LOAD RESISTOR SERVE AS A VOLTAGE DIVIDER THAT ROUTES DIFFERENT VOLTAGES TO DIFFERENT PARTS OF THE CIRCUIT.

However, as soon as another resistor (load) is added as in (Fig 10), there is a further change. The load resistor serves to drop the total resistance of the lower part of the voltage divider. Use this formula for finding the equivalent resistance (R_{eq}) of resistors of equal value in a parallel circuit:

$$R_{eq} = \frac{r}{N}$$

$$R_{eq} = \frac{15}{2} = 7.5\text{ohms,}$$

The equivalent resistance of these two 15 ohm resistors in the lower part of the voltage divider is 7.5 ohms. What will happen to the current and voltage in the circuit as a result of this resistance change?

Remember that, as resistance goes down, current goes up. Therefore, with the addition of the load resistor, the circuit will now carry higher amperage but the voltage between points A and B as well as A and C changes. It is important, then, when constructing a voltage divider circuit, to watch the resistance values which change both voltage and current values. Study Figure 10 carefully to make sure you understand how a voltage divider works.

Battery

Objectives: At the end of the lesson you shall be able to
- **state the classification of cells**
- **describe the primary cells**
- **describe the secondary cells**
- **describe the construction of a lead acid battery**
- **describe the chemical action during discharging**
- **describe the chemical action during charging**
- **describe the maintenance of a battery**
- **describe the testing of a battery.**

A cell is an electrochemical device consisting of two electrodes and an electrolyte. The chemical reaction between the electrodes and the electrolyte produces a voltage.

Cells are classified as:

- dry cells
- wet cells.

Dry cells : A dry cell has paste or gel electrolyte. It is semi-sealed and could be used in any position.

Wet cells : It consists of two plates and a liquid electrolyte. These cells have vent holes to allow the gases to escape during charging and discharging. The most common wet cell is the lead acid cell; wet cells can be recharged for reuse.

Primary cells : Primary cells are those cells which are not rechargeable. Chemical reaction that occurs during discharge is not reversible. The following types of primary cells are used.

- Voltanic cell
- Carbon zinc cell
- Alkaline cell
- Mercury cell
- Silver oxide cell
- Lithium cell.

Secondary cell (Lead acid battery) : These cells can be recharged by supplying electric current in the reverse direction to that of a discharged battery.

Lead acid battery (Figs 1 & 2)**:** This battery is an electrochemical device for converting electrical energy into chemical energy and vice versa. The main purpose of the battery is to store electrical energy in the form of chemical energy. It provides supply of current for operating various electrical accessories, when the engine is not running. When the engine is running it gets electric supply from the dynamo/alternator. It is also known as accumulator and storage battery.

Fig 1

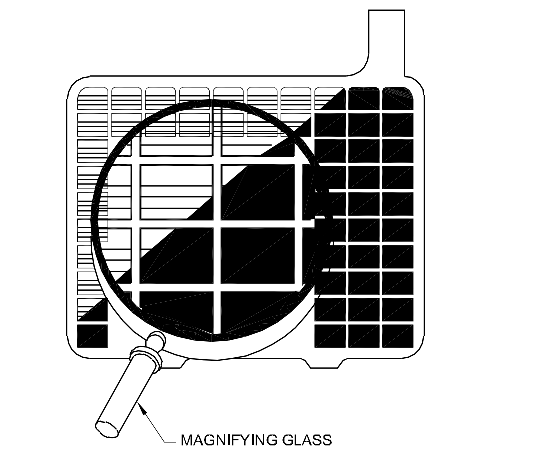
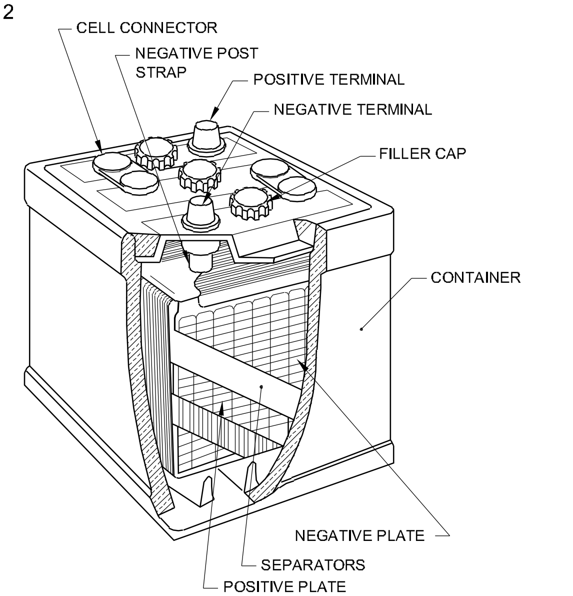


Fig 2



Construction: The automobile battery's plates are rectangular. They are made of lead. Antimony alloy is used to provide them strength.

The group of plates, which are connected to the positive terminal of the cell, consists of grids filled with a paste of lead peroxide. This lead is brown in colour. The group of plates, which are connected to the negative terminal of the cell, consists of grids filled with metalic lead which is spongy in nature. This lead is dull grey in colour.

Each a group of plates is held together by a post strap, to which individual plates are welded. The post strap is extended up to the cell cover to provide battery terminals. The positive and negative plates are arranged alterna-tively, and in between the plates, seperators are used to prevent contact of the positive and negative plates. Separators are made of specially treated wood, hard rubber, resin, integrated fibre or in combination with rubber or mats of glass fibres. The container in which the plates are placed is made of hard rubber which is not affected by the electrolyte. A solution of sulphuric acid and distilled water is added until the level of the liquid in the container is about 1/4" to 3/8" above the top of the plates. A filler cap with air vents is provided to allow gases to escape From battery cells..

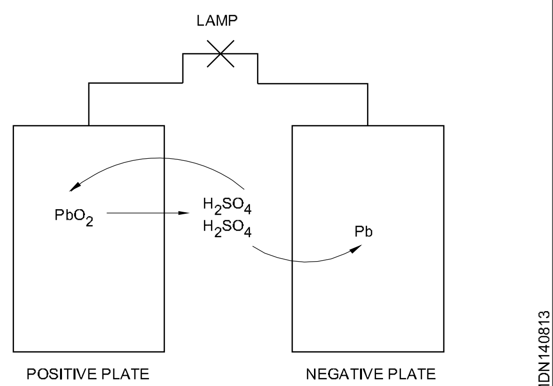
Chemical Reactions

Discharging (Fig 3)**:** During discharging, the sulphuric acid is broken into two parts, hydrogen (H_2) and sulphate (SO_4). The hydrogen is liberated at the lead peroxide plates (PbO_2) reducing them to lead oxide (PbO) which combines with parts of the sulphuric acid to form lead sulphate ($PbSO_4$) and water (H_2O). The SO_4 is liberated at the spongy lead plate (Pb) and combines with them to form lead sulphate ($PbSO_4$). During this process the electrolyte becomes less concentrated due to absorption of the sulphate by the lead plates.

$$PbO_2 + 2H_2SO_4 + Pb \rightleftharpoons PbSO_4 + 2H_2O + PbsO_4$$

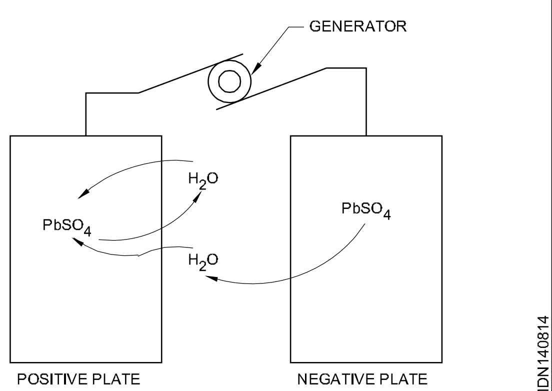
(+ve) (electrolyte) (-ve) (+ve) (water) (-ve)

Fig 3



Charging (Fig 4)

Fig 4



When the battery is charged (Fig 4) by passing current through a dynamo or charger in the opposite direction, the reverse chemical reaction takes place. The lead sulphate on one plate becomes lead peroxide (+ve plate). The lead sulphate on the other plate (-ve plate) becomes spongy lead and the electrolyte becomes more concentrated because of the increased amount of sulphuric acid.

$$PbSO_4 + 2H_2O + PbSO_4 \rightleftharpoons PbO_2 + 2H_2SO4 + Pb$$

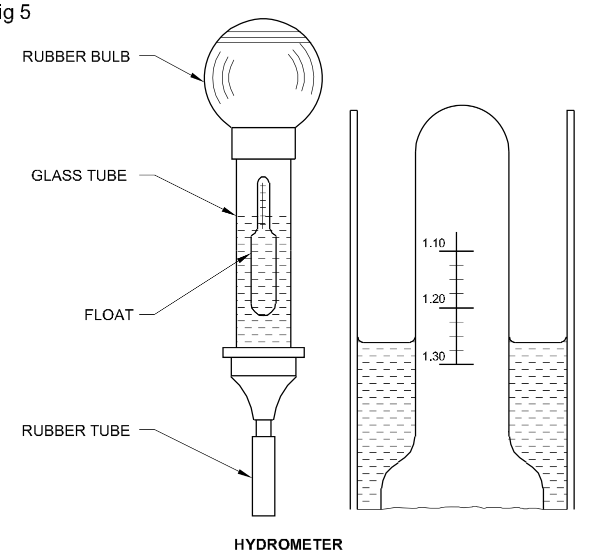
(+ve) (water) (-ve) (+ve) (Electrolyte) (-ve)

Maintenance of battery : Batteries are expensive items to replace. They should be serviced regularly as recommended by the manufacturer. If maintained properly, they can be used for longer periods. The following aspects are to be checked to maintain the battery in good condition.

Check and top up electrolyte level every week. Electrolyte should be 10 mm to 15 mm above the plates.

Check the specific gravity of the battery with a hydrometer.(Fig 5) If the specific gravity falls below 1.180 then add a few drops of sulphuric acid.

Fig 5



Sp. gravity readings and the state of charge of the battery are as follows.

Sl.No.	Specific	State of charge of the battery
1	1.260 - 1.280	Fully charged
2	1.230 - 1.260	3/4 charged
3	1.200 - 1.230	1/2 charged
4	1.170 - 1.200	1/4 charged
5	1.140 - 1.170	About run down
6	1.110 - 1.140	Discharged

Check the voltage across the cell terminals of each cell by using a cell tester. Cell voltage is 2 to 2.3 volts per cell for fully charged condition.

If the voltage of each cell is less than specified, then the battery should be recharged.

While charging do not overcharge the battery.

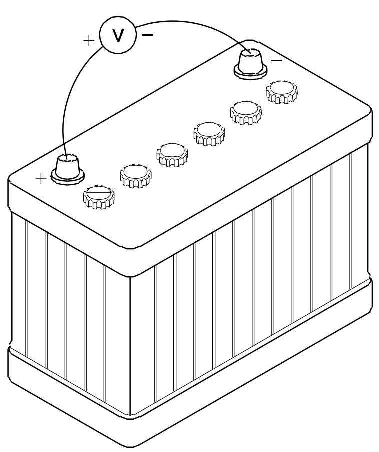
Keep the battery terminals always tight and clean.

To prevent formation of corrosion on the terminals smear petroleum jelly on it.

Voltage check of battery : With the help of a voltmeter the voltage of battery is tested. This will commonly vary from 12-13V

Battery selection (Fig 6)**:** Most cars in current production are equipped with a 12V battery. When a manufacturer installs a battery in a new car that battery is chosen to meet the requirements of that particular car. Prime importance is the battery's ability to crank and start the engine. The current required to crank on engine can range from 150A to over 1000A depending on the size of the engine, the temperature and the viscosity of the oil in the engine. Those factors are all considered in battery selection. The number and type of electrical options installed in the car are also considered.

Fig 6



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The lead acid batteries are made for different vehicle application to suit the electrical demands, While the voltage of the battery remains same for all application, the ampere-hour rate changes as per demand.

The following examples reveal the importants of ampere-hour of a battery.

Vehicle type	Battery applicable
2.5 Amps 12V	Two wheeler without starter
7 Amps 12V	Two wheeler with starter motor
35 Amps 12V	800CC - 1000 car petrol
40 - 45 Amps 12V	1300CC Diesel vehicles
60 Amps 12V	2.5 Ltrs LCV
80 Amps 12V	4 Ltrs medium
120 Amps 12V	6 Ltrs Diesel HCV
180 Amps 12V	6 Ltrs Diesel passenger

Battery rating

Ampere-hour rating: The ampere-hour rating provides a measure of how much current a battery at 80^0F (27^0C) will deliver for a fixed period of time without the cell voltage dropping below 1.75V (10.5 total terminal volts). Due to a specified 20 hour time period, this test is sometimes referred to as the "20 hour test". The rating number is determined by multiplying the current delivered by 20. If a battery can deliver 3A for the 20 hour period, it receives a 60 ampere-hour rating. If a battery can deliver 5A for the 20 hour period, it receives a rating of 100 ampere-hour.

CONVENTIONAL BATTERIES

BATTERY CAPACITY (AMPERE HOURS)	DISCHARGE RATE (AMPERES)
36	155
41	145
45	190
53	175
54	225
68	220
77	228

MAINTENANCE-FREE BATTERIES

BATTERY CAPACITY (AMPERE HOURS)	DISCHARGE RATE (AMPERES)
53	200
63	215
68	235

Battery charging: A discharged battery in good condition can be charged and retuned to service.

Many types of battery in use, but all chargers operate on the same principle. They apply an electrical pressure that forces current through the battery to reverse the electro chemical action in the cells.

Charging rates: The amount of charge a battery receives is equal to the rate of charge, in amperes, multiplied by the amount of time, in hours, that the charge is applied. As an example, a battery charged at the rate of 5A for a period of 5 hours would receive a 25 ampere-hour charge. To bring a battery to a fully charged condition.

Initial rate for constant voltage taper rate charger.

To avoid damage, charging rate must be reduced or temporarily halted if:

1 Electrolyte temperature exceeds 125^oF.

2 Violent gassing or spewing of electrolyte occurs.

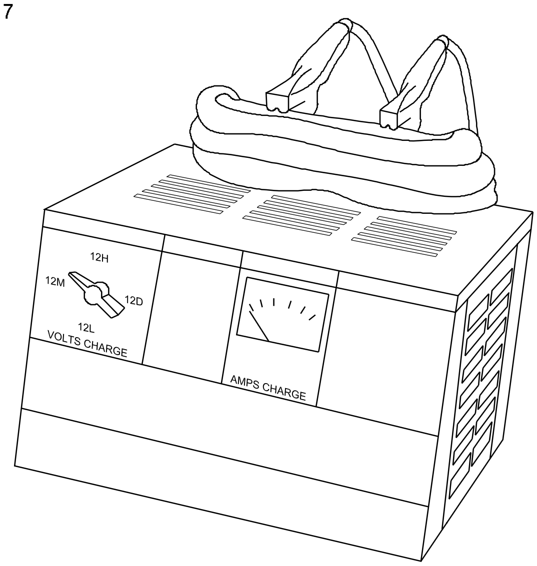
Battery is fully charged when over a two hour period at a low charging rate in amperes all cells are gassing freely and no change in specific gravity occurs. For the most satisfactory charging, the lower charging rates in amperes are recommended.

Full charge specific gravity is 1.260 - 1.280 corrected for temperature with electrolyte level at split ring.

Slow charging (Fig 7)**:** Slow charging consists of charging a battery at a rate of about 5A for a time sufficient to bring the specific gravity of the electrolyte to its highest reading. Slow charging many require from 12 to 24 hours of time. A battery that is sulphated may require even more time. During the charging period, the electrolyte temperature should not exceed 110^0F (43^0C). If the electrolyte temperature rises above 110^0F (43^0C), the charging rate should be decreased.

A conventional battery with vent plugs is considered fully charged when the electrolyte is gassing freely and when no further rise in the specific gravity is noted at intervals of 1 hours. a sealed battery should be slow charged until the green dot appears in the built-in hydrometer. in some instances, a sealed battery must be slightly shaken to allow the green dot to appear.

Fig 7



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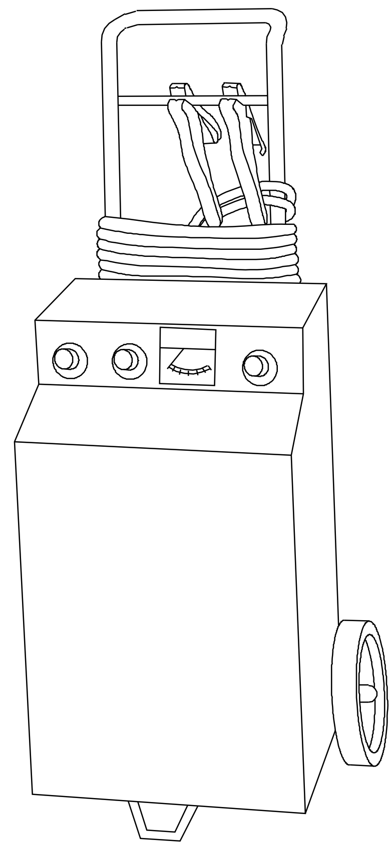
A TYPICAL SLOW CHARGER

Fast charging (Fig 8)**:** Fast charging will not fully recharge a battery, it will restore the charge sufficiently to allow the battery to be used.

Fast charging consists of charging a battery at a rate from 10 to 50A. The exact charging rate depends on the construction of the battery, the condition of the battery and the time available. The temperature of the electrolyte provides an indication of the current charging rate. If the electrolyte temperature rises above 125^0F (65^0C), the charging rate is too high and should be reduced. Since a high charging rate and the resultant high temperature can damage a battery, a battery should be charged at the lowest possible rate.

Fig 8



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A TYPICAL FAST CHARGER

Features of sealed maintenance free battery

- No need for checking electrolyte level and tapping throughtout the life.
- Seal construction ensures no leakage of electrolyte from terminal or casing.

Benefits

- Saving of 100 litres of distilled water through out its life time as compared to convention batteries.
- Saving of man power for regular topping up & cleaning corroded terminals as in conventional batteries.
- No damage of flooring by spoilage of batteries acid or water during maintenance.
- No need of separate battery room.
- It indicates the battery current charging rate through inbuilt indictor.

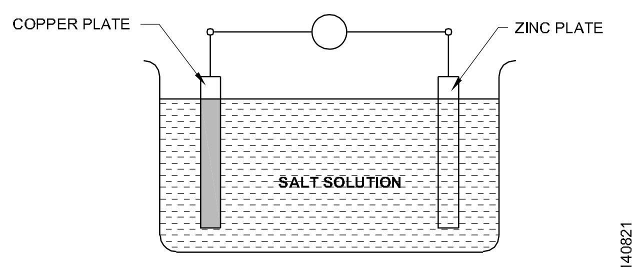
Electricity effects

Objectives: At the end of this lesson you shall be able to
- **state the electro chemical process**
- **state the effect of an electric currents.**
- **state the thermo couple**
- **state the thermo electric energy**
- **state the piezo electric energy.**
- **state the photo voltaia energy.**

Chemical sources (Electro chemical process) (Fig 1)

If two electrically conducting materials (metals) are immersed in salt solutions, an electric charge is produced between the two metals (electrodes, poles). Two examples are given below.

Fig 1



ELECTRICITY GENERATION BY DISSOLVING IN ELECTROLYTES

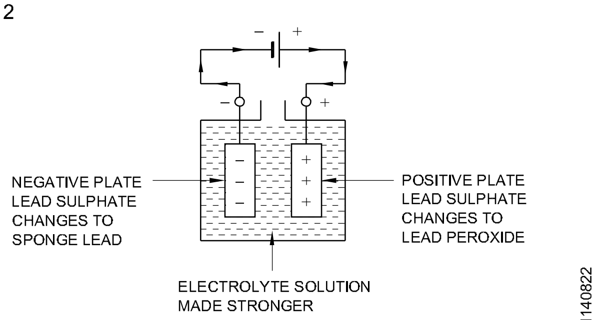
Copper and Zinc in salt solution is one combination

Lead and sulphuric acid is another combination.

This arrangement is known as wet cell and gives direct current. The second combination is used in a Lead Acid Battery for Motor vehicles.

Dynamic electricity (Fig 2)

Fig 2



DURING CHARGING PROCESS

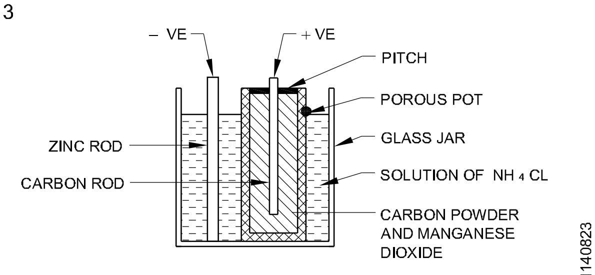
The current is produced by A/C or D/C generators, by conversion of mechanical energy into electrical energy. The generation of electric current is based on the fact when a conductor is moved in a magnetic field an E.M.F is set up in the conductor. When a large number of conductors are moved in a powerful magnetic field, high voltages and current are produced. This is the Principle of Dynamo.

The effect of an electric current

Let us now study effects of an electric current. When an electric current flows through a circuit, its presence could be analysed by its effects. They are stated below.

Chemical effect (Fig 3)

Fig 3



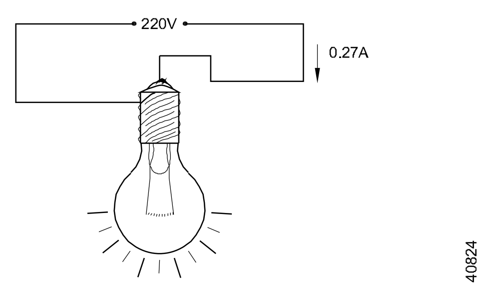
LECLANCHE CELL

When a current is applied to a battery from a battery charger various chemical reactions are produced which enable the electrical energy to be stored in a chemical form.

The process is called charging a battery by electrolysis method (using electric current).

Heating effect (Fig 4)

Fig 4



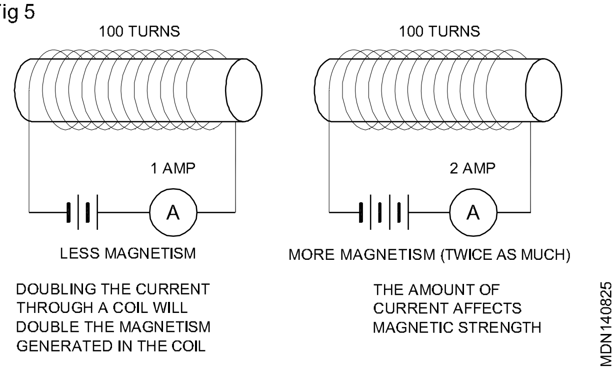
HEATING EFFECT

When a current is applied to a bulb filament (fine wire) it becomes white hot and thus produces light.

Magnetic effect (Fig 5)

- If a soft iron bar is placed in a coil of wire and a current is passed through the wire, the iron bar becomes magnetised. If the current is withdrawn the bar with retain some magnetism depending on the materials.
- If a bar magnetic is moved in a coil of wire, to and fro then Current flow is occurred in the coil of wire. This can be find by connecting a "Galvanometer".The current, will flow only when the bar magnet is moving actually. Because, the turns of coil of wire should cut the lines of force.

Fig 5



Shock effect

If the current flow through Human body, it may give a severe stock or cause even death of the individuals so one must be careful in dealing with electrical current during work.

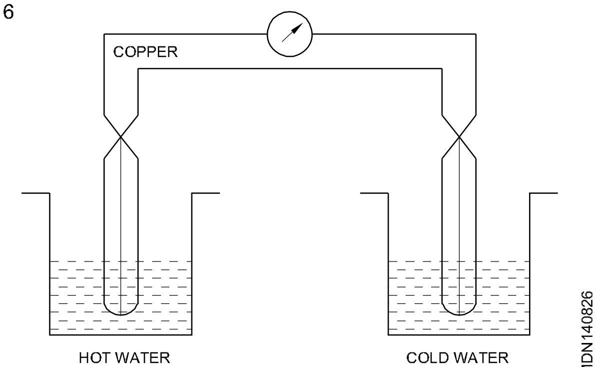
Note :

In motor vehicle trade application, the following effect electric current are widely used

- Chemical effect-for battery.
- Heating effect-Head lamp bulbs for lighting.
- Magnetic effect-Electro magnets in relays and cuts.

Thermocouple (Fig 6)

Fig 6



This is such an arrangment where circuit is closed by wires of different metals. One metal wire is kept at low temperature and the other at high temperature. In this way thermo-electro motive force is created which can be seen by galvanometer. This works on the effect of seebake.

Thermo electric energy

Thermo electric energy is the electrical energy produced by waste heat of an IC engine using seeback effect.

Thermo electric generation can convert waste heat from an engine coolant or exhaust into electricity.

Piezo - electric energy

Piezo electric sensor is a device that uses the piezo electri effect to measure the changes in pressure, acceleration or force, by convertring them to an electrical charge.

Application

It is used to initiate combustion in the IC engine mounted into a holes into the cylnider head.Glow plug is a in-built miniature piezo-electric sensor.

Photo voltaic energy:

Photo volatile (PV) is a term which covers the conversion of light into electricity by using semiconducting materials that exhibit the photovoltaic effect. This effect is seen in combination of two layers of semi conductor materials, one layer of this combination will have it depleted number of electrons.

When sunlight strikes on this layer, it absorbs the photons of sunlight ray and consequently the electrons are excited and jump to the other layer. This phenomenon creates a charge difference between the layer and resulting to a tiny potential difference between them.

The unit of such combination of two layers of semi conductor materials, for producing electric potential deference in sunlight is called solar cell. Silicon is normally used as solar cell. For building cell, silicon material is cut and very thin wafers. Some of these wafers are doped with impurities. Then both doped and undated wafers are and switched together to build solar cell. A metallic strip is reached to two extreme layers to collect current.

A desired number of solar cell are connected together in both parallel and series to form a solar module for producing desired electricity.

The solar cell can also work in cloudy weather as well is moon light but the rate of production of electricity low as and it depends up on intensity of incident light ray.

Fig 1 describes the typical system of solar panels, controller, energy storage, inverter for converting DC into AC and how the system is connected to power grid.

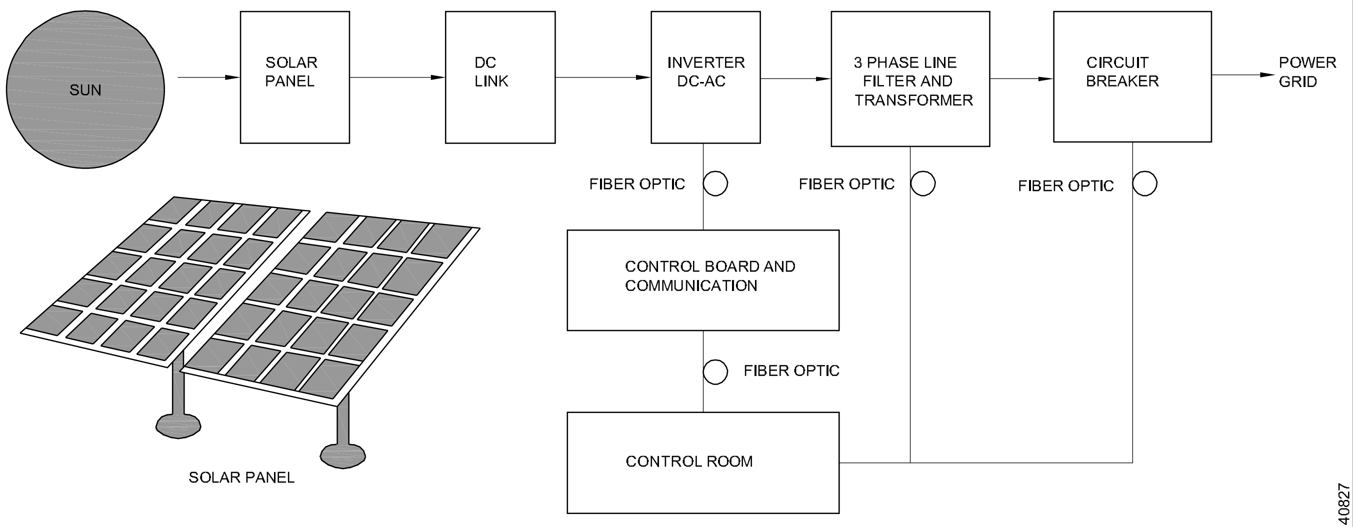
Solar panels installation may be ground, rooftop or wall mounted. The solar panels mount may be fixed a solar tracker to follow the sun across the sky.

Photo voltaic systems have long been used in specialized applications and stand alone and grid-connected PV systems have been in use since the 1990. After hydro and wind powers, PV is the third renewable energy source in term of global capacity. The PV energy covering approximately two percent of global electricity demand. It is an environmentally clean source of energy and it is free and available in adequate quanties in all the parts of world.

Advantages of solar photo voltaic: Solar panels once installed. Its operation generates no pollution and no green house gas emissions it is simple salability in respect of power needs and silicon has large availability in earth

Disadvantages of solar photovoltaic (Fig 7) : The power output is dependent on direct sunlight. That 10-25% is lost, if a tracking system is not used. Dust, clouds and other obstruction in the atmosphere also diminish the power output. Solar photovoltaic power needs to be stored for later use.

Fig 7



SOLAR POWER PLANT

Electromagetic induction, self-induced emf - inductors

Objective: At the end of this lesson you shall be able to
- **state the principle and law of electromagnetic induction.**

Faraday's Law of Electromagnetic induction are also applicable for conductors carrying alternating current.

What are Faraday's Law of Electromagnetic Induction?

Faraday's First Law states that whenever the magnetic flux is linked with a circuit changes, an emf is always induced in

The second Law states that the magnitude of the induced emf is equal to the rate of change of flux linkage.

According induced emf can be produced either by moving the conductor in a stationery magnetic field by changing magnetic flux over a stationery conductor. When conductor moves and produces emf, the emf is called as dynamically induced emf Ex. generators.

When changing flux produces emf the emf is called as statically induced emf as explained below. Ex: Transformer.

Tracing auto electrical components in circuit - Solenoid & relay

Objectives: At the end of the lesson you shall be able to
- **define a realy**
- **classify relays according to the operating force and function**
- **describe the function of current sensing relay & Voltage sensing relay**
- **state the function of solenoid.**

Relay : A realy is a device which opens or closes an auxiliary circuit under predetermined conditions in the main circuit.

Relays are extensively used in electronics, electrical engineering and many other fields.

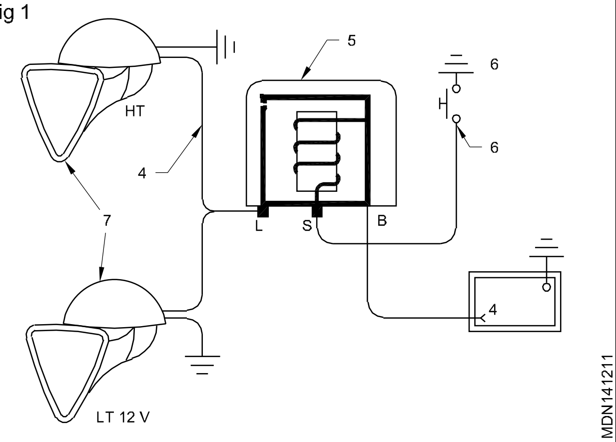
The relays are sensitive to conditions of voltage, current, temperature, frequency or some combination of these conditions.

Relays are also classified according to their main operating force as stated under

- Electromagnetic relays
- Thermal relays

Electromagnetic relay : A relay switch assembly is a combination of movable and fixed low - resistance contacts that open or close a circuit. The fixed contacts are mounted on springs or brackets, which have soem flexibility. The movable contacts are mounted on a spring or a hinged arm that is moved by the electromagnet int he relay as shown in (Fig 1).

Fig 1



The other types of relays coming under this group are as follows.

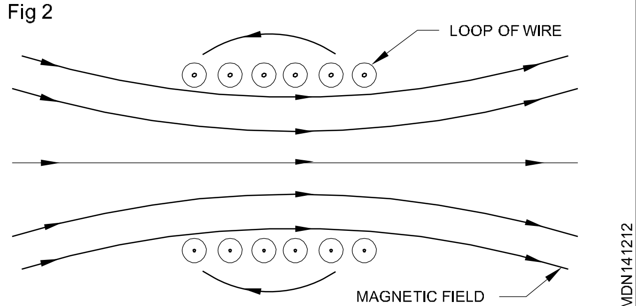
Current sensing relay : A current sensing relay functions whenever the current the coil reaches an uppe limit. The difference between the current specified for pick up (must operate) and non - pick up (must non operate) is usually closely controlled. The difference in current may also be closely controlled for drop out (must release) and non - drop out (must not release).

Voltage sensing relay : A voltage sensing relay is used where a condition of under - voltage or over - voltage may cause a damage to the equipment. For example, these types of relays are used in voltage stabilizers. Either a proportional AC voltage derived from a transformer or a proportional DC derived from a transformer and rectifier is used for this purpose.

Solenoid

Solenoid is a coil wound into a tightly packed to a long thin loop of wire, often wraped arrouned a metalic core, which produces a uniform magnetic field in a volume of space. (Fig. 2)

Fig 2



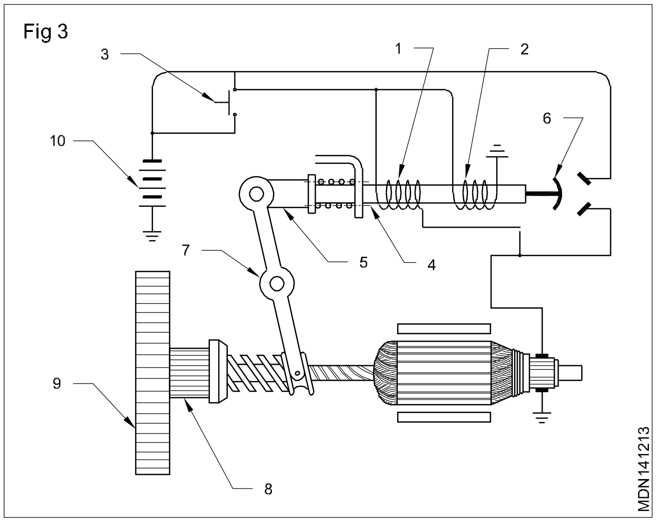
Application

Need for solenoid switch: The solenold switch is a strong electromagnetic switch. It is used to operate the over running clutch drive pinion to engage with the fly wheel ring gear. It also acts as a relay to close the contacts between the bettery and the staring motor.

Construction fo solenoid switch (Fig 3) : In a solenoid there are two windings, a pull-in winding (1) and a hold - in winding (11). The pull - in winding (10) is wound with thick wires (series winding) and the hold - in winding (11) is of thin wires (shunt winding). The pull-in winding (10) is connected to the starter switch (3) in the solenoid.

The hold in winding (2) is connecteed across the switch terminal and ground. The two windings are wound around a hollow core (4). An iron plunger (5) is placed inside the core (4). The other end of the plunger moves a shift lever (7) to engage the pinion (8) with the fly wheel ring gear (9).

Fig 3



Function of solenold switch : When the starter switch (3) is turned, current flows from the battery to the solenoid windings (1) and (2). This energises the windings which pull the plunger (5). The plunger (5) operates are shift lever (7) to engage the pinion (8) on the flywheel ring gear (9). Then it closes the circuit between the battery (10) and the starting motor.

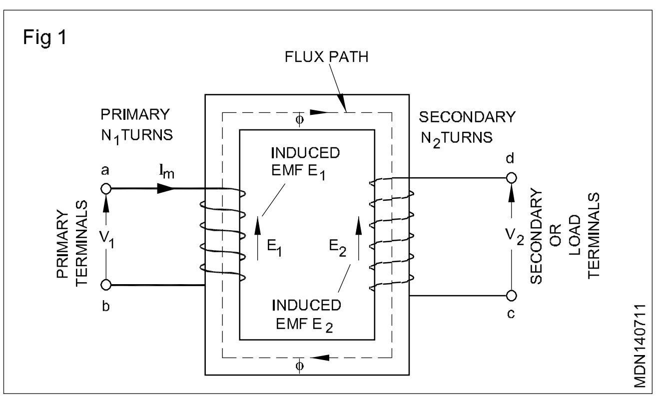
Primary and secondary winding, transformers, stator and rotor coil.

Objectives : At the end of this lesson you shall be able to
- **define the primary and secondary of a transformer**
- **state the constructional features of a power transformer and the function of each part**
- **state the reasons for laminated silicon steel being used as core material.**

Two- winding transformers

A transformer in its simplest form consists of two stationary coils coupled by a mutual magnetic flux (Fig 1). The coils are said to be mutually coupled because they link a common flux.

Fig 1



Laminated steel core transformers are used in power applications. As shown in Fig 1, the current flowing in the coil connected to the AC source is called the primary winding or simply primary. The primary is the input to a transformer. It sets up the flux in the core, which varies periodically both in magnitude and direction. The flux links the second coil, called the secondary winding or simply the secondary.

The flux is changing; therefore, it induces a voltage in the secondary by electromagnetic induction. Thus the primary receives its power from the source while the secondary supplies this power to the load. This action is known as transformer action. There is no electrical connection between these two coils.

Transformers are afficient and reliable devices used mainly to change voltage levels. Transformers are efficient because the rotational losses are absent; so little power is lost when transforming power from one voltage level to another. Typical efficiencies are int he range of 92 to 99%. The higher values apply to the large power transformers. There is no change in frequency of voltage.

Transformer

A transformer is an electrical device that transforms the AC voltage between two circuit through an electromagnetic induction.

A transformer may be used as a safe and efficient voltage convertor to change the AC/DC voltage and its to a higher / lower voltage its ouput without changing the frequency and power.

Types

1. Step up transformer

2. Step down tranformer

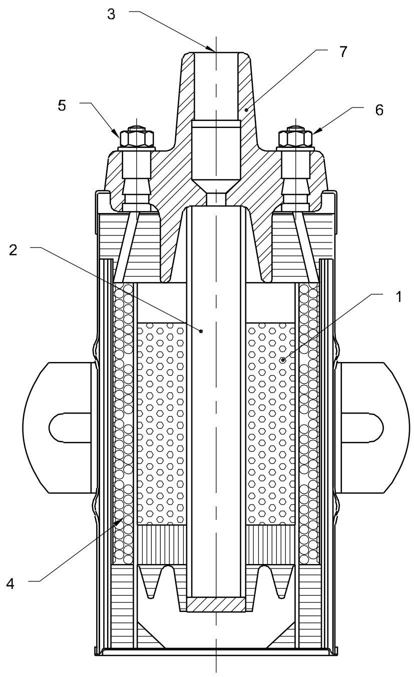
Application

Transformer is used in (1) ignition coil in petorl engine igrition system and battery charger.

Ignition coil (Fig. 2)

It is used to step up low voltage to high voltage to generate sparks. It consists of two windings, one wound over soft iron core. The secondary winding (1) is wound over the core (2). It consists of about 21,000 turns. One end of the winding is connected to the secondary terminal (3) and the other end to the primary winding (4). The primary winding (4) is wound over the secondary winding (1) and consists of about 200-300 turns. The ends are connected to the external terminal (5,6) of coil. The bakelite cap (7) insulates the secondary terminal from the container and primary terminals.

Fig 2



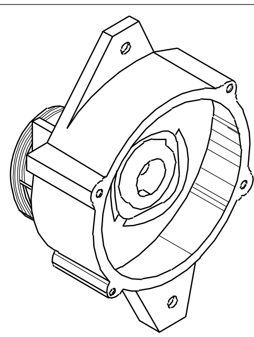
Rotor

Rotor is the moving part of a rotary electric motor, electric generator alternated which rotates because the wire and magnitive field of the motor are arranged so that them to develop about the rotar axis.

Description of parts of an alternator

Drive end frame (Fig 3)

Fig 3



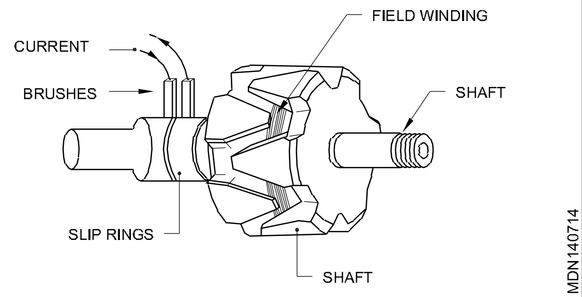
DRIVE END FRAME

The drive end frame supports a pre - lubricated sealed sliprimgs in which the drive end of rotor shaft rotates.

The rotor and its shaft is mounted and encased between drive end frame and slip ring end frame.

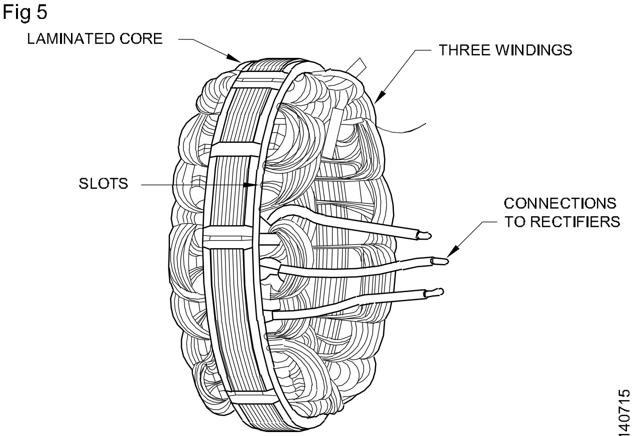
The rotor assembly (Fig 4)

Fig 4



This consists of a steel shaft which carries the driving pulley and cooling fan, a cylindrical iron core, and two stationary part which is held between two end covers. (Fign 5)

Fig 5



STATOR ASSEMBLY

Diodes

Objectives: At the end of the lesson you shall be able to
- **state the meaning of semiconductors**
- **state how P and N materials are formed**
- **state the unique property of a PN junction**
- **list the different classifications of diodes**
- **state the polarity**
- **list a few type numbers/code numbers of diodes.**

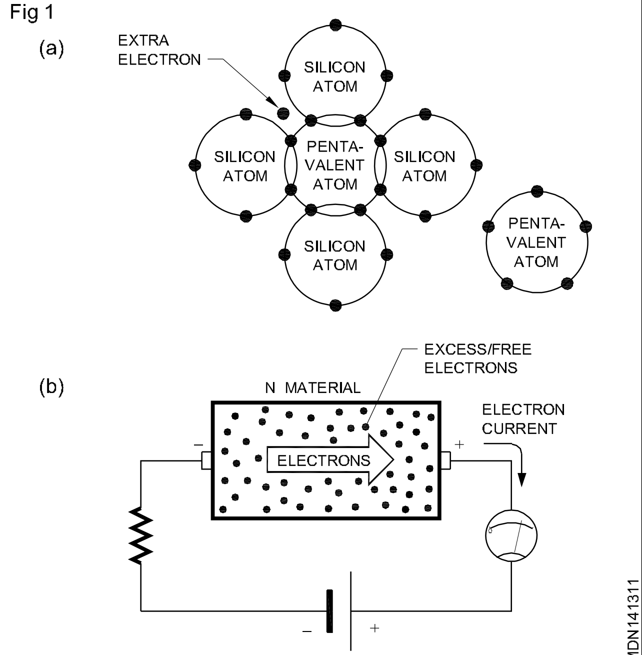
Semiconductors

Semiconductors are materials whose electrical property lies between that of Conductors and Insulators. Because of this fact, these materials are termed as semiconductors. In conductors the valence electrons are always free. In an insulator the valence electrons are always bound. Whereas in a semiconductor the valence electrons are normally bound but can be set free by supplying a small amount of energy. Several electronic devices are made using semiconductor materials. One such device is known as Diode.

1) N-type semiconductors

When a pentavalent material like Arsenic (As) is added to a pure Germanium or pure Silicon crystal, one free electron results per bond as shown in Fig 1a. As every arsenic atom donates one free electron, arsenic is called the *donor impurity.* Since a free electron is available and since the electron is of a Negative charge, the material so formed by mixing is known as **N type material.**

Fig 1



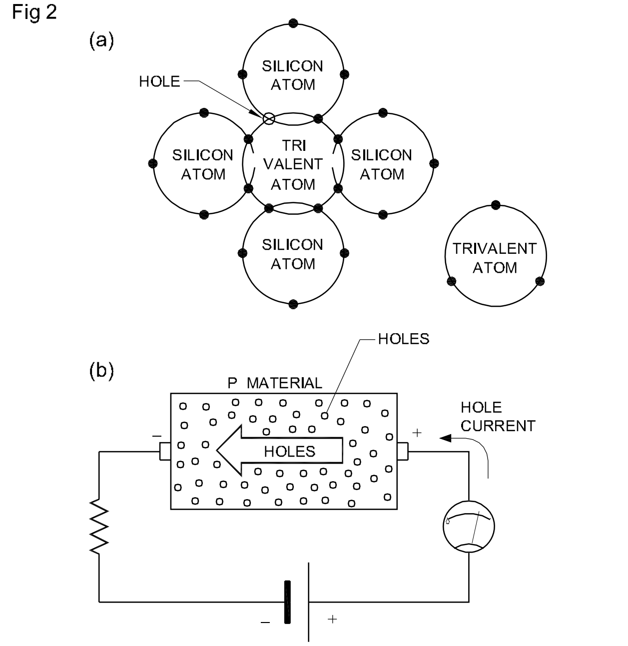
When a N-type material is connected across a battery, as shown in Fig 1b, current flows due to the availability of free electrons. As this current is due to the flow of free electrons, the current is called electron current.

2) P-type semiconductors

When a trivalent material like Gallium(Ga) is added to a pure Germanium or pure Silicon crystal, one vacancy or deficit of electron results per bond as shown in Fig 2a. As every gallium atom creates one *deficit of electron or hole,* the material is ready to accept electrons when supplied. Hence gallium is called *acceptor impurity*. Since vacancy for an electron is available, and as this vacancy is a hole which is of Positive charge, the material so formed is known as **P-type material**.

When a P-type material is connected across a battery as shown in Fig 2b, current flows due to the availability of free holes. As this current is due to flow of holes, the current is called *hole current.*

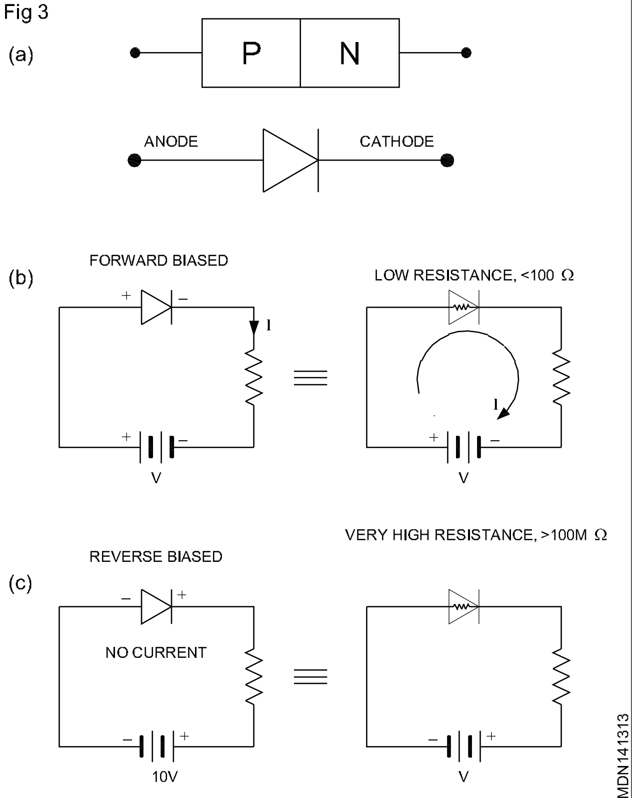
Fig 2



P-N junction

When a P-type and a N-type semiconductors are joined, a contact surface between the two materials called PN-junction is formed. This junction has a unique characteristic. This junction, has the ability to pass current in one direction and stop current flow in the other direction. To make use of this unique property of the PN junction, two

Fig 3



terminals one on the P side and the other on the N side are attached. Such a PN junction with terminals attached is called a **Diode.** The typical symbol of a PN-junction diode is shown in Fig 3a.

Types of diodes

The PN junction diodes discussed so far are commonly referred to as *rectifier diodes.* This is because these diodes are used mostly in the application of rectifying AC to DC.

Classification of Diodes

1 **Based on their current carrying capacity/power handling capacity, diodes can be classified as**

– **low power diodes**

can handle power of the order of several milliwatts only

– **medium power diodes**

can handle power of the order of several watts only

– **high power diodes**

can handle power of the order of several 100's of watts.

2 **Based on their principal application, diodes can be classified as,**

– **Signal diodes**

low power diodes used in communication circuits such as radio receivers etc. for signal detection and mixing

– **Switching diodes**

low power diodes used in switching circuits such as digital electronics etc. for fast switching ON/OFF of circuits

– **Rectifier diodes**

medium to high power used in power supplies for electronic circuits for converting AC voltage to DC.

Polarity marking on the diodes

The cathode end of a diode is usually marked by a circular band or by a dot or by plus (+) sign. In some diodes the symbol of the diode, which itself indicates the polarities, is printed on the body of the diode.

Type number or diode code number

Unlike resistors, capacitors or inductors, the diodes do not have any value that can be printed or coded on its body. The other reason for this is, there are almost innumerable types of diodes with varied current handling and other specifications. Hence, instead of printing its specifications on its body, all diodes will have a type number printed on their body. This type number carries a set of specifications which can be found out by referring to a *diode data manual*. Diode data manuals give data of several thousands of diodes from different manufacturers. Some of the popular type numbers of diodes are

OAxx,	xx - from 70 to 95.	examples: OA79, OA85 etc.,
BYxxx,	xxx- from 100 onwards,	examples: BY127, BY128 etc.
DRxxx,	xxx- from 25 onwards.	examples: DR25, DR150 etc.,
1Nxxxx	examples: 1N917	1N4001, 1N4007 etc.

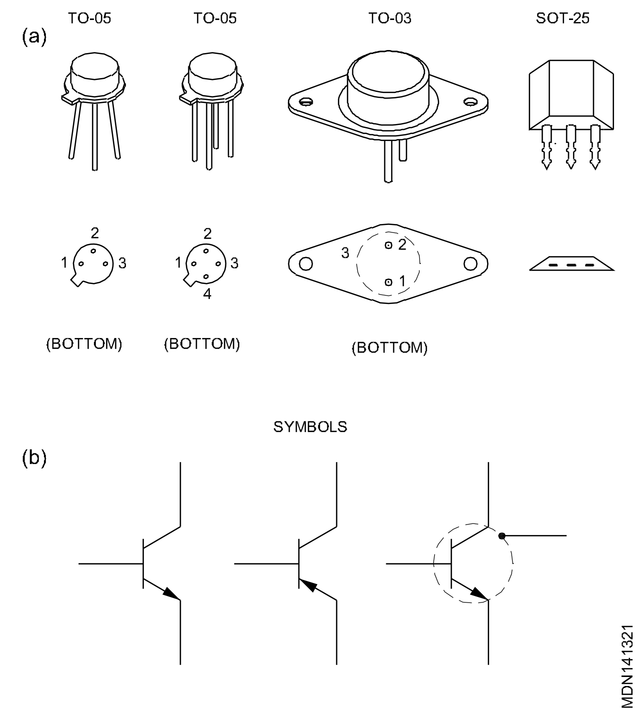
Transistors and classification

Objectives: At the end of this lesson you shall be able to
- **state the two main uses of transistors**
- **list the advantages of transistors over vacuum tubes**
- **list the important classifications of transistors**
- **state the use of a transistor data book**
- **state the names given to the leads of a transistor**
- **state the functions of the three sections of a transistor**
- **state the uses of putting sleeves to transistor leads**
- **describe the two tests to be conducted on a transistor before using it.**

Introduction to Transistors

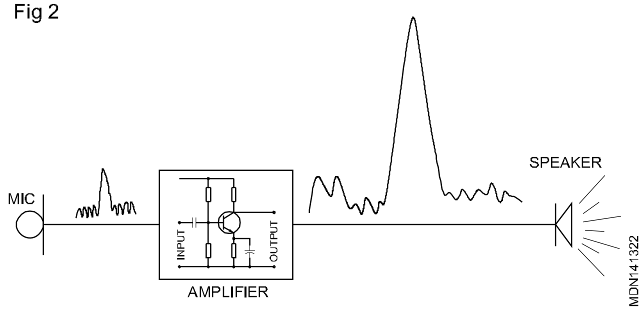
Transistors are the semiconductor devices having three or four leads/terminals. Fig 1a shows some typical transistors. Fig 1b shows the symbols used for different types of transistors.

Fig 1



Transistors are mainly used for enlarging or amplifying small electric/electronic signals as shown in Fig 2. The circuit which uses transistors for amplifying is known as a transistor amplifier.

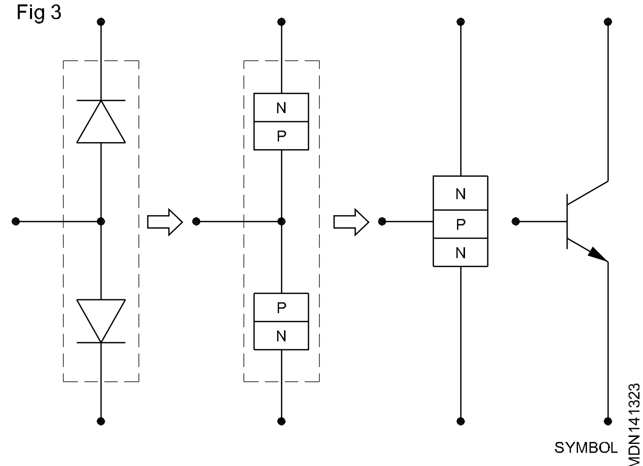
Fig 2



Other important application of transistors is its use as a solid state switch. A solid state switch is nothing but a switch which does not involve any physical ON/OFF contacts for switching.

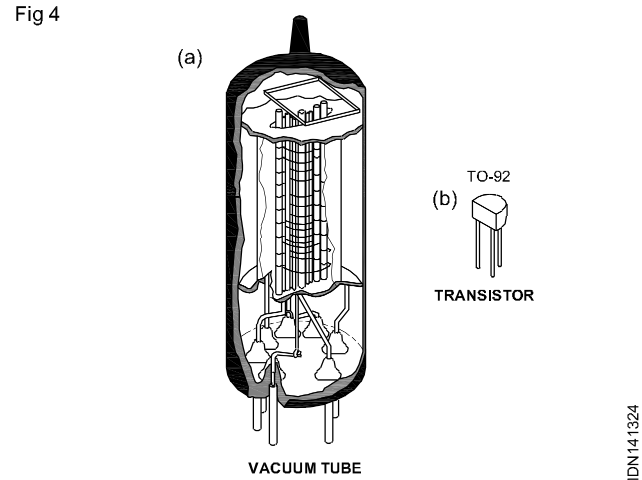
Transistors can be thought of as two PN junction diodes connected back to back as shown in Fig 3.

Fig 3



Before the transistors were invented (1947), there was vacuum tubes which were used in amplifiers. A typical vacuum tube is shown in Fig 4a.

Fig 4



Compared with the present day transistors the vacuum tubes were big in size , consumed more power, generated lot of unwanted heat and were fragile. Hence vacuum tubes became absolute as soon as transistors came to market.

Transistors were invented by Walter H. Brazil and John Barlow of Bell Telephone Laboratories on 23rd Dec. 1947. Compared to vacuum tubes (also known as valves), transistors have several advantages. Some important advantages are listed below;

– Very small in size (see Fig 4b)
– Light in weight
– Minimum or no power loss in the form of heat
– Low operating voltage
– Rugged in construction.

To satisfy the requirements of different applications, several types of transistors in different types of packaging are available. As in diodes, depending upon the characteristics, transistors are given a type number such as BC 107, 2N 6004 etc., The characteristics data corresponding to these type numbers are given in Transistor data books.

Classification of Transistors

1 Based on the semiconductor used.

– Germanium transistors

– Silicon transistors

Like in diodes, transistors can be made, using any one of the above two important semiconductors. However, most of the transistors are made using silicon. This is because, silicon transistors work better over a wide temperature range (higher thermal stability) compared to germanium transistors.

Transistor data books give information about the semiconductor used in any particular transistor.

2 Based on the way the P and N junctions are organized as shown in Fig 5.

– NPN transistors

– PNP transistors

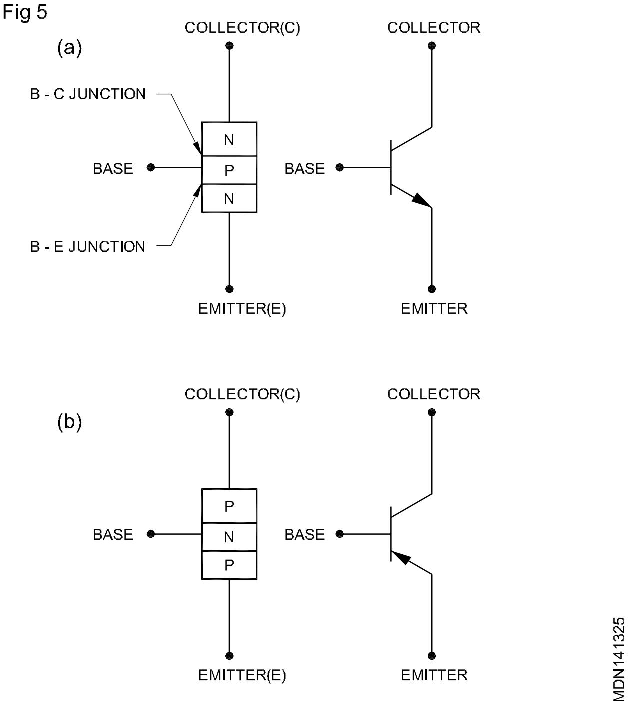
Both NPN and PNP transistors are equally useful in electronic circuits. However, NPN transistors are preferred for the reason that NPN has higher *switching speed* compared to PNP.

Whether a transistor is PNP or NPN can be found with the help of transistor data book.

3 Based on the power handling capacity of transistors as shown in Table below (Fig 6).

Low power transistors, also known as small signal amplifiers, are generally used at the first stage of amplification in which the strength of the signal to be amplified is low. For example, to amplify signals from a microphone, tape head, transducers etc.,

Fig 5



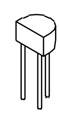
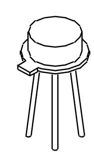
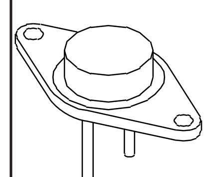
Low power transistors (less than 2 watts)	**Medium power transistors** (2 to 10 watts)	**High power transistors** (more than 10 watts)
TO-92 	TO-05 	TO-03 

Fig 6

Medium power and high power transistors, also known as large signal amplifiers are used for achieving medium to high power amplification. For example, signals to be given to loudspeakers etc. High power transistors are usually mounted on metal chassis or on a physically large piece of metal known as heat sink. The function of heat sink is to, take away the heat from the transistor and pass it to air.

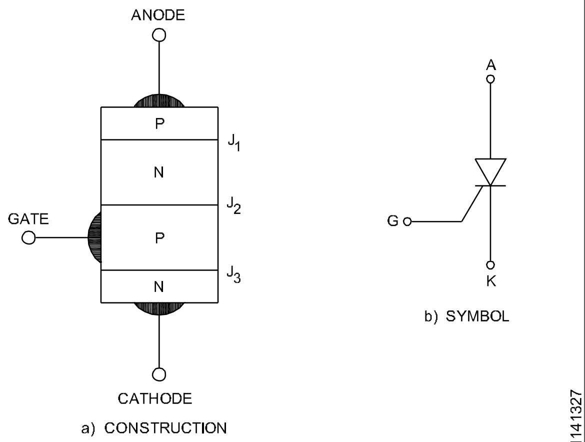
Transistor data books give information about the power handling capacity of different transistors.

Thyristor and the characteristics of SCR

Introduction: Thyristors are four layer device which can be switched 'on' or 'off' electronically to control relatively large amounts of current for motors and other electrical equipments. The Silicon Controlled Rectifier (SCR) and the triac are examples of thyristor. Almost all electronic controls used in modern industries consist of electronic circuits with thyristors.

Working of SCR: The SCR is a four-layer device with three terminals, namely, the anode, the cathode, and the gate. When the anode is made positive with respect to the cathode (Fig 7), junction J_2 is reverse-biased and only the leakage current will flow through the device. The SCR is then said to be in the forward blocking state or off-state. When the anode-to-cathode voltage is increased, the reverse-biased junction J_2 will break down due to the large voltage gradient across the depletion layers. This is the avalanche breakdown. Since the other junctions J_1 and J_3 are forward-biased, there will be free carrier movement across all the three junctions, resulting in a large anode-to-cathode forward current I_F. The voltage drop V_F across the device will be the ohmic drop in the four layers, and the device is then said to be in the conduction state or on-state.

Fig 7



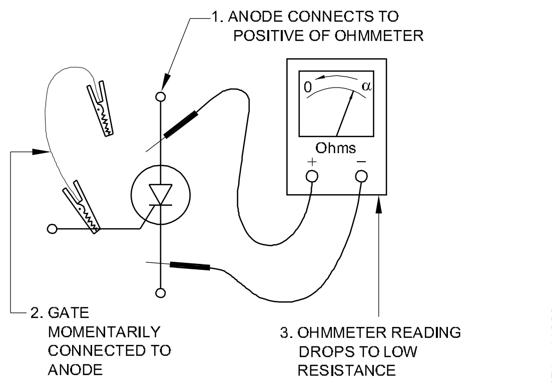
SILICON CONTROLLED RECTIFIER

In the on-state, the current is limited by the external impedance. If the anode-to cathode voltage is now reduced, since the original depletion layer and the reverse-biased junction J_2 no longer exist due to the free movement of the carriers, the device will continue to stay on. When the forward current falls below the level of the holding current I_h, the depletion region will begin to develop around J_2 due to the reduced number of carriers, and the device will go to the blocking state. Similarly, when the SCR is switched on, the resulting forward current has to be more than the latching current I_L. This is necessary for maintaining the required amount of carrier flow across the junctions; otherwise, the device will return to the blocking state as soon as the anode-to-cathode voltage is reduced. The holding current is usually lower than, but very close to the latching current; its magnitude is in the order of a few milliampere(mA). When the cathode is made positive with respect to the anode, junctions J_1 and J_3 are reverse-biased, and a small reverse leakage current will flow through the SCR. This is the reverse blocking state of the device.

Set the multimeter to a low range. Adjust to zero and infinity with the adjustment knob. Connect the SCR as shown in Fig 8. The meter will not indicate any reading. Even the test prods are interchanged because of the junctions. The multimeter shows infinite resistance. Connect the SCR as shown in Fig 8. When the gate is touched momentarily with the anode prods, the meter reads low resistance between 30 and 40 Ohm. When the gate is removed, the meter still continues to read the same value of 30 and 40 Ohm.

This means that the SCR is in good working condition. If the meter does not show any reading, the SCR is faulty. When the gate is given a small forward bias, the gate switching the SCR and the internal resistance of the junction is low, so the current can flow easily from the cathode to the anode. Once the SCR is conducted, even if the gate's forward bias is removed, the SCR anode-to-cathode current will flow through the meter, and the multimeter will continue to read a low resistance, ie 30 to 40 Ohm.

Fig 8

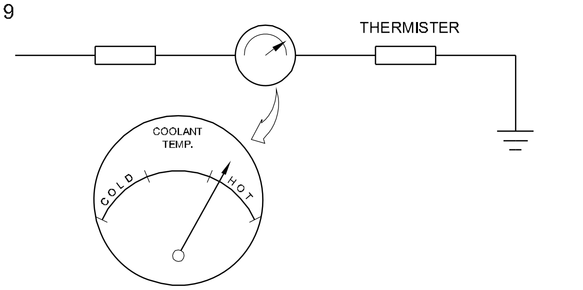


Thermistor: It is also semiconductor device used in most vehicles today. They are named because they are actually a temperature sensitive resistor. It is made of powdered nickel, cobalt, copper, iron and manganese which has been fused together at a higher temperature. The electrical resistance of a thermistor changes greatly with temperature.

Thermistors are used to detect various temperatures or changes in temperature. Their most frequent use involves the measurement of engine coolant temperature, or inlet air temperature.

In the most common type of thermistor, the resistance decreases as the temperature increases. This type is called a negative temperature coefficient (NTC) thermistor. Some thermistors are of the positive temperature coefficient (PTC) type. This means that the resistance of the thermistor increases with temperature. NTC type thermistors are used in automobiles as engine coolant temperature sensors as shown in Fig 9.

Fig 9



Thermistors can also be used to detect the temperature of the air. Many of the computer controlled fuel system in use utilize air temperature as an input. These are easily installed and wired into the computers and will have their resistance changes seen as temperature changes.

Uni-junction transistor (UJT)

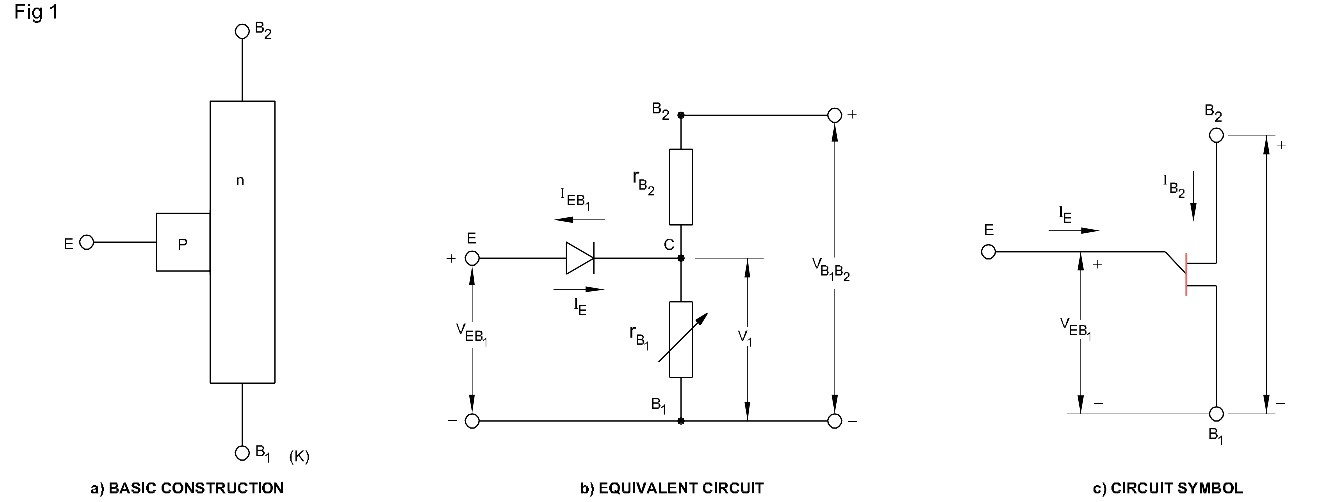
Objectives: At the end of this lesson you shall be able to

- **explain the construction, equivalent circuit and symbol of an UJT**
- **state the application of UJT.**

The Uni-junction transistor (UJT): The uni-junction transistor consists of a bar of lightly doped n-type silicon with small piece of heavily doped P-type material joined to one side at 60% of height from the base as shown in Fig 1a. The end terminals are named as base 1(B_1) or Cathode (K) and base 2(B_2) or anode (A) and the P-type material as emitter (E). The highly doped n-type material has a high resistance and can be represented by two resistor r_{B1} and r_{B2}. The sum of r_{B1} and r_{B2} is designated as R_{BB} (Refer Fig 1b). The emitter (P-type) form a PN junction with the n-type silicon bar and this junction is represented by a diode in the equivalent circuit (Fig 1b). The circuit symbol is shown in Fig 1c.

Application of UJTs: UJTs are employed in a wide variety of circuits involving electronic switching and voltage or current sensing applications.

Fig 1



Field effect Transistors

Objectives : At the end of this lesson you shall be able to

- **explain the difference between bi-polar transistors and field effect transistors**
- **write the basic construction and symbol used.**
- **explain the theory of operation of FETs**
- **explain a typical FET a.c voltage amplifiers.**

Field Effect Transistor (FET)

The main difference between a Bi-polar transistor and a FET is that,

Bi-polar transistor is a current controlled device.

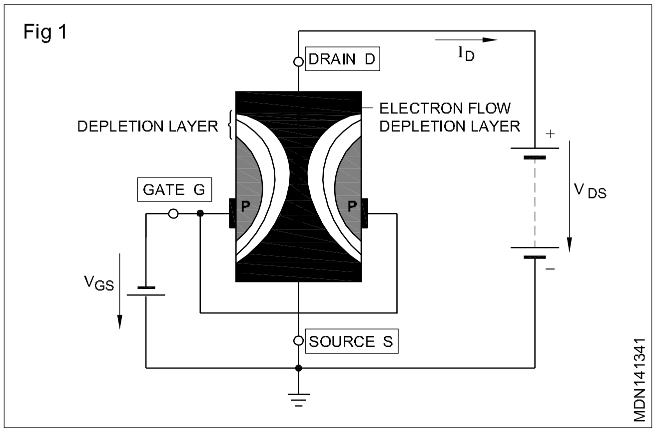
In simple terms it means that the main current in a bi-polar transistor is controlled by the base current.

FET is a voltage controlled device.

This means that the voltage at the gate controls the main current.

In addition to the above, in a bi-polar transistor,the main current always flows through N-doped and P-doped semiconductor materials.Where as in a FET the main current flows either only through the N-doped semiconductor or only through the P-doped semiconductor as shown in Fig 1.

Fig 1



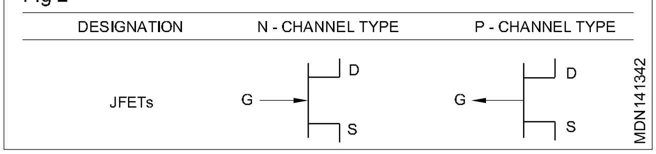
If the main current flow is only through the N-doped material,then such a FET is reffered as a P-channel or P type FET.The current through the P-doped material in the P-type FET is only by Holes.

Unlike in bipolar transistors in which the main current is both by electrons and holes.In contrast in FETs depending on the type(P or N type) the main current in either by electrons and holes and never both.for this reason FETs are also known as Unipolar transistors or unipolar device.

Junctin Field Effect Transistor(JFET)

It is a three terminal device and looks similar to a bi-polar transistor.The standard circuit symbols of N-channel and P-channel type FETs are shown in Fig2.

Fig 2

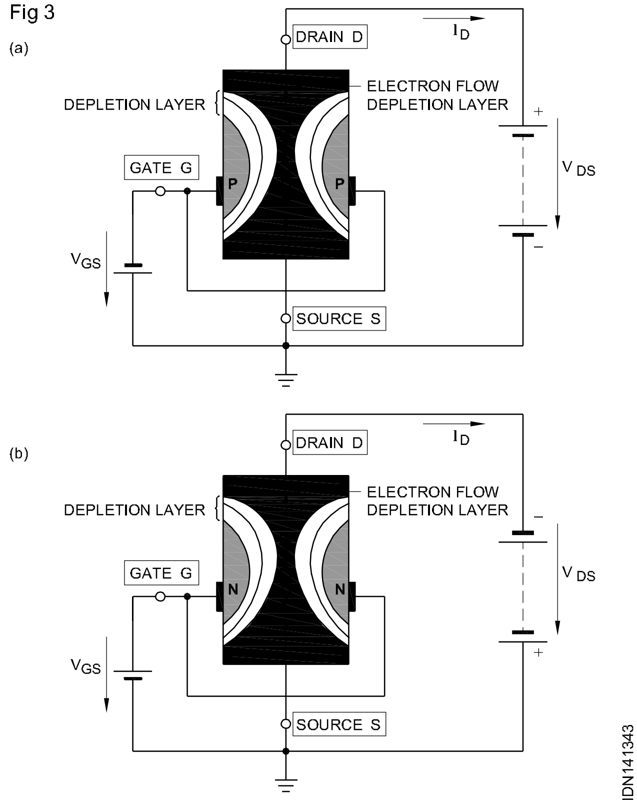


Construction

As shown in Fig 3a, a N-channel JFET has a narrow bar of n-type. To this,two p-type junctions are diffused on opposite sides of its middle part fig 3a.These diffused junctions form two PN diodes or gates.The N-type semiconductor area between these junctions/gates is called the channel. The diffused P regions on opposite sides of the channel are integrally connected and a single lead is brought out which is called gate lead or terminal.Direct electrical connections are made at the two ends of the bar. One of which is called source terminal S and the other terminal,D is called drain-D.

A P-channel FET very similar to the N-channel FET in construction except that it uses P-type bar and two N-type junctions as shown in Fig 3b.

Fig 3



FET notation listed below are essential and worth memorizing.

1 Source terminal: It is the terminal through which majority carriers enter the bar (N or P bar depending upon the type of FET).

2 Drain terminal: It is the terminal through which majority carriers come out of the bar.

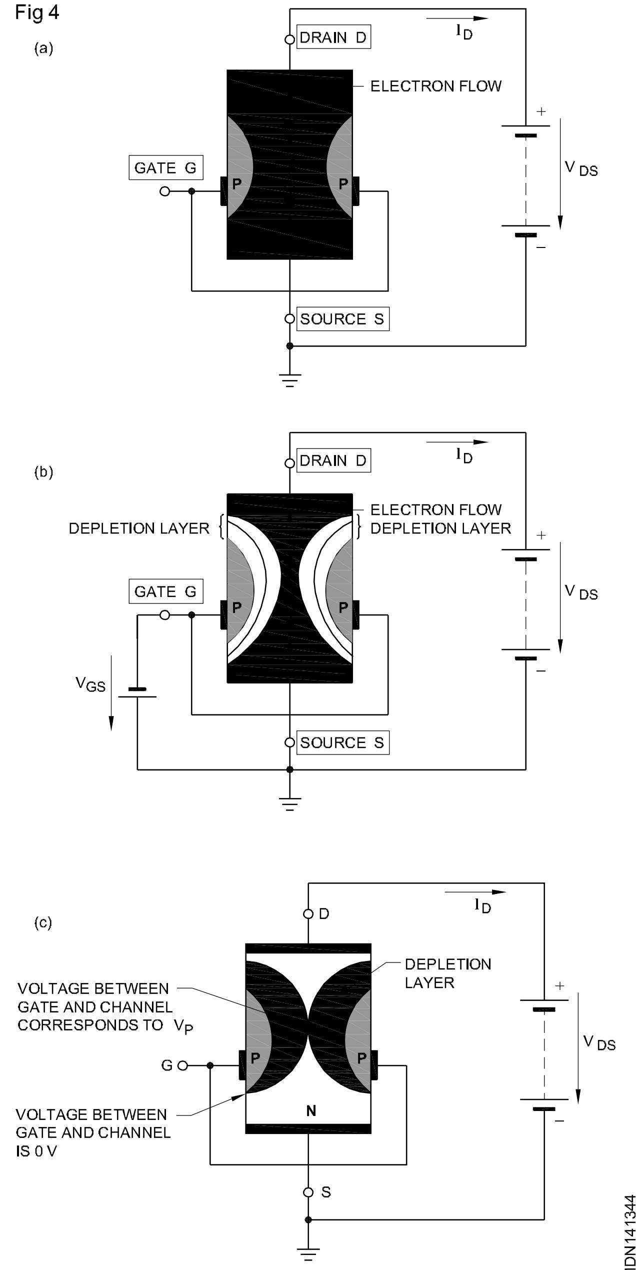
3 Gate terminal: These are two internally connected heavily doped regions which form two P-N junctions.

4 Channel: It is the space between the two gates through which majority carriers pass from source to drain when FET is working (on).

Working of FET

Similar to Bipolar transistors, the working point of adjustment and stabilization are also required for FETs.

Fig 4



Biasing a JFET

The biasing arrangement of JFET is shown in Fig 4. In which the gates are always reverse biased. Therefore the gate current Ig is practically zero.

The current source terminal is always connected to that end of the supply which provides the necessary charge carriers. For instance, in a N-channel JFET source terminal S is connected to the negative of the d.c power supply.And, the positive of the d.c power supply is connected to the drain terminal of the JFET.

Where as in a P channel JFET,Source is connected to the positive end of the power supply and the drain is connected to the negative end of the for the drain to get the holes from the P-channel Where the holes are the charge carriers.

Where as in a N channel JFET, the drain is made positive with respect to source by voltage Vds as shown Fig 4a.When gate to source voltage Vgs is zero, there is no control voltage and maximum electron current flows from source(S)-through the channel-to the drain (D).This electron current from source to drain is referred to as Drain current,Id.

When gate is reverse biased with a negative voltage as shown in Fig 4b,the static field established at the gate causes depletion region to occur in the channel as shown in Fig 4b.

This depletion region decreases the width of the channel causing the drain current to decrease.

If Vgs is made more and more negative, the channel width decreases further resulting in further decreases in drain current. When the negative gate voltage is sufficiently high, the depletion regions meet and block the channel cutting off the flow of drain current as shown in Fig 4c.This voltage at which this effect occurs is referred to as the pinch off voltage, Vp.

Thus, by varying the reverse bias voltage between gate and source (-Vgs),the drain current can be varied between maximum current (with –Vgs=0) and zero current (with –Vgs=pinch off voltage).So,JFET can be reffered as a voltage controlled devices.

P channel JFET operates in the same way as explained above except that bias voltages are reversed and the majority carrier of channel are holes.

Metal oxide field effect transistor (MOSFET)

Objectives: At the end of the lesson you shall be able to
- **state the MOSFET's operation principle and its types**
- **list the special type of MOSFET**
- **explain the features of MOSFET.**

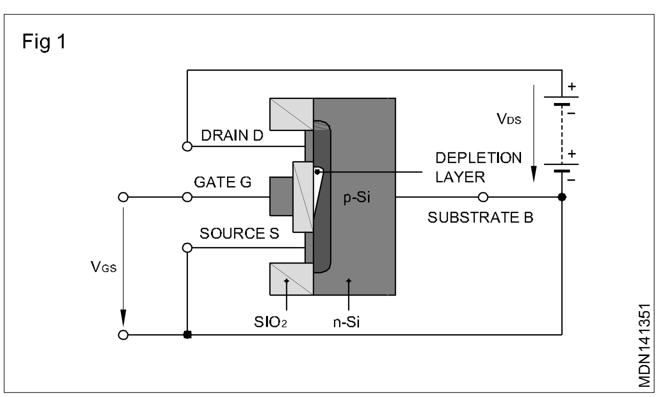
In MOSFETs, control is via an insulating layer instead of a junction (as in JFETS). This insulating layer is generally made of silicon dioxide, from which the very name MOSFET is derived(Metal Oxide Semiconductor). Some times the MOSFETs are also referred to as Insulated-gate FET, for which the abbreviation used are IFET or IGFET.

Type of MOSFET

Depletion-type MOSFET

Construction and mode of operation

Fig 1 shows the construction of a depletion MOSFET of the n-channel type.



Here, two highly doped n-zones are diffused into p-doped silicon plate, which is referred to as the substrate, and are provided with junction-free drain and source connections. Between the two zones there is a thin weakly n-doped channel, which produces an electrical connection between the source and drain without an external field-action. This channel is covered by an insulting layer of silicon dioxide (SIO_2), to which a metal electrode is applied as the gate connection.

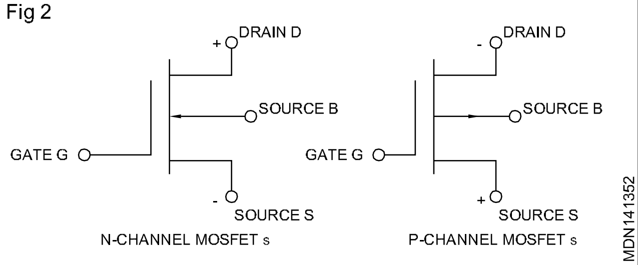
If a voltage U_{DS} is applied between source and drain, at U_{GS} =)V an electron current flows from the source electrode via the n-channel to the drain electrode. If, however, a negative voltage is applied to control electrode G, the electrons present in the n-channel are forced out of the vicinity of the gate electrode, so that a zone depleted of charge carriers is produced there. This causes a constriction of the n-channel and consequently also a reduction of its conductivity. If the gate voltage becomes more negative, the conductivity of the channel is reduced, as is consequently also the drain current I. Another peculiarity of depletion type MOSFET s is that they can also be controlled with a positive gate-voltage. charge carries are then drawn out of the P- doped substrate into then-channel and its conductivity is increased even further, compared with the conductivity at U_{GS}- OV

Designations and circuit symbols

The same designations are used for the connections of MOSFETs as they are for JFETs, I,e. source, drain and gate. MOSFETs, however, have another electrode, which is referred to as the substrate connection. Together, which is referred to as the substrate connection, Together with the semiconductor material of the channel, this substrate forms a P-N junction, which can be used as a second control- electrode. It is then led out of the casing. Like the other electrodes is connected directly to the additional control possibility.

Fig 2 Shows the circuit symbols for depletion- type n-channel MOSFETs and p-channel MOSFETs. For the n-channel type, the arrow points towards the line representing the channel, in the case of the P-Channel type, on the other hand, it points away from the line representing the channel. The continuous line representing the channel indicates that it is depletion-type MOSFET.

Fig 2



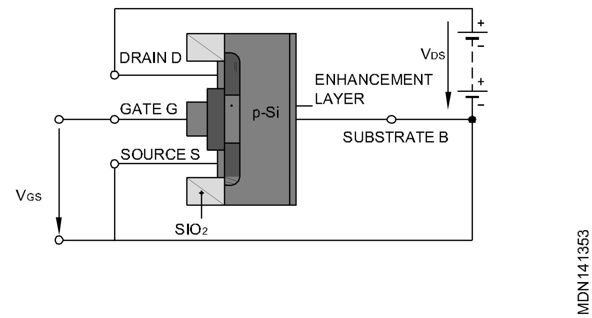
N- Channel MOSFETs are operated with a positive drain-source Voltage. They have a considerably greater practical significance than p-channel MOSFETs, which require a negative drain-source voltage for their operation.

Enhancement-type MOSFET

Construction and mode of operation

Enhancement-type MOSFETs have a similar technological construction to the depletion types. Without the external action of a field. However no conducting channel exists between the drain connection and the source connection, so that at U_{GS}=)V, no drain current can flow, Fig 3. shows the construction of an enhancement-type n-channel MOSFET.

Fig 3

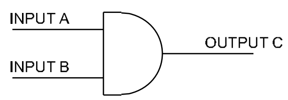


Basic logic gates

Objectives: At the end of this lesson you shall be able to
- **describe the AND, OR, NOT & NAND gate and their applications with simple digital circuits.**

Logic circuits (Fig 1)**:** Digital ICs are made up of many different elements. Most important of these are transistors. This transistor circuits are called logic circuits or digital circuits and are made up of combinations of different types of so-called gates. These gates have the special ability to logically process two or more signals. Thus they are also called logic gates.

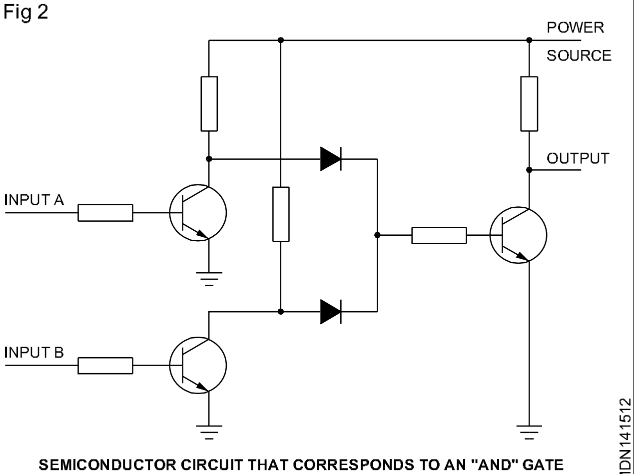
Fig 1



The "AND" Gate:

Logic circuits are usually indicated by a special symbol. Such a circuit, however is actually composed of semiconductor elements as shown in (Fig 2).

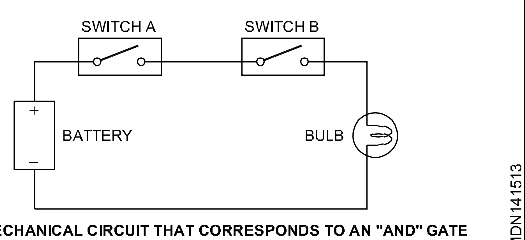
Fig 2



SEMICONDUCTOR CIRCUIT THAT CORRESPONDS TO AN "AND" GATE

To make an AND gate easily understand, a simple mechanical circuit without the use of semiconductors is shown in (Fig 3). In this circuit the switches A and B are equivalent to (C). The light bulb lights only if both switches A and B are closed. If either switch is open, the bulb will (or it both are open), not come on.

Fig 3



SIMPLE MECHANICAL CIRCUIT THAT CORRESPONDS TO AN "AND" GATE

Similarly, in an actual AND gate, there will be an "on" signal (often represented as the number 1) at the output terminal (C) only if there is a voltage at both input terminals (A and B). If either A or B is zero (off) or if both are zero, C will also be zero. These combination can be shown in a truth table.

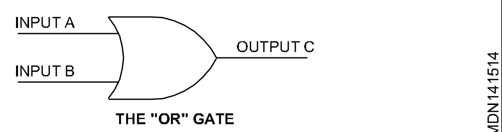
AND - gate truth table

Inputs		Output
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

The "OR" Gate (Fig 4, 5 & 6)

Fig 4 shown the symbol for an "OR" gate, its corresponding semiconductor circuit, and an equivalent mechanical circuit.

Fig 4



THE "OR" GATE

Fig 5

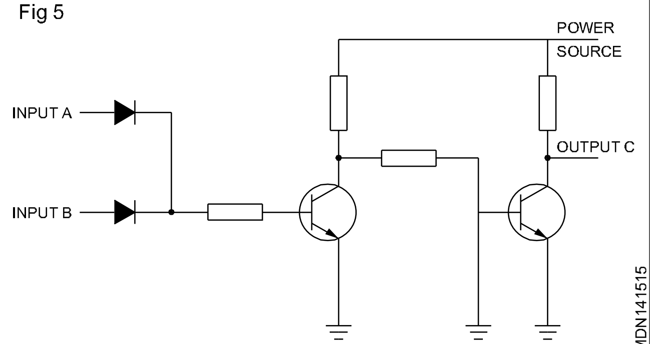
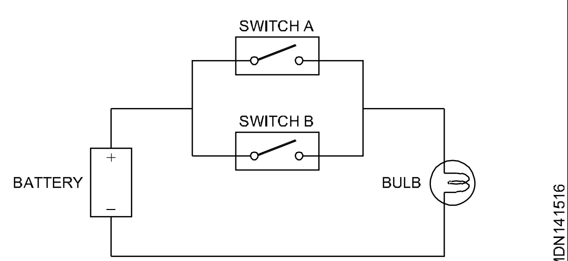


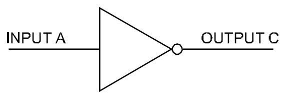
Fig 6



If there is voltage at either input terminal (or if there is a voltage at both inputs) there will be voltage at the output terminal "OR" gate truth table is given.

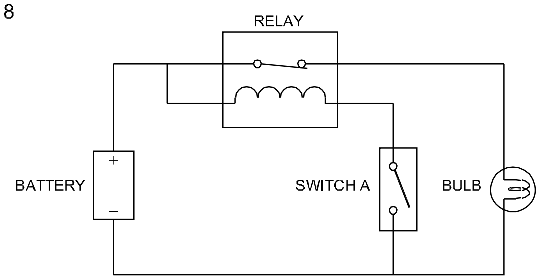
The symbol for a "NOT" gate is shown in (Fig 7). A corresponding semiconductor circuit and an equivalent mechanical circuit are as shown in (Fig 8).

Fig 7



"NOT" GATE

Fig 8

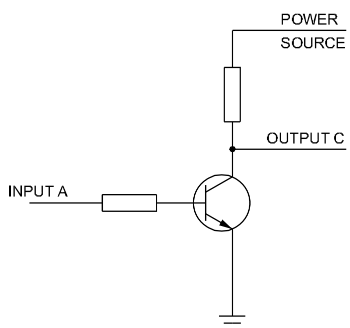


SIMPLE MECHANICAL CIRCUIT THAT CORRESPONDS TO "NOT" GATE

In the mechanical NOT circuit, the light bulb doesnot go on if switch A is closed. When switch A is opened the relay closes and the bulb is turned on.

As can be seen in the truth table, the "NOT" gate inverts the signal so that the output is always the opposite of the input. For this reason it is called as "inverter". (Fig 9)

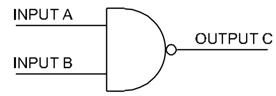
Fig 9



SEMICONDUCTOR CIRCUIT THAT CORRESPONDS TO "NOT" GATE

"NAND" is a combination of "AND" gate and a "NOT" gate as shown in (Fig 10).

Fig 10



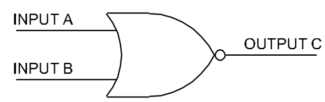
"NAND" GATE

A zero will appear at the output terminal (C) only if there is a voltage at both input terminals (A and B). If there is a zero at either A or B, an "on" signal (number 1) will appear at C.

This can be observed in Truth Table as shown.

A "NOR" gate is a combination of an "OR" gate and a NOT gate (Fig 11). For this reason, an "on" signal will appear at the output terminal only if there is an "off" signal (zero) at both input terminals. If there is an "on" signal at either A or B, terminal C will zero as shown in the truth table.

Fig 11



"NOR" GATE