# British Rail

## Chief Signal and Telecommunications Engineers Department

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# ELECTRICAL PRINCIPLES, 1.

Training School YORK



Eastern Region

The contents of this notebook are to be read in conjunction with the Lectures given on the Electrical Principles.1. training course.
They do not form a Departmental instruction and do not countermand any instruction contained in the "Rule Book" or "Instructions to staff engaged on the maintenance of Signalling equipment".
It is the responsibility of the holder of the book to ensure that the information is updated with changes in equipment or methods.
Keep this book in a safe place. You will be required to bring it with you when you attend the next training course(Basic Electrical Signalling) and subsequent training courses.

Contents.



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COURSE. Electrical Principles.1.

SUBJECT. Electricity, The structure of matter and the Electron theory.

Electricity first came to the notice of man in the form of lightning and in the light of the aurora borealis. The Greek philosophers knew of the Electrical properties of the eletric eel and of the effects of static electricity such as that which causes a charge on a comb when combing hair on a dry day. It was in the field of static charges that the first experiments were made in attempts to gain understanding of the phenomena. In about 1660 the first machines were made to create static (frictional) charges. These machines could develop high charges, but there was no means of holding or storing the charge. In 1745 the great step forward of storing the charge in a Leyden jar was taken. The glass of the jar was charged with a static charge and caused to discharge via an uncharged rod.
The English scientist Watson spoke of the charged glass as "plus electricity" and the rod as "minus electricity", the discharge was from glass to rod and one can presume it was at this stage that the electricity was said to flow from Positive (plus) to Negative (minus).
CONVENTIONAL CURRENT FLOW IS TAKEN AS BEING FROM POSITIVE TO NEGATIVE AND ALL THE RULES ESTABLISHED BY THE EARLY SCIENTISTS ASSUMED THIS TO BE SO.
The Italian scientist Volta, constructed the first primary cell after discovering that an electrical charge was developed by placing any acid, alkaline or salt between two different metal plates. The cell gave the world the first constant source of electrical energy and opened the way for the development of electricity and an understanding of it.
Humphry Davy experimented in the field of Electro chemistry, Michael Faraday is famous for his work in Magnetism and Electro Magnetism. Many others with well known names, Ampere, Ohm, Wheatstone, Kelvin, all contributed in their own chosen fields.
It was during the time of these early scientists that many of the "rules" of electrical engineering were established. Ohms Law, Kirchoffs Laws, Lenzs Law, Flemings left and right hand rules for motors and generators etc. These rules are still used today but, some of them have to be reversed to suit our new understanding of electricity.
The whole attitude to electricity was altered following the work of Edison in 1883 and the subsequent work of Fleming in 1904, when the first Valve was made. The development of the valve led to the realisation of the existence of Electrons and that ELECTRICITY WAS THE FLOW OF ELECTRONS. This discovery also caused an upset in the understanding of current flow.
ELECTRONS ARE NEGATIVE CHARGES AND THEY MOVE TOWARD ANY POSITIVE CHARGE.
This meant that we had now estabished what electricity was and how it moved and in which direction it moved. All these ideas are expessed as the ELECTRON THEORY.
THE ELECTRON THEORY IS THE PRESENT METHOD USED TO TEACH AND UNDERSTAND ELECTRICITY.
THIS IS THE METHOD THAT YOU WILL BE TAUGHT.
USING THE ELECTRON THEORY WE CONSIDER ELECTRONS MOVING FROM NEGATIVE TO POSITIVE.

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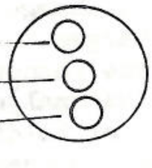
The structure of matter.

THE SMALLEST PARTICLE OF ANY SUBSTANCE IS THE MOLECULE.
If we take Water as an example the smallest particle of Water is the Water Molecule.
MOST MOLECULES ARE COMPOUNDS, ie. THEY ARE COMBINATIONS OF ELEMENTS.
There are 92 basic elements, from these basic elements all matter is constructed, either as an individual element or as a combination of elements. A list of elements is attached.
WATER IS $H_2O$ THAT IS, THE WATER MOLECULE IS 2 HYDROGEN ELEMENTS AND 1 OXYGEN ELEMENT.
(The Element is also called the Atom and the Element number is the Atomic number.)

The Water Molecule. — Hydrogen Atom. / Oxygen Atom. / Hydrogen Atom.

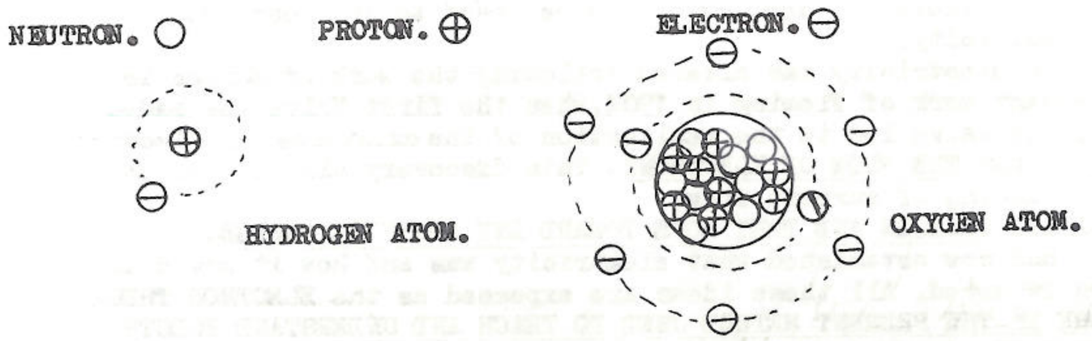


ATOMS HAVE THREE PARTS. NEUTRONS. PROTONS. ELECTRONS.

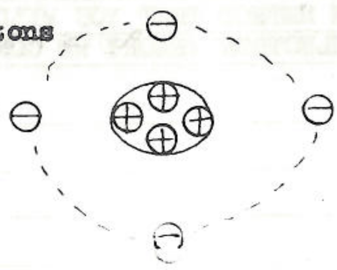
The Atomic Number of the atom tells us the number of Electrons the atom has, and in a neutral atom the number of Protons and Electrons are equal.
The charge of these parts differs
THE NEUTRON HAS NO CHARGE. THE PROTON HAS A POSITIVE CHARGE. THE ELECTRON HAS A NEGATIVE CHARGE.

The Protons and the Neutrons are together in the Nucleus of the Atom. The Electrons "orbit" about the nucleus in a planetary manner.
THE ELECTRONS LIE IN BANDS OR SHELLS SOME NEAR TO THE NUCLEUS SOME FURTHER AWAY.
ELECTRONS NEAR THE NUCLEUS ARE CALLED BOUND ELECTRONS.
ELECTRONS IN THE OUTER SHELLS ARE CALLED FREE ELECTRONS.
As we shall see Electricity is the movement of Electrons and it is the Atoms that have a lot of free Electrons that are most useful as electrical conductors.

THE ATOMS OF CONDUCTORS HAVE MANY FREE ELECTRONS.
THE ATOMS OF INSULATORS HAVE NO OR FEW FREE ELECTRONS.




If we consider an atom of copper it will have 29 Protons and 29 Electrons, but we need only consider the free Electrons in the outer band, so, assume there to be 4.



The number of + is = to the number of −
so 4+ plus 4− = 0
IN A NORMAL ATOM THE NUMBER OF PROTONS + CHARGES EQUALS THE NUMBER OF ELECTRONS − CHARGES.
THE ATOM HAS THUS NO CHARGE, IT IS A NEUTRAL ATOM.

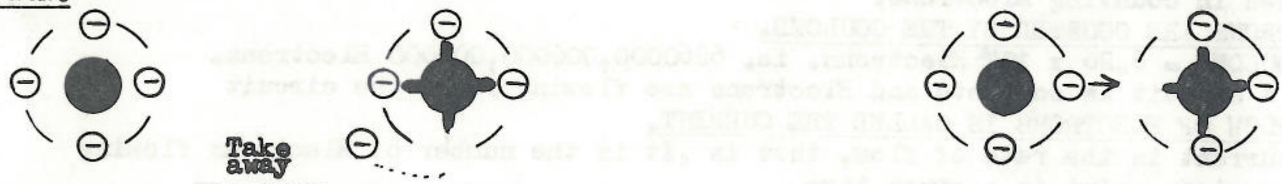
ALL ATOMS WILL TRY TO KEEP NEUTRAL.

The Electron Theory.

IN THE NORMAL ATOM THE NUMBER OF PROTONS ARE EQUAL TO THE NUMBER OF ELECTRONS.

If by some means we can cause an Atom to give up an Electron the balance will be upset. The Atom will have more Protons than Electrons and will thus be positive in charge.( Protons 4+ plus Electrons 3- will leave the atom +1 of charge.)

ANY ATOM LOSING ELECTRONS WILL BE POSITIVE IN CHARGE,IT BECOMES A CHARGED ATOM OR ION.




Neutral Atom Charged Atom. Electrons will be attracted to Charged Atoms.

Remember two facts:-

UNLIKE POLES OR CHARGES ATTRACT EACH OTHER.&. AN ATOM WILL TRY TO BE NEUTRAL.

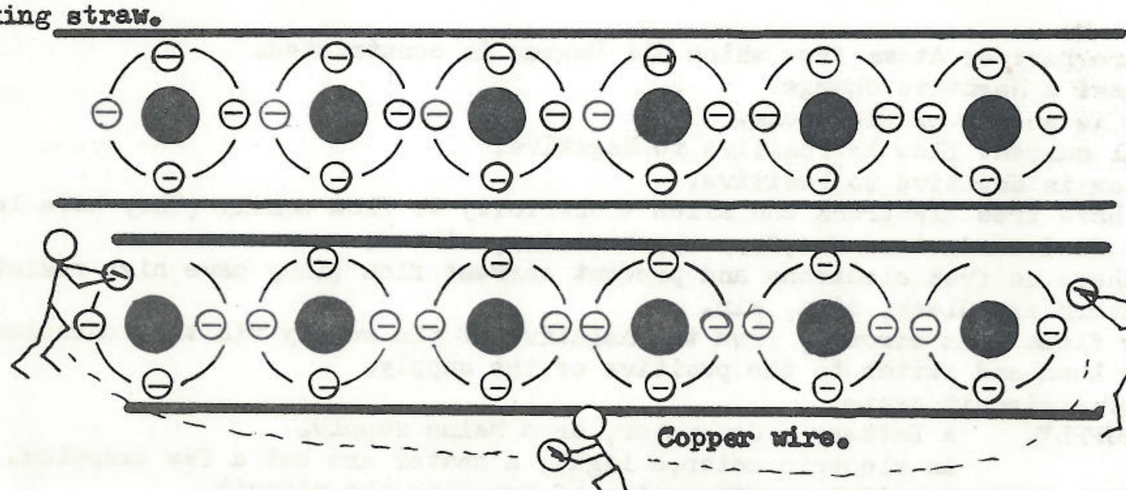
With these two facts in mind, it will be seen that:-

A CHARGED ATOM WILL ATTRACT ELECTRONS FROM AN OTHER ATOM.

Consider the diagram below,it represents a piece of Copper wire. The Atoms of copper are shownwith only four Electrons in fact there would be Twentynine.

COPPER IS A GOOD CONDUCTOR IT HAS FREE ELECTRONS.

The diagram shows the electrons side by side in a simple line. In fact there would be millions of Atoms packed together ,rather like grains of Sugar in a drinking straw.



Copper wire.

ELECTRON MOTIVE FORCE.or E.M.F.
(Electro motive force.)

If an Electro moving force draws Electrons from one end of a wire then a movement of Electrons along the wire will take place.

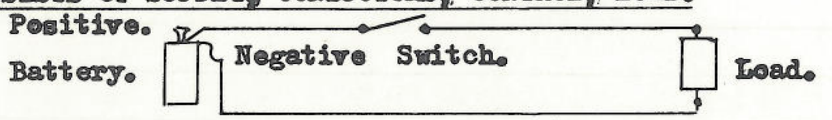
MOVEMENT OF ELECTRONS ALONG A WIRE IS THE PHENOMENON CALLED ELECTRICITY.

To get Electrons to move we need to create a CIRCUIT.

A CIRCUIT IS A PATH OR ROUTE FOR THE ELECTRONS TO FOLLOW.

The circuit will require some electro motive force to drive the electrons round it will also require connecting wires or conductors and a switch or some form of control to enable us to stop the electrons flowing,and finally a load which may be a lamp,a heater,or a motor or any device we wish to operate. Summing up

A CIRCUIT CONSISTS OF SUPPLY, CONDUCTORS, CONTROL, LOAD.




The cicuit operates as follows :- The battery positive terminal pulls electrons from the wire which in turn pulls — from the load, which pulls — from the negative wire, which pulls them from the negative terminal of the battery.

If the route of the electron is traced it will be:- Electrons leave the Negative terminal of the battery and flow through the conductor, then through the load to continue through the other conductor and switch to the Positive terminal of the battery.

ELECTRONS FLOW FROM THE NEGATIVE OF THE SUPPLY TO THE POSITIVE OF THE SUPPLY.

This is the opposite direction to conventional current flow.)

The Electron is very small, so small there would be approx Three thousand million million. (3000,000000,000000) on the end of a piece of copper wire. A larger unit is used in counting Electrons.

ELECTRONS ARE COUNTED BY THE COULOMB.

1. COULOMB = $6.26 \times 10^{18}$ Electrons. ie. 6260000,000000,000000 Electrons.

When a circuit is complete and Electrons are flowing round the circuit

THE FLOW OF ELECTRONS IS CALLED THE CURRENT.

The current is the rate of flow, that is ,it is the number of Electrons flowing past a given point in a given time.

A RATE OF FLOW OF 1 COULOMB PER SECOND IS CALLED 1 AMPERE. (1 Amp)

When current is taken from a Battery the polarity of the battery is constant, ie. the + terminal is always + and the - terminal is always -. Because of this the current always flows in the same direction round the circuit.

DIRECT CURRENT ALWAYS FLOWS IN THE SAME DIRECTION ROUND THE CIRCUIT.

When the current for a circuit is supplied from an Alternator(Generator)the polarity of the alternator is always changing + becomes - and - becomes+ alternately every fiftieth of a second. The electrons are changing the direction that they flow round the circuit every fiftieth of a second .

ALTERNATING CURRENT CHANGES DIRECTION EVERY FIFTIETH OF A SECOND.

SUMMARY.

Electrons are part of Atoms from which all Matter is constructed.
Electrons have a Negative charge.
Electricity is a Flow of Electrons.
Conventional current flow is Positive to Negative.
Electron flow is Negative to Positive.
Conductors have free Electrons and allow electricity to flow easily (They have low Resistance) Good conductors are, Copper,, aluminium, silver.
Insulators have no free electrons and prevent current flow (They have high resistance)
Good insulators are Glass, mica, air.
Electricity flows in a circuit, from the negative of the supply via the conductors through the load and switch to the positive of the supply.
The parts of a circuit are:-

| | |
|---|---|
| SOURCE OF SUPPLY. | A Battery a Generator, or a Mains supply. |
| THE LOAD. | An electric motor, a light, a heater are but a few examples. |
| THE CONTROL. | A switch or some means of breaking the circuit. |
| CONDUCTORS. | Used to connect all the components together. |

Direct current always flows in the same direction.
Alternating current changes direction of flow (On a mains supply fifty times a second)

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COURSE. Electrical Principles.1. - 1 JAN 1983

SUBJECT. The effects of Electrical Currents, Electrical Units.

The character of Electricity has been discussed and defined as the Movement of Electrons. The movement of Electrons achieves nothing, but the effects caused by the movement can be manifold. The predominant feature of an Electrical circuit is ELECTRICITY ALLOWS US TO CHANGE ONE FORM OF ENERGY TO ANOTHER FORM OF ENERGY. ELECTRICITY IS A FORM OF ENERGY.

To create an Electrical circuit we something that will start the Electron moving.

THERE ARE SIX SOURCES OF ELECTRICAL ENERGY.

CHEMICAL ACTION. MAGNETISM. HEAT. LIGHT. PRESSURE. FRICTION.

Friction does not really produce power but tends more to produce static charges.

CHEMICAL ACTION. PRIMARY CELLS. As will be seen later the chemical action of an electrolyte on two different metals will produce an electrical current.

MAGNETISM. GENERATORS. Wire moving in a magnetic field creates a current flow in the wire. This is the principle of the Generator or Alternator used in power stations.

(REMEMBER GENERATORS NEED SOME MECHANICAL ENERGY TO DRIVE THEM)

HEAT. THERMO COUPLES. Heat can be a means of creating electrical currents one example is the thermo couple. A junction of two different metals, will, when heated create a small current flow over the junction.

LIGHT. SOLAR CELLS. Certain substances will, when exposed to light give rise to small currents within the substance. e.g. Selenium as used in Photo exposure meters.

PRESSURE. CRYSTALS. Certain crystals when subjected to pressure will give rise to electrical currents
Crystals also respond to electrical currentsin that they will expand or contract with changes in current.

FRICTION. STATIC CHARGES. Lightning, Static charges on aircraft are but two examples.

We do not generally make much use of Friction to obtain power.

BECAUSE GENERATORS NEED MECHANICAL ENERGY TO DRIVE THEM, WE CAN SAY THAT GENERATORS CONVERT MECHANICAL ENERGY INTO ELECTRICAL ENERGY.

All of the above are means of converting one form of energy into electricity.

ELECTRICITY CAN BE CONVERTED INTO OTHER FORMS OF ENERGY

Electricity can be used for obtaining the following forms of energy or work.

CHEMICAL ACTION. ELETROLYSIS. Electro plating and electro chemical processes.

MAGNETISM. ELECTRIC MOTORS. CONVERT ELECTRICAL ENERGY TO MAGNETIC ENERGY.

HEAT. ELECTRIC FIRES AND HEATERS CONVERT ELECTRICAL ENERGY INTO HEAT ENERGY.

LIGHT. ELECTRIC LAMPS CONVERT ELECTRICAL ENERGY TO LIGHT ENERGY.

The above are the main electrical effects with which you must be familiar.

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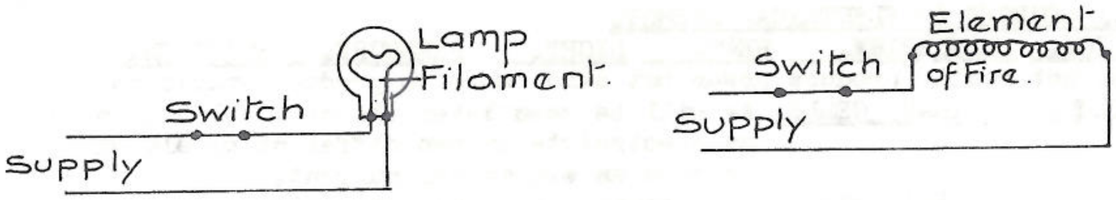
When ever an Electrical Current flows in a conductor certain effects take place.

HEATING EFFECT.

WHEN AN ELECTRICAL CURRENT FLOWS IN A CONDUCTOR HEAT IS CREATED IN THAT CONDUCTOR. At times this heat can be a problem in that conductors over heat and cause fires. However by using heavy gauge conductors the effect can be reduced and the heat dispersed. This is why it is essential to use the correct size wire for conductors. We can however utilise this heating effect.

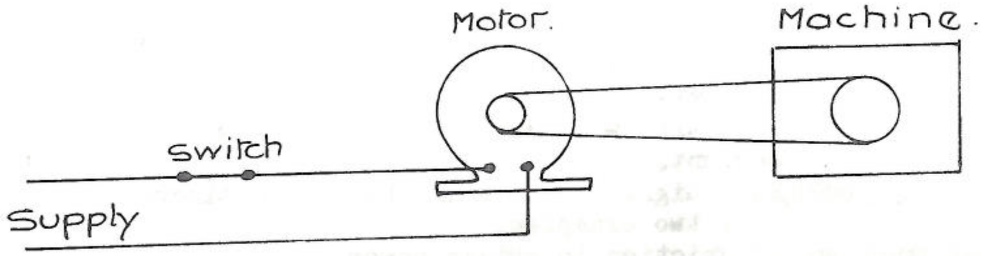
THE ELECTRIC LAMP USES VERY THIN WIRE FOR ITS FILAMENT WHICH GLOWS WHITE HOT AND THUS GIVES OFF LIGHT. The wire does not burn out because it is contained in a vacuum or inert gas.

THE ELECTRIC FIRE USES THICKER WIRE WHICH GLOWS RED HOT AND GIVES OFF HEAT WHEN ELECTRIC CURRENT FLOWS THROUGH IT.



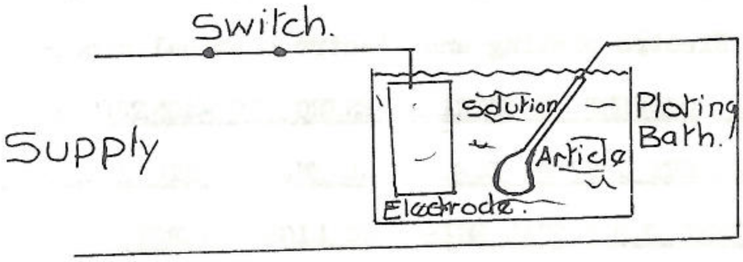

MAGNETIC EFFECT.

WHEN AN ELECTRIC CURRENT FLOWS IN A CONDUCTOR A MAGNETIC FIELD IS CREATED IN AND AROUND THAT CONDUCTOR. By coiling the wire we increase the magnetic effect and use it to make electro magnetic devices. Bells,Buzzers,Relays, and Electric motors. MAGNETISM GIVES US ELECTRIC MOTORS WHICH CONVERT ELECTRICAL ENERGY TO MECHANICAL ENERGY.




CHEMICAL EFFECT.

WHEN AN ELECTRICAL CURRENT FLOWS THROUGH A SUBSTANCE CHEMICAL CHANGES CAN TAKE PLACE IN THE SUBSTANCE. Electrical currents can cause chemical changes to take place in certain substances. The effect is called the Electro Chemical effect. An example is the obtaining of gasses by passing electrical current through liquids. Yet another example is the Electro plating process.




WHEN WE CHANGE ELECTRICAL ENERGY INTO HEAT,LIGHT,OR MECHANICAL(MAGNETIC) ENERGY WE CALL THE OUT PUT POWER.

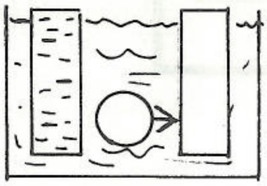
POWER IS MEASURED IN A UNIT CALLED WATTS.

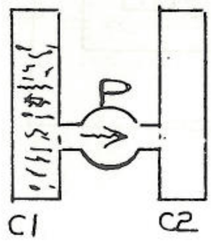
Watts together with many other terms are Electrical units. If Electricity is to be of use to us we need to be able to calculate its effect. Several Electrical " rules " enable us to do this,but first we must be familiar with some Electrical terms.

## ELECTRICAL TERMS AND UNITS.

### THE VOLT.IS THE MEASURE OF ELECTRICAL PRESSURE.

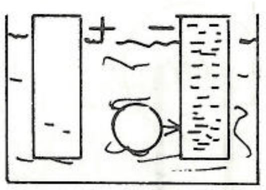
Any circuit requires a source of supply.This source of supply will be the means of getting the electrons moving round the circuit.The simplest source of electrical energy is the primary cell. It may be compared to a Water pump.Indeed an electrical circuit may be compared to a water circuit and we will use this comparison to explain the electrical terms.

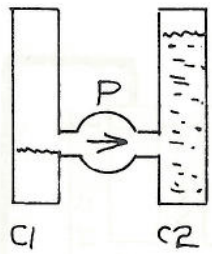





**THE CELL.**
Chemical action acts like a pump moving Electrons from the Pos. plate to the Neg. plate.

**THE PUMP.**
The pump pumps water from one cylinder to the other.

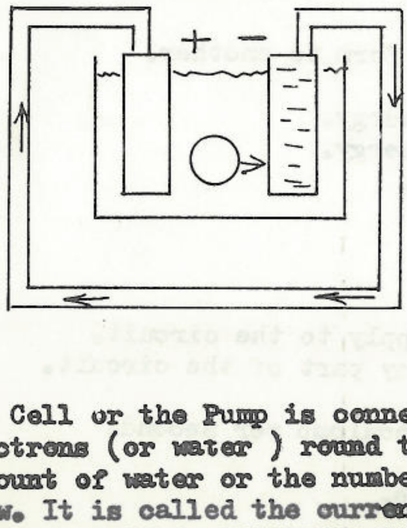


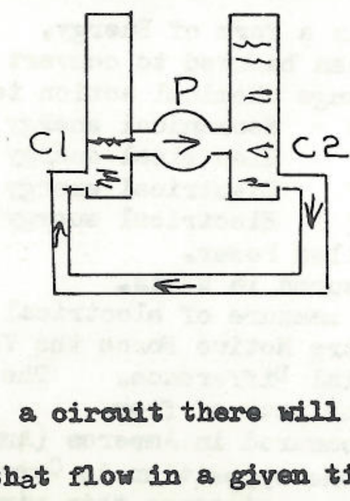




The chemical action has pumped electrons onto the Neg. plate leaving the pos. plate short of Electrons. There is thus a pressure difference between the plates. The Neg. plate is at high pressure (many electrons and the Pos. plate low pressure.

The pump has pumped water from No1. Cylinder to No.2. There is a lot of water in No.2. it is at high pressure but No1. is empty and at low pressure.

THERE IS A PRESSURE DIFFERENCE BETWEEN THE TWO PLATES OF THE PRIMARY CELL
The pressure difference in the pump would be measured in pounds per square inch.
PRESSURE DIFFERENCE IN ELECTRICAL WORK IS MEASURED IN VOLTS.
The battery will be used to supply the power to drive the electrical circuit.
It is thus the Electromotive force called the E.M.F.
E.M.F. ELECTRO MOTIVE FORCE. THE SUPPLY OF THE CIRCUIT IS MEASURED IN VOLTS.




If the Cell or the Pump is connected up to form a circuit there will be a flow of Electrons (or water ) round the circuit.
The amount of water or the number of electrons that flow in a given time is the rate of flow. It is called the current.
THE RATE OF FLOW OF ELECTRONS IS CALLED THE CURRENT. IT IS MEASURED IN AMPERES. OR AMPS

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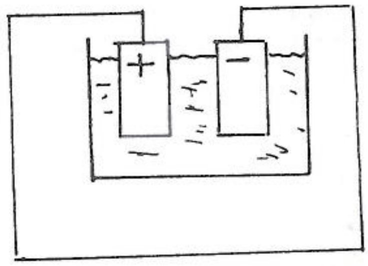
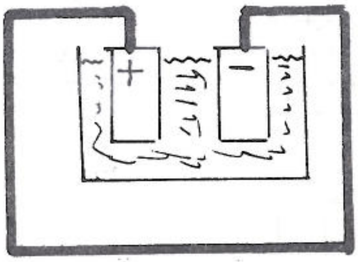
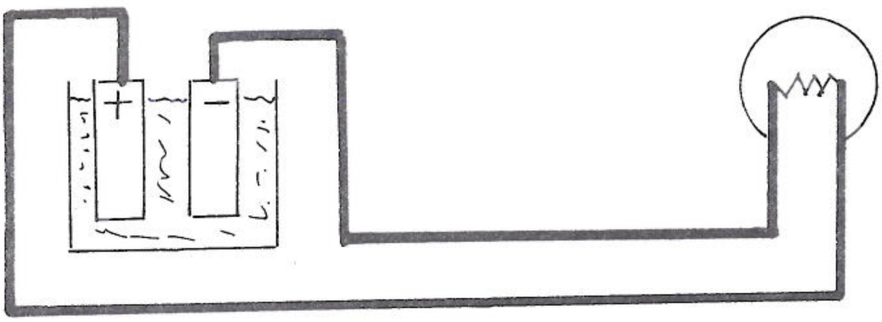
Resistance.

RESISTANCE IS ANYTHING THAT OPPOSES CURRENT FLOW.





When the circuit is connected up we will use thick pipes or thick wires to get the Maximum current flow through them. If we consider the Electrical circuit.
THE CONNECTING WIRES OF A CIRCUIT WILL BE THICK TO OFFER LOW RESISTANCE.



The circuit is often required to work a load. In the electrical circuit it may be a lamp with a thin wire filament, that filament being thin will offer resistanc to the Electrons.
THE LOAD IN THE CIRCUIT OFFERS RESISTANCE.
RESISTANCE IS MEASURED IN OHMS.
When the current flows through the resistance of the filament one side of the resistance will be "high " pressure, the other end will be " low " pressure.
WHEN CURRENT FLOWS THROUGH A RESISTANCE IT CREATES A PRESSURE DIFFERENCE OR POTENTIAL DIFFERENCE ACROSS THE RESISTANCE.
POTENTIAL DIFFERENCE (PD) IS MEASURED IN VOLTS.

SUMMARY.
Electricity is a form of Energy.
Electricity can be used to convert energy from one form to another.
Batteries change chemical action to Electricity.
Generators " Mechanical energy to Electrical energy.
Motors " Electrical energy to Mechanical energy.
Lamps " Electrical energy to light energy.
Heaters. " Electrical energy to Heat energy.
Energy is called Power.
Power is measured in Watts.
Voltage is a measure of electrical pressure.
E.M.F. Electre Motive Force the Voltage of the Supply to the circuit.
P.D. Potential Difference. The Votage across any part of the circuit.
Current is the rate of flow.
Current is measured in Amperes (Amps.) 1 amp is 1 coulomb per second.
Resistance the opposition to Current flow.
Thick wire low resistance thin wire high resistance.
Resistance is measured in Ohms.

Sometimes quantities to be measured are much too large or too small for the basic units to be conveniently used in practice and a range of multiples and submultiples can be used instead.

| PREFIX. | ABBREVIATION. | MULTIPLE. |
|---|---|---|
| Mega. | M | 1,000,000 |
| Kilo. | k | 1,000 |
| Milli | m | $\frac{1}{1,000}$ or 0.001 |
| Micro | | $\frac{1}{1,000,000}$ or 0.000,001 |

The above terms can be applied to electrical terms. Volts Amps and Ohms.

VOLTAGE. E.M.F. P.D.

Measured in Volts BASIC UNIT 1. VOLT.

| | | | | |
|---|---|---|---|---|
| Milli volt. | mV | $\frac{1}{1,000}$ V | or | 0.001 V |
| Micro volt. | uV | $\frac{1}{1,000,000}$ V | or | 0.000,001 V |
| Kilo volt. | kV | 1,000 V | or | 1,000x 1 V |

CURRENT. RATE OF FLOW

Measured in Amps. Basic unit 1,Amp.

| | | | | |
|---|---|---|---|---|
| Milli amp. | mA | $\frac{1}{1,000}$ A | or | 0.001 A |
| Micro amp. | uA | $\frac{1}{1,000,000}$ A | or | 0.000,001 A |

RESISTANCE. OPPOSITION TO CURRENT FLOW.

Measured in Ohms. Basic Unit 1. Ohm.

| | | | |
|---|---|---|---|
| Kilohm. | k | 1,000 | or 1,000 x 1 |
| Megohm. | M | 1,000,000 | or 1,000,000 x 1 |

TO CONVERT.

Amps to Milliamps.
Volts to Millivolts.
Kilovolts to Volts.
Kilohms to Ohms.

MULTIPLY BY 1,000

Milliamps to Amps.
Millivolts to Volts.
Volts to Kilovolts.
Ohms to Kilohms.

DIVIDE BY 1,000

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Complete the following exercise.

CONVERT THE FOLLOWINGTO MILLIAMPS.

| | | |
|---|---|---|
| 1. | 1 Amp. | 1000 mA |
| 2. | ½ Amp. | 500 mA |
| 3. | ¾ Amp. | 750 mA |
| 4. | ¼ Amp. | 250 mA |
| 5. | ⅛ Amp. | 125 mA |
| 6. | 0.1 Amp. | 100 mA |
| 7. | 0.01 Amp. | 10 mA |
| 8. | 0.001 Amp. | 1 mA |
| 9. | 0.25 Amp. | 250 mA |
| 10. | 0.05 Amp. | 50 mA |

CONVERT THE FOLLOWING TO AMPS.

| | | |
|---|---|---|
| 11. | 1,000 mA. | 1 A |
| 12. | 500 mA. | ½ A |
| 13. | 250 mA. | ¼ A |
| 14. | 75 mA. | .075 A |
| 15. | 50 mA. | .050 A |
| 16. | 25 mA. | .025 A |
| 17. | 10 mA. | .01 A |
| 18. | 5 mA. | .005 A |
| 19. | 2 mA. | .002 A |
| 20. | 1 mA. | .001 A |

Complete the following.

| | | | | |
|---|---|---|---|---|
| 21. | 200V | = | .2 | kV. |
| 22. | 250 mA | = | ¼ | A. |
| 23. | 2 kΩ. | = | 2000 | Ω. |
| 24. | 5mA | = | .005 | A. |
| 24. | 0.075 A. | = | 75 | mA. |
| 26. | 50V | = | .05 | kV |
| 27. | 0.25A | = | 250 | mA |
| 28. | 30mV | = | .03 | V |
| 29. | 300V | = | .3 | kV |
| 30. | 300mA | = | .3 | A |
| 31. | 200kΩ | = | .2 | MΩ |
| 32. | 0.5 MΩ | = | 500 | kΩ |
| 33. 32 | 32kV | = | 32000 | V |
| 34. | 0.125mA | = | .000125 | A |
| 35. 0 | 0.025mA | = | .000025 | A |
| 36. | 0.025 A | = | 25 | mA |
| 37. | 350mA | = | .35 | A |
| 38. | 1v | = | .001 | kV |
| 39. | 10v | = | .01 | kV |
| 40. | 100V | = | .1 | kV |
| 41. | 20,000V | = | 20 | kV |
| 42. | 1mA | = | .001 | A |
| 43. | 10mA | = | .01 | A |
| 44. | 100mA | = | .1 | A |
| 45. | 1,000mA | = | 1 | A |
| 46. | 1 00,000Ω | = | 100 | kΩ |
| 47. | 1,000,000Ω | = | 1000 | kΩ |
| 48. | 10Ω | = | .01 | kΩ |
| 49. | 1MΩ | = | 1000 | kΩ |
| 50. | 1kΩ | = | .001 | MΩ |

Ω = OHMS.

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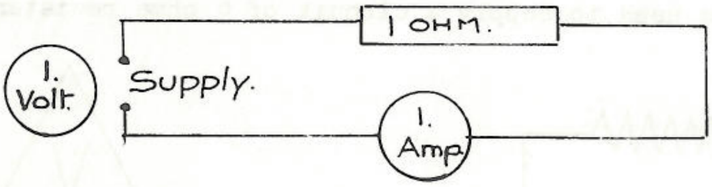
COURSE. Electrical Principles.1.

SUBJECT. Ohms Law.




Consider the diagram above.
The Voltage is 1.Volt. The Resistance is 1.Ohm. The Current is 1.Amp.
If the voltage is doubled the current will double, if the resistance is kept the same.
If the voltage is halved the current will be halved, if the resistance is kept the same.

If the resistance is doubled the current will be halved, if the Voltage. is kept same.
If the resistance is halved the current will double, if the Voltage. is kept the same.

THE CURRENT FLOWING IN THE CIRCUIT IS DIRECTLY PROPORTIONAL TO THE APPLIED VOLTAGE AND INVERSELY PROPORTIONAL TO THE RESISTANCE.

Increase Voltage. Increase current.
Decrease Voltage. Decrease current.
Increase Resistance Decrease current.
Decrease Resistance Increase current.

THIS CAN BE EXPRESSED. AS:-

$$\text{CURRENT} = \frac{\text{VOLTAGE}}{\text{RESISTANCE.}}$$

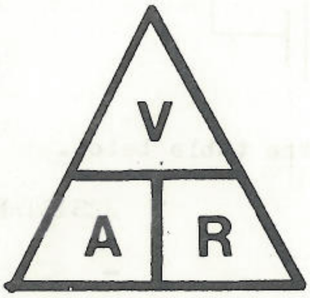
AND.:- $$\text{RESISTANCE} = \frac{\text{VOLTAGE}}{\text{CURRENT}}$$

AND.:- VOLTAGE = CURRENT X RESISTANCE.

The following Mnemonic will help you to remember. To use it cover the value you require and the method of calculating it is left.

ABBREVIATIONS.

VOLTS abbreviation. V. (It is preferable to use E.for EMF. and V.for PD.
CURRENT(AMPS) abbreviation. A. or I.
RESISTANCE abbreviation.R.



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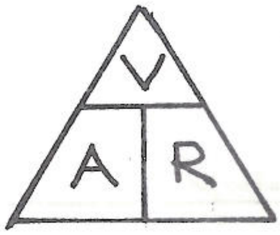


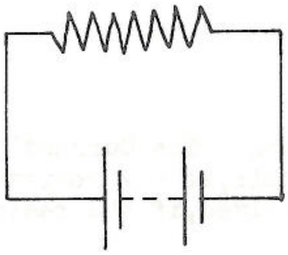

Example.1.

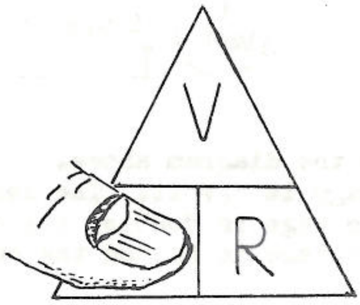
A Battery of 12 volts is used to supply a circuit of 6 ohms resistance. Find the Current.

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

$A = \frac{12}{6}$

A = 2 Amps.





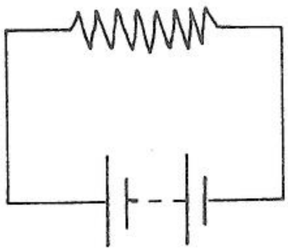

Example. 2.

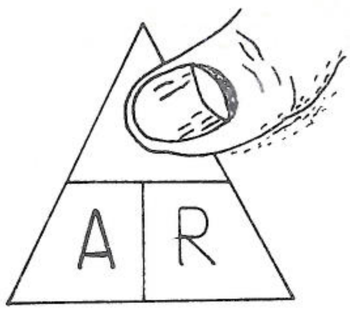
If 3 Amps of current is found to be flowing through a 25 ohm resistor Find the Voltage of the supply.

V = A x R

V = 3 x 25

V = 75 Volts.





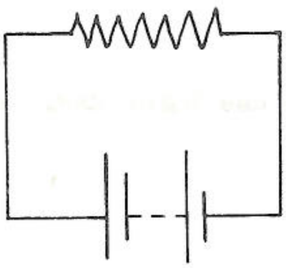

Example. 3.

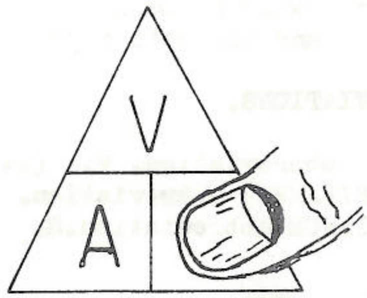
A Battery of 100 volts is supplying 10 amps to a circuit. Find the Resistance of the circuit.

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

$R = \frac{100}{10}$

R = 10 Ohms.






Fill in the blank spaces in the table below.

| VOLTS. | AMPS. | RESISTANCE. |
|---|---|---|
| 10.00 | 2.00 | - 5 Ω |
| 5.00 | - ½ | 10.00 |
| -2·5 | 0.50 | 5.00 |
| 1.20 | 0.20 | - 6 Ω |
| 6.00 | -60mA | 100.00 |

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POWER IN A D.C. CIRCUIT.

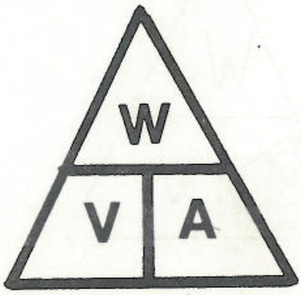
POWER IS THE WORK PRODUCED BY A CIRCUIT IT IS THE RATE AT WHICH ENERGY IS USED.
The Electrical circuit ,as we have seen can produce energy in the form of, Heat, Light, Mechanical energy. This output "is Power."
IT IS MEASURED IN A UNIT CALLED WATTS.
POWER IS THE PRODUCT OF THE VOLTAGE OF THE CIRCUIT AND THE CURRENT OF THE CIRCUIT.

POWER = WATTS = VOLTS X AMPS.

If the voltage is increased the power will be increased.
If the current is increased the power will be increased.

THE SYMBOL FOR POWER IS W. (WATTS.)

Again a Mnemonic may be used.




WATTS. = VOLTS X AMPS.

$$\text{AMPS.} = \frac{\text{WATTS.}}{\text{VOLTS.}}$$

$$\text{VOLTS.} = \frac{\text{WATTS.}}{\text{AMPS.}}$$

Another form of this calculation can be made using Resistance.

POWER ( WATTS) = $A^2 \times R$

That is $W = A \times A \times R$

ALSO.

POWER (WATTS) = $\frac{V^2}{R}$

That is $W = \frac{V \times V}{R}$

You will learn more of this method in Electrical Principles .2. Course.

Complete the Table below.

| VOLTS. | AMPS. | WATTS. |
|---|---|---|
| 12. | 2. | 24 |
| 50 | 0.5 | 25 |
| 240 | ·25 | 60 |
| 1000 | ·1 | 100 |
| 25 | 2 | 50 |
| 300 | 0.25 | 75 |

E.P.1./3.4.



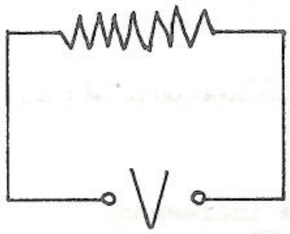
EXAMPLE. 1.

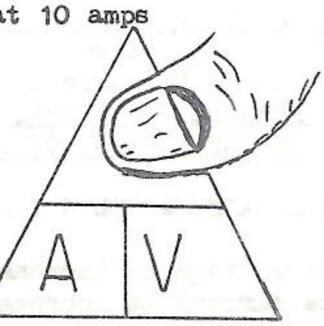
How many watts are produced in a circuit of 100volts at 10 amps

$W = V \times A$

$W = 100 \times 10$

$W = 1000$ Watts.



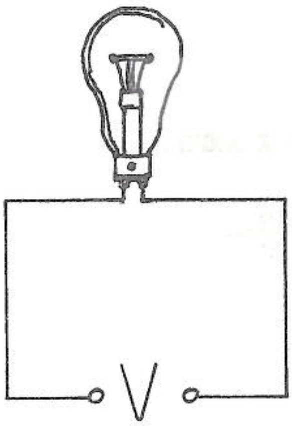

EXAMPLE. 2.

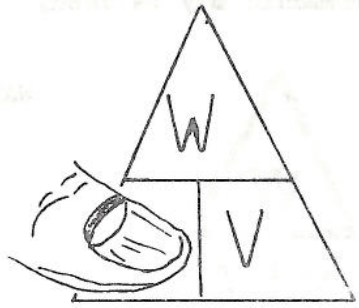
What current flows when a lamp rated 250 volts 100 watts is lit.

$A = \frac{W}{V}$

$A = \frac{100}{250}$

$A = 0.4$ Amps



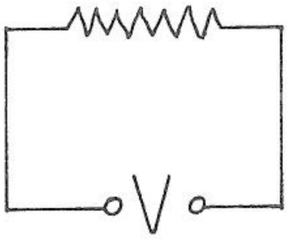

EXAMPLE.3.

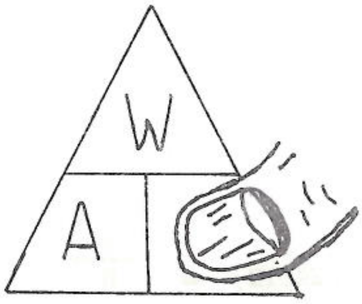
Find the voltage of a cicuit producing 100 watts and drawing 10 amps.

$V = \frac{W}{A}$

$V = \frac{100}{10}$

$V = 10$ volts.




Power is consumed over a period of time. (HOURS)

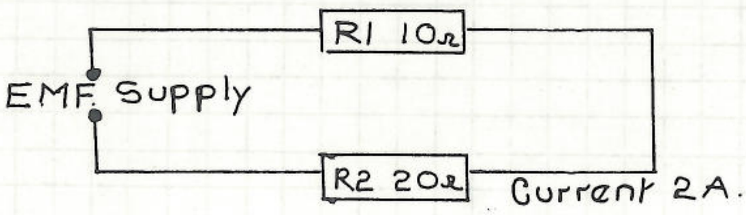
1000 Watts is called 1 Kilowatt

1 Kilowatt for 1 Hour is 1 Kilowatt Hour.

1 Kilowatt Hour is 1 UNIT.

E.P.1./3.5.

1 JAN 1923




In a circuit where there is just the Load or a Single resistor, the E.M.F. and the P.D. across the load or resister will be equal.

WHEN A CIRCUIT HAS TWO OR MORE COMPONENTS THERE WILL BE THREE OR MORE VOLTAGES IN THE CIRCUIT. IE. THE E.M.F. AND THE P.D. ACROSS EACH RESISTANCE.

Consider the circuit above.

The voltage across R1. R1. P.D. V = A x R.

V = 2 x 10

R1. P.D. = 20 volts.

The voltage across R2. R2. P.D. V = A x R

V = 2 x 20

R2. P.D. = 40 volts.

If there is 10 volts across R1 and another 20 volts across R2 the EMF which is the source of supply must be the SUM of the two.

The E.M.F. is the sum of the individual P.D.s.

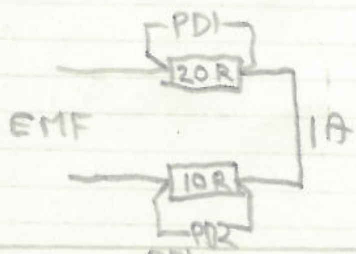
EMF = V1 + V2

= 20 + 40

EMF = 60 volts.

The above circuit is called a Series circuit, there will be another lecture dealing in detail with Series and Parallel circuits.

Space is provided below and overleaf for the exercises that the Instructor will give you.




PD1 = 20V

PD2 = 10V

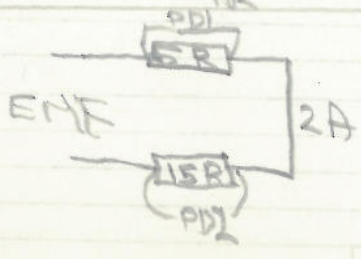
EMF = 30V

R1 = 8R R2 = 12R
A = ·5

PD1 = 4V

PD2 = 6V

EMF = 10V




PD1 = 10V

PD2 = 30V

EMF = 40V

E.P.1./3.6.

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COURSE. Electrical Principles.1.

SUBJECT. Resistance and Series / Parallel Circuits.

**RESISTANCE IS THE OPPOSITION TO CURRENT FLOW.**
All electrical circuits will have resistance, it is always there, at times it is the resistance of the load or the connecting wires. At other times it is deliberately introduced to control the current.

**RESISTANCE IS DETERMINED BY FOUR MAIN FACTORS.**

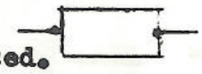
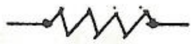
**TYPE OF MATERIAL.** Material the atoms of which have many "Free Electrons" make good conductors of low resistance. If the Electrons are "Bound Electrons" the substance has High Resistance.

High Resistance Materials are:- Glass Mica Rubber Air.
Low resistance Materials are:- Copper Iron Aluminium.

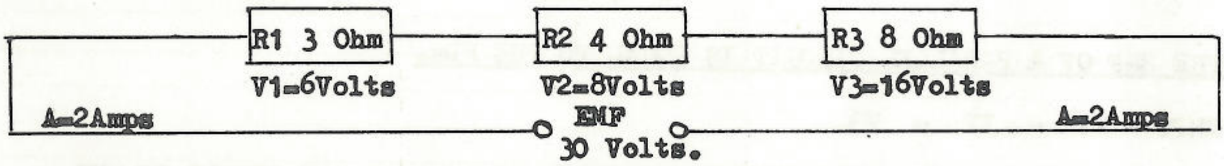
**LENGTH AND CROSS SECTION.** Thick wire has less resistance than thin. Ashort wire has less resistance than a long wire.

**TEMPERATURE.** Most materials increase in resistance as the temperature increases. ( There are exceptions to this rule)

**RESISTANCE IS MEASURED IN OHMS.**

**THE SYMBOL FOR A RESISTANCE IS.**  OR. 
The former is the Standard now used.

**RESISTORS IN SERIES.**
**RESISTORS ARE IN SERIES WHEN THE SAME CURRENT FLOWS THROUGH ALL THE RESISTORS.**




**THE TOTAL RESISISTANCE OF THE CIRCUIT R/T IS THE SUM OF ALL THE RESISTORS.**

R/T = R/1 + R/2 + R/3

E.G. R/T = R/1 + R/2 + R/3
= 3 + 4 + 8
R/T = 15 ohms.

**IN A SERIES CIRCUIT THE SUM OF THE PDs ACROSS EACH RESISTOR WILL EQUAL THE EMF**

E=EMF V=PD

E = V1 + V2 = V3

E.G. E = V1 + V2 + V3
= 6 + 8 + 16
E = 30 volts.

**THE TOTAL CURRENT IN THE CIRCUIT IS THE QUOTIENT OF. EMF AND THE TOTAL RESISTANCE.**

A = E/R

E.G. A = E / R
= 30 / 15
= 2 Amps.

**THE PD ACROSS A RESISTOR WILL BE THE PRODUCT OF THE RESISTOR VALUE AND THE CURRENT THROUGH THE RESISTOR.**

V = A x R

E.G. V1 = A x R1
= 2 x 3
= 6 volts

V2 = A x R2
= 2 x 4
= 8 volts

V3 = A x R3
= 2 x 8
= 16 volts.

E.P.1/4.2.

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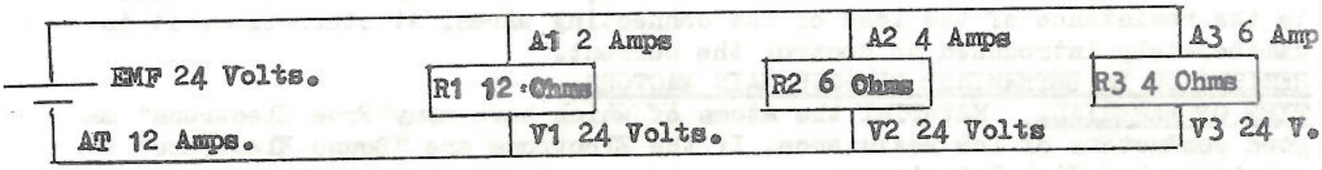
REMEMBER ** WHEN RESISTORS ARE ADDED IN SERIES THE TOTAL RESISTANCE INCREASES.
IN A SERIES CIRCUIT THE CURRENT IS THE SAME IN ALL PARTS.
IN A SERIES CIRCUIT THE EMF (SUPPLY) IS THE SUM OF ALL THE PDs.

RESISTORS IN PARALLEL.

RESISTORS ARE IN PARALLEL MODE. WHEN THE SAME VOLTAGE APPEARS ACROSS EACH RESISTANCE.




THE TOTAL RESISTANCE CAN BE FOUND BY ADDING THE RECIPROCALS OF THE RESISTORS.

1/RT = 1/R1 + 1/R2 + 1/R3 E.G. 1/RT = 1/R1 + 1/R2 + 1/R3
= 1/12 + 1/6 + 1/4
= (1 + 2 + 3) / 12

1/RT = 6/12
RT/1 = 12/6
RT = 2 Ohms.

Another method is :-

RT = (R1 x R2) / (R1 + R2)

E.G. R1/2 = (R1 R2) / (R1 + R2)
= (12 x 6) / (12 + 6)
= 72/18
= 4 ohms.

RT = (R1/2 x R3) / (R1/2 R3)
= (4 x 4) / (4 + 4)
= 16/8
RT = 2 ohms

THE EMF OF A PARALLEL CIRCUIT IS EQUAL TO THE PDs.

EMF. = V1 = V2 = V3.

THE CURRENT THROUGH EACH LEG OF A PARELLEL CIRCUIT IS THE RESULT OF THE VOLTAGE OVER THE RESISTANCE AND THE VALUE OF THE RESISTANCE.

A = V/R E.G. A1 = V1 / R1
= 24 / 12
A1 = 2 Amps..

A2 = V2 / R2
= 24 / 6
A2 = 4 Amps.

A3 = V3 / R3
= 24 / 4
A3 = 6 Amps.

THE TOTAL CURRENT IS THE SUM OF THE INDIVIDUAL CURRENTS.

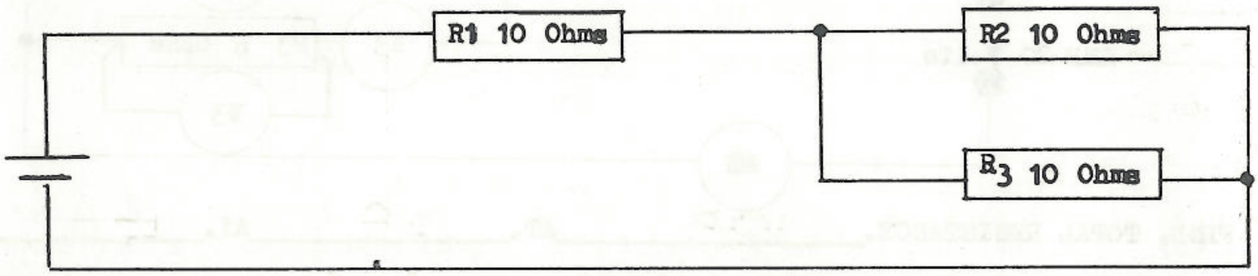
AT = A1 + A2 + A3 E.G. AT = A1 + A2 + A3
= 2 + 4 + 6
AT = 12 Amps.

THE TOTAL CURRENT IS ALSO THE TOTAL VOLTAGE OVER THE TOTAL RESISTANCE.

AT = E / RT E.G. AT = E / RT
= 24/ 2
AT = 12 AMPS

REMEMBER** WHEN RESSISTANCES ARE ADDED IN PARALLEL THE TOTAL RESISTANCE DROPS
THE TOTAL RESISTANCE MUST BE LESS THAN THE LOWEST RESISTOR.
THE VOLTAGE IS THE SAME IN ALL PARTS OF A PARALLEL CIRCUIT.
THE TOTAL CURRENT IS THE SUM OF THE INDIVIDUAL CURRENTS.

Both series and parallel connections may be used in the same circuit, it is called a <u>SERIES / PARALLEL CIRCUIT.</u>




The rules for calculating this type of circuit are simple:-
**CALCULATE THE PARALLEL PATHS THEN ADD THE SERIES PATHS.**

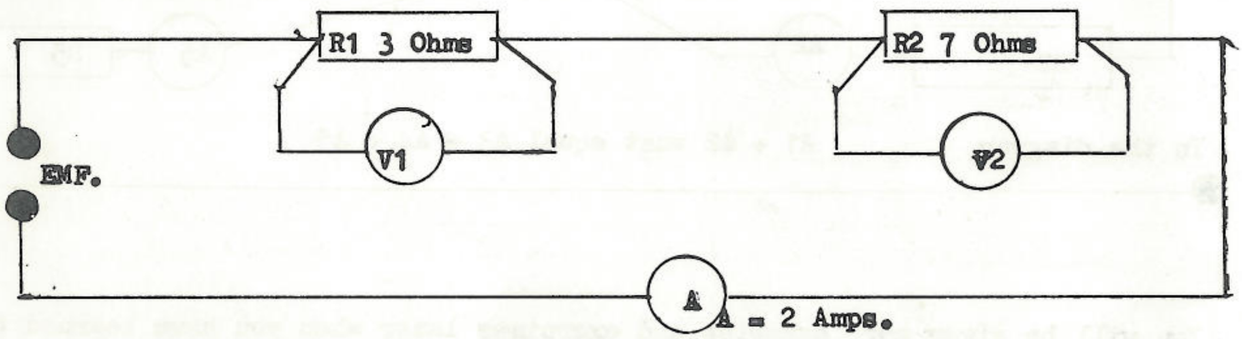
E.G. Find total Resistance of R3 and R2.

$$= \frac{R3 \times R2}{R3 + R2} = \frac{10 \times 10}{10 + 10} = \frac{100}{20} = 5 \text{ Ohms.}$$

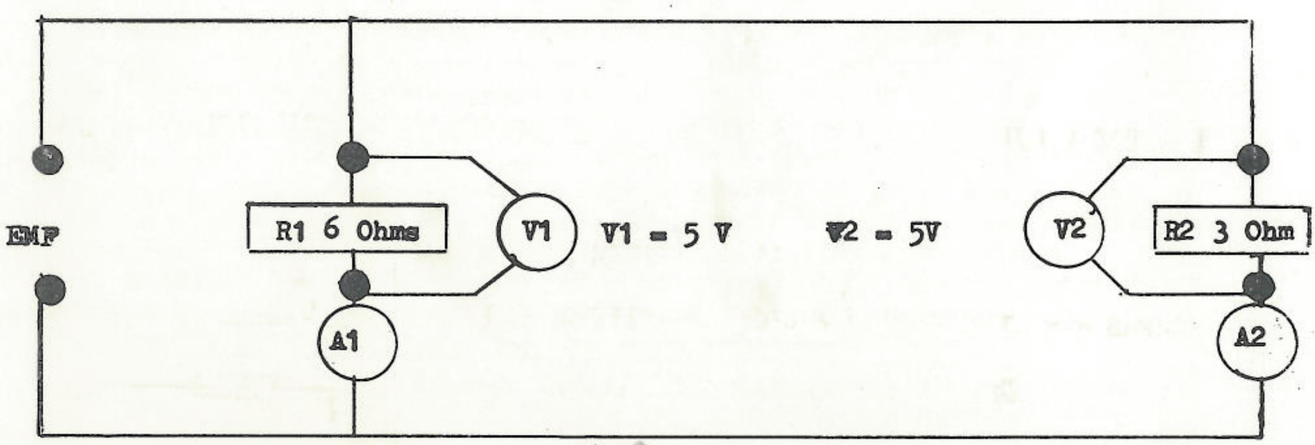
Having found a value for R 3/2 we can now add it to the series resistance R1.

Total Resistance = 5 + 10
= 15 Ohms.

Calculate the values for the following circuits.




FIND. TOTAL RESISTANCE. 10R V1. 6V V2. 14V EMF. 20V




FIND. TOTAL RESISTANCE. 2 A1. 1⅙A A2. 1⅔A EMF. 5V

$\frac{1}{6}+\frac{1}{3} = \frac{1+2}{6} = \frac{3}{6} = \frac{6}{3} = 2$

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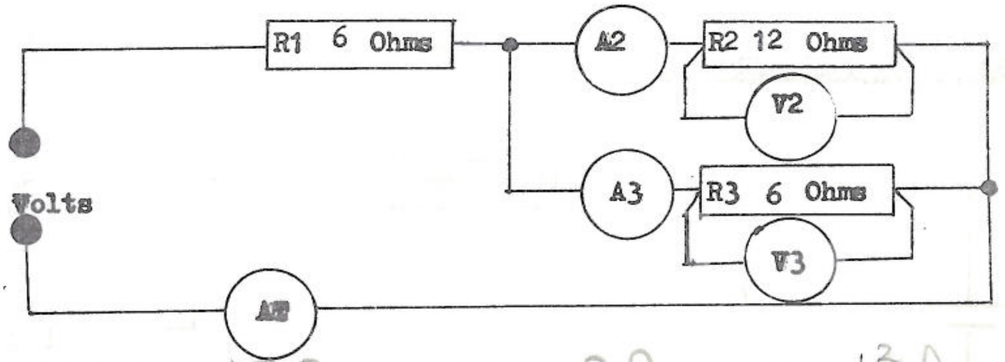



FIND. TOTAL RESISTANCE. 10R AT. 2A A1. 1⅔A

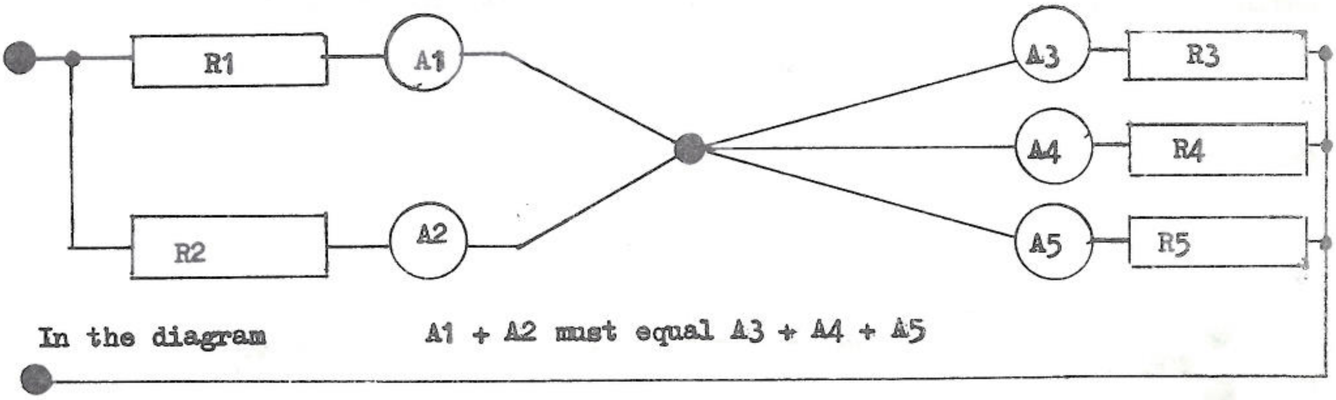
A2. ⅓A V1. 1.338 V2. 2.7

$\frac{1}{12}+\frac{1}{6}=\frac{1+2}{12}=\frac{3}{12}=\frac{12}{3}=4R+6R=10R_T$

An electrical rule which can help a lot in electrical work is:-

KIRCHOFFS LAW.

THE SUM OF THE CURRENTS FLOWING TOWARDS A POINT IN A CIRCUIT, MUST EQUAL THE SUM OF THE CURRENTS FLOWING AWAY FROM THAT POINT.




In the diagram A1 + A2 must equal A3 + A4 + A5

You will be given more examples and exercises later when you have learned to use a Meter so that you can take readings in an electrical circuit.

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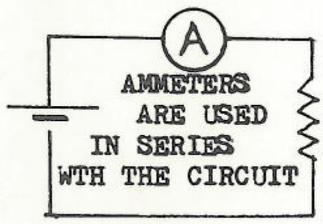
COURSE. Electrical Principles.1.
SUBJECT. Meters and their use.

There are several basic types of meter.e.g. Moving iron, moving coil,hot wire. The type that will be discussed is the Moving Coil meter, the same as will be found in the Technicians Avo meter.
The basic movement of a meter is a DC movement requiring a specific current to cause the meter needle to traverse the meter scale.
Thus the movement is classified by its Full Scale Deflection current, typical examples being. 1mA F.S.D. 1uA F.S.D.
Generally it may be said that the more sensitive the meter movement the better the quality of the meter.
From the basic movement three types of meter can be constructed.

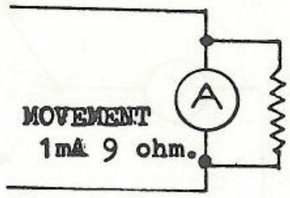
AMMETER.
VOLTMETER.
OHM METER.

From the initial letters of these three we get the trade name for the meter which combines all the three:- The AVO meter.

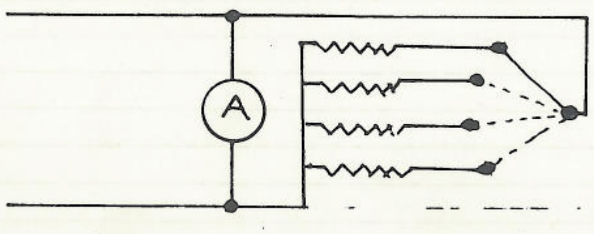
The Ammeter.
The Ammeter is used to measure the current flow in a circuit.
If the meter is to record accurately, all of the current that is to be measured must flow through the meter,and , if the meter is not going to effect the circuit resistance and give false readings,it must be of low resistance.
Two rules apply to ammeters.
1. Ammeters must be low resistance.
2. Ammeters are always connected in series with the circuit.




Making a 1mA movement read 10 mA.




From the basic movement ammeters can be made to read higher currents than the basic movement by the use of Meter shunts. Meter shunts are resistances connected in parallel to the movement which draw current away from the meter. eg. If we have a meter movement giving 1mA F.S.D. and having a resistance of 9 ohms, we can convert it to a 10mA F.S.D. meter by using a 1 ohm shunt resistance. The shunt would take nine times more current than the meter, so if the combination were connected into a circuit of 10mA, 9mA would flow through the shunt and 1Ma through the meter. The meter would be rescaled to read 0 to 10 mA. Intermediate values would be in the same ratios.
By using a switch to select from a range of shunt values a multi meter may be constructed to give a range of current scales from one movement.




Multimeter using switched shunt resistances.

E.P.1./5.2.



The Voltmeter.

Voltmeters are used to measure the voltage or eletrical pressure across all or part of a circuit.

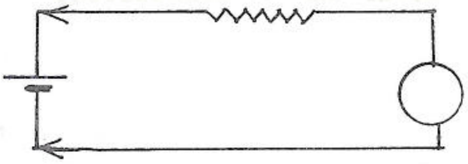
If the meter is to record accurately it must be High resistance, or the meter will draw a high current, or"short" the circuit.

Two rules apply to voltmeters.

1. Voltmeters are connected across a circuit.
2. Voltmeters must be high resistance.


The basic movement for a voltmeter is in fact an ammeter,it is used with a series resistor and scaled to read voltage.

To convert a basic 1mA movement to a 1 volt F.S.D. meter a 1K ohm series resistor would be used. * Ohms Law. 1volt 1000 ohms 1 mA. *

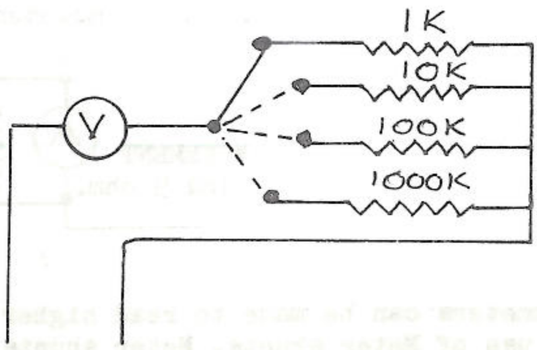


If we wished to make a 10 volt F.S.D. meter a 10 K ohm resisistor would be used and pro rata. From this we can say that for each volt full scale deflection 1000 ohms resistance is required.

THE TERM 1000 OHMS PER VOLT TELLS US THE METER RESITANCE.

more accurate (Higher ohms per volt ) meter could be made using a 1uA meter movement. The series resistor in this case would need to be 1 meg ohm for each volt F.S.D.

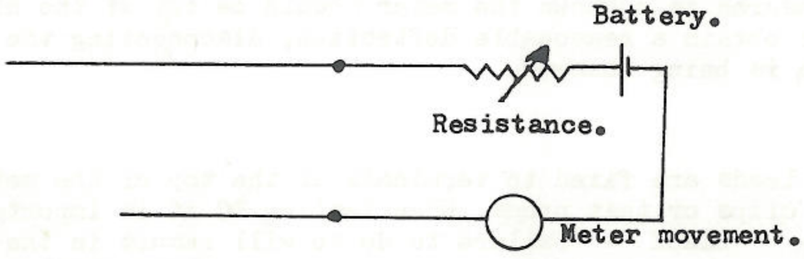
Again a multi meter could be constructed by using a switch to select the series resistor for a given F. S.D.



1 JAN 1983

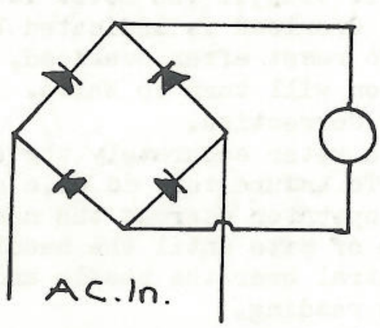
The Ohm meter.
The ohm meter is really an ammeter conected in series with a battery of known voltage. By Ohms law it is known that when a given voltage is applied to a given resistance a specific current will flow. Thus when the ohm meter is connected to a specifis resistance the current flow will be recorded on the scale. The scale however is marked to give a reading in ohms relative to the current flowing.

Ohm meters must always be adjusted to the zero mark prior to reading.(this sets the voltage to the correct level.)
The scale is read in the opposite direction to normal ie. right to left., and is non linear.




THE EQUIPMENT TO BE TESTED MUST BE REMOVED FROM THE CIRCUIT PRIOR TO TESTING WITH THE OHM METER. WHEN CONTINUITY TESTING IS CARRIED OUT THE POWER SUPPLY MUST BE SWITHCHED OFF.

AC. Scales.
The voltmeter and Ammeter may be converted to read AC values by the use of a rectifier. It must be remembered that corrections must be made in the scaling of the meter. It is important to remember also that the readings of the meter will be R.M.S. values and on certain equipment allowance must be made for peak values. The technicians AVO meter is designed for use on AC sine wave input only and is restricted in its frequency range.



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The Technicians AVO meter.

This meter is a multi range meter capable of reading AC and DC. volts and current an ohm meter is also provided. The ranges avaiable are.:-

VOLTS DC.
750.150.75.15.3.1.5
VOLTS AC.
750.150.15.3.
A MPS DC
15.1.5.
MILLIAMPS DC.
300.75.
AMPS AC
15.1.5.
RESISTANCE.
0 to 500 ohms
0 to 50,000 ohms.

The range is selected by the RANGE SELECTOR SWITCH. This switch must be set prior to connecting the meter to the circuit. The correct setting should be one that will give a FSD. of greater value than the circuit is known to carry. If the level to be measured is unknown the meter should be set at the highest level and then reduced to obtain a reasonable deflection, disconnecting the meter while the switch position is being changed.

The meter test leads are fixed to terminals at the top of the meter and can be used with test clips or test prods. When testing DC it is important to observe polarity. RED + BLACK - Failure to do so will result in the needle "kicking back."

EXTRA CARE MUST BE TAKEN IN THE HANDLING OF THE TEST LEADS WHEN TESTING ON A HIGH VOLTAGE.

Three controls appear on the meter front.

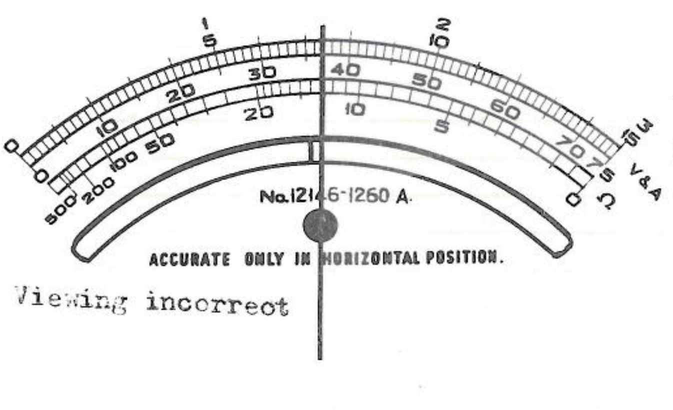
1. The Ohms range Adjustment screw.:- Used to zero the needle when using the Ohms ranges.

2. The needle zero screw :- Used to zero the normal position of the needle. THE METER IS DESIGNED TO BE USED IN THE HORIZONTAL POSITION AND MUST BE ADJUSTED WHEN HORIZONTAL. The zero adjustment is turned clockwise or anticlockwise as required until the needle rest over the 0 mark. The meter should not be connected during adjustment.Once set no further adjustment should be required for a long period.

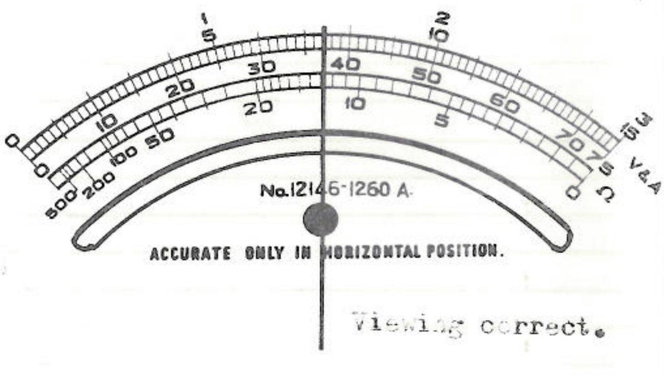
3. Cut out reset knob.:- The meter movement is fitted with an overload cut out which will trip if the meter is connected into a circuit at the wrong range setting. Overload is indicated by a Red spot appearing under the centre of the scale. To reset after overload, the reset knob is turned clockwise,when the Red indication will turn to White.

Parallax Correction.

To read a meter accurately the eyes of the operator must be directly over the needle. To ensure this is so,a mirror is provided beneath the scale. In use the operator observes the needle relection in the mirror, he then repositions his line of site until the needle reflection falls under the needle,his eyes are then central over the needle and by casting his eyes upto the scale he can make an accurate reading.

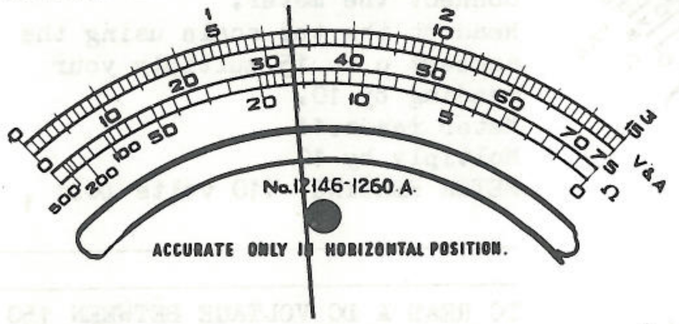



Viewing incorrect

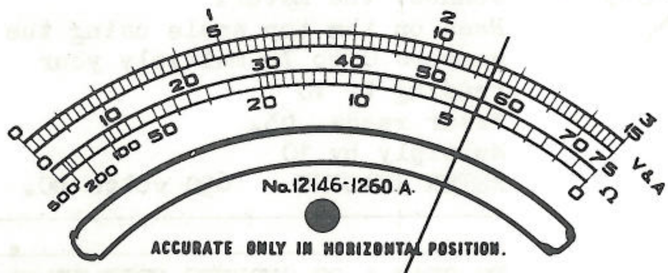



Viewing correct.

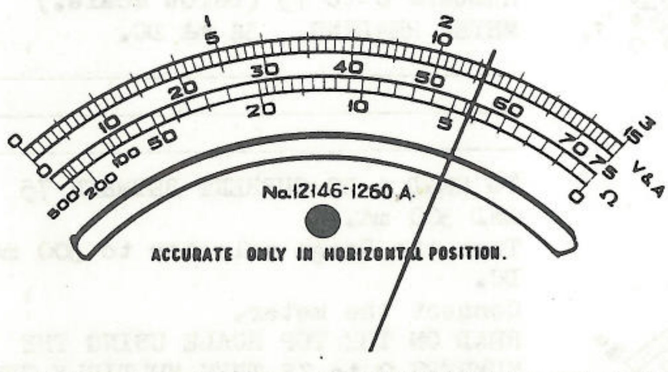
The meter has two scales, upper and lower. The lower scale is used for ohms reading only. The upper scale (marked V&A) is used for all voltage and current readings. There are ^tree^ sets of figures associated with this scale.
0 to 3.          0 to 15.          0 to 75.
All the ranges of the meter can be read from these three sets by multiplying up or dividing down as required.



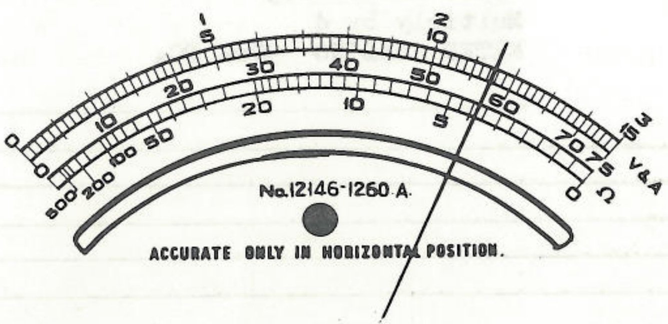

TO READ A DC VOLTAGE LESS THAN 1.5
Turn the Range selector to 1.5 volts DC.
Connect the meter.
Read the meter on the top scale using numbers 0 to 15. Divide answer by ten.
EG. Meter reads 6.6
÷ by 10
METER READING   0.66 volts.DC.




TO READ A DC VOLTAGE BETWEEN 1.5 AND 3.0 VOLTS.
Turn the Range selector to 3.0 volts DC.
Connect the meter.
Read the meter on the top scale using numbers 0 to 3.
METER READING. 2.28 volts DC.




TO READ A DC VOLTAGE BETWWEN 3.0 AND 15 VOLTS.
Turn the Range selector to 15.0 volts DC.
Connect the meter.
Read on the top scale using the numbers 0 to 15.
METER READING. 11.2 volts DC.




TO READ A DC VOLTAGE BETWEEN 15.0 AND 75 VOLTS.
Turn the Range selector to 75 volts DC.
Connect the meter.
Read on the top scale using the numbers 0 to 75 (figures below the scale.)
METER READING. 57.5 volts DC.

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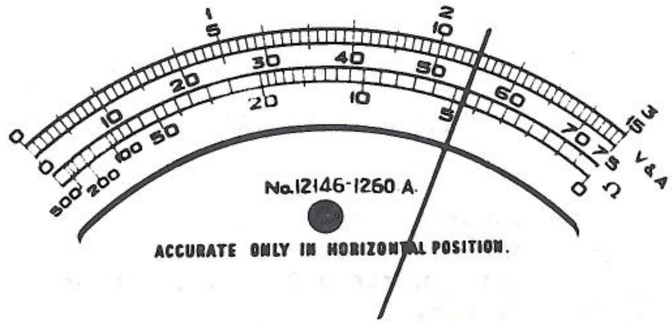
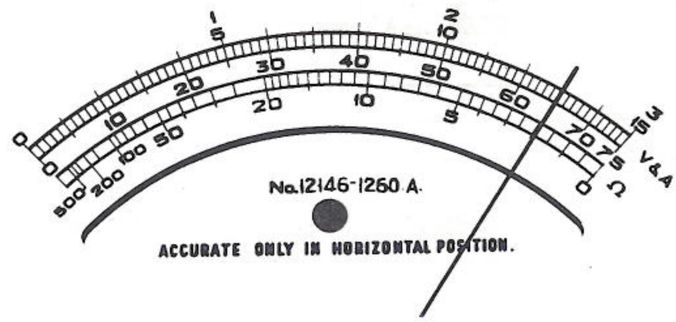
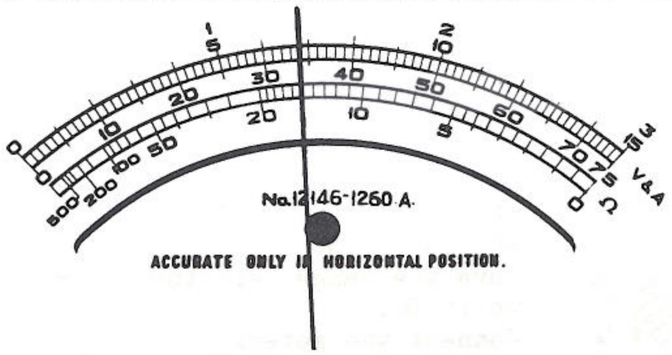



TO READ A DC VOLTAGE BETWEEN 75 AND 150 VOLTS.
Turn the Range selector to 150 volts DC.
Connect the meter.
Read on the top scale using the numbers o to 15 multiply your reading by 10.
Meter reads.11
Multiply by 10
METER READING 110 volts DC.

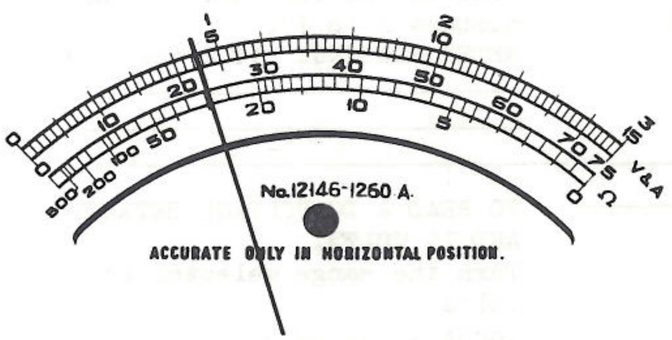



TO READ A DC VOLTAGE BETWEEN 150 AND 750 VOLTS.
Turn the Range selector to 750 volts DC.
Connect the meter.
Read on the top scale using the numbers 0 to 75 multiply your reading by 10
Meter reads. 65.
Multiply by 10
METER READING 650 volts DC.

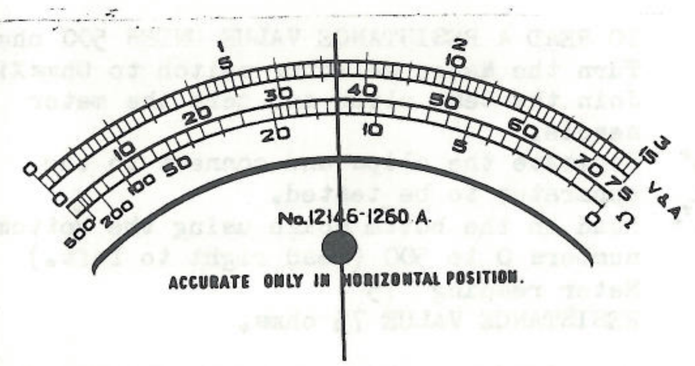
TO USE THE DC CURRENT SCALES.



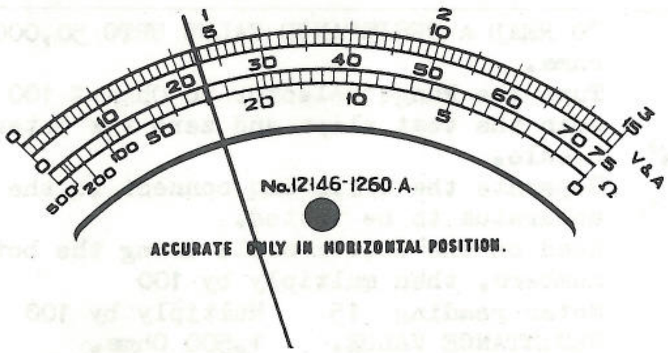

TO READ A DC CURRENT UPTO 75 mA
Turn the Range selector to 75 mA DC.
Connect the meter.
Read on the top scale using the numbers 0 to 75 (below scale.)
METER READING. 34 mA DC.




TO READ A DC CURRENT BETWEEN 75 AND 300 mA.
Turn the Range selector to 300 mA DC.
Connect the meter.
READ ON THE TOP SCALE USING THE NUMBERS O to 75 THEN MULTIPLY THE READING BY 4.
Meter reads 22.5
Multiply by 4
METER READING 90mA DC.




TO READ A DC CURRENT BETWEEN 300 mA AND 1.5 Amps.
Turn the Range selector to 1.5 Amps DC.
Connect the meter.
Read on the top scale using the numbers 0 to 15. Divide the answer by 10.
Meter reads 7.3
Divide by 10
METER READING 0.73 Amps DC.




TO READ A DC CURRENT BETWEEN 1.5 Amps AND 15 Amps.
Turn the Range selector to 15 Amps DC.
Connect the meter.
Read the top scale using the numbers 0 to 15.
Meter reads 4.5
METER READING 4.5 Amps DC.

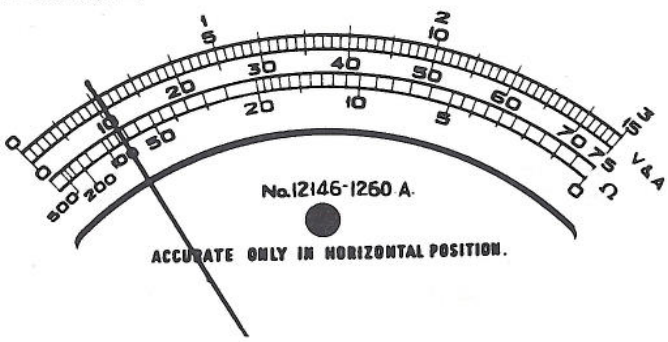
To use the meter to read Alternating Currents and Voltages the same scale is used and the same number sets BUT the Rangeselector switch is turned to the AC side of the switch.

USING THE OHM METER.

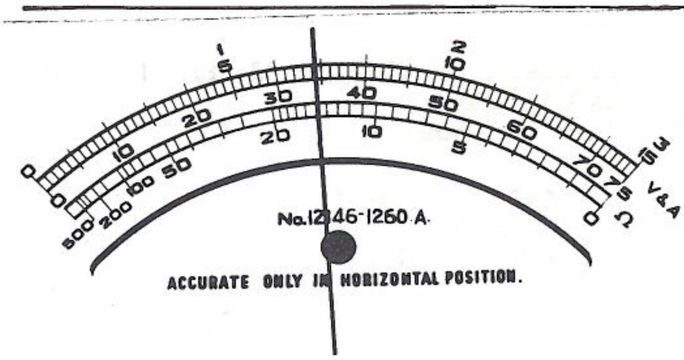
When the ohm meter is used to measure resistance or continuity, an internal battery is bought into use. The condition of this battery should be checked at regular intervals.
WHEN TESTING FOR CONTINUITY THE POWER SUPPLY MUST BE DISCONNECTED FIRST.
WHEN TESTING A PIECE OF APPARATUS FOR ITS RESISTANCE, IT MUST BE REMOVED FROM THE CIRCUIT.
WHEN TESTING ANY POLARITY CONSCIOUS EQUIPMENT (E.G. A DIODE.) IT MUST BE REMEMBERED THAT THE POLARITY OF THE INTERNAL BATTERY IS REVERSE TO THE MARKED POLARITY OF THE METER TERMINALS. I.E. THE POSITIVE TERMINAL IS NEGATIVE POLARITY, AND THE NEGATIVE TERMINAL IS POSITIVE POLARITY.

THE OHM METER MUST FIRST BE SET PRIOR TO TESTING, THIS IS DONE BY CLIPPING THE TWO TEST LEADS TOGETHER AND TURNING THE ADJUST KNOB UNTIL THE NEEDLE COMES TO REST OVER THE 0 MARK ON THE LOWER SCALE.

Resistance is read on the lower ,non linear scale. Two ranges are available. The lowest set of numbers are read (under the scale) The sub divisions are not of the same value over the scale and care is needed in this respect when reading the meter.

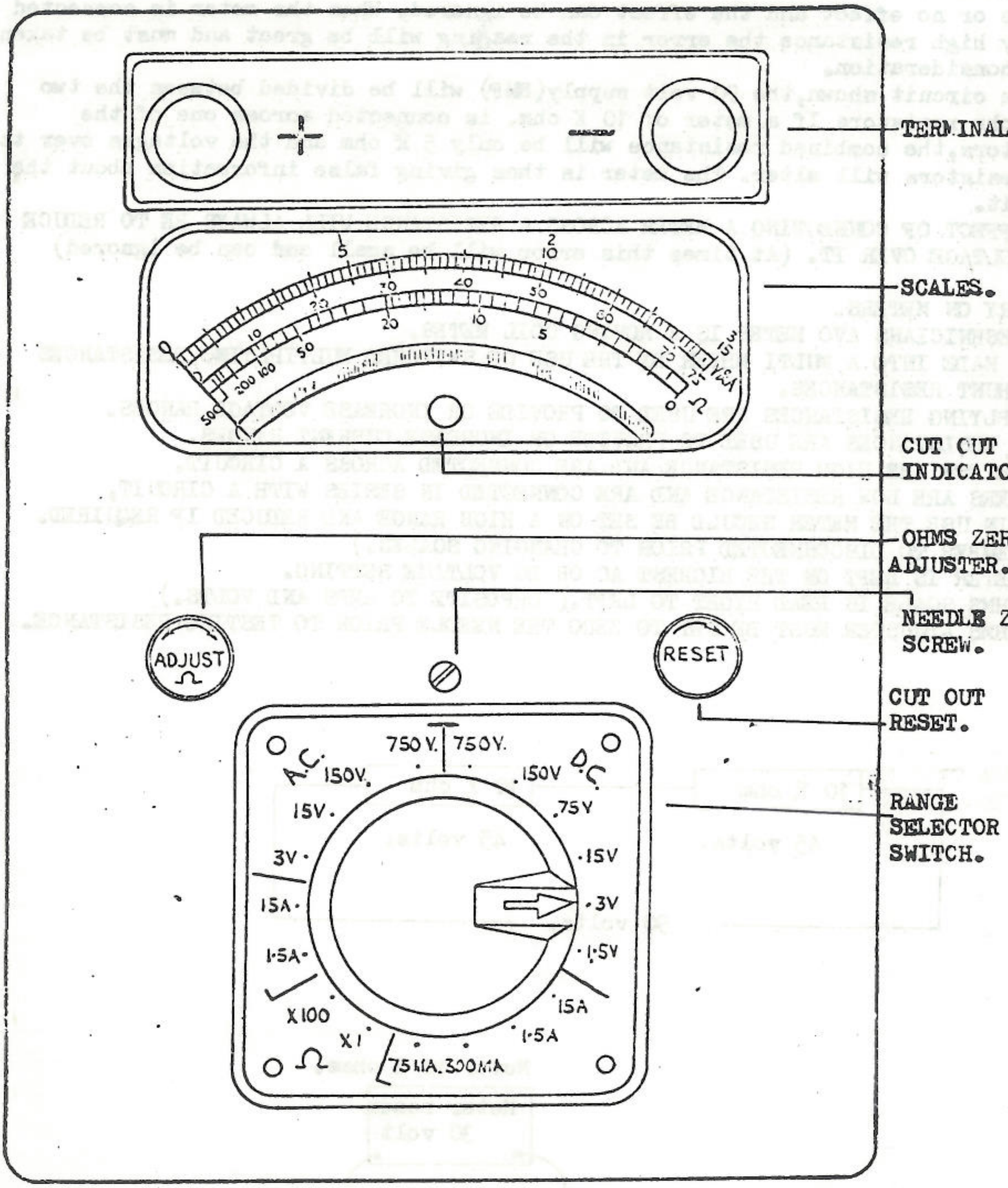



TO READ A RESISTANCE VALUE UNDER 500 ohms
Turn the Range selector switch to Ohms X1
Join the test clips and zero the meter needle.
Seperate the clips and connect to the apparatus to be tested.
Read on the bottm scale using the bottom numbers 0 to 500 (read right to left.)
Meter reading 75
RESISTANCE VALUE 75 ohms.




TO READ A RESISTANCE VALUE UPTO 50,000 ohms.
Turn the Range selector to Ohms X 100
Join the test clips and zero the meter needle.
Seperate the clips and connect to the apparatus to be tested.
Read on the bottom scale using the bottom numbers, then multiply by 100
Meter reading 15 Multiply by 100
RESISTANCE VALUE. 1,500 Ohms.

WHEN A TEST METER IS NOT IN USE IT MUST ALWAYS BE LEFT IN THE HIGHEST VOLTAGE SETTING. THIS IS A SAFETY POSITION FOR METER AND CIRCUIT PROTECTION.
( ON SOME METERS AN OFF POSITION IS PROVIDED.)


TERMINALS.
SCALES.
CUT OUT INDICATOR.
OHMS ZERO ADJUSTER.
NEEDLE ZERO SCREW.
CUT OUT RESET.
RANGE SELECTOR SWITCH.
ADJUST Ω
RESET
A.C.
D.C.
750 V.
750 V.
150 V.
150 V
15 V.
75 V
3 V
15 V
15 A
3 V
1·5 A
1·5 V
X 100
15 A
X 1
1·5 A
75 MA. 300 MA
Ω

When a high resistance voltmeter is connected to a circuit it will affect the circuit to be tested. When connected to a low resistance circuit it will have little or no effect and the effect can be ignored. When the meter is connected to a Very high resistance the error in the reading will be great and must be taken into consideration.

In the circuit shown, the 90 volt supply(EMF) will be divided between the two 10 K ohm resistors If a meter of 10 K ohm. is connected across one of the resistors, the combined resistance will be only 5 K ohm and the voltages over the two resistors will alter. The meter is thus giving false information about the circuit.

THE EFFECT OF CONNECTING A METER ACROSS A RESISTANCE WILL ALWAYS BE TO REDUCE THE VOLTAGE OVER IT. (At times this error will be small and can be ignored)

SUMMARY ON METERS.

THE TECHNICIANS AVO METER IS A MOVING COIL METER.

IT IS MADE INTO A MULTI METER BY THE USE OF SWITCHED MULTIPLYING RESISTANCES AND SHUNT RESISTANCES.

MULTIPLYING RESISTANCES ARE USED TO PROVIDE OR INCREASE VOLTAGE RANGES.

SHUNT RESISTANCES ARE USED TO PROVIDE OR INCREASE CURRENT RANGES.

VOLTMETERS ARE HIGH RESISTANCE AND ARE CONNECTED ACROSS A CIRCUIT.

AMMETERS ARE LOW RESISTANCE AND ARE CONNECTED IN SERIES WITH A CIRCUIT,

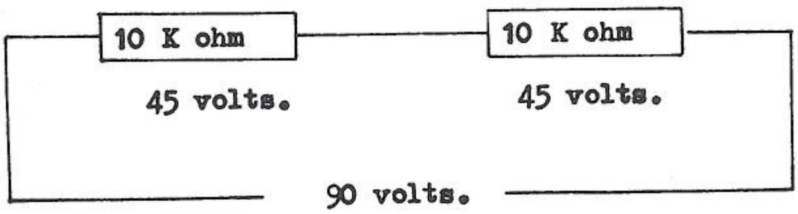
WHEN IN USE THE METER SHOULD BE SET ON A HIGH RANGE AND REDUCED IF REQUIRED.

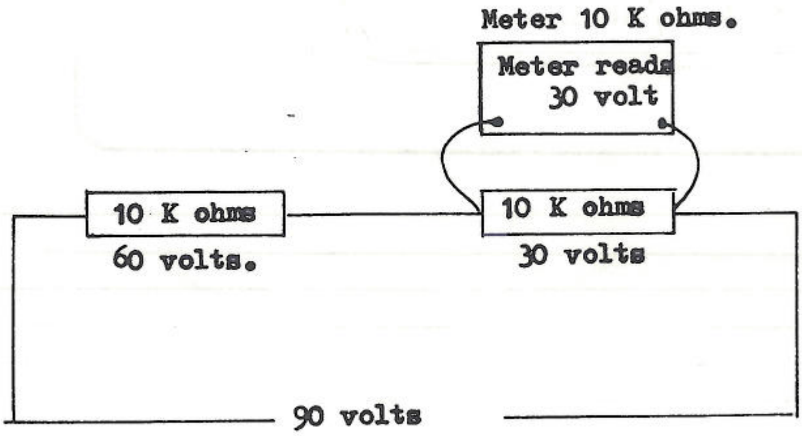
( REMEMBER TO DISCONNECTED PRIOR TO CHANGING SCALES.)

THE METER IS LEFT ON THE HIGHEST AC OR DC VOLTAGE SETTING.

THE OHMS SCALE IS READ RIGHT TO LEFT.( OPPOSITE TO AMPS AND VOLTS.)

THE OHMS ADJUSTER MUST BE SET TO ZERO THE NEEDLE PRIOR TO TESTING RESISTANCE.




THE METER EFFECTS THE CIRCUIT.

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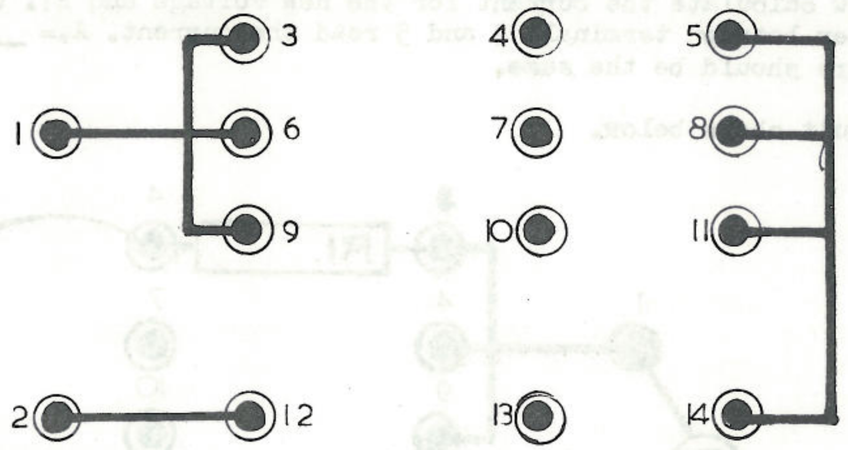
REF. E.P.1./6.1.

01 JAN 1983

COURSE. Electrical Principles.1.

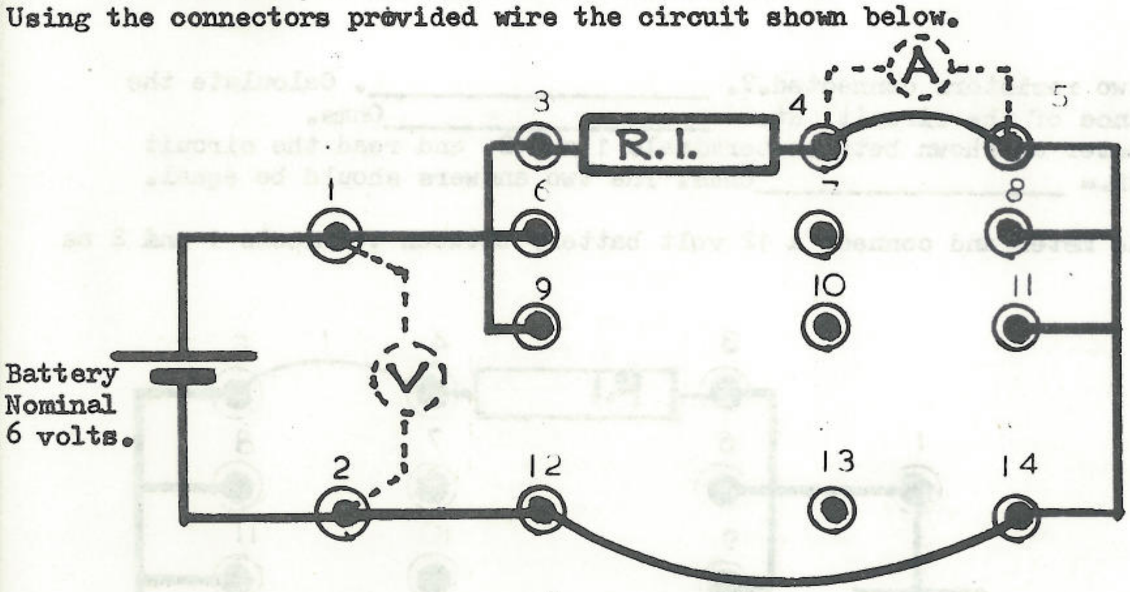
SUBJECT. Practical Circuits.

TEST BOARD LAYOUT.




You will be supplied with a test board as shown above, terminals 1,3,6,9. and 5,8,11,14. and2,12, are pre wired as shown.The board is so designed, that resisistances may be connected between terminals, 3&4, 6&7, 9&10,12&13. Wiring and power supplies may be added by the use of plug in connectors and loops.

You will be issued with a nominal 500 ohm resistor. Using the Avo meter on Ohms scale read the exact value of the resistor and record it here. R1= ________ Ohms. this is the value you will use in all calculations.
Using the connectors provided wire the circuit shown below.




Using the Avo meter read the EMF. between terminals 1 & 2. record it here, EMF. = __________ volts. Using the values that you now know,use Ohms law to calculate the current. A = V/R record your answer here. A = __________ Amps. Disconnect the loop betwwen terminals 4 & 5 and connect the Avo meter set on Current scale into the circuit by plugging the Red lead into terminal 4 and the Black lead into terminal 5 How is the Meter connected ?. is it in Series or Parallel __________________. Read the meter to check the ammount of current in the circuit and record your answer here. A= __________ Amps. This answer should be the same as your calculation result.

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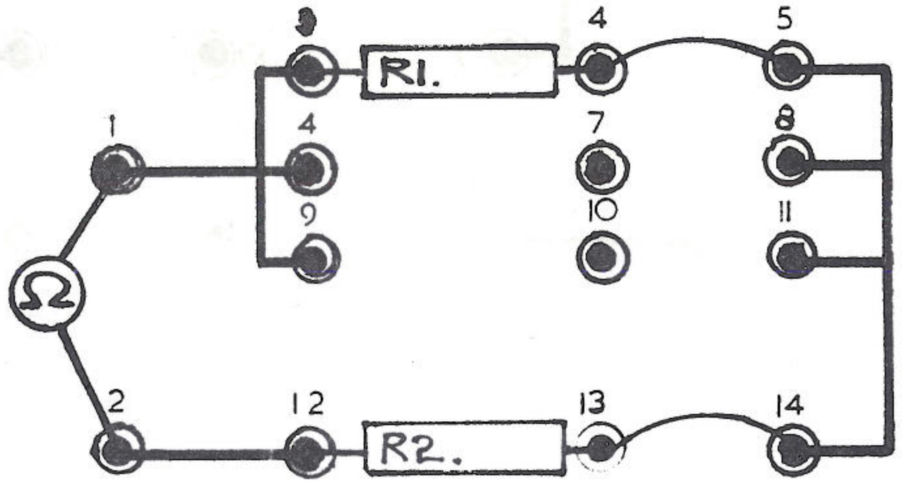
You will be issued with a second resistance R2. Using the Avo meter measure its resistance. R2.= _______________ . Remove R1 from the board and replace it with R2. R2 is less resistance than R1, what would you expect the current to do ? _______________________. With the meter connected between terminals 4 and 5. read the current. A. = _____________Amps. How dees this current compare to the first current reading. __________________. Using Ohms law calculate the current. By calculation A.= _______________ Amps. The two answers should be the same.

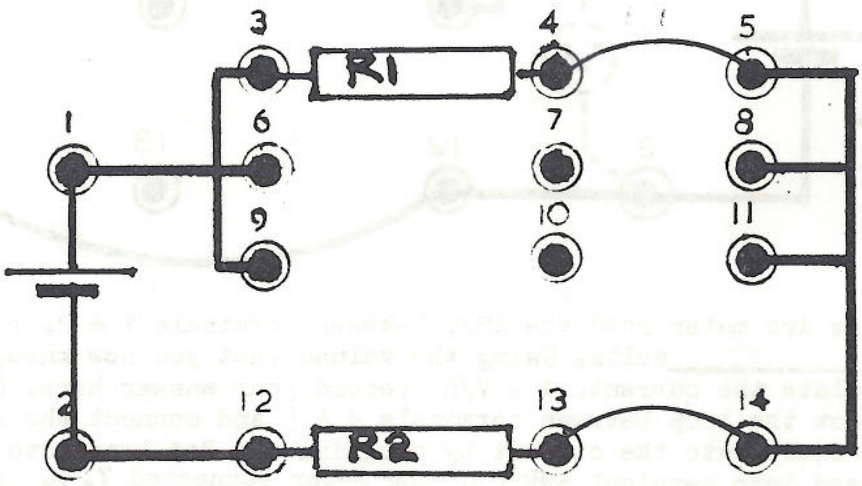
Take out R2. and replace R1. Alter the battery to a 12 volt battery. Using Ohms law calculate the current for the new voltage and R1. V.= ________volts Using the meter between terminals 4 and 5 read the current. A.= ___________Amps. The two answers should be the same.

Wire the circuit shown below.




How are the two resistors connected.?. ____________________. Calculate the total resistance of the circuit. Rt. = ____________________Ohms. Connect the meter as shown between terminals 1 and 2. and read the circuit resistance. Rt.= ___________________Ohms. The two answers should be equal.

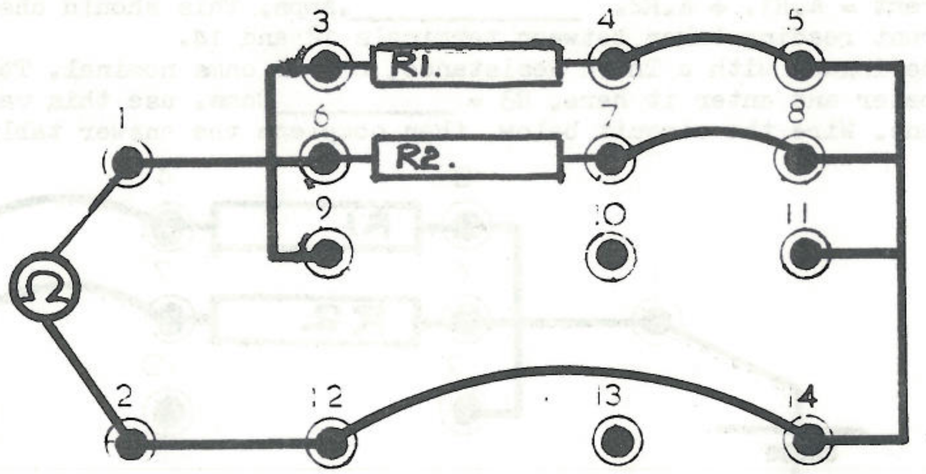
Disconnect the meter and connect a 12 volt battery between terminals 1 and 2 as shown below.



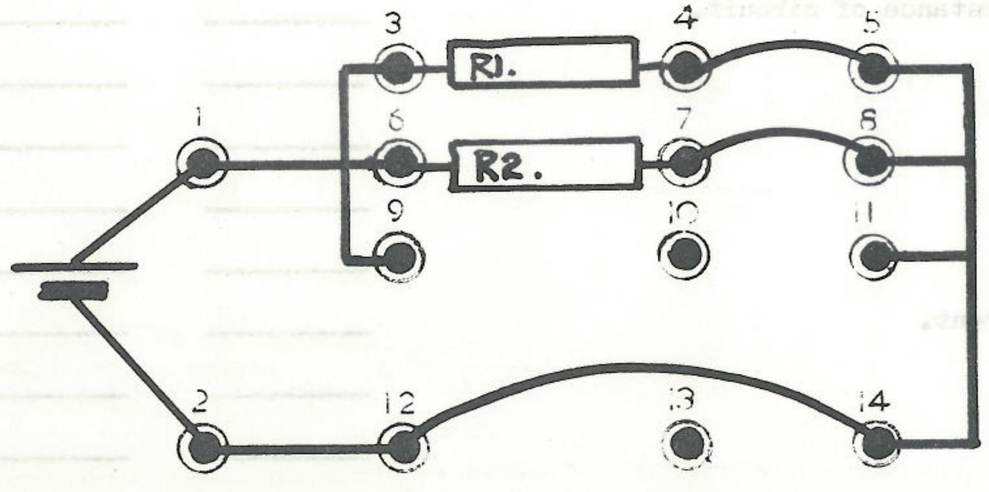

Calculate the total current for the circuit. A.= ____________________Amps. Disconnect terminal 4 to 5 loop and connect the meter on Amps in series with the circuit and read the current. A.= _____________Amps . The two answers should be the same.

**Now that you know the current in the circuit,calculate the PD for R1.**
**R1. PD = _____________volts. Connect the meter on volts betwwen terminals 3 and 4 to measure the Pd over R1. R1.PD = _____________volts the two answers should be equal.**
**Calculate the PD for R2. R2.PD = _____________volts. Measure R2 PD by connecting the voltmeter between terminals 12 and 13. R2.PD = ___________volts. the two answers should be the same.**
**The sum of the PDs should equal the EMF.**
**Read the EMF by connecting the meter across the battery,(terminals 1 and 2.) EMF.= ________________volts. now add the PDs. R1.PD plus R2.PD = ________volts. the two answers should be equal.**
**NOTE THE GREATEST RESISTANCE HAS THE GREATEST PD.**

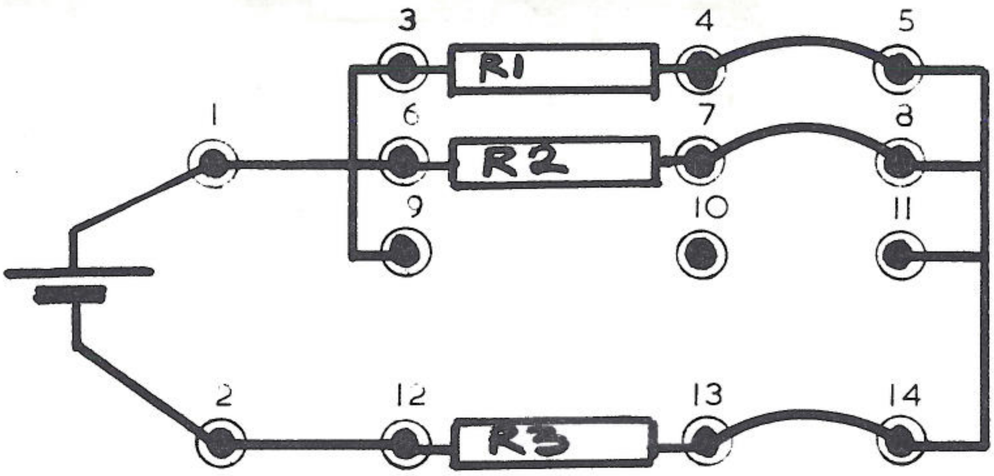
**Construct the circuit shown below.**




**How are the two resistors connected.? ____________________ Would you expect the total resistance to be more than 250 ohms or less.? __________________.**
**Calculate the total resistance of the circuit. Rt.= __________________.Ohms.**
**Connect the meter on the resistance range between terminals 1 and 2. read the resistance of the circuit. Rt.= __________ohms. The two answers should be the same.**
**Complete the circuit as shown below.**



Measure the EMF of the circuit by connecting your meter across the supply terminals 1 and 2. EMF. = ______________volts. Measure also the voltage across R1 and R2 that is the PD across each resistor. They should all be the same. The EMF and the PDs are equal in a parallel circuit.
Calculate the total current for the circuit. A = ________________Amps.
Measure the total current by connecting your meter between terminals 12 and 14 and removing the loop. A = ________________Amps.
Re connect the loop then calculate the current for R1. R1 current = ________Amps.
Measure R1 current by connecting your meter between terminals4 and 5.
A= ____________Amps.,check answers the same.
Re connect the loop from 4 to 5.then calculate the current for R2. R2 current= ______________Amps. Remove the loop from terminals 7 and 8 and insert meter Measure the current im R2. R2 current = ____________ Amps both answer should be equal. The sum of the currents in a Parallel circuit should Equal the total current.
Total Current = A.R1. + A.R2. _____________.Amps. This should check with your Total current reading taken between terminals 12 and 14.
You will be issued with a Third Resistance. of 100 ohms nominal. Test its value with the meter and enter it here. R3 = __________Ohms. use this value in calculations. Wire the circuit below, then complete the answer table provided.




What is the name of this type of circuit.________________________
In the table below,first calculate the values then measure them with a Meter.

| VALUE REQUIRED. | CALCULATED | MEASURED. |
|---|---|---|
| Total value of R1 and R2. | | |
| Total resistance of circuit. | | |
| EMF. | | |
| R1 PD. | | |
| R2 PD. | | |
| R3 PD. | | |
| Total Current. | | |
| R1 A. | | |
| R2 A. | | |
| R3 A. | | |

British Railways Eastern Region

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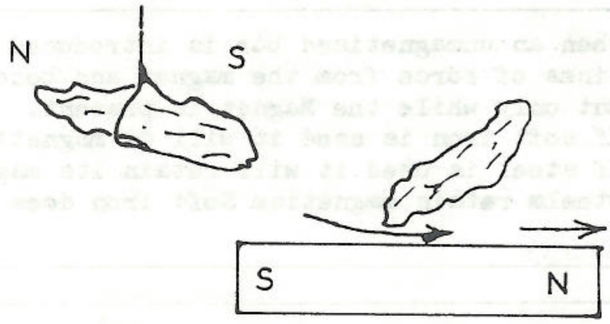
REF. E.P.1./7.1.

0 1 JAN 1983

COURSE. Electrical Principles.1.

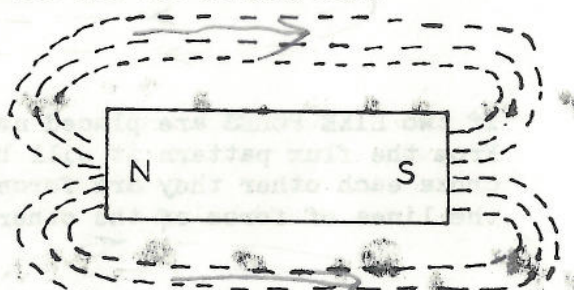
SUBJECT. Magnetic Properties.

The first known Magnets were natural magnetic ores called Lodestone. They were actually Iron ores found in the area of the city of Magnesia by the ancient Greeks.The ore was called Magnetite and from this name the term Magnets and Magnetism was derived.
It was discovered that if a piece of the ore was freely suspended one end of it would always swing in one direction pointing to the Pole star.
Thus one end was called the north seeking pole.
The opposite end being termed the South seeking pole.
The names have been abbreviated to NORTH POLE & SOUTH POLE.

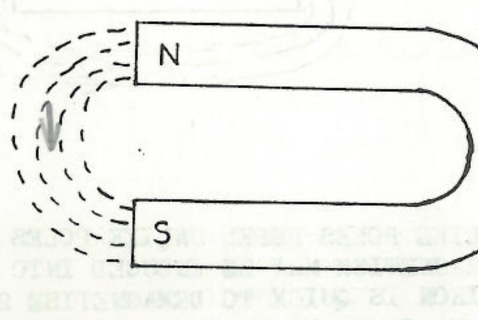



It was later discovered that by stroking a piece of Iron with a natural magnet that the Iron itself became magnetic for a short time.
From this discovery we now know that IRON WILL MAGNETISE EASILY BUT DOES NOT RETAIN THE MAGNETISM.
When in later years Steel was made it too had magnetic properties but, STEEL WAS HARDER TO MAGNETISE AND RETAINED IT MAGNETISM.
Steel alloys containing Cobalt or Nickel making very good permanent magnets.
(Magnets are not made now by rubbing but by Electrical means as will be seen later).

Magnetism is an invisible force, it cannot be seen but its effect can.
The invisible LINES OF FORCE or FLUX LINES can be traced by sprinkling iron filings on a sheet of paper over a Magnet
The number of lines of force is expressed as FLUX DENSITY.
It can be observed that the lines of force are between the two poles and that they are the most dense at the Pole Faces.




The lines of force in a Bar magnet have to travel through the air from the north to the south pole and air is not avery good condutor to magnetism,it has " high resistance" called RELUCTANCE for magnetic circuits.
The field density can be increased by bringing the pole faces close together as in a Horseshoe Magnet.



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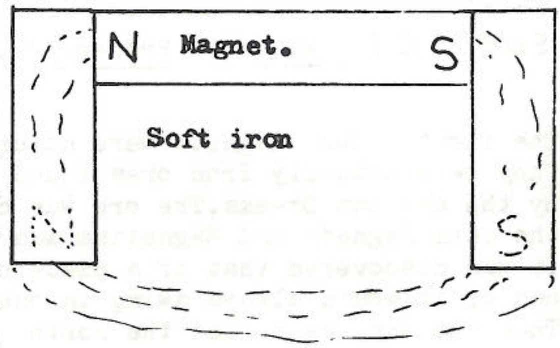
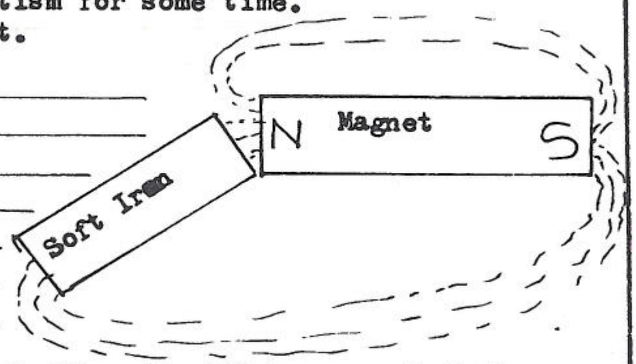
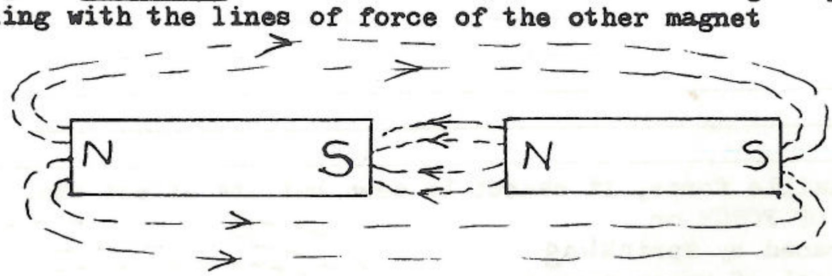
Magnetic lines of force will take the path of least Reluctance.
Air has High reluctance Iron has Low reluctance, if Iron is introduced into a Magnetic field the lines of force will flow through the iron.
By using soft iron a magnetic field can be shaped or bent or diverted.
For example a Bar magnet can be made into a Horse shoe Magnet.



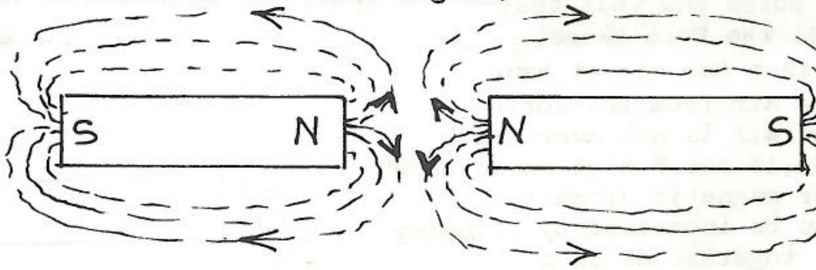

When an unmagnetised bar is introduced into a Magnetic field it takes up the lines of force from the magnet and becomes a magnet itself
But only while the Magnet is present.
If soft iron is used it will de magnetise as soon as the magnet is removed
If steel is used it will retain its magnetism for some time.
Steels retain magnetism Soft iron does not.




If two UNLIKE POLES are placed near to each other it will be seen that the two magnets attract The lines of force from one magnet passing to and combining with the lines of force of the other magnet




If two LIKE POLES are placed near each other they will repel each other
From the flux pattern it will be seen that :- as the lines of force cannot cross each other they are forced to turn aside and travel back, thus repelling the lines of force of the other magnet.




LIKE POLES REPEL UNLIKE POLES ATTRACT.
MAGNETISM MAY BE INDUCED INTO IRON OR STEEL BY ANOTHER MAGNET.
IRON IS QUICK TO DEMAGNETISE STEEL IS USED FOR PERMANENT MAGNETS.
THE STRENGTH OF A MAGNETIC FIELD IS MEASURED BY ITS FLUX DENSITY(No of LINES OF

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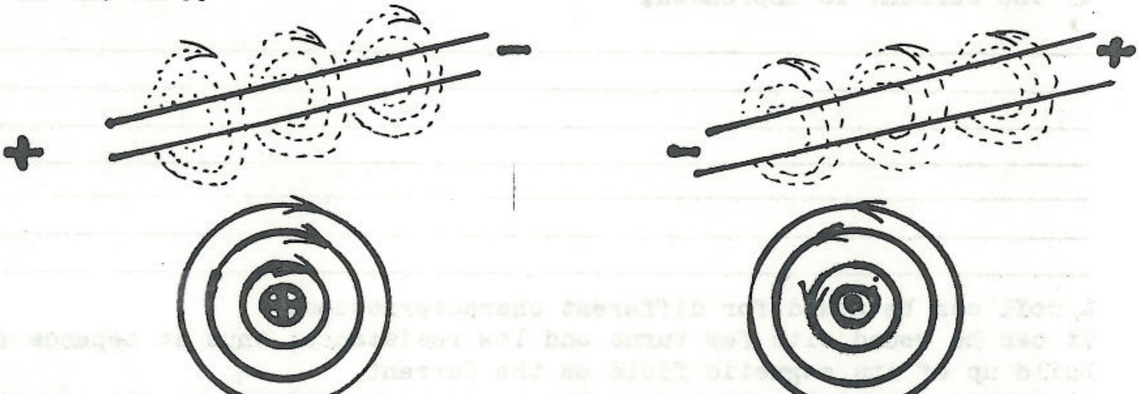
COURSE. Electrical Principles.1.

SUBJECT. Electro Magnetism.

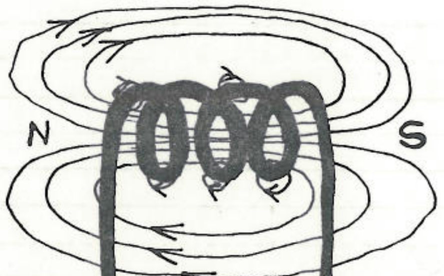
An electric current flowing in a conductor gives rise to a Magnetic field arround the conductor. It is called an Electro magnetic field.
The direction of the magnetic field is determined by the Direction of the electric current flow in the wire.



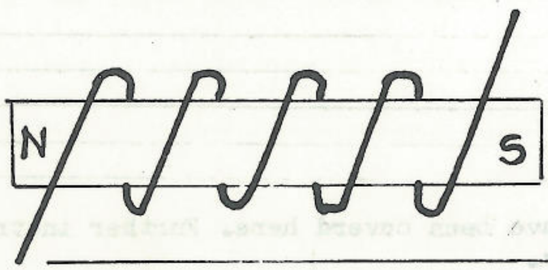

The density of the magnetic field round the wire is determined by the current flow in the wire.

If the wire is formed into a coil of many loops the magnetic fields of all the loops combine or reinforce each other and form a single magnetic field extending inside and outside the coil, thus the coil appears like and behaves like a Bar Magnet. But, Only while current flows in the coil.

**THIS COIL IS CALLED AN ELECTRO MAGNET OR SOLENOID.**




The strength of the electro magnet can be increased by using a soft iron core in the coil. The iron provides a path of low reluctance to the lines of force and increases the flux desity of the coil.



The magnetic field strength of a coil can be increased in two ways.
1. By inceasing the number of turns.
2. By increasing the current

The magnetic field is determined by the Ampereturns.
It is possible to Saturate a particular coil. Saturate means that the point has been reached where the coil will not produce any more magnetic flux, even if the current is increased.

A coil can be wound for different characteristics.
It can be wound with few turns and low resistance, thus it depends for the build up of its magnetic field on the Current.
Alternatively it can have many turns and high resistance, its magnetism is thus obtained by low current but many turns
These are often refered to loosely as Current operated and Voltage operated devices repectively.

Only the basics of Electro Magnetism have been coverd here. Further instruction will be given later with other subjects.

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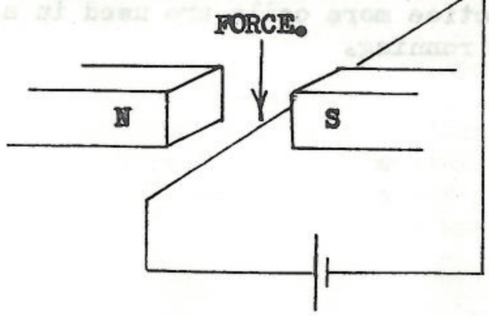
COURSE. Electrical Principles.1.

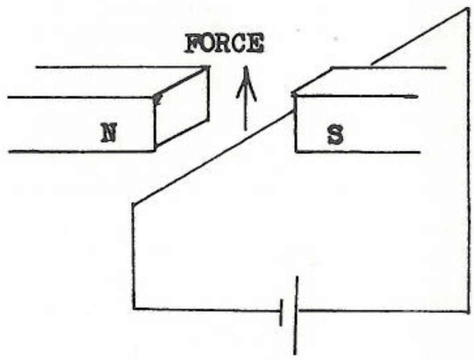
SUBJECT. Electric Motor Principle.

If a conductor carrying an Electric current is in a Magnetic field a force will be exerted on that conductor causing it to move.
If the conductor is placed central in a Magnetic field and the current is switched on it will be obseved that the conductor will move,up,or,down. The direction of the movement will be determined by the direction of the current flowing in the conductor in relation to the polarity of the Magnetic field.
If the direction of the current is reversed, the direction of movement will be reversed.
If the polarity of the magnetic field is reversed the direction of movement will be reversed.
If BOTH the direction of current and the polarity of the field xxxx are reversed the direction of movement will be the same.

If a current carrying conductor is placed in a magnetic field.
A force will be exerted on the conductor tending to cause the conductor to move.

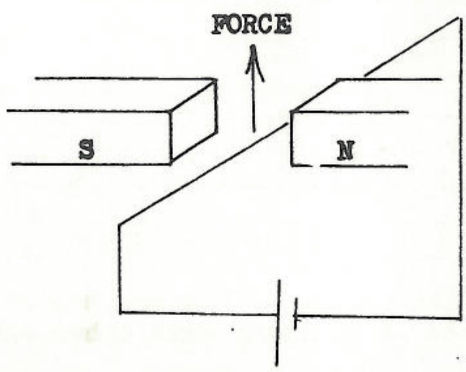



The direction of the force can be reversed by changing the direction of the current

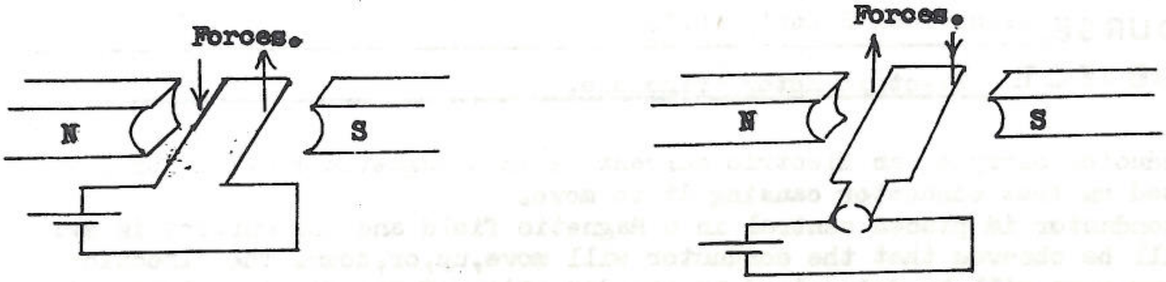



OR

By changing the polarity of the field.




BUT NOT BOTH. IF BOTH ARE CHANGED THE DIRECTION OF FORCE WILL BE UNALTERED.




If the conductor is replaced by a loop or a coil then the force will be exerted on each side of the loop which will tend to retate. The loop will only rotate until it reaches the vertical. To enable it to contimue to rebate a Commutator must be used. The commutator reverses the direction of current in the doil(and the forces)in the loop which will then continue to rotate.
As in the case of the conductor the direction of rotation of the motor can be reversed by changing the direction of the current OR the field.
In practice more coils are used in a motor,allconnected to the commutator to give smooth running.

A battery, or a Galvanic Cell, is a device for transforming chemical energy into electrical energy. The word "Battery" implies two or more cells, but common usage has made its application to a single cell acceptable.

A primary cell may be constructed using almost any two dis-similar metals, referred to as the Electrodes, and a solution of salt or acid, referred to as the Electrolyte. For instance, consider a rather simple cell having copper and zinc Electrodes and a solution of sulphuric acid for the Electrolyte.

Whenever any acid or salt is mixed with water (in that order) to make an Electrolyte solution, two actions occur. First, the acid or salt is dissolved in the water; and second, a process known as "Ionization" takes place. Ionization is the name given to the effect in which some of the substance dissolved in the water breaks up into tiny particles which carry electrical charges. These particles are called "Ions". An Ion is a particle of subatomic, atomic or molecular size which carries either a positive or negative electrical charge. The Ion is positive if it has a deficiency of electrons and negative if it has an excess of electrons.

The entire solution in this condition is electrically neutral as it contains an equal number of positive and negative Ions.

If a zinc electrode is immersed in the electrolyte, some of the zinc dissolves in the solution and produces positively charged zinc Ions because the chemical action is such as to leave behind negative charges (electrons), on the electrode. The solution is then positively charged and the zinc electrode in negatively charged and an electrical potential exists between them. The positive zinc Ions are attracted to the negatively charged zinc electrode and tend to accumulate around it.

If a copper electrode, is now immersed in the electrolyte some of the solutions positively charged Ions go to the copper electrode, each Ion then combines with an electron from the copper to form an atom of hydrogen gas. As the copper electrode loses electrons it becomes positively charged with respect to the solution.

Because the zinc electrode is negative with respect to the solution and the copper electrode is positive with respect to the solution, it follows that the copper electrode is positive to the zinc electrode and that a difference of potential or voltage exists between them.

If the two electrodes are connected with a conductor, electrons will flow through the conductor from the negatively charged zinc electrode to the positively charged copper electrode and providing some control on this current flow is exercised, say, by offering some form of resistance to the electron flow so that the rate of flow does not exceed the rate of the chemical action providing the difference in potential this continuing process will provide, energy to perform work by electrical means. The chemical action is such as to cause the zinc electrode to dissolve which will bring the process to a stop eventually. Not all the energy generated is available to the external electrical circuit as the internal resistance of the cell accounts for some loss.

A primary cell is one which transforms chemical energy into electrical energy, depleting its elements in the process. Secondary cells or storage type cells also transform chemical energy into electrical energy, and then have the original materials restored by passing current through them in the reverse direction, thus storing electrical energy as chemical energy.

While the chemistry of various types of cells is different with respect to complexity of chemical action, the fundamental principles of Ionization to establish an electrical potential or voltage remain the same.

POLARISATION

This is the term applied to describe a rapid increase in the internal resistance of a cell and a consequent falling off in the current output as a result of minute bubbles of hydrogen gas.forming on the positive element. It is apparent that as the surface of the carbon becomes more densely coated, the smaller becomes the surface area available for the passage of current, and so the resistance increases.

A depolarizing agent is used in the primary cell to prevent or lessen this undesirable feature. The principle being to allow oxygen to enter the cell at the point where the hydrogen bubbles form (around the positive plate) and the combination of H2O forms water. This eventually results in the saturation of the depolarizing agent which must then be renewed.

The greater the capacity of the depolarising agent to convert hydrogen to water, the greater will be the current output of the cell due to a lower internal resistance being maintained.

TAKING VOLTAGE TEST OF CELL

A voltage test of a cell is taken to ensure that it is capable of functioning correctly, and as a check to it's condition. The "open circuit" voltage of a cell when new is approximately 1.5 volts, but in order to test the cell as to it's behaviour when it is actually working, the "on load" condition is simulated by means of a 1OHM shunt connected across the voltmeter terminals. The voltmeter and shunt should be applied for about 5 seconds and the new cell voltage reading should be about 1.3 volts.

The "on load" condition is the true indication of the efficiency of the cell and if at the time of testing the cell is working into it's normal load then the 1OHM shunt resistance is not required for the test. The overall voltage of the battery on load will indicate the soundness of the connections from cell to cell.

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Since the early days of railways the primary cell has supplied the electricity required to work the telegraph system, train signalling instruments and block bells. Signals, points, telephones etc. all of which are vital to the operation of Railways, depend to a large extent on the electric cell in one form or another.

The use of Primary Cells has been gradually extended to include the operation of various types of signalling apparatus, such as arm repeaters, light repeaters, indicators for track circuits, depression bars, telephones etc.

There are various types of Primary Cells in use, and it will be found that all are constructed from basic materials as follows:-

1. Container or outer case.
2. Positive element.
3. Negative element.
4. Electrolyte.
5. Depolariser.

The Primary Cell, due to it's chemical action, generates electricity, and this energy gained results in the destruction of the negative element. This could prove extremely costly, but the primary cell has been developed to the point of utmost economy, using materials which are fairly cheap and which require minimum maintenance. Requirements for Primary Cells are as follows:-

1. The E.M.F. should be large and remain constant.
2. The Internal Resis should be small and remain constant.
3. The materials consumed should be cheap.
4. The waste of materials when a cell is not in use should be as small as possible.
5. The condition of the cell should be capable of being easily inspected and/or tested.
6. It should be easy to renew or replace.
7. It should give off no offensive fumes.
8. It's first cost should be small.

The two main types in use on this Region are as follows:-

 

## "LECHLANCHE" TYPE DRY CELL

Zinc container covered with cardboard
Carbon for Positive Element
Zinc Container acts as Negative Element
Salamoniac Paste for Electrolyte
Manganese Dioxide as Depolarising Agent
"On Load" voltage approx. 1.3 volts (when new)

## INERT "AIR DEPOLARISED" CAUSTIC SODA CELLS.

Fibre or Plastic Container
Carbon for Positive Element
Zinc for Negative Element
Booster Zinc fitted for extra life
Porous Carbon as Depolarising Agent
"On Load" voltage 1.2 volts (when new)
Caustic Potash solution as Electrolyte
Instructions for servicing on container side.

There are two inert caustic cells in use. The 618A and 608A. The former should be removed from service and replaced when the "on load" voltage reaches 1.1 volts. The 608A cell should be likewise dealt with when the "on load" voltage reaches 1.0 volt. Dry cells do not have this sharp fall off characteristic and should be replaced when the overall battery voltage falls below the required value or when individual cell "on load" voltages drop to 0.8 volts, whichever occurs first.

Ventilation is important for all primary cells and a continuous supply of fresh air is essential across the top of each cell. Inert Caustic Cells will not operate satisfactorily if ventilation is not provided.

## RECOMMENDED DISCHARGE RATES

| Type of | "Rated" Capacity Continuouse | Weight lbs | Maximum Recommended Discharge Rates | | |
|---|---|---|---|---|---|
| | | | Continuous | Intermittent | |
| | | | | 60 x 5 secs Daily | 2 x 2 hrs Daily |
| DS.3 | 2,000 hours | 2 | 50 mA | 375 mA | 100 mA |
| DS.1 | 2,600 hours | 6 | 100 mA | 500 mA | 200 mA |
| AD.513 | 850 Watt hrs. | 16 | 200 mA | 5 Amps | 600 mA |
| AD.618A | 1,000 " " | 10* | 400 mA | 800 mA | 800 mA |
| AD.608A | 2,500 " " | 22* | 1 Amp | 2.5 Amps | 1.5 Amps |

* Weight before filling with water.

## PRIMARY CELLS : TYPES AND APPLICATIONS. 01 JAN 1983

| Type of Cell | Description | Applications |
|---|---|---|
| DS 1 | 1.4V dry cell | Electric detection, Track circuit repeating, |
| DS 3 | 1.4V dry cell | Telephones (Ringing and Microphone), Signal repeating, Light repeating. |
| DS 7 | 1.4V dry cell | Portable Field type Telephones. |
| AD 513 | 1.4V Air Depolarised Cell | Circuits requiring intermittent currents:- Lever locks, Signal motors, AWS Inductors. |
| AD 608A | 1.4V Air Depolarised Cell Inert type. | Continuous loads:- Track circuits, and Semaphore signal lights requiring over 400mA. |
| AD 618A | 1.4V Air Depolarised Cell Inert type. | Continuous loads under 400mA. |

NOTE.

1. As it is BR policy to eliminate the use of primary cells in signalling circuits their installation must be kept to a minimum.
2. As far as possible the type of cell chosen must be such that the continuous load is within the discharge rates shown in the table.
3. A single cell or bank of cells of the appropriate size should be used in preference to paralleled banks of smaller cells.

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COURSE. Electrical Principles.1. 01 JAN 1983

SUBJECT. Secondary Cells.

## ALKALINE STORAGE BATTERIES

A storage battery is commonly known as a battery made up of secondary cells. However, the term "Storage" is most appropriate to these batteries which require a minimum of care and attention, but that minimum is vitally necessary in order to obtain the trouble-free operation and long life which means economy.

A storage battery cell consists essentially of an assembly or "Group" of positive plates and a "Group" of negative plates immersed in a solution known as the electrolyte. Between the plates are separators to prevent physical contact and the entire unit is assembled in a suitable jar or container.

The alkaline cell, e.g. THE NIFE CELL, requires charging from a power supply. The rate of charging is dependent on size and type, and the manufacturer's instructions lay down values. Whilst the function of this cell is similar to that of the LEAD ACID CELL, the chemical constituent of the two types is entirely different and each must be installed and maintained in accordance to their individual requirements and instructions.

NOTE.

Both Alkaline and Lead acid cells give off an EXPLOSIVE GAS during the charging cycle and care must be taken to ensure no means of ignition such as naked lights, sparks, etc, are permitted near to the cells or within the battery room or location case.

1. THE NICKEL CADMIUM CELL

The cells active materials are :-

1.1 On the positive plates, Nickel Hydroxide, the action that takes place on discharge being a reduction from a higher form of nickel hydroxate to a lower form, and vice-versa on charge.

1.2 On the negative plates, metallic cadmium, which is oxidized on discharge to cadmium oxide (or hydroxide) and vice-versa on charge.

1. THE NICKEL CADMIUM CELL (CONTINUED)

1.3 The active material is enclosed in steel tubes or pockets, which are perforated with a very large number of minute holes over the whole of their surface, a number of these pockets being assembled into steel retaining frames to form complete positive or negative plates. The required number of plates of the same polarity are mounted on collecting bolts with suitable steel spacing washers and terminal pillars and are then bolted firmly together. The positive and negative plates are separated by means of ebonite or plastic rod insulators and the whole assembly is mounted in a sheet-steel or rigid polystyrene container having welded joints, the terminals being brought through the cover in suitably insulated glands.

1.4 The electrolyte is a solution of pure potassium hydroxide (caustic potash), having a normal specific gravity of about 1.190. The strength of the solution, apart from evaporation, does not vary during either discharge or charge, and has no action on cadmium or steel, so that there is no possibility of internal corrosion. The potassium hydroxide electrolyte takes no active part in the reactions of the cell and functions merely as a conductor.

1.5 It is important to note that the presence of acid in alkaline cells will destroy the cells.

1.6 The following Chief S & T Engineer's instructions in respect of alkaline cells must be followed.

Preparation of Nickel Cadmium Cells for Service.

The cells are delivered with electrolyte but in a Discharged condition.

a. WEARING GOGGLES remove the black transit plugs from the top of the vent and discard.

b. Check the electrolyte level in all cells and correct where necessary by adding distilled water only, using the plastic filler bottle type PB4. For details of 'First Charge' refer to Section 2.2c

2. SAFETY PRECAUTIONS

2.1 GOGGLES ARE TO BE WORN when dealing with the cells.

2.2 Ensure there is good air circulation to disperse any accumulation of gas before starting work.

2.3 NEVER examine with naked lights or do anything likely to cause sparks near a battery.

2.4 DO NOT SMOKE NEAR THE CELLS.

2.5 NEVER tap the cells to check the electrolyte level or tighten or loosen connections whilst the cells are on charge, or discharge, and gassing.

2.6 DO NOT use utensils which have been used for lead acid cells. ACID will destroy alkaline cells.

2.7 DO NOT SPILL electrolyte on the skin or clothing.

2.7.1. ACCIDENTAL BURN OR ELECTROLYTE IN THE EYES

The affected eyes and skin should be well washed with liberal amounts of clean water. The filler bottle must not be used for this purpose.

2.8 CARE MUST BE TAKEN when examining steel-cased cells as the outer case is 'live'. Never allow tools or metal objects to rest across the cells or fall between them. This may cause sparking and damage the cell containers.

3. MAINTENANCE PROCEDURE

3.1 PUT ON GOGGLES (this is for your own protection).

3.2 Switch off battery charger and allow air to circulate so that any accumulation of gas can disperse. (Enforce air circulation by wafting or fanning where no motion of air is apparent).

3.3 Check the electrolyte level and top up with distilled water where necessary, using Filler Bottle type FB4 with Filler Tube and Probe.
(N.B. for PA and PV cells with modified vent plugs, the insulated Probe No. 3 (2¼" long) must be used).

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3. MAINTENANCE PROCEDURE (CONTINUED)

3.3.1 METHOD OF USING BOTTLE

The bottle should be kept clean and contain pure distilled water. With the probe inserted through the filler vent the bottle should be raised in an inverted position above the cell. Gently squeezing the bottle will then force a little water into the cell. The bottle should then be held upright at a 'lower than cell' level and the finger pressure on the bottle relaxed. This will cause the probe to suck and extract electrolyte until the correct level is achieved. Care must be taken to ensure that whilst the sucking is taking place that some electrolyte is extracted initially, followed by the sucking of air. This indicates that the correct level is achieved even without a visible view of the cell interior.

3.3.2 At not less than yearly intervals test and record the specific gravity of cells. This should be between 1,160 - 1,200. This test should not be carried out on a cell which has been topped-up on the same day.

3.4 Ensure the exterior of the cells are clean and dry.

3.5 Ensure that all cell inter-connectors are secure, using an insulated box spanner to eliminate spark risk. Do not turn the bottom gland retaining nuts which lie beneath the connectors.

3.6 Terminals must be kept lightly greased with petroleum jelly.

3.7 Measure and record the total battery voltage. Measure and record individual cell voltage on a progressive basis as frequently as directed.

3.7.1 If a cell is found to be faulty, it must be replaced. The new cell must have its transit stopper removed and electrolyte level checked. Before installation at site, the cell must be given an initial bench charge in accordance with installation instructions for first charge rates.

3.8 All cases containing cells must always be well ventilated by top and bottom louvres, and must never be completely sealed. Check that the ventilation louvres are not obstructed.

4. CHARGING RATES :

4.1 EXCESSIVE CHARGING RATE results in heavy water consumption, i.e. the electrolyte level drops more than ½" per month and excessive gassing is evident.

4.2 INSUFFICIENT CHARGING RATE results in little or no water consumption.

4.3 The desirable charging rate is indicated by a consumption rate which gives a fall in water level of between ⅛" and ¼" per month.

4.4 If the charger is a Constant Voltage type, it is normally set to give the correct voltage per cell connected, provided that the correct number of cells are installed for the size of the charger. The voltage and charging current rating is pre-determined to suit the battery operating conditions and no adjustments are necessary once in service.

4.5 Where a charger is not as in 4.4, the charging rate must be set to give the minimum charge necessary to keep the battery in a fully-charged state under normal operating conditions, bearing in mind there may be intermittent peak loads.

It is essential the battery is not continually over-charged which produces excessive quantities of explosive gas.

E.P.1./11.6.

01 JAN 1983

# NICKEL CADMIUM ALKALINE SECONDRY CELLS.

## DESIGN CONSIDERATIONS:

Alkaline secondary cells are used in two ways, for which there are different design requirements as follows:-

a. BUFFER BATTERIES
Where there is a guaranteed power supply and batteries are only installed to supply peak current requirements ( e.g. point machines ) they will normally remain fully charged and provide about 1.45 V per cell.

b. STANDBY BATTERIES
Where the batteries act as a 10 hr. standby power supply ( 12 hrs. in barrier applications ), their capacity will be as shown in the table below.

| TYPE | DESCRIPTION | CAPACITY | APPLICATIONS |
|---|---|---|---|
| RE16 | Single crated cell | 16amp.hrs. discharged at 1.6 amps over 10 hrs. | Track circuits, Line circuits, AWS, Electrically lit semaphore signals, Motor operated and Colour light signals, Internal S.Box circuits, |
| RE16 | Five crated cells | " | " |
| RE44 | Five crated cells | 44amp.hrs. discharged at 4.4 amps over 10 hrs. | " |
| DLS4 | Five crated cells | 40amp.hrs. discharged at 8amps over 5 hrs. | Point Machines. |
| RV8 | Five crated cells | 80amp.hrs. discharged at 6.7amps over 12 hrs. | Barriers and other forms of crossings. |

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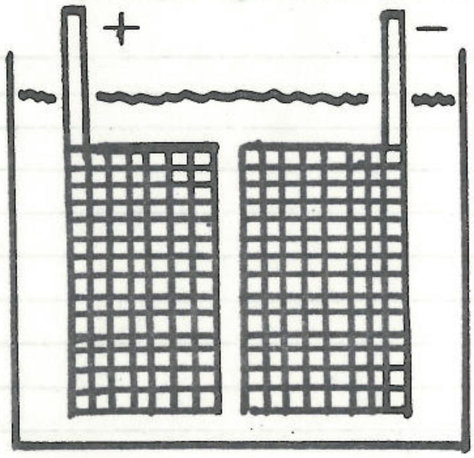
TRAINING SCHOOL. REF. E.P.1./12.1
YORK. 0 1 JAN 1983
COURSE.
SUBJECT. LEAD ACID CELLS

A storage battery cell consists essentially of an assembly or "group" of positive plates and a "group" of negative plates immersed in a solution known as the electrolyte. Between the positive and negative plates are thin, porous "separators" to prevent physical contact between them, and the entire unit is assembled in a suitable jar or container.




In a fully charged lead-acid battery all of the active material of the positive plates is lead peroxide, and that of the negative plates is pure sponge lead. The active material of both positive and negative plates is porous so that it has absorbtion qualities similar to a sponge, and the pores are therefore filled with some of the electrolyte which is a mixture of sulphuric acid and water.

In a fully charged battery, all the acid is in the electrolyte and the specific gravity is at maximum. As the battery discharges, some of the acid separates from the electrolyte which is in the pores of the plates, and forms a chemical combination with the active material, changing it to lead sulphate and producing water. As the discharge continues, additional acid is drawn from the electrolyte and further sulphate and water is formed. As this process continues the specific gravity of the solution gradually decreases, because the proportion of acid is decreasing and the water is increasing.

When a battery is placed on charge, the reverse action takes place. The acid in the sulphated active material is driven out and back into the electrolyte. This return of the acid to the electrolyte reduces the sulphate in the plates and increases the specific gravity of the electrolyte. The specific gravity will continue to rise until all the acid is driven out of the plates, therefore, further charging will not raise the specific gravity higher and the cells are fully charged. In practice it can be considered that on discharge the cell plates absorb acid and on charge they return the acid back to the electrolyte.

As secondary cells approach full charge they cannot absorb all of the energy from the charging current, and the excess acts to break up water from the electrolyte into its two components, hydrogen and oxygen, which are liberated from the cells as gases. This is the main reason for the required addition of distilled water to secondary cells periodically.

The drop in specific gravity on discharge is proportional to the amount in ampere-hours discharged. On recharge the rise in specific gravity as indicated by a hydrometer is not uniform or proportional to the amount of charge (in ampere-hours).

During the early part of the charge there is nothing to mix or stir the electrolyte and some of the heavier acid coming from the plates does not rise to the top of the cell and cannot be reached or read by the hydrometer. During this part of the charge the hydrometer does not represent the true state of charge of the cell. Later in the charge when gassing begins, the electrolyte becomes more completely mixed and the specific gravity rises rapidly. This lag in specific gravity rise does not necessarily mean that the cell is not taking the charge and does not reduce the discharge capacity available.

INSTALLATION

The battery location should be clean, dry and have reasonable ventilation. Cells are usually connected in series, with the positive of each cell connected to the negative of the adjoining cell. The positive terminal of the battery as a whole should be connected to the positive of the charging source and the negative terminal of the completed battery connected to the negative of the charging source. All points of contact should be thoroughly clean and coated with petroleum jelly. Bolted connections should be firmly tight. Each cell should be checked with a voltmeter to ensure that polarity is correct.

The strength of the electrolyte is measured in terms of "specific gravity," which is the ratio of the weight of a given volume of electrolyte to an equal volume of water. Concentrated sulphuric acid has a specific gravity of about 1.835 and that of water (pure) is 1.000. The acid and water are mixed in proportion to give the specific gravity required. For example, electrolyte of 1.210 gravity is about 20% concentrated acid and 80% water, by volume.

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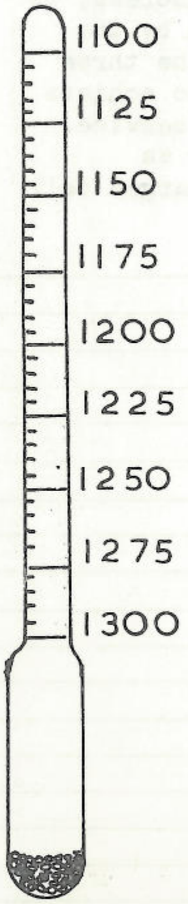
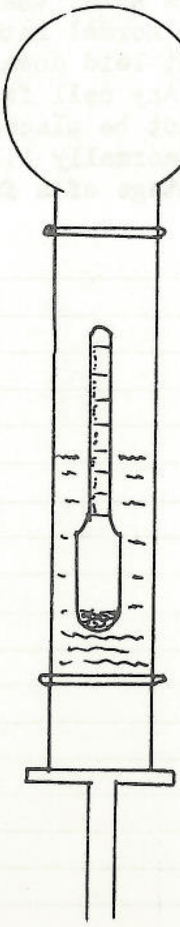
Specific gravity readings are given by a hydrometer. This consists of glass container with a suitably weighted stem, which is calibrated and marked with a range of Sp. Gr's. It works on the principle that it will sink into the liquid to an extent dependant upon the density of the solution. The specific gravity is affected by temperature and the hydrometer reading requires correction if the temperature of the electrolyte is much above or below 25°C (77°F). For an electrolyte of specific gravity 1.220 at 25°C the hydrometer reading would be 1.205 at 50°C (122°F) or 1.235 at 0°C (32°F - freezing point of water). The full charge specific gravity is also affected by the electrolyte level and reads approx. 0.01 high for each quarter inch the electrolyte level is below the upper level line i.e. assume electrolyte level is half inch below upper level line then the hydrometer will read 1.220 although the specific gravity of the electrolyte would be 1.200 if the cell was topped up after the reading was taken. To obtain accurate and comparable specific gravity readings, allowances and corrections for temperature and level of the electrolyte should be applied and the hydrometer carefully read.

The capacity of a lead acid cell is reduced at low temperatures due to the increased viscosity of the electrolyte, but no permanent harm will result if freezing is avoided. An electrolyte in good condition of Sp. Gr. 1.220 at 25°C (77°F) has a freezing point of approx minus 37°C (-35°F) whereas electrolyte with Sp. Gr. 1.170 at 25°C has a freezing point of approx minus 20°C (-4°F). High temperatures sustained for some time above say 45°C (113°F) will considerably reduce the life of the lead acid storage cell.

When it is necessary for the installer (or maintainer) to mix sulphuric acid with water to the specic gravity desired for an electrolyte, the acid must be added to the water. If water is poured into a container of concentrated acid the heat so generated will cause spurts of acid solution to fly off in all directions perhaps causing danger to persons and damage to equipment.



USING THE HYDROMETER & SYRINGE

PROTECTIVE GOGGLES MUST BE WORN.

Remove the cap from a battery cell, squeeze the suction bulb and insert the flexible tube into the cell. Slowly release all pressure in the suction bulb which will allow the maximum volume of electrolyte into the syphon jacket thus ensuring the Hydrometer floats freely at any of the markings between 1.100 – 1.300 Specific Gravity.

Lift the instrument clear of the cell and make certain that the electrolyte in the syphon jacket is free from air bubbles as these can cause an inaccurate reading.

Take readings at eye level. If sighted below eye level an ellipse is observed around the stem of the Hydrometer, lift the eyes until this ellipse disappears and then take the reading. Repeat to ensure accuracy.

Repeat for each cell.

NEVER MIX ACID & ALKALINE
USE CLEAN UTENSILS

Syringes, hydrometers, filling bottles and other containers which have been used on one type of cell should be thoroughly rinsed in clean water before using on the other type.

All types of batteries lose some of their charge during shipment, and while standing idle, therefore, upon installation it should be made certain that the battery is fully charged by giving it a freshening or booster charge. This initial charge should be given before the battery is connected to its ultimate load and should be given for as long as the specific gravity and voltage of any cell show any increase and then for some three hours after the last increase is observed. This charge should be carried out at the normal rate given by the manufacturer. If the charge rate is lower than that laid down then the three hour period should be lengthened proportionately. Any cell failing to achieve maximum specific gravity or charge voltage should not be placed into service. The specific gravity of lead acid storage cells is normally 1.220 (or as recommended by the makers) whilst the "on load" voltage of a fully charged cell is slightly in excess of 2 volts.

**MAINTENANCE**

Regular tests should be made. These consist of hydrometer and voltage readings. The use of the hydrometer has already been covered and for lead acid cells it is important to take readings regularly and frequently as the specific gravity of the electrolyte is a clear indication of the cells condition and whether or not it is receiving a satisfactory charge.

Voltage tests are indicative of the condition of the cell plates establishing that a satisfactory electrical potential is existing between positive and negative electrodes. This test should be carried out with the cell discharging into a load, therefore the charging current must be switched off previously and the cells should have ceased gassing. If it is impracticable to take voltage tests while "on load" conditions exist then a 1 ohm shunt resistance connected across the cell will allow a voltage test to be made with the cell discharging quite heavily. The voltage should be steady for a 10 second period, at approx 2 volts.

It is essential to keep the level of the electrolyte above the plates and topping up should be done with distilled water. Metal containers should not be used for the topping up water and alkaline introduced into a lead acid cell will cause serious damage to the cell. To prevent leakages to earth batteries should be stood on insulating material and location cupboard shelves kept dry and clean. Adequate ventilation is important as secondary cells of all types give off considerable amounts of explosive gases. Naked lights and smoking should be prohibited in battery rooms and cells should not be disconnected while charging or discharging or while the cells are gassing as a spark may cause an explosion.

If cells, either when new or later, are to be put into storage for several months or longer, they should first be given a charge until all cells are gassing and the specific gravity has reached its normal full charge value. Cells should then be stored in as cool and dry a location as possible and must not be placed near a radiator or other source of heat. To properly maintain lead acid cells they should be periodically discharged and charged. A thorough recharge is necessary before returning them to service.

One of the important things to remember for a lead acid cell is that it should never be allowed to remain in a discharged condition for any appreciable time. If allowed to do so, the lead sulphate in the solution will grow on the plates in the form of hard white crystals. This is known as <u>SULPHATION</u>. Abnormal sulphation closes the pores of the active material in the plates and in time will destroy them. When the battery is again placed on charge, after a period of standing in a discharged condition, some of the lead sulphate, instead of changing back to spongy lead or lead peroxide, is dislodged from the plates in small particles and drops to the container bottom as sediment. This active material is lost forever. In normal operation all lead acid cells shed a small amount of active material from the positive plates.

REMEMBER

(1) Do not overcharge lead acid cells.

(2) Do not undercharge lead acid cells.

(3) Do not allow lead acid cells to stand in a discharged condition

(4) Do not allow the electrolyte in a lead acid cell to fall below plate tops.

(5) Carry out regular hydrometer and voltage tests on lead acid cells.

Storage battery cells are rated by three measurements

(a) VOLTAGE:- The voltage of a battery depends on the number of cells and the voltage of each cell used and is NOT dependent of the size or capacity of the cells.

(b) CURRENT:- The current that a battery will deliver depends upon the total area of the plates comprising a cell, the internal resistance of the cell and connections, and the rate at which the chemical reaction takes place.

(c) CAPACITY:- The capacity is a current-time rating and is measured in ampere-hours. This capacity is determined by multiplying the amperes of current the battery will deliver by the number of hours it will deliver it to a predetermined limiting voltage at a rooms nominal temperature. The lower the temperature, the lower the available capacity. Thus, a battery capable of delivering 5 amperes of current to the limiting voltage for 8 hours has a rating of 40 ampere-hours.

C S & T E DEPT.
TRAINING SCHOOL.
YORK.

REF. E.P.1./13.1.

COURSE. Electrical Principles.1. 0 1 JAN 1983

SUBJECT. Charging of Secondary Cells.

Storage batteries can be recharged after being discharged partially or fully. The elements of a storage cell are never renewed except due to breakage or spilling of the electrolyte. To charge a cell it is necessary to pass direct current through a cell in the direction opposite to that in which the current flows when the cell is discharging. For charging, it is necessary to have a source of direct current available. The source must usually employed in railway signalling is a rectifier which receives its power from an A.C. supply and delivers D.C. for use in charging circuits.

There are several different methods of charging batteries :-

## First Charge Rates for Nickel Cadmium Cells.

Charge for 10 hours at the appropriate rate for the type of cell required.If lower charging currents are used the charging time has to be increased proportionately.

| RE16 | RE44 | DLS4 | RV8 |
|---|---|---|---|
| 4 amps average | 11 amps average | 10 amps average | 20 amps |

(1) FRESHENING OR INSTALLATION CHARGE

All types of batteries lose some of their charge during shipment and while standing idle. Before installation of a battery can be considered as completed, the battery should receive a freshing charge.

This charge for lead acid cells should be continued until all cells show no further increase in specific gravitiy and then for three hours more, if the normal charge rate is used. If the charge rate is lower than the manufacturers recommended figure then the 3-hour period should be lengthened in proportion.

The charge for nickel-cadmium(NIFE)alkaline cells requires to be continuous until the voltage on all cells in the battery is constant on discharge through a 1 ohm. shunt resistor for 10 secs.

At the end of this pre-installation charge a record should be taken of specific gravity, voltage, temperature readings and electrolyte level for future comparison with later readings.

BRITISH RAILWAYS

BR 13286/2

SIGNAL ENGINEER'S DEPT.

SECONDARY CELL RECORD CARD

Signal Box ..........

Location ..........

Nature of Load ..........

* Track Circuit, Colour Light Signal, Point Machine, etc.

Cell No. ..........

Make ..........

Type ..........

Capacity .......... Ah. at .......... hour rate

Date installed ..........

| Volts (Power on) | Volts (Power off) | Charging Current | Specific Gravity | REMARKS * | Date | Lineman's Initials | Inspector's Initials |
|---|---|---|---|---|---|---|---|
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* To include adjustments to charging current, any changes in appearance of plates, amount of gassing, sediment, topping up, etc.

Note. This sheet to be returned to Inspector when filled, or when cell is taken out of service. BR. 13286/2

(2) FLOATING CHARGE

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The term "floating" can be applied to three general methods of charging, namely, "Full Float", "Modified Float" and "Average Current Float".

(a) FULL FLOAT means maintaining a constant voltage at the battery terminals which allows enough current to flow through the battery to offset local action losses in each cell and also carry the entire load. The current value will vary with the needs of the battery and the load requirements. The voltage, however, will remain constant at the preset value, preferably that recommended by the cell manufacturer. With a full float system, the rectifier must be of a size to handle the maximum loads.

The battery will never discharge except when a power failure occurs, then the battery will carry the entire load until the power is restored.

Definition.

Floating battery.

A battery which is constantly connected, on the one hand to a discharge circuit which it supplies, and on the other hand to a charging circuit set so that the mean charging current compensates for both discharge quantities.

(b) MODIFIED FLOAT System is similar except that the rectifier unit is not capable of dealing with the maximum load condition. The battery carries any load in excess of the rectifier capacity. The rectifier will not be damaged as it will protect itself by lowering its voltage output. When the load is reduced or terminated, the rectifier will supply charging current to the battery in proportion to the state of discharge, starting at a high rate and tapering off as the charge progresses until the battery is fully charged. At this point the current to the battery is just sufficient to maintain the recommended float voltage per cell. The amount of current necessary to produce this voltage per cell will vary with temperature, age and general cell conditions.

Buffer battery.

A battery of secondary cells connected across a D.C. supply in order to diminish variations of the voltage and the current supplied by the main supply.

(c) With the AVERAGE CURRENT FLOAT method of charging a constant current rectifier is normally used. The battery discharges during the load periods and the rectifier unit charges the battery during the idle period. The rectifier output is set to equal the 24 hour discharge in empere-hours plus the local action loss of the battery. This method works well when the rectifier output is adjusted properly and the load averages the same from day to day. If the load changes, the battery will either be overcharged or undercharged, depending on whether the load decreases or increases, unless the rectifier output is also changed by manual adjustment.

(3) TRICKLE CHARGE

Trickle charge in signalling applications refers to the current requirements to compensate for the cells internal losses only. For example, suppose it is desired to hold in reserve a battery which must be ready for immediate use. In order to maintain the battery in a fully charged condition at all times it is necessary to continually charge it at a rate that will just make up for the internal losses only. This rate is called the "Trickle Rate". In trickle charging, the battery is usually connected only to the charging circuit and is connected to the load circuits through a power-off relay when the regular source of power fails or becomes overloaded.

Trickle charge.
A steady charge with a very small current so as to compensate for losses, due to local action, allowing the battery to always be in a fully charged state.

## (4) TWO-RATE CHARGE

In certain signalling installations the load is irregular and varies over wide limits. For example, at auto half-barrier and level crossing boom gate or full barrier installations. Since such a variable load makes it difficult to maintain the battery in a fully charged condition and not over-charge it excessively, a method of charging, called "Two-Rate Charging" is employed. It involves the use of a relay to control the output of a rectifier so that normally the relay is energised, and a low rate of charge is delivered which is sufficient to supply the internal losses of the battery and any steady connected load.

When the relay is de-energised due to the battery being called upon to deliver additional current, a high charge rate is automatically applied and this rate continues until the battery voltage reaches its fully charged value, when the relay will again be energised and restore the low charge rate.

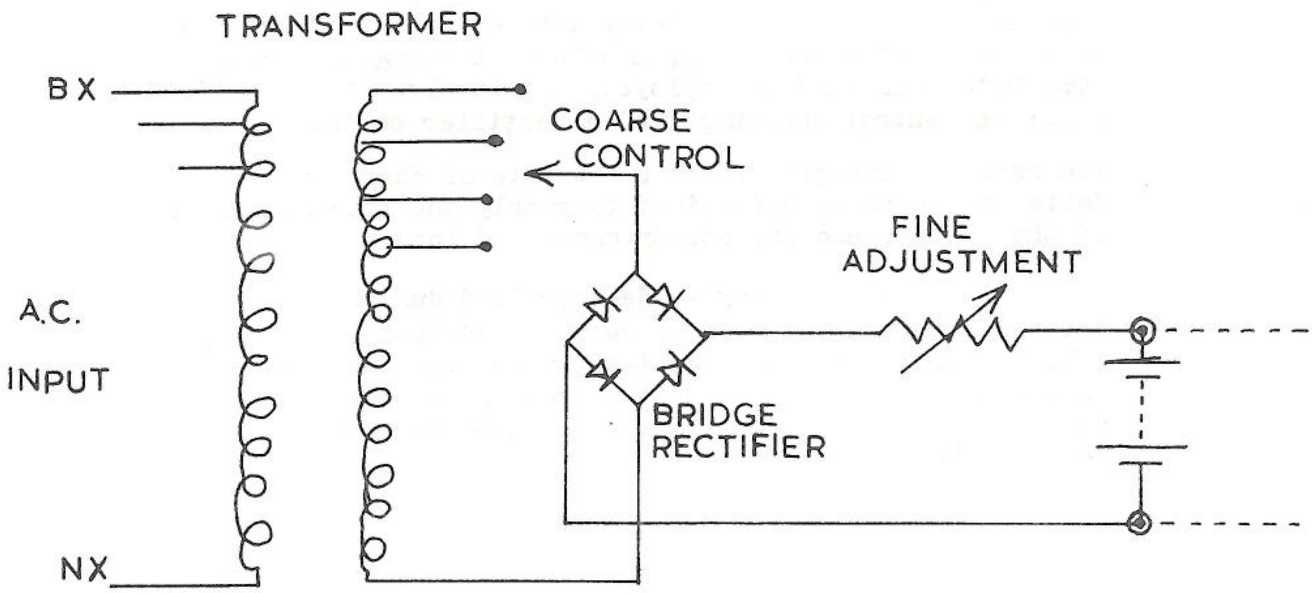
NOTE (1) All these charging methods aim at the maintaining of an average voltage under steady conditions. Normally the individual cell voltages should be for (a) Lead acid types :- 2.0 volts to 2.2 volts maximum. (b) Nickel cadmium types 1.4 volts to 1.45 volts maximum.

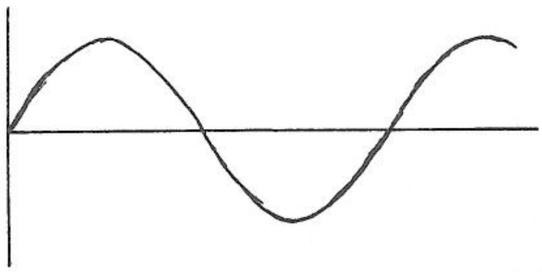
NOTE (2) The charging current required to compensate for the internal or local action losses of a secondary cell should be calculated at a minimum of 1 milliampere per ampere-hour of the cells rated capacity, i.e. a cell rated at 50 A.H. would require a charging current of at least 50 milliamps to compensate for local action losses. As the cells deteriorate over the years then it may be necessary to increase this figure.

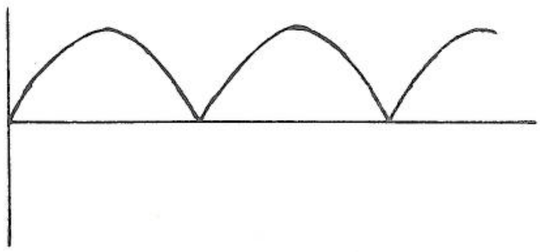
E.P.1./13.6.

0 1 JAN 1983

TYPICAL BATTERY CHARGER





C S & T E DEPT.
TRAINING SCHOOL.
YORK.

REF. E.P.1./14.1.

01 JAN 1983

COURSE. Electrical Principles.1.

SUBJECT. Power Supplies, Safety Precautions.

Safety Precautions to be observed at all times.when working with Secondary cells.

a. Goggles Must Be Worn when dealing with cells.

b. Keep batteries upright.

c. Ensure there is good air circulation to disperse any accumulation of gas before starting work.

d. Do not smoke or permit naked lights near batteries or do anything likely to cause sparks near a battery.

e. Do not allow metal objects to rest on the battery or fall across the terminals.

f. When mixing or handling electrolyte goggles and rubber gloves must be worn.Do not spill electrolyte on the skin or clothing.

Accidental Skin Burn or Electrolyte in the Eyes.

Skin Burns:- Wash liberally with clean water.

Electrolyte in the Eyes:- Immediately use the eye wash bottle or wash out thoroughly with clean water.The filler bottle should not be used for this purpose.

Electrolyte on Clothing:- Immediately remove the contaminated clothing.

All the above instructions are contained in a Safety Notice,as shown below and a copy of the notice must be prominently displayed in battery rooms.

## BATTERY CHARGING PRECAUTIONS

## Prevent Explosions

Ensure that there is a good circulation of air to disperse any accumulation of gas before starting work.

Never smoke or use naked flames in the battery charging area.

Do nothing that may cause a spark:

- never tighten or loosen connections while cells are on charge or discharge or gassing.
- keep all connections tight using an insulated spanner.
- keep other metal objects away from the tops of batteries.

## Avoid Injury from Electrolyte

Wear protective clothing and eye protection. If electrolyte splashes —
in EYES: Immediately use eye-wash bottle or wash out thoroughly with water.
on SKIN: Rinse liberally with water.
on CLOTHING: Immediately remove contaminated clothing.

## Don't Spill Electrolyte

but if you do so accidentally, swill down the spillage immediately with plenty of water—BUT NEVER DO THIS IN SUB STATIONS WHERE THERE IS HIGH TENSION ELECTRICAL EQUIPMENT.—Report the situation and obtain advice.

E.P.1./14.2.

01 JAN 1983

Instruction SM 12 section 3.3 states:-

"Switch off the battery charger and allow air to circulate so that any accumulation of gas can disperse.
(Ensure air circulation by wafting or fanning where no motion of air is apparent )."

The instruction requires the battery charger switched off for two reasons

1. From a safety angle ,gassing will be reduced whilst maintenance work is carried out.

2. The bank of cells will supply the load current and any faulty cell will be detected when the cells are tested.

It must be realised of course that the battery charger must be switched on again to check charging current and before leaving the Location/Battery Room.

Safety Precautions to be observed when working with Primary Cells.

Both the 618 & 608 type Inert cells use Caustic Soda as the electrolyte so the following precautions need to be taken.

Always ensure the cell is kept upright when being transported,stored or is in service.Cells in service must be well ventilated.

Caustic Soda and its solutions coming in contact with skin or eyes can cause serious burns.Goggles must be worn.

If caustic soda comes into contact with skin or eyes wash thoroughly with clean water.

Remember. Batteries are no more dangerous than any other equipment as long as they are handled correctly.

01 JAN 1983

Safety Precautions to be observed when working on Power Supplies.

Railway signalling utilises power supplies at various voltages, a typical voltage of 650V being used considerably when feeding from power cubicles to apparatus cases located alongside the track.

Power supply cubicles, disconnection links etc. connected to a 650V supply should have prominent labels displayed stating or indicating that the equipment is connected to a High Voltage scource. Transformers or other equipment having exposed terminals should be fitted with insulated protective covers. Individual terminals can be fitted with insulated sleeves and insulated nuts to give the required protection.

If it becomes necessary to have to work on live equipment it is essential that rubber gloves suitable for High Voltages are used in conjunction with a rubber mat and any tools used are insulated.
Rubber gloves and mats can be found in relay rooms etc. where power supply cubicles are installed. The rubber gloves are marked on the cuff with the year of manufacture, month and size and that they are to be tested in accordance with BS 697.
Replacement tested gloves are provided on a regular basis.