Phase 2

Trade of Motor Mechanic

Module 2

Unit 2

Basic Electricity

Produced by

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Curriculum Revision 2.2 16-01-07

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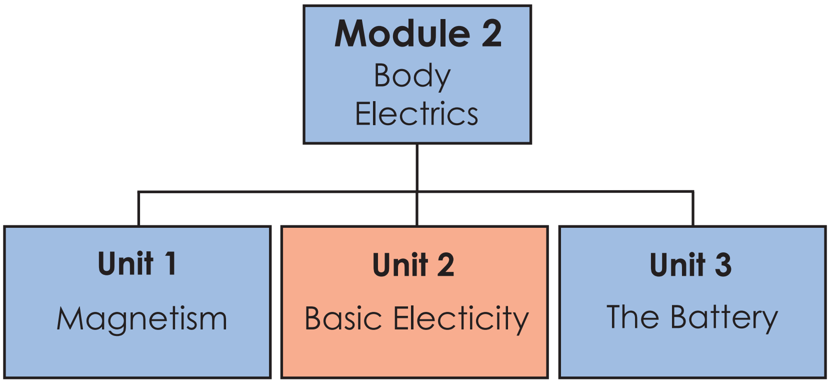
Introduction

There are six Units in this Module. In Theory 1 we cover Units 1, 2 and 3 which focuses on the basics of electricity. In Theory 2 we cover Units 4, 5 and 6 which focuses on the fundamental electrical circuits in the vehicle.



In module 2 unit 2, an overview of the basic electrical principles, the terms used and the related maths/science are explained. The construction of simple electrical circuits involving components used within the automotive industry and the use of the multimeter are also covered in this unit.

Unit Objective

By the end of this unit each apprentice will be able to:

- Define the electrical terms and symbols
- State the effects of current flow
- State Coloumb's Law
- State the main components of a basic electric circuit
- Select the correct scale, range and test lead arrangement of a multimeter in preparation to measure quantities of current, voltage and resistance
- Define the electrical circuit terms
- Construct basic series and parallel circuits that use bulbs and low value fixed and variable resistors as loads
- Measure quantities of current, voltage, fixed and variable electrical resistances using standard and inductive Multimeters
- Use Ohm's Law formula to calculate an unknown value in basic series and parallel circuits
- Calculate electrical power in watts
- Carry out fault finding procedures for open/short circuits, overloads and excessive resistances on connectors, terminations/connections and switches on circuits constructed on training systems/units
- Draw basic schematic, series and parallel fused circuit diagrams.
- Describe the magnetic effect resulting from current flow through straight and coil conductors
- Describe how coils/windings of electrical conductors are used to make electromagnetic relays or solenoid devices
- Describe the use of 'right-hand grip rule' for straight conductors
- State a basic definition of the terms semi-conductor, diode and transistor
- Construct basic electrical circuits that demonstrate the use of diodes and transistors

1.0 Electrical Terms and Symbols

Key Learning Points

- Electrical terms; current, atomic theory, matter, atom, electron, difference between conductor, semi-conductor and insulator, electron random and directed drift, static, direct and alternating current (DC and AC), direction of current flow - electron and conventional theories, current measurement - ampere (A) use of 'I' symbol
- S.I. units; Ampere, Volt, Ohm, Watt
- Prefixes; M, K, m
- Voltage; electromotive force (EMF), generators - inductive, chemicals, friction etc., potential difference - Volt (V)
- Resistance; resistivity of matter, effects of length, temperature and cross-sectional area, Ohm (Ω)
- Definition of the Ohm in terms of current and voltage, use of Ohm's Law formula
- Power; Watt, (W) product of current and voltage
- Power supply; voltage rise to a circuit/load
- Conductor, insulator; basic structural and electrical reaction differences
- Load; resistor, device to perform function by effect of current flow
- Fuse; function and requirement as circuit protection device, importance of suitable size

1.1 Electricity

Our world is made up of various materials e.g. it contains soil, water, rock, sand etc. and is surrounded by an invisible layer of gas called air. The scientific name given to each of these materials is matter.

"Matter is anything which occupies space and which has mass"

All matter is composed of atoms, which often arrange themselves into groups called molecules. An atom is the basic building block of matter.

Atoms are made up of smaller particles called *Protons, Neutrons and Electrons.*

1.2 Atomic Theory and Definitions

Atom

The smallest portion of an element that still exhibits all the characteristics of that element.

Molecule

The smallest piece of material, which has all the same properties as the material itself, is called a molecule. A molecule is a group of atoms of one element or several elements.

Proton

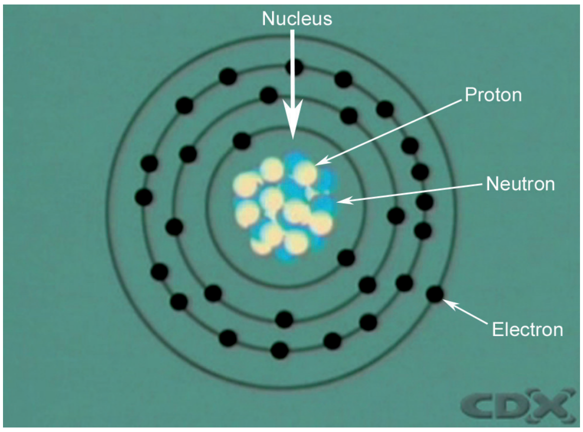
The Proton is a particle of matter having a Positive charge of electricity. It is situated in the nucleus (or core) of the atom.

Neutron

The Neutron is a particle of matter, which is electrically Neutral. It is also situated in the nucleus of the atom.

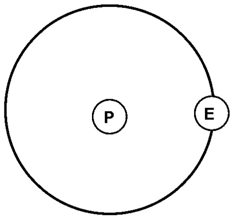
Electron

The Electron has a Negative charge of electricity. The electrons orbit the nucleus of the atom at great speed.



Simplified Representation of Atoms

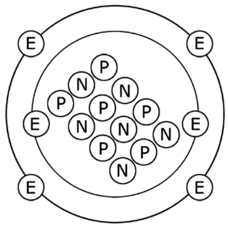
The models of three different atoms are shown in Figures 1a, 1b and 1c. They illustrate how the electron(s) are arranged around the nucleus.



Hydrogen Atom
1 Electron, 1 Proton

Figure 1a

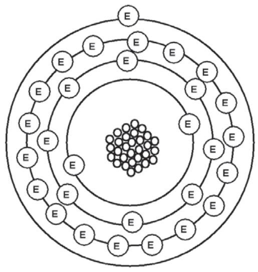
Figure 1a represents the simplest atom of all - the Hydrogen atom, which consists of a single electron orbiting a nucleus, which, is composed of a single proton.



Carbon Atom
6 Electrons, 6 Protons, 6 Neutrons

Figure 1b

Figure 1b illustrates the carbon atom, which contains 6 electrons orbiting a nucleus of 6 protons and 6 neutrons.



Copper Atom
29 Electrons, 29 Protons, 35 Neutrons

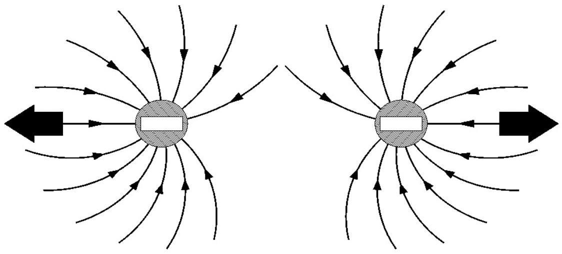
Figure 1c

Figure 1c illustrates the copper atom, which contains 29 electrons and a nucleus of 29 protons and 35 neutrons.

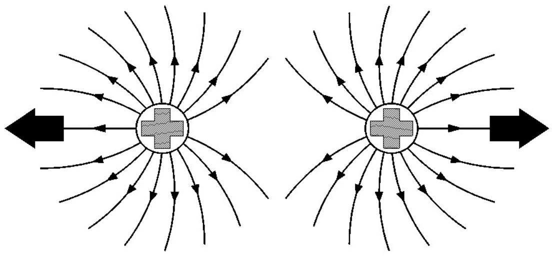
1.3 Laws of Electric Charge

There are basic laws of nature, which describes the action of electric charges. These laws state:

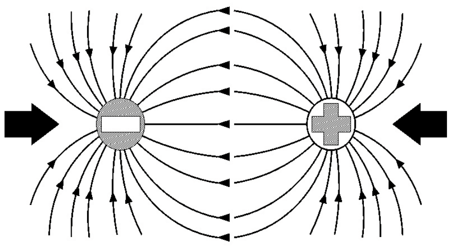
- Like charges repel each other.
- Unlike charges attract each other.



Electrons Repel



Protons Repel



Electrons and Protons Attract

The Balanced Atom

In the previously mentioned examples (hydrogen, carbon and copper) you may have noticed that the number of electrons is always equal to the number of protons.

This is normally true of any atom. When this is the case, the atom is said to be neutral, balanced or normal. However, external forces can upset this state.

1.4 Conductors and Insulators

In some materials the electrons in the outer orbits are easily moved, they tend to transfer themselves from atom to atom and so can wander freely about inside the material. Such a movement of electrons constitutes an electric current and those materials in which electric currents can flow freely are called conductors. Some typical conductors are copper, brass, silver, gold, carbon, mercury etc.

In other materials the electrons are tightly bound to their own particular atoms, with the result that electric currents cannot flow freely in them. These materials are known as insulators. Some typical insulators are PVC (Poly-vinyl chloride), rubber, plastic, glass, paper, oil etc.

1.5 'Random Drift' of the Electrons in Conductors

Random electrical drift occurs in conducting materials when no current is flowing. This is due to the fact that the conductor has free electrons available in its outer shell.

1.6 Directed Electron Drift

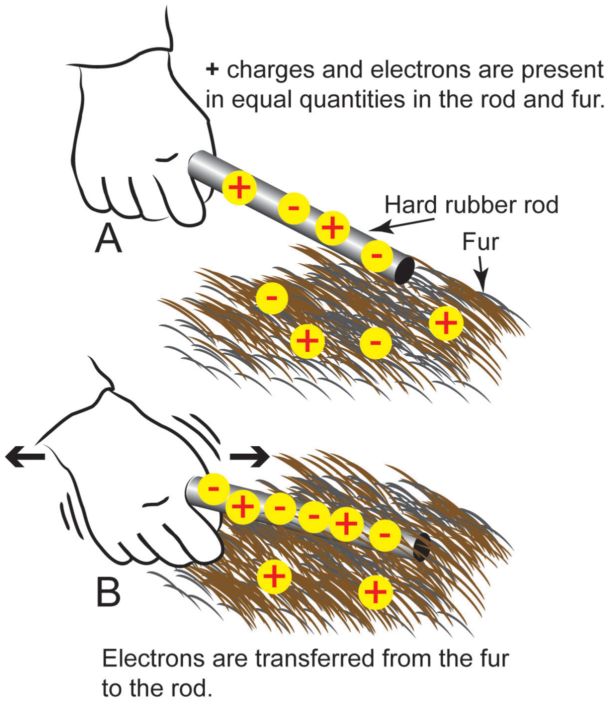
While random drift of electrons is happening in conductor material, nothing external is noticeable, but if any force is applied that cause the electrons to move in any one direction, then we have what is termed 'directed drift' of electrons which is electric current. Current is measured in Amperes.

1.7 Static Electricity

Static electricity can be induced by rubbing 2 insulators together. One material loses electrons to the other. The one losing electrons becomes positively charged the other gains electrons to become negatively charged.

When these 2 charged surfaces are brought close enough together, a spark may jump, as electrons leap the gap to cancel out the charge imbalance. This can be experienced as an electric shock.

This applies to any charged surfaces where the imbalance in charge is large enough to make the electrons leap the gap. The spark can be dangerous.



1.8 Semiconductors

Semiconductors are a crystalline material which allows current to flow under certain conditions. Common semiconductor materials are silicon, germanium (diodes and transistors) and gallium arsenide (photo cell and light emitting diodes).

Semiconductors are used to make diodes, transistors, silicon chips and other "solid state" electronic devices. For example silicon has 4 electrons in its outer shell if this is changed at manufacture to 3 or 5 electrons in the outer shell; two different types of semiconductor material have been created. The 3 electron version becomes p type semiconductor material and the 5 type becomes n type semiconductor material becomes. By a suitable combination of p type and n type materials, transistors, diodes, silicone chips etc. can be manufactured.

1.9 Current

Electric current is the movement of free electrons. Electrons have a negative charge and are attracted to a positive charge. In a battery a chemical reaction takes place that forces electrons towards a negative plate and away from the positive plate. The symbol for a Battery is shown below in Figure 2. The positive plate is represented by the longer line.

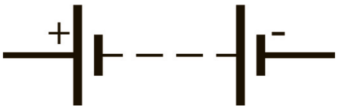


Figure 2

When a battery is connected as shown in Figure 3 below, the free electrons in the conductor drift in one direction only, away from the negative plate and towards the positive plate. Current that flows in one direction only, is called *Direct Current (DC)*.

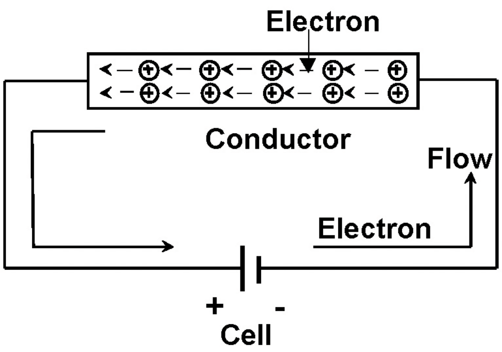


Figure 3

The electrons close to the positive plate of the battery are attracted to it. Each electron that enters the positive plate causes an electron to leave the negative plate and move along the circuit. The number of electrons in the conductor remains constant.

Alternating Current (AC)

Alternating Current acts in two directions (positive and negative) and has a shape, which is shown in the drawing; this shape is called a sine wave.

A sine waveform consists of equal positive and negative half cycles.

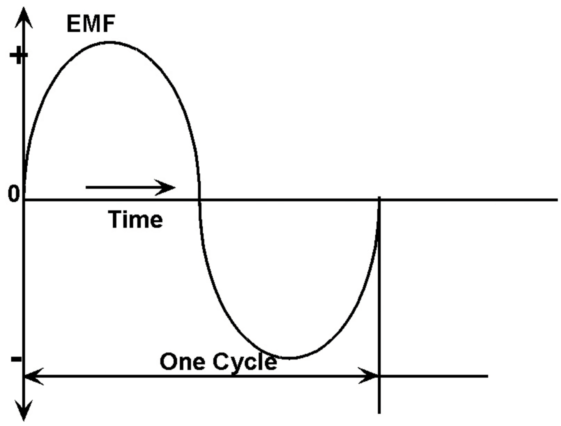


Figure above shows the variation of the Voltage over time and is termed *one cycle*.

Frequency (Symbol f)

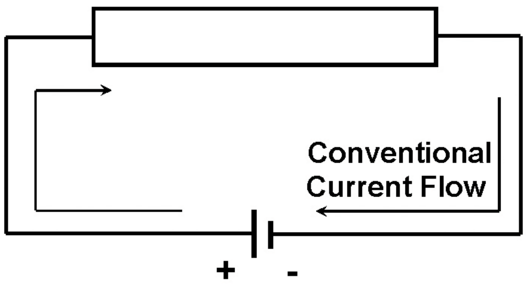
This is the number of cycles completed in one second (t). It is measured in cycles per second or Hertz (Hz). A frequency of 50 Hz is the standard for the supply system in Ireland.

The movement of electrons in a circuit is from negative to positive. Long before this theory was proposed, it was thought that current flowed from the positive plate to the negative plate of a cell. This direction of current flow is now called *conventional current* flow. We say that conventionally current flow is from Positive to Negative, Electron flow is from negative to positive.

Note: In this course we will use conventional current flow in all diagrams.

1.10 'Conventional' Current Flow

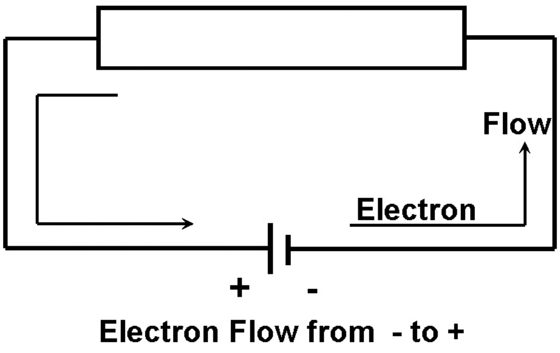
Before science had a true knowledge about electric current, it was arbitrarily assumed that it flowed from what they then termed 'positive' to 'negative', time and science prove this to be incorrect but by then conventions had consolidated and it was decided to retain the format of 'Positive' as live for all automotive wiring diagrams , meters etc. Therefore, we simply accept the convention: Positive = Live and Negative = Earth and conventional current flow theory is Positive to Negative.



Conventional Current Flow from + to -

1.11 'Electron Flow'

In actual electronics the term 'electron flow' is used to describe the now known reality, but as described above, all automotive electrical circuits use the 'conventional' current flow to describe the electrical circuit layout.



1.12 The Ampere

The Ampere is the SI (an abbreviation of System International) unit of measurement used to express the rate of current flow in a circuit. This movement of electrons within a conductor is known as an Electric Current and is measured in Amperes (Amps), symbol I.

When 6.25 x 10^{18} electrons pass a given point in one second a current of One Ampere is said to flow in that circuit. *See Figure 4.*

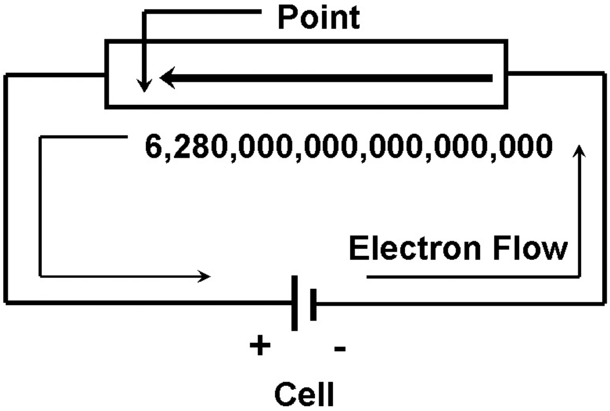


Figure 4

1.13 SI Units

A unit is what we use to indicate the measurement of a quantity. For example, the unit of current is the ampere; the unit of length could be the inch or the metre, etc.. However, the metre is the SI unit of length.

Name	*Symbol*	*Quantity*
Volt	u	Voltage in volts
Ohm	Ω	Electrical resistance
Watt	w	Power
Ampere	A	Electric current

Metric Prefixes

In order that we all work to a common standard, an international system of unit's known as the SI (System International) system is used. Throughout the course a number of prefixes will be used e.g. microamps and milliamps, millivolts and kilovolts, kilohms.

Prefix	*Symbol*	*Multiplying Factor*	*Power Index*
mega*	M	1 000 000	106
kilo*	k	1 000	103
unity		1	100
centi*	c	0.01	10-2
milli*	m	0.001	10-3

* Denotes frequently used prefixes.

Examples

To convert amps to milliamps multiply by 1,000 (10^3)

To convert milliamps to amps multiply by 0.001 (10^{-3})

Examples

Convert the following:

1. 13,000,000 Ohms to megohms
2. 0.5 Volts to millivolts
3. 100 Volts to millivolts
4. 15,000 Volts to kilovolts
5. 600 milliamps to Amps
6. 0.03 Amps to milliamps

Solutions

1. 1,000,000 Ohms = 1 megohm = 1MΩ

   13,000,000 Ohms = 13 megohms = 13MΩ

2. Volt = 1000 millivolts = 1000mV

   0.5 Volts= 500 millivolts = 500mV

3. 100 Volts= 100,000 millivolts = 100,000mV

4. 1,000 Volts = 1 kilovolt = 1kV

   15,000 Volts = 15 kilovolts = 15kV

5. 1,000 milliamps = 1 Amp = 1A

   600 milliamps = 0.6 Amps = 0.6A

6. 1 Amp = 1,000 milliamps = 1000mA

   0.1 Amps = 100 milliamps = 100mA

   0.01 Amps = 10 millamps = 10mA

   0.03 Amps = 30 milliamps = 30mA

1.14 Voltage

Voltage is the electrical potential difference (PD) between two points of an electric circuit. The S.I unit of measurement is volts (V) and the symbol for voltage is (U). 1 volt refers to the voltage or potential that can cause 1 ampere of current to flow in a circuit having a resistance of 1 ohm.

Electromotive force (EMF) is the difference in electric potential or voltage between the terminals of a source of electricity e.g. a battery from which no current is being drawn, this sometimes called a voltage rise. When current is drawn the potential difference drops below the (EMF) value. Electromotive force is measured in volts. *See Figure 5.*

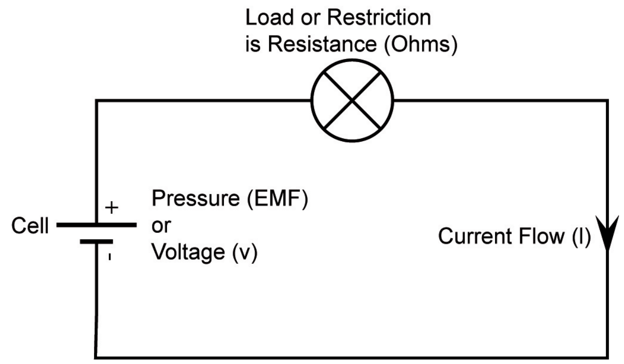
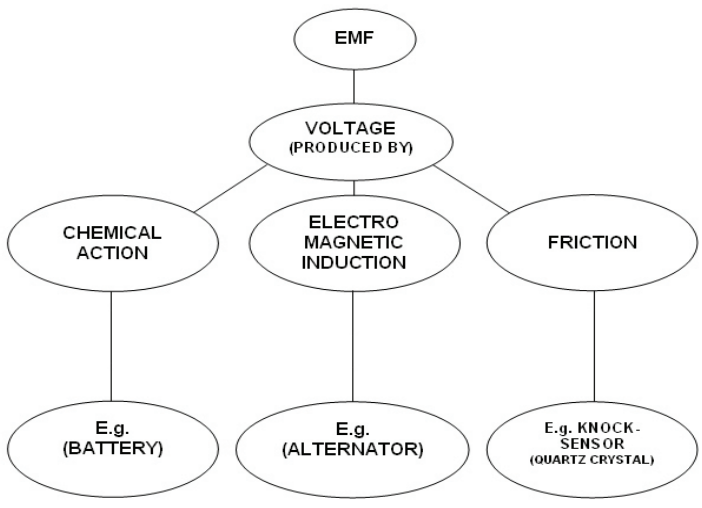


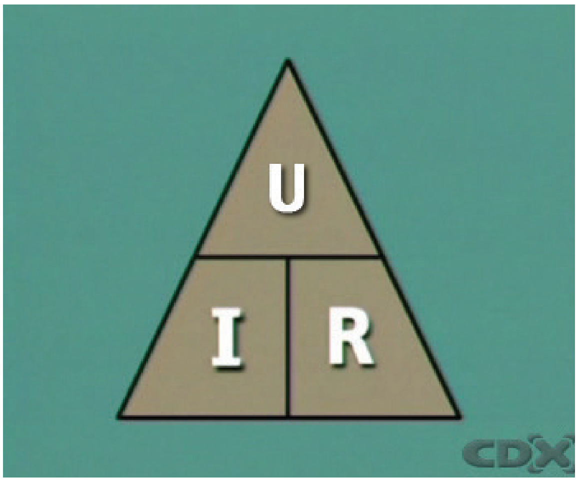
Figure 5

The international symbol for "supply voltage" or "voltage drop" has changed from V to U, the symbol for the unit of voltage (the volt) remaining as V.

The diagram below describes how EMF is generated in the vehicle.



1.15 Ohm's Law



Ohm's Law states that the current (I) flowing through a circuit is directly proportional to the potential difference (U), across that circuit and inversely proportional to the resistance (R), of that circuit, provided the temperature remains constant i.e. A circuit with 1 volt applied with a resistance of 1 ohm will cause 1 amp to flow in the circuit.

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

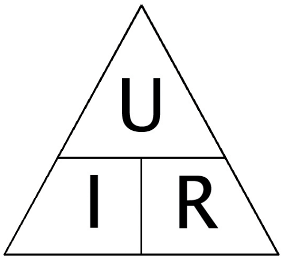
This formula can also be written as:

$$U=R x I$$

Or

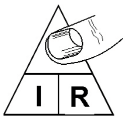
$$R=\frac{U}{I}$$

You can use the UIR triangle to help you remember the three versions of Ohm's Law.

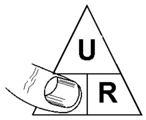


Now consider any circuit in which you know the values of any two of the three factors - voltage, current and resistance - and you want to find the third. The rule for working the "UIR Triangle" to give the correct formula is as follows:

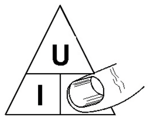
U =



I =



R =



Place your thumb over the letter in the triangle whose value you want to know - and the formula for calculating that value is given by the two remaining letters.

1.16 Resistance

The S.I. unit of resistance is the *Ohm*, symbol *Ω*, pronounced *Omega*.

Every circuit offers some opposition or restriction to current flow, which is called the circuit resistance. The unit of resistance is the *Ohm*, symbol *Ω*, pronounced *Omega*. (The letter "R" is sometimes used instead of the *Ω* but this is not the S.I. symbol).

Load is the general term for whatever item or device current acts on. The load is normally represented as *resistor*.

The following three factors determine the resistance of a conductor at a constant temperature:

1. Resistivity of conductor material
2. Length of conductor
3. Cross sectional area of conductor

Resistivity

The first of these is the *resistivity* of the conductor material, or how good a conductor the material is (copper is a better conductor than aluminium, but neither is as good as silver).

The resistivity of a material is defined as the resistance measured between the opposite faces of a unit cube of the material.

The resistance between opposite faces of a cube of material is called resistivity or specific resistance. Symbol: Greek letter *p* (pronounced Rho)

Resistance (R) is proportional (∞) to Resistivity (*p*)

$$R \infty p$$

Resistivity of Different Materials

The values of resistivity for different conductor materials makes it clear that conductor resistance will depend on the material from which it is made, as well as, its length and cross-sectional area. The table below shows clearly why copper is so widely used as a conductor material. It is second only to silver in its resistivity value. Aluminium is about half as resistive again as copper, but its lightness and cheapness have led to its increasing use as conductors.

Resistivity of Common Conductors Materials

Material	*Resistivity* (10-8 ohm metres)
Silver	1.63
Copper (annealed)	1.72
Aluminium	2.85
Brass	6.0 - 9.0
Iron	10
Tin	11.4
Lead	21.9
Mercury	95.8

Note: The lower the value, the better the conductor.

Length of Conductor

The resistance of a conductor depends on its length. If we increase the length of conductor leaving the area the same, its resistance will increase.

If the length of conductor is doubled, its resistance is doubled. The resistances are in series. The resistance of a conductor is directly proportional to its length. If the length of a conductor is halved its resistance is halved.

$$R \infty l$$

Cross-Sectional Area of a Conductor

The resistance of a conductor depends on its cross-sectional area (CSA). If we increase the CSA of conductor leaving the length the same, its resistance will decrease.

If the CSA of the conductor is doubled, its resistance is halved. The resistances are in parallel. The resistance of a conductor is inversely proportional to its cross-sectional area.

$$R \infty \frac{1}{A}$$

Temperature Coefficient of Resistance

The temperature coefficient of resistance is the change in resistance of a conductor resulting from a change in temperature of one degree centigrade.

- The resistance of conductors vary with temperature changes (up or down).
- The resistance of most conductors (including copper) increase as their temperature increases and are said to have a positive temperature coefficient (P.T.C.) of resistance.
- The resistance of carbon decreases as its temperature increases and is said to have a negative temperature coefficient (N.T.C.) of resistance.
- Most insulators have a negative temperature coefficient of resistance.

In summary for a given temperature the Resistance of a conductor is:

$$R = \frac{pl}{A}$$

R = Resistance

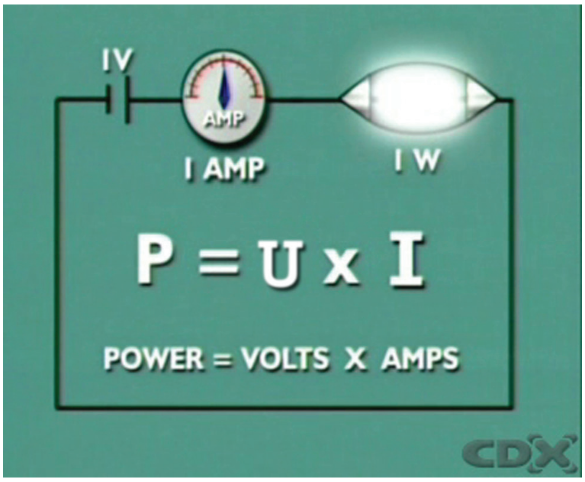
p = Resistivity of the material (ohm metre)

l = Length of the conductor (metre)

A = Cross sectional area of conductor (metre^2)

1.17 Power (watt)

The rate at which the work is done is called power. Power is represented by the symbol (p). Power (W) is a product of current and voltage.



The basic unit in which electric power is measured is the Watt. The Watt is defined as, the rate at which work is done in a circuit when an EMF of one Volt causes a current of one Amp to flow.

Power = Voltage x Current

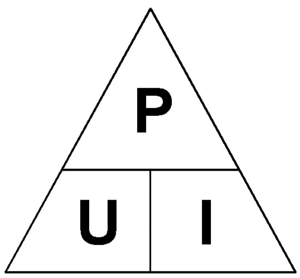
$$P = U \times I$$

$$U = \frac{P}{I}$$

$$I = \frac{P}{U}$$

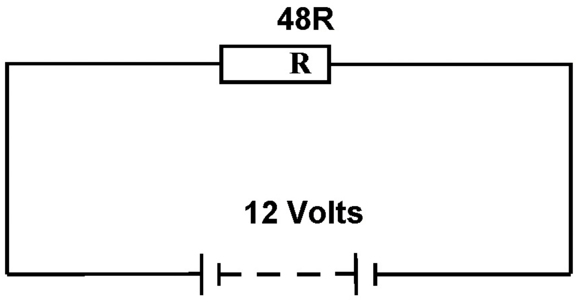
The Power Triangle

This power triangle can be used in the same way as the Ohms Law Triangle.



Example

Calculate the Power used or dissipated by the resistor in the circuit below.



Solution

From Ohm's law:

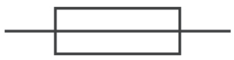
$$I = \frac{U}{R} = \frac{12}{48} = 0.25 Amps$$

P = U x I , therefore: P = 12 x 0.25 = 3 W

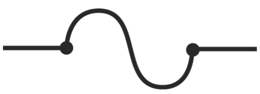
1.18 Fuses

A fuse is the deliberate "weak link" in the circuit, which will break when too much current flows. This offers circuit protection which prevents damage to the circuit and its components. The replacement fuse must have the correct current rating.

The symbol for a fuse is shown below



or



2.0 Effects of Current Flow

Key Learning Points

- Effects of current flow; heat, light, magnetic etc.

Note: When an electric current flows in a circuit it can have one or more of the following effects:

- *Heating Effect*
- *Magnetic Effect*
- *Chemical Effect*

2.1 The Heating Effect

As current flows through motor vehicle circuits, most of the electrical energy is transformed into other kinds of energy. Headlamps transform it into intense heat that makes the bulb filaments glow white hot and produce light. It can demist a window, or can be used to provide circuit protection from excessive current flow i.e. fuse.

The movement of electrons in a circuit, which is the flow of an electric current, causes an increase in the temperature of the load resistance. The huge amount of electrons being pushed through the load resistance (e.g. bulb filament) results in high friction and collision of these electrons. *The amount of heat generated depends upon the type and dimensions of the load resistance wire and the quantity of current flowing.*

By changing these variables, e.g. a 21w bulb will have a different resistance value compared to a 60w bulb this will also change the amount of current flowing. *See Figure 6.*

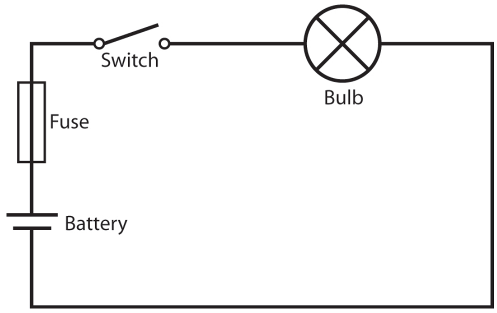
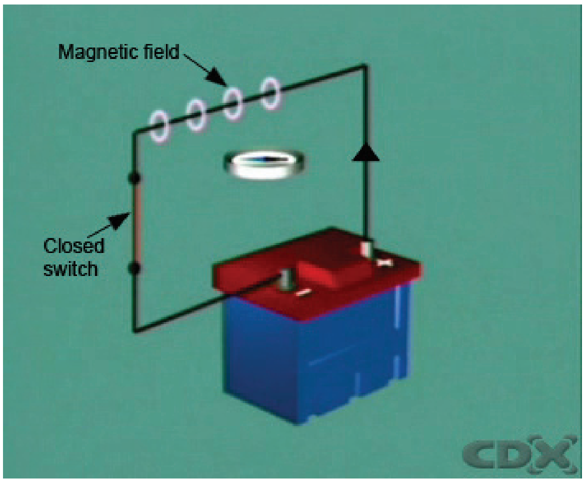


Figure 6

2.2 The Magnetic Effect



Whenever a current flows in a conductor a magnetic field is set up around that conductor. *See Figure 7 below.*

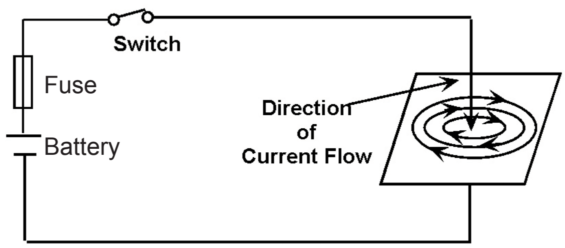


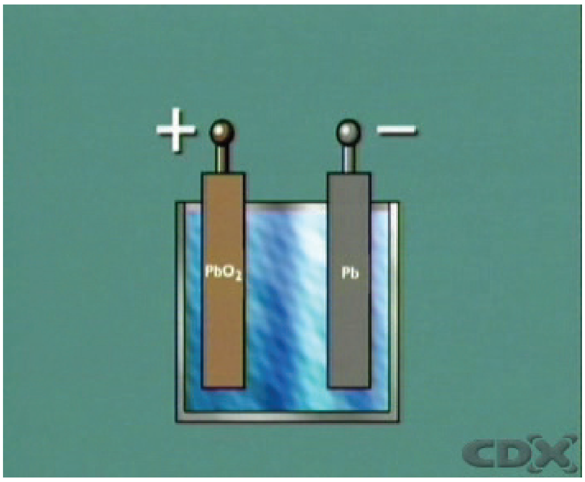
Figure 7

This magnetic field increases in strength if the current is increased and collapses if the current is switched off. A "current carrying conductor", wound in the form of a solenoid (coil), produces a magnetic field very similar to that of a permanent magnet, but has the advantage in that it can be switched on or off by any switches controlling the circuit current.

The magnetic effect of an electric current is the principle upon which electric bells, relays, moving coil instruments, motors and generators work.

The strength of the magnetic field is directly proportional to the current in the circuit. The "clamp on" type ammeter measures the strength of the magnetic field and produces a reading in Amps.

2.3 The Chemical Effect



When an electric current flows through an electrolyte (conducting liquid / paste), this electrolyte is separated into chemical parts. The two conductors, which make contact with the electrolyte, are called the anode (positive plate) and the cathode (negative plate).

An anode or cathode of dissimilar metals placed in an electrolyte can react chemically and produce an EMF. When a load is connected across the anode and cathode, a current will flow in the circuit. *See Figure 9*.

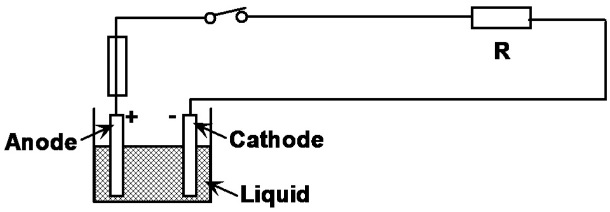


Figure 9

3.0 Coloumb's Law

Key Learning Points

- Coloumb's Law; 'like' and 'unlike' charge reaction

3.1 Coulomb's Law

Coulomb's Law states that *"charged bodies attract or repel each other with a force that is directly proportional to the product of their individual charges and inversely proportional to the square of the distance between them"*.

Coulomb's Law describes the relationship between electrical charges.

Coulombs Law:
1. Like charges repel
2. Unlike charges attract

The Coulomb

A coulomb is the quantity of electricity, which passes a point when a steady current of 1 Ampere flows for one second.

Formula: Q = I x 1

Where: Q = Quantity of Electricity (Coulombs)

I = Current in Amperes (Amps)

t = the time for which current flows, measured in seconds.

4.0 Components of an Electric Circuit

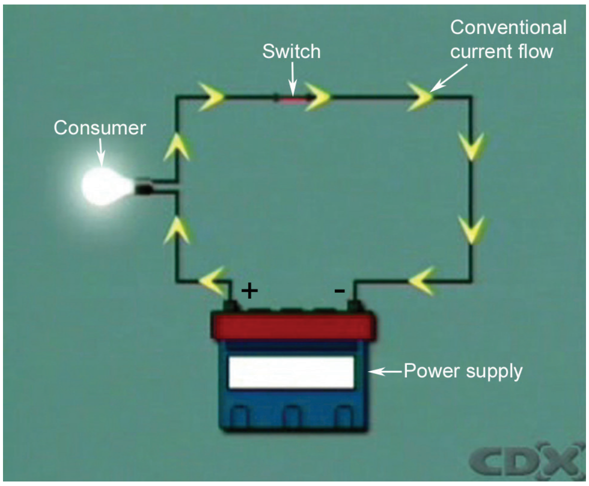
Key Learning Points

- Component parts of a basic electric circuit; power supply, load connectors

4.1 Electrical Circuit Requirements

The Electrical Circuit

To have a continuous current flowing, there must be a complete circuit. If the circuit is broken, by opening a switch for example, the electron flow and therefore the current will stop immediately.



To cause a current to flow continuously around a circuit, a driving force is required, just as a circulating pump is required to drive water around a central heating system. *See Figure 10.*

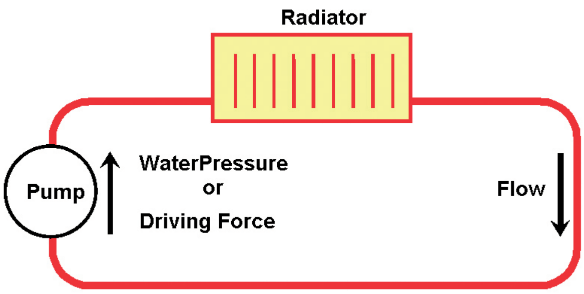


Figure 10

This driving force is the electromotive force (abbreviated to EMF) and is the energy, which causes the current to flow in a circuit. Each time an electron passes through the source of EMF, more energy is provided to send it on its way around the circuit. *See Figure 11.*

A circuit must have:

1. A source of supply (EMF)
2. A load (Lamp)
3. Connecting cables (Conductors)

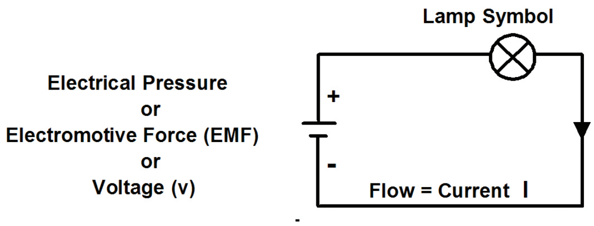


Figure 11

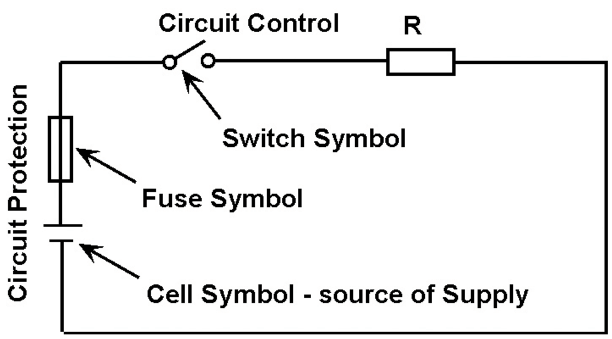
- The source of supply 'power supply' is always associated with energy conversion:
    - Generator (converts mechanical energy to electrical energy)
    - Battery (converts chemical energy to electrical energy)

The source of supply will have pressure called *Voltage* or *Electromotive Force*, (both measured in Volts).

Note: The international symbol for "supply voltage" or "voltage drop" has changed from V to U, the symbol for the unit of voltage (the volt) remaining as V.

- The load is any device that is placed in the electrical circuit that produces an effect when an electric current flows through it. When an electric current flows through an incandescent lamp, the lamp gives off light from heat.
- The connecting leads or cables form the circuit to complete it. The cable consists of the conductor to carry the current and the insulation to prevent leakage just like the water pipes must have a bore to carry the water and the pipe material (e.g. copper) to prevent leakage.

Note: Circuits also usually contain some form of control in the form of a switch that can be used to turn on and off the load. A fuse or circuit breaker is fitted as close to the origin of the circuit as possible to cut off the supply if too much current flows in the circuit. This is called circuit protection.



5.0 Preparing a Multimeter

Key Learning Points

- Preparation of multimeter for use; probe/test leads in correct terminal, correct scale, i.e. voltage, current, resistance, correct electrical property and scale selected
- Correct use of the multimeter to measure quantities of current, voltage and resistance

5.1 Electrical Measurement

Meters are used to measure circuit Current (Ammeter), Voltage (Voltmeter) or Resistance (Ohmmeter).

Digital Multimeter

The Multimeter

A multimeter is an instrument that can be set to measure voltage, current or resistance. Most modern multimeters have a number of other functions such as diode checking, dwell, rpm and capacitance measurement to name but a few. These instruments can measure Direct Current (DC) or Alternating Current (AC) over several ranges. The main types are:

Volt-Ohm-Multimeter (VOM)-Analogue

Digital Multimeter (DMM)

Comparison of Analogue and Digital Multimeters

Analogue Type	Digital Type
Features:	*Features:*
Analogue Display	Digital Display
Manual Range Setting	Range Setting Automatic / Manual

It is important that the instruction manual supplied with a meter is studied prior to operation of the meter. These manuals normally contain warnings and information, which must be followed to ensure safe operation and retain the meter in a safe condition.

Meter Operating Suggestions

1. Ensure that the instrument is set to measure the desired unit e.g. Volts to measure voltage.
2. Set the range switch to the proper position before making any measurement.
3. Ensure the instrument test leads are connected to the appropriate jack sockets. When the voltage, current or resistance to be measured is not known, always start with the highest range first and work your way down to a lower range that gives an accurate reading.
4. Always observe correct test lead polarity when making DC voltage and current measurements.
5. Set the range selector switch to the OFF position when the tester is not in use or during transit.
6. Remove the battery before storing the meter for a long period of time.

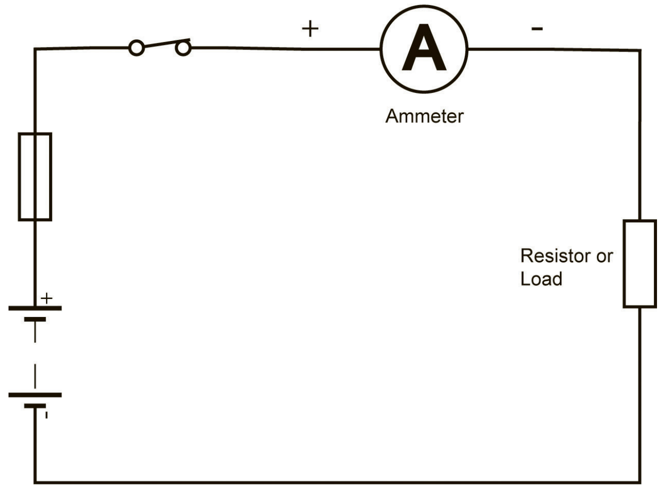
Great care must be taken to ensure that the instrument range setting is not exceeded when measuring a voltage or current.

The Ammeter

The device, which is used to measure the rate of current flow through a conducting material and to display this information in such a way that you can use it, is called an "ammeter". An ammeter indicates, in terms of amperes, the number of coulombs passing a given point in a circuit, in one second.

To be able to do this, the ammeter must somehow be connected into the circuit in such a way that it is able to measure all the electrons passing. One way to do this is to break the conductor, or "open the line" as it is called and to physically connect in the ammeter.

When an ammeter is inserted in this way into a circuit being used to carry current to an electric lamp or resistor, the ammeter is said to be "in series" with the lamp or resistor.

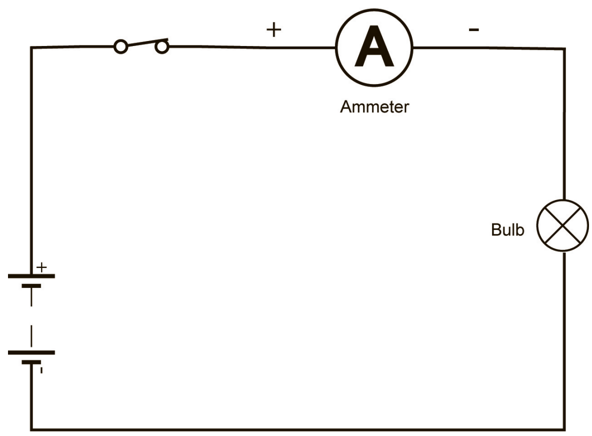


Note: The ammeter may be damaged if incorrectly connected.

A direct current (DC) meter must be connected with the correct polarity for the meter to read up-scale. Reversed polarity makes the meter read down scale, forcing the pointer against the stop at the left, which may damage the needle or pointer.

Activity

Install an ammeter into a circuit as shown and measure the current.

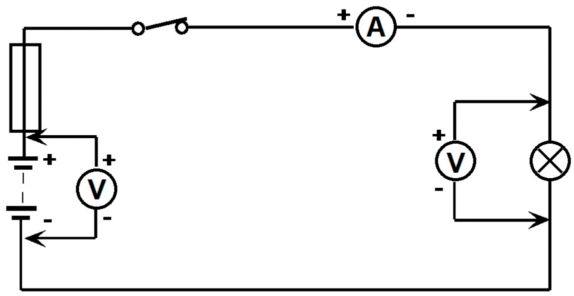


Tip

Use different bulbs to demonstrate different current values.

Voltmeter

A voltmeter measures electromotive force (EMF) or potential difference (PD) and it must be connected across the supply or load resistance in order to indicate the voltage. That is, it must be connected in parallel with the component.

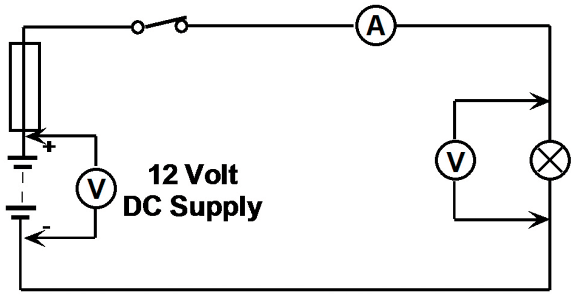


Note: The voltmeter may be damaged if incorrectly connected.

A DC voltmeter (analogue type) must be connected with the correct polarity for the meter to read up scale. When selecting a meter to measure voltage, choose one having a maximum range a good deal higher than the value of any voltage you expect to be measuring. The reason for this is that a voltage in excess of the maximum rated value of the meter will not only fail to register properly on the scale, but will probably cause serious damage to the meter.

Activity

Measure the voltage at the supply (EMF) and the voltage across the load (PD) for the circuit shown.



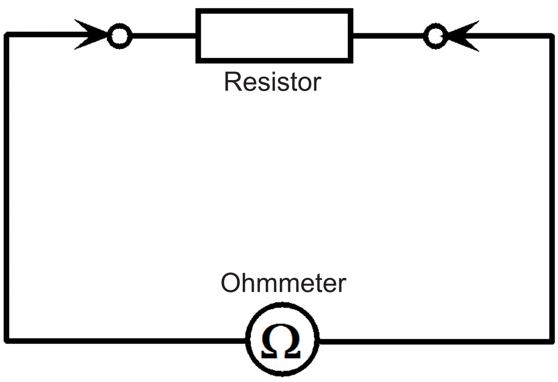
The Ohmmeter

The ohmmeter is a useful instrument, which can be used to check the electrical continuity of components and to measure their resistance. The instrument is powered by its own internal battery. Before connecting an ohmmeter in circuit it is important to ensure that:

1. There is no voltage across the component (supply disconnected).
2. The component to be measured is not connected in parallel with any other component.
3. Check for Zero Ohms with the leads connected together.

Note Repeat step 3, if the position of the scale multiplier switch is changed.

Measurements are taken by connecting the meter across the unknown resistor as shown. It is important to select the most suitable scale for the resistance under test if the resistance ranges are to be set manually. Some meters have automatic ranging.



6.0 Electrical Circuit Terms

Key Learning Point

- Definition of electrical terms; standard industry definitions; e.g. voltage drop - the drop in voltage across loads/switches connectors etc..
- Short to Negative/Short to Positive

6.1 Basic Circuit Concepts

Closed Circuit

Closed circuit refers to an electrical circuit that is switched on.

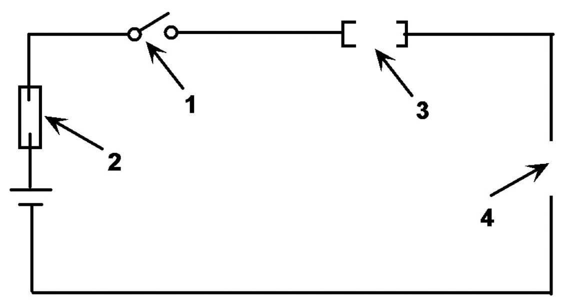
Open Circuit (break)

An open circuit exists when there is a break in the circuit, which will stop current flowing.

Example shown consists of

1. A switch is open
2. A fuse is blown or a circuit breaker is tripped
3. A physical break in the resistor or element
4. A connecting cable is broken

An open circuit exists, when a break occurs in a circuit resulting in an extremely high resistance in the circuit. This value of extremely high resistance is referred to as infinity, denoted by the symbol (∞).



Open circuit (break)

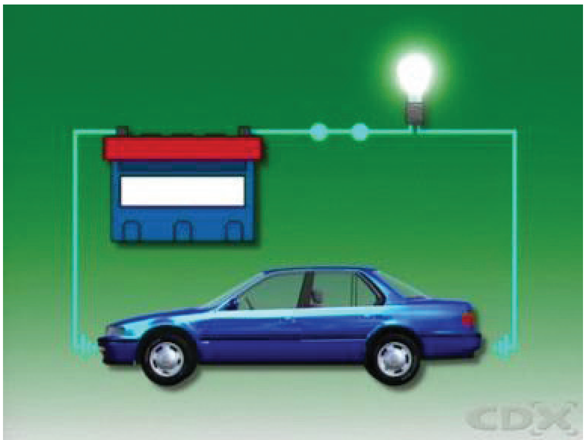
Short Circuit

A *short circuit* allows a current to flow along a different path from the one intended. This can occur for numerous reasons e.g. the insulated power supply cable to the starter damaged and the unprotected cable touching the body earth.

Earth Return

In an automobile the steel body of the vehicle is used as one of the conductors. A cable connects the negative plate of the battery to the steel bodywork of the vehicle. A cable supplies current from the positive terminal of the battery to the load (e.g. a light bulb), usually through a control device such as a switch.

The other side of the load is then connected to the steel bodywork completing the return circuit to the negative terminal of the battery through the vehicle bodywork.



Insulated Return

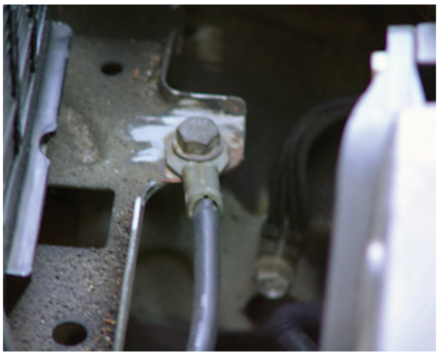
The term insulated return refers to an electrical consumer that has its earth wire returning directly to the negative side of the battery.

Ground or Earth

Ground or "earth" is a term used to indicate connecting a component to the vehicle frame or chassis.

Current flows from the positive terminal of the battery, through a controlling device such as a switch, then through the component. The return path is through the vehicle chassis or frame, to complete the circuit and allow the component to operate.

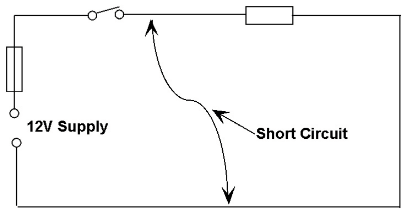
Using the vehicle frame in this way simplifies the circuit wiring.



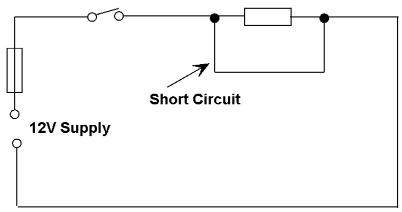
Short Circuit

A short circuit can occur for several reasons as shown below:

1. The "load" is shorted out and the current takes the path of least resistance to ground.



2. The connecting cables are damaged prior to or after the wiring process.



3. The connecting cables in the circuit are connected together during the wiring process.

High Resistance

High resistance occurs when the resistance value is higher than the desired value e.g. Poor connection on the battery terminals.

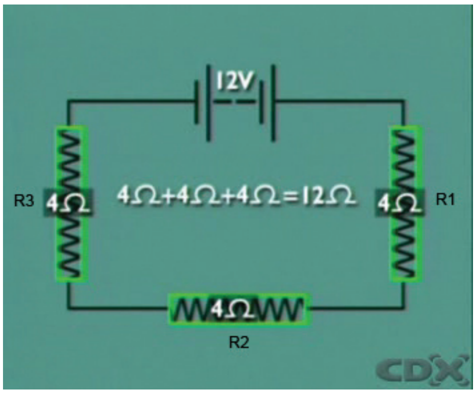
Low Resistance

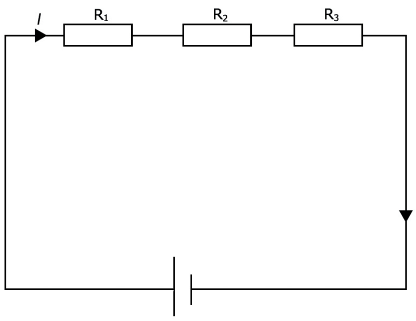
Low resistance occurs when the resistance value is lower than the desired value e.g. 55w bulb replaced by a 100w bulb.

6.2 Series Circuit

In a series circuit there is only one path for the current to follow. Where two or more resistances are connected end to end they are said to be connected in series. The figure below shows three resistors connected in series in a circuit.

The same current flows through each component in a series circuit.





The formula used to find the total resistance (R_T) for the circuit is shown below.

Formula: $R_T = R_1 + R_2 + R_3$

Example

What is the total resistance in this circuit?

$R_T = R_1 + R_2$

$R_T = 100 + 150$

$R_T = 250\Omega$

Voltage Drop

Voltage drop in automotive terms is the drop in voltage across loads/switches connectors and cables. It is even present internally in the battery when under load.

Series Circuit Volt Drop

The Total resistance of the circuit shown below is 100Ω + 150Ω or 250 Ω.

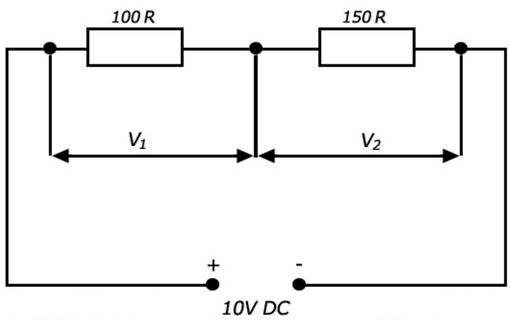
From ohms law we can calculate that a current of 40 mA flows through *both* the 100R resistor and the 150R resistor.

$I = V/R$

$I = 10/250$

$I = 0.04A \text{ (or } 40mA)$

If we wish to calculate the voltage drop across each resistor we can apply Ohm's Law.



V_1 is applied across the 100R resistor and V_2 is applied across the 150R resistor.

$U_1 = I x R_1$

$= 0.04 * 100$ (40mA is 0.04 Amps)

$= 4$ Volts

There is a drop of 4 Volts across the 100 Ω resistor.

$U_2 = I x R_2$

$= 0.04 \times 150$

$= 6$ Volts

There is a drop of 6 Volts across the 150Ω resistor.

In a series circuit the sum of all the volt drops is equal to the applied voltage.

$U_T = U_1 + U_2$

10 Volts = 4 Volts + 6 Volts

Summary of a Series Circuit

1. In a series circuit the same current flows in all resistances.
2. If there is a break in the circuit no current flows in any part of the circuit.
3. The total resistance is the sum of all resistors in the series circuit.

$R_T = R_1 + R_2 + R_3 + \ldots\ldots R_N$

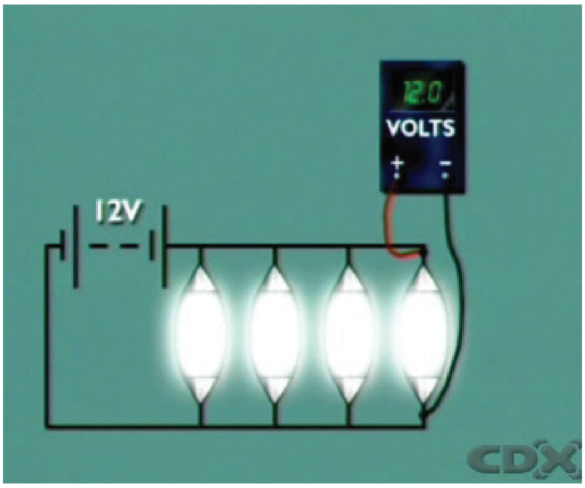
The sum of all the volt drops in the circuit is equal to the Applied Voltage.

$V_T = V_1 + V_2 + V_3 + \ldots\ldots V_N$

1. The Volt Drop is proportional to the value of resistors in the circuit. The larger the resistor the larger the voltage drop across it (for any given current).
2. An example of a Series Circuit can be the dash panel lighting.

6.3 Parallel Circuits

A circuit with two or more paths for current to follow, with all resistance located in those separate paths, is called a PARALLEL CIRCUIT. A parallel circuit is one that provides more than one path for the current to flow.



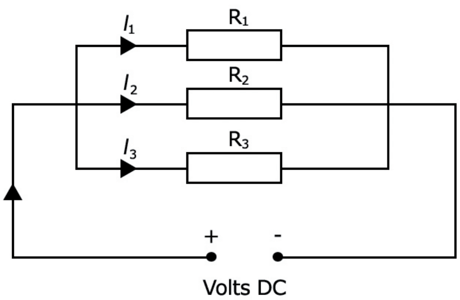


Figure 13

Refer to *Figure 13*. Here the circuit current (I_T) divides itself among the resistors, so that some current flows through R_1 (I_1), some through R_2 (I_2) and some through R_3 (I_3).

$$I = I_1 + I_2 + I_3$$

From Ohm s Law

$$I_1 = \frac{V}{R_1} \quad I_2 = \frac{V}{R_2} \quad I_3 = \frac{V}{R_3}$$

$$I_T = \left(\frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}\right)$$

$$I_T = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{I_T}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\left(as\ R = \frac{V}{I}\right) \frac{I_T}{V} = \frac{1}{R_T}$$

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

The total resistance of a parallel circuit is found by this formula:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \frac{1}{R_N}$$

The total resistance in a parallel branch is always less than the smallest resistance in the branch.

Summary of Parallel Circuits

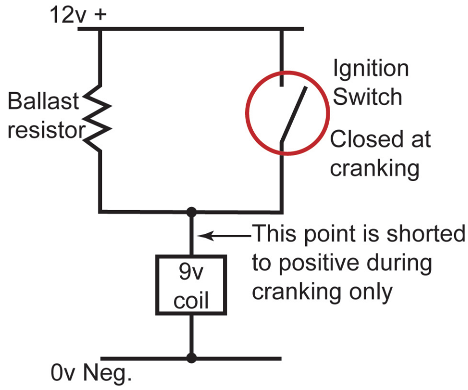
1. There is only one voltage across all resistors in a parallel branch.
2. The total current IT is equal to the sum of all the branch currents $I_T = I_1 + I_2 + \ldots I_N$
3. The total resistance of a parallel circuit is less than the resistance of the smallest branch.
4. The total resistance is calculated by:
5. An open circuit in one branch results in no current in that branch but the other branches are unaffected.
6. A short-circuit in any branch results in a short circuit for the whole network and an excessive current flow in the total circuit.
7. When electrical devices are connected to the car battery they are connected in parallel with each other.

6.4 Short to Negative/Short to Positive

Short to Positive

When a part of a circuit makes contact with the positive voltage supply.

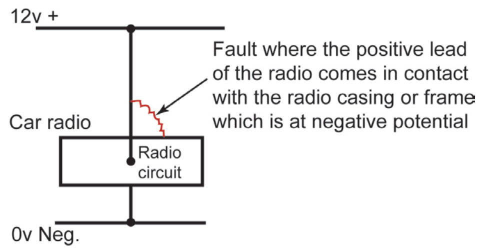
This part would normally be switched or negative potential.



Example

Shown is an ignition circuit that uses a ballast resistor. The coil is 9 v but receives battery voltage when cranking over.

Short to Negative



7.0 Basic Series and Parallel Circuits

Key Learning Points

- The construction of basic series and parallel circuits that use bulbs and low value fixed and variable resistors as loads on training units/systems that have a variable voltage supply

Practical Task

This is a practical task. Please refer to your instructor.

8.0 Using Inductive Multimeters

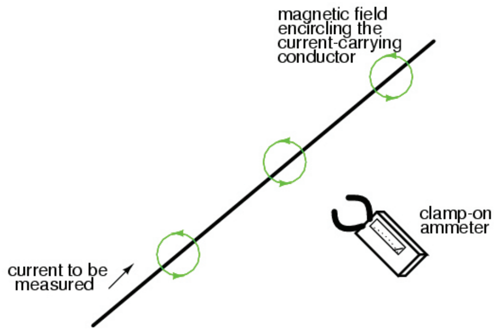
Key Learning Points

- Multimeter; standard type-ammeter fitted in series in circuit, meter capable of handling load, circuit opened correctly etc.., inductive type, clamp around the conductor, D.C. measurement - Hall effect technology, high speed sampling e.g. 10 KHz, advantages – circuit intact etc..

8.1 Clamp Meters (Inductive type)

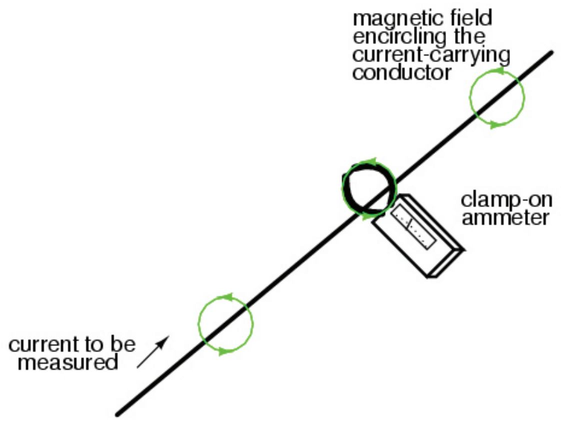
To Measure AC or AC-DC Amperage without Contacting Conductors

All current-carrying wires produce a magnetic field, the strength of which is in direct proportion to the strength of the current. By building an instrument that measures the strength of that magnetic field, a no-contact ammeter can be produced. Such a meter is able to measure the current through a conductor without even having to make physical contact with the circuit.



Ammeters of this design are made and are called *"clamp-on"* meters because they have "jaws" which can be opened and then secured around a circuit wire. Clamp-on ammeters make for quick and safe current measurements, especially on high-power industrial circuits the circuit can be left intact this can be seen as an advantage.

Because the circuit under test has had no additional resistance inserted into it by a clamp-on meter, there is no error induced in taking a current measurement.



Modern designs of clamp-on ammeters utilize a small magnetic field detector device called a *Hall-effect sensor* to accurately determine field strength.

9.0 Fault Finding on Circuits

Key Learning Point

- Correct use of the multimeter to fault find; opens, shorts, voltage drops/losses on basic electrical/electronic circuits

Practical Task

This is a practical task. Please refer to your instructor.

10.0 Fused Circuit Diagrams.

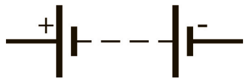
Key Learning Points

- Schematic diagrams, circuits and symbols; battery, conductor, conductor crossing/joined, earth connection, fuse, resistor, variable resistor, diode, transistor etc.., primary terminal designations; 30, 15, 31

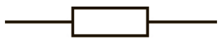
10.1 Graphical Symbols

Symbols used in Electric Circuits

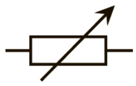
Battery



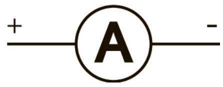
A load/ Resistor - Fixed Value



Resistor - Variable



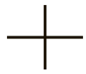
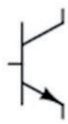
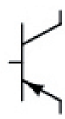
Ammeter



Voltmeter

Ohmmeter

Earth Connection

Cables Crossing (not jointed)	
Cables Crossing (formerly)	
Cables Jointed	
Bulb (a load)	
A Fuse	
Switch Open	
Switch closed in circuit — Diagrams switches are shown in their at Rest position.	
NPN transistor	
PNP transistor	

10.2 Primary Terminal Designation

The purpose of the terminal designation system for automotive electrical systems is to enable correct and easy connections of the conductors to the various devices especially in the event of repairs and equipment replacement.

DIN 72552* is a DIN standard for Automobile electric terminal numbers, standardizing almost every terminal in an automobile with a number code.

If the number of terminal designations is not sufficient (multiple-contact connections), the terminals are consecutively numbered using numbers or letters whose representations of specific functions are not standardized.

The following codes are used by the major automobile manufacturers in basic standard dual filament head and parking light circuits.

Electrical Connection (DIN) Numbers

Terminal Designations: (Excerpts from DIN Standard 72 552), these terminal designations do not identify the conductors, because device with different terminal designations can be connected at the two ends of each conductor. If the number of terminal designations is not sufficient (multiple-contact connections), the terminals are consecutively numbered using numbers or letters whose representations of specific functions are not standardized.

Terminal	*Definition*
15	Switched + downstream of battery (output of ignition/driving switch)
Battery	
30	Input from + battery terminal, direct
31	Return line to battery - battery terminal or ground, direct

**DIN* “Deutsches Institut für Normung” is the German national organization for standardization and is that country's ISO member body

Additional information is available from the “Autodata®” materials supplied to training centres.

Source: Bosch Automotive Handbook, 3rd edition.

11.0 The Magnetic Effect in Conductors

Key Learning Point

- Basic electrical circuits drawn to industry recognised formats. Use of 'Dart Notation' where relevant
- Description of magnetic effect from current flow through straight and coil conductors, use of iron filings and compass

11.1 Direction of Magnetic Fields and Currents

The direction of the field depends on the direction of the current - clockwise for a current flowing away from the observer, in the example illustrated in the figure below.

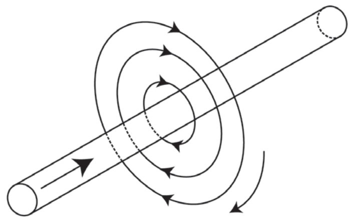
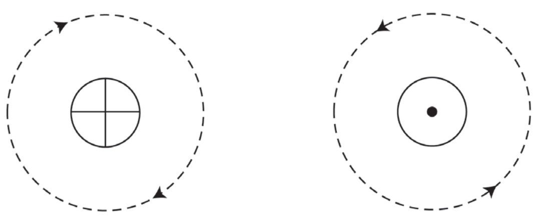


Figure 14a below illustrates how a current flowing in a conductor in a direction which is away from the observer may be depicted by a "crossed line" and that the direction of the current flowing towards the observer may be depicted by a point or dot, *see Figure 14b*. The associated magnetic fields are also shown.



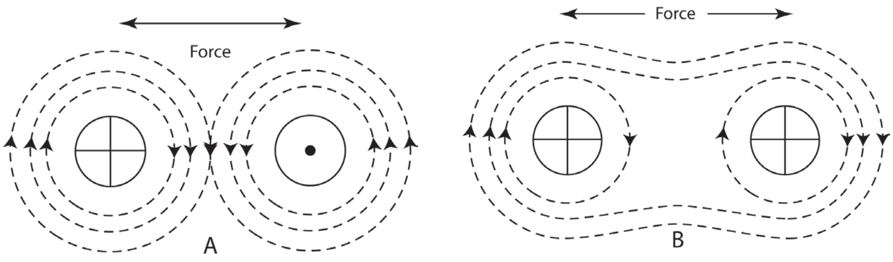
Figures 14a and b

Also Known As Dart Notation

11.2 Magnetic Field Strength Conductors

Figure 15a below illustrates the magnetic fields between two conductors through which current is flowing in opposite directions. There will be a force of repulsion exerted between the conductors.

Conversely, *Figure 15b* below illustrates the magnetic fields between two conductors in which current is flowing in the same direction. There will be a force of attraction exerted between the conductors.

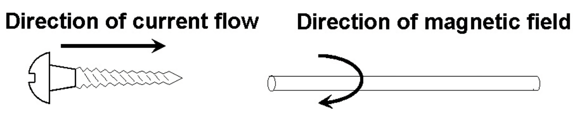


Figures 15a and b

There is a definite relationship between the direction of current flow in a conductor and the direction of the magnetic field around that conductor. The direction can be determined by the use of either the Right Hand Grip Rule or the Corkscrew Rule.

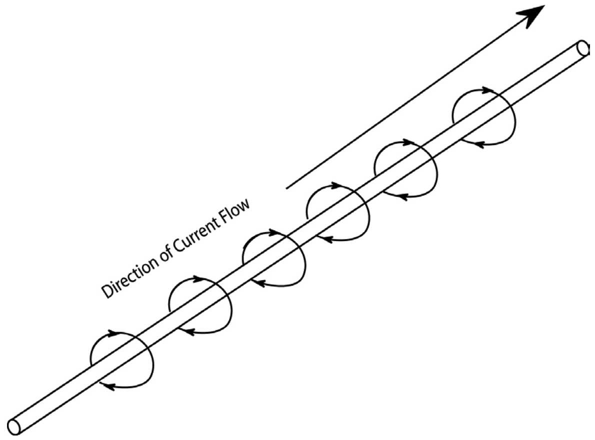
11.3 Corkscrew Rule

Refer to the figure below, visualise a screw being twisted into or out of the end of a conductor in the same direction as the current flow. The direction of rotation of the screw will indicate the direction of the magnetic field.



Magnetic Field of a Straight Conductor

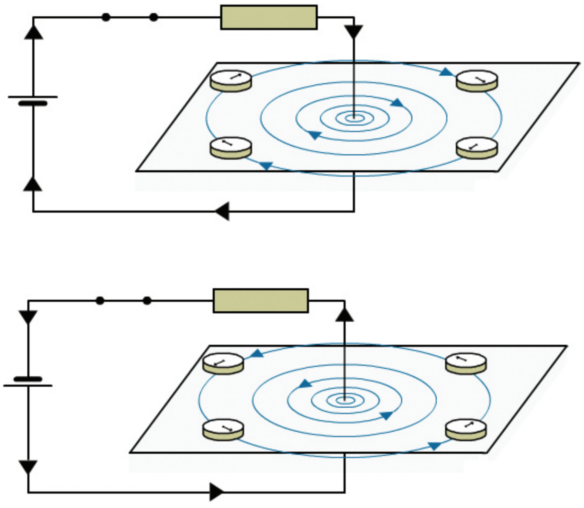
The figure below illustrates how the magnetic field of a straight conductor is in the form of concentric circles along the whole length of the conductor.



Experiment

Refer to the figure below and assemble the circuit shown. Use a number of plotting compasses to view the direction of the magnetic field, the larger the current the more effective it will be.

Reverse the polarity and notice the difference in direction of the plotting compasses.



12.0 Electromagnetic Relays or Solenoid Devices

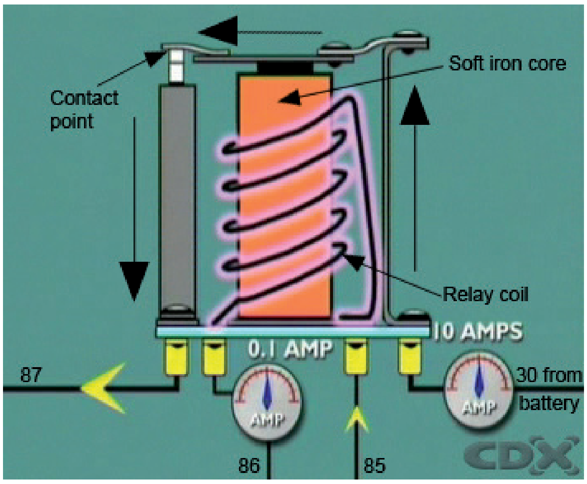
Key Learning Points

- Coil/winding of conductor, wrapped around a soft iron core - a relay, or a moving core/armature - a solenoid. The cumulative and focusing effects of multiple windings and the addition of soft iron core

12.1 Electromagnetic Relays

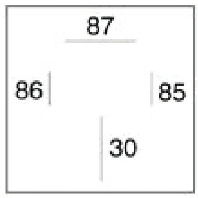
A relay is an electro-magnetically operated switch. A relay consists of a coil, an armature and one or more sets of contacts. When current flows through the coil the armature is attracted towards it and operates the contact. The pole piece is magnetically soft so that when the current in the coil is switched off it retains virtually no magnetism, thus allowing the contact return to their de-energised or normal state.

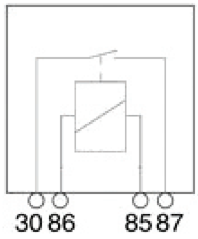
Relays are switches that are turned on and off by a small electrical current. Inside a relay is an electromagnet. When a small current energizes this electromagnet, it attracts an armature blade and closes contact points. The large current that the relay is designed to switch "on or off" can then flow across these points. As long as the small switching current flows through the relay coil the much larger current will flow through its contact points.



A relay is fitted to a lighting circuit to reduce the current demand on the control switch. These contacts can be either normally-open, normally-closed, or change-over contacts.

Normally-open contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive. Normally-closed contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive.





Change-over contacts control two circuits: one normally-open contact and one normally-closed contact.

Pin no.	*Designation*	*Description*
85	Switching relay	Earth (end of winding to ground or negative)
86	Switching relay	Positive (start of winding)
87	Switching relay	Output (to consumer e.g.: driving lamp)
87a	Switching relay	Alternative output (1st output, break side)
30	Battery	Positive supply (Input from + battery terminal, direct)

Principle of an Electrical Relay

A typical relay in which a low voltage and current can operate the relay and cause the contact to close, the contact controlling a larger current and voltage. A relay or contactor may have several sets of contacts, which are operated simultaneously by the armature mechanism.

12.2 Solenoids

Solenoid definition: linear movement from an electrical signal. The modern starter motor is an example of where a solenoid switch, works in a similar way to a relay. It is used as an "intermediate" switch where very high amperage is required to start the vehicle.

When current is applied to a solenoid winding, usually through a key switch, the magnetic effect that is generated in the solenoid winding will attempt to move a central sliding armature. In the starter, this action brings the pinion into mesh with the ring gear also closes high-current contacts to activate the starter motor.

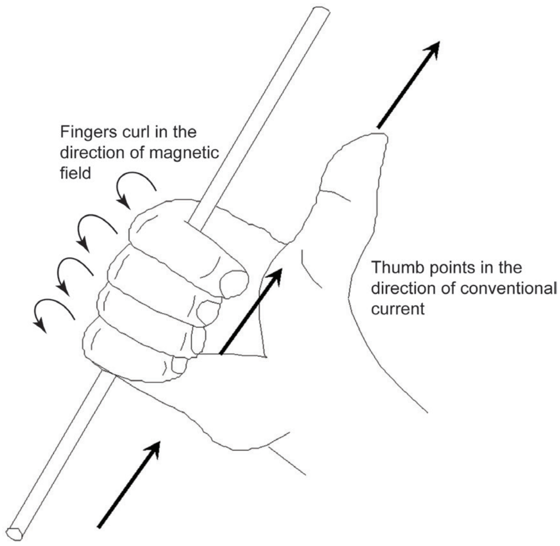
13.0 The 'Right-Hand Grip Rule'

Key Learning Points

- Right-hand grip rule; fingers point in the direction of current flow, thumb points to North Pole

13.1 Right Hand Grip Rule

In a current carrying conductor which is a straight wire, the direction of the magnetic field lines may be found quite simply by using the method shown below. Fingers point in the direction of current flow, thumb points to North Pole.



14.0 Semi-Conductor, Diode and Transistor Terms

Key Learning Point

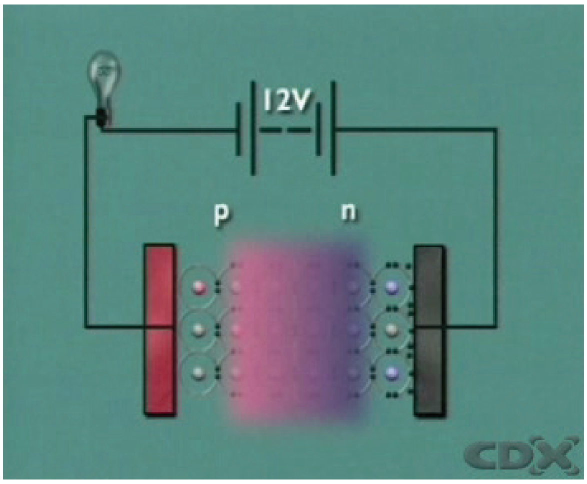
- Definition of semi-conductor, 4 electrons in outer shell, diode-PN junction, transistor-solid state electrical switch, terminal identifier names

14.1 Semiconductors

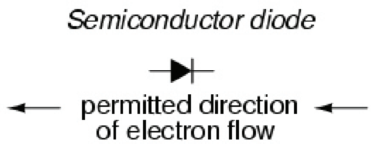
Semiconductors are a crystalline material which allows current to flow under certain conditions. Common semiconductor materials are silicon, germanium (diodes and transistors) and gallium arsenide (photo cell and light emitting diodes).

Semiconductors are used to make diodes, transistors, silicon chips and other "solid state" electronic devices. For example silicon has 4 electrons in its outer shell if this is changed at manufacture to 3 or 5 electrons in the outer shell; two different types of semiconductor material have been created. The 3 electron version becomes p type semiconductor material and the 5 type becomes n type semiconductor material becomes. By a suitable combination of p type and n type materials, transistors, diodes, silicone chips etc. can be manufactured.

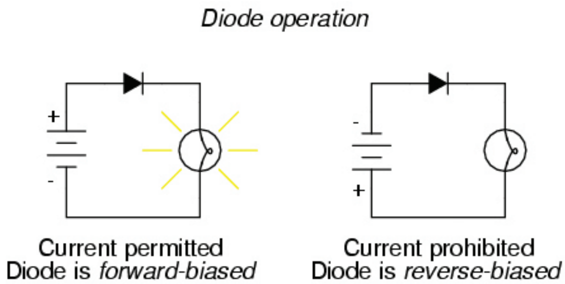
14.2 Diode



A *diode* is an electronic device allowing current to move through it in one direction with far greater ease than in the other. The most common type of diode in modern circuit design is the semiconductor diode. Semiconductor diodes are symbolized in schematic diagrams.

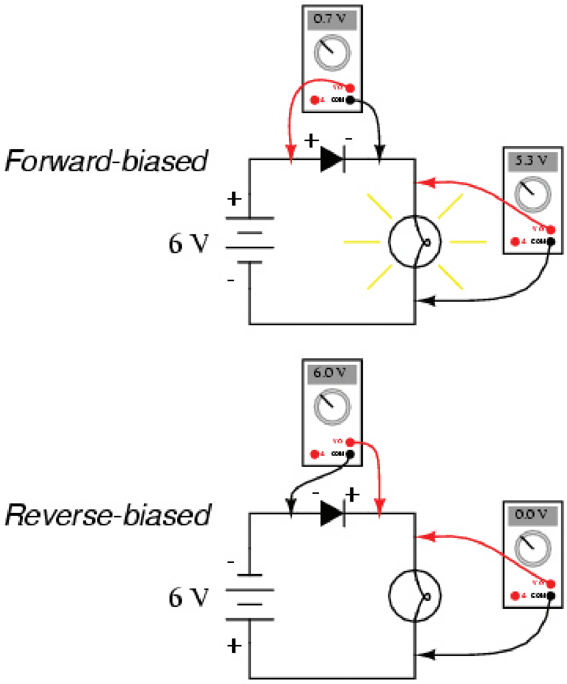


When placed in a simple battery-lamp circuit, the diode will either allow or prevent current through the lamp, depending on the polarity of the applied voltage.



When the polarity of the battery is such that electrons are allowed to flow through the diode, the diode is said to be forward-biased. Conversely, when the battery is "backward" and the diode blocks current, the diode is said to be reverse-biased. A diode may be thought of as a kind of switch: "closed" when forward-biased and "open" when reverse-biased.

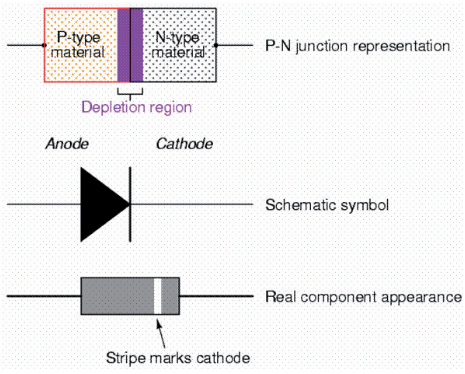
Oddly enough, the direction of the diode symbol's "arrowhead" points against the direction of electron flow. This is because the diode symbol was invented by engineers, who predominantly use conventional flow notation in their schematics, showing current as a flow of charge from the positive (+) side of the voltage source to the negative (-). This convention holds true for all semiconductor symbols possessing "arrowheads:" the arrow points in the permitted direction of conventional flow and against the permitted direction of electron flow.



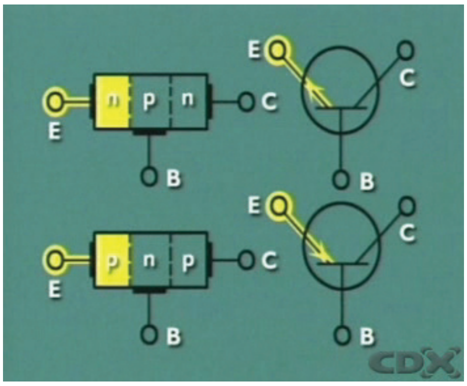
Above shows typical diode test.

When the diode is forward-biased and conducting current, there is a small voltage dropped across it, leaving most of the battery voltage dropped across the lamp. When the battery's polarity is reversed and the diode becomes reverse-biased, it drops all of the battery's voltage and leaves none for the lamp. If we consider the diode to be a sort of self-actuating switch (closed in the forward-bias mode and open in the reverse-bias mode), this behaviour makes sense.

The most substantial difference here is that the diode drops a lot more voltage when conducting than the average mechanical switch (0.7 volts versus tens of millivolts).



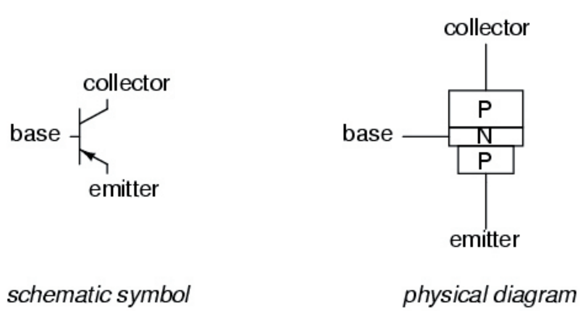
14.3 Transistors

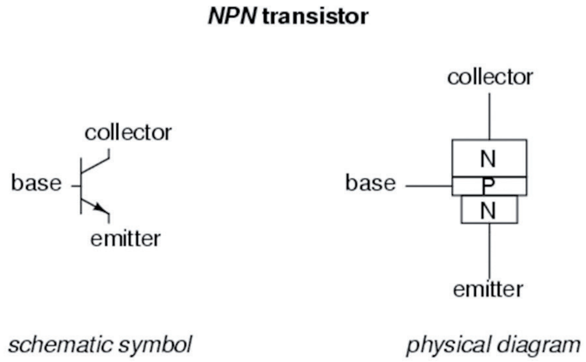


A transistor consists of a three-layer "sandwich" of semiconductor materials, either P-N-P or N-P-N. Each layer forming the transistor has a specific name and each layer is provided with a wire contact for connection to a circuit.

Shown here and on the following page are schematic symbols and physical diagrams of these two transistor types:

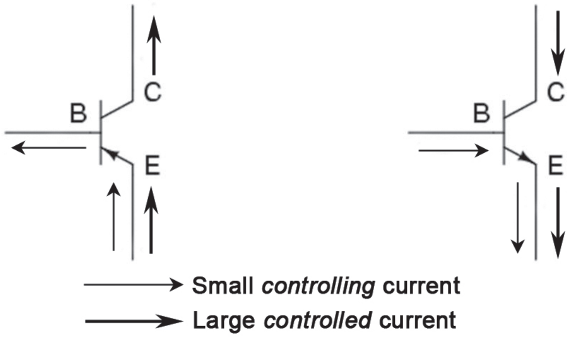
***PNP* transistor**





The only functional difference between a PNP transistor and an NPN transistor is the proper biasing (polarity) of the junctions when operating. For any given state of operation, the current directions and voltage polarities for each type of transistor are exactly opposite each other.

Transistors work as current-controlled current regulators. In other words, they restrict the amount of current that can go through them according to a smaller, controlling current. The main current that is controlled goes from collector to emitter, or from emitter to collector, depending on the type of transistor it is (NPN or PNP, respectively). The small current that controls the main current goes from base to emitter, or from emitter to base, once again depending on the type of transistor it is (PNP or NPN, respectively).



If there is no current through the base of the transistor, it shuts off like an open switch and prevents current through the collector. If there is a base current, then the transistor turns on like a closed switch and allows a proportional amount of current through the collector.

Summary

- Bipolar transistors are so named because the controlled current must go through two types of semiconductor material: P and N.
- Bipolar transistors consist of either a P-N-P or an N-P-N semiconductor "sandwich" structure.
- The three leads of a bipolar transistor are called the Emitter, Base and Collector.
- Transistors function as current regulators by allowing a small current to control a larger current. The amount of current allowed between collector and emitter is primarily determined by the amount of current moving between base and emitter.

15.0 The Use of Diodes and Transistors

Key Learning Points

- Construction of basic electrical circuits that demonstrate the use of diodes and transistors

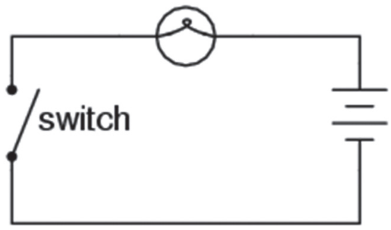
Practical Task

Please refer to your instructor

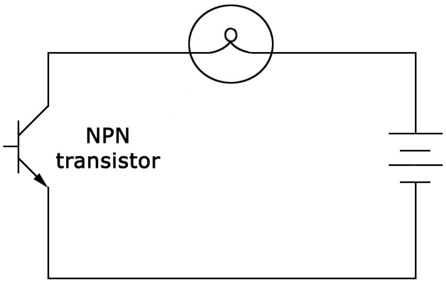
15.1 The Transistor as a Switch

Because a transistor's collector current is proportionally limited by its base current, it can be used as a sort of current-controlled switch. A relatively small flow of electrons sent through the base of the transistor has the ability to exert control over a much larger flow of electrons through the collector.

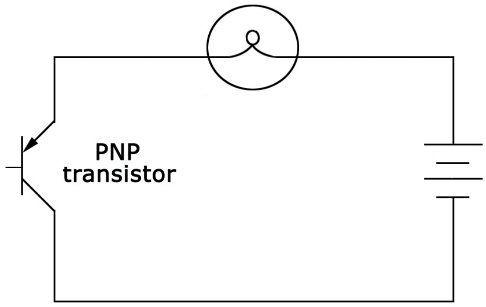
Suppose we had a lamp that we wanted to turn on and off by means of a switch. Such a circuit would be extremely simple:



Let's insert a transistor in place of the switch to show how it can control the flow of electrons through the lamp. Remember that the controlled current through a transistor must go between collector and emitter. Since it's the current through the lamp that we want to control, we must position the collector and emitter of our transistor where the two contacts of the switch are now.



For example we used an NPN transistor. A PNP transistor could also have been chosen for the task and its application would look like this:



The choice between NPN and PNP is really arbitrary. All that matters is that the proper current directions are maintained for the sake of correct junction biasing (electron flow going against the transistor symbol's arrow).

Self Assessment

Q1: For electrons to move in a circuit they need a complete pathway and: (Tick one box only)

- ❑ 1. A rise in temperature
- ❑ 2. Insulators to hold them in
- ❑ 3. A force to make them move
- ❑ 4. A switch

Q2: Two factors affect the strength of current flowing in a circuit, they are: (Tick one box only)

- ❑ 1. Resistance and protons
- ❑ 2. EMF and resistance
- ❑ 3. EMF and protons
- ❑ 4. EMF and neutrons

Q3: An example of a series-parallel circuit in a vehicle is the: (Tick one box only)

- ❑ 1. Headlights
- ❑ 2. Indicators
- ❑ 3. Panel lights
- ❑ 4. Trailer lights

Q4: All matter is made up of: (Tick one box only)

- ❑ 1. Nucleus
- ❑ 2. Protons
- ❑ 3. Atoms
- ❑ 4. Electrons

Q5: A material with more free electrons is commonly referred to as: (Tick one box only)

- ❑ 1. A conductor
- ❑ 2. A resistor
- ❑ 3. An insulator
- ❑ 4. A semi-conductor

Q6: What is the most common automotive conductor material? (Tick one box only)

- ❑ 1. Copper
- ❑ 2. Aluminium
- ❑ 3. Carbon impregnated fibreglass or linen

Q7: The term 'insulator' refers to a material that: (Tick one box only)

- ❑ 1. Will not readily allow current to flow through it
- ❑ 2. Has a low resistance factor

Q8: The unit of 'power' is the: (Tick one box only)

- ❑ 1. Ampere
- ❑ 2. Ohm
- ❑ 3. Watt
- ❑ 4. Volt

Q9: The formula for calculating power is: (Tick one box only)

- ❑ 1. P = R x I
- ❑ 2. P = V x R
- ❑ 3. P = V x I
- ❑ 4. P = E x V

Q10: To conduct a 'continuity' test with a DVOM circuit power is: (Tick one box only)

- ❑ 1. On
- ❑ 2. Off

Suggested Exercises

1. Construct simple series and parallel electrical circuits on electrical circuit training units/system

2. Observe, measure, calculate, interpret and predict the action/reaction of a selection of known/unknown electrical resistances/loads under various supply voltages (e.g. 6V - 9V - 12V)

3. Construct simple circuits that demonstrate the use of a diode as an electrical one way valve and a transistor as an electrical switch

Training Resources

- Technical information in book/electronic form on the physics of electricity, its generation, measurement and predictability of action
- Principles of electrical circuit construction
- Training units/system that are fitted with master regulated voltage and current supply
- Suitable circuit construction exercises and work sheets
- Supply of components e.g. bulbs, fuses etc., multimeters

Task Sheets

Using a DVOM to Measure Continuity

Preparation and Safety

Objective

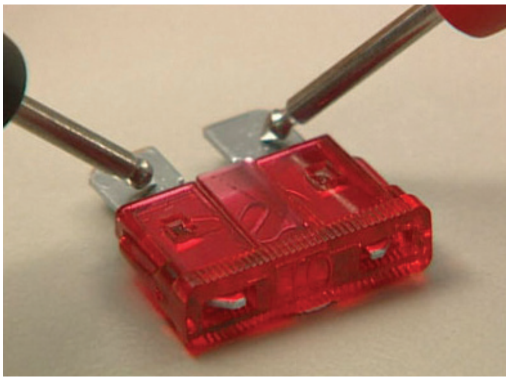
Use a DVOM to measure continuity.

Safety Check

- Make sure the bonnet rod is secure.
- Always make sure that you wear the appropriate personal protection equipment before starting the job. It is very easy to hurt yourself even when the most exhaustive protection measures are taken.
- Always make sure that your work area/environment is as safe as you can make it. Do not use damaged, broken or worn out workshop equipment.
- Always follow any manufacturer's personal safety instructions to prevent damage to the vehicle you are servicing.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

- DVOM stands for Digital Volt Ohm Meter.
- DVOMs come in many forms. Always follow the specific manufacturer's instructions in the use of the meter, or serious damage either to the meter and/or to the electrical circuit could result.



- When checking continuity with a DVOM, the power supplied to the circuit during operation MUST be switched OFF.

Step-by-Step Instruction

1. *Set up the meter for a continuity check:* Make sure there is no power connected to any circuit that you test for continuity, then prepare the Digital Volt Ohm Meter or DVOM for testing voltage by inserting the black probe lead into the "common" input port and the red probe lead into the "Volt/Ohms" input port.

2. *Check the meter function:* Turn the rotary dial of the DVOM to the mode that includes the term "Continuity". The Digital Display should now give you an 'Out of Limits' reading indicating that there is not a continuous circuit connection between the two probes. Touch the probe ends together. The display should now give a zero reading, which indicates no resistance. This means that there is a continuous circuit through the probes. Some meters also indicate continuity with an audible tone.

3. *Check a fuse:* One typical use of the test is to determine whether a fuse needs to be replaced. If the fuse has been overloaded and 'blown', then it will no longer complete a circuit when a DVOM is used to test it. To check this, place the black probe on one end of the fuse and the red probe on the other. If the fuse is functioning correctly then the reading will be zero, indicating a complete, or closed, circuit. If the fuse is open, then there will be no reading and no tone, indicating an incomplete, or open, circuit.

4. *Test other components:* A continuity test is used to check for a broken circuit caused by a break in a cable or lead, or caused by a component becoming disconnected. The same test can

also confirm whether there is continuity between components, which are not supposed to be connected. When this occurs, it is known as a ‘short circuit’. This test can also be used to check circuits that are suspected to have a high resistance

Using a DVOM to Measure Voltage

Preparation and Safety

Objective

Use a DVOM to measure voltage.

Safety Check

- Make sure the bonnet rod is secure.
- Always make sure that you wear the appropriate personal protection equipment before starting the job. It is very easy to hurt yourself even when the most exhaustive protection measures are taken.
- Always make sure that your work area/environment is as safe as you can make it. Do not use damaged, broken or worn out workshop equipment.
- Always follow any manufacturer's personal safety instructions to prevent damage to the vehicle you are servicing.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

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- DVOM stands for Digital Volt Ohm Meter.
- DVOMs come in many forms. Always follow the specific manufacturer's instructions in the use of the meter, or serious damage either to the meter and/or to the electrical circuit could result.

Step-by-Step Instruction

1. *Set up the meter for a voltage check:* Prepare the Digital Volt Ohm Meter or DVOM for testing voltage by inserting the black probe lead into the "common" input port and the red probe lead into the "Volt/Ohms" input port.

2. *Check the meter function:* Turn the rotary dial until you have selected the mode for "Volts DC". The reading on the meter should now be at Zero. Some meters will automatically sense the correct voltage range when a voltage is detected. On other meters you will have to set the voltage range before using the meter.

3. *Check the voltage of a battery:* Place the Black probe onto the Negative terminal of the battery, which will be marked with a Minus sign and place the Red probe onto the Positive terminal of the battery, which is marked with a Plus sign.

4. *Interpret the results:* Note the voltage reading from this 12-volt battery. If the battery is fully charged the meter will give a reading that is 12.6 volts or more. If it is NOT fully charged the reading will be less than 12.6 volts.

Suggested Further Reading

- Advanced Automotive Diagnosis. Tom Denton. ISBN 0340741236
- Automobile Electrical and Electronic Systems (3rd Edition). Tom Denton. ISBN 0750662190
- Automotive Mechanics (10th Edition). William H. Crouse and Donald L. Anglin. ISBN 0028009436
- Bosch Automotive Electrics Automotive Electronics: Systems and Components (4th Edition). Robert Bosch. ISBN 0837610508
- Bosch Automotive Handbook (6th Edition). Robert Bosch. ISBN 1860584748
- Bosch Automotive Technology Technical Instruction booklet series (numerous titles)
- Hillier's Fundamentals of Motor Vehicle Technology: Book One (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780823
- Hillier's Fundamentals of Motor Vehicle Technology: Book Two (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780998
- Modern Automotive Technology. James E. Duffy. ISBN 1566376106
- Motor Vehicle Craft Studies - Principles. F.K. Sully. ISBN 040800133X
- National Car Test (NCT) Manual (Department of Transport, Vehicle Testers Manual - DoT VTM). Department of Transport
- Transmission, Chassis and Related Systems (Vehicle Maintenance and Repair Series: Level 3) (3rd Edition) John Whipp and Roy Brooks. ISBN 186152806X
- Vehicle and Engine Technology (2nd Edition). Heinz Heisler. ISBN 0340691867
- http://www.cdxglobal.com/
- http://auto.howstuffworks.com/
- http://www.autoshop101.com/
- http://www.cdxetextbook.com/
- Automotive Encyclopedia and Text Book Resource (CD version of e-textbook), Available from your instructor.

Notes

SOLAS
An tSeirbhís Oideachais Leanúnaigh agus Scileanna
Further Education and Training Authority

27-33 Upper Baggot Street
Dublin 4