

ELEKTRON

ELECTRICAL EXPERIMENTS



INSTRUCTIONS

FOR

No. 1 OUTFIT

Price 1/-

MECCANO LIMITED, BINNS ROAD, LIVERPOOL 13.



ELEKTRON

ELECTRICAL EXPERIMENTS

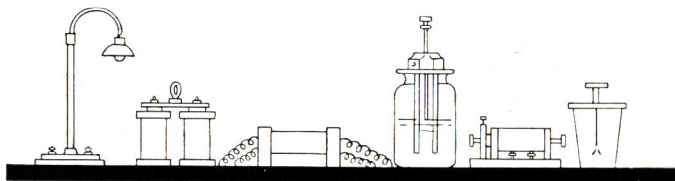
Electricity is being employed on an ever-increasing scale for heating, lighting, driving machinery, and many other purposes. The Elektron Outfits have been specially designed to show, by a series of fascinating experiments, how this wonderful power is generated, transmitted, and put to work to serve our everyday needs.

With the No. 1 Elektron Outfit you can explore the marvels of magnetism, map out the tracks of magnetic forces, and learn of the wonderful properties of the mariner's compass. It enables you also to carry out experiments in Electricity produced by friction, and to realise the enormous energy behind Nature's awe-inspiring displays in thunderstorms.

The No. 2 Elektron Outfit completes the scheme commenced in the No. 1 Outfit. It deals with the electric current, and explains the working of electrical apparatus of all kinds, ranging from electric bells to dynamos and electric motors.

To get the greatest fun from your Outfit, you should read the "*Meccano Magazine*," special articles in which link up with the Elektron Outfits, and describe new and interesting experiments in all branches of Electricity. The "*Meccano Magazine*" is read by over 100,000 boys every month. It is published on the 1st of the month and may be ordered from any Meccano dealer or newsagent.

MECCANO LIMITED
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Magnesia

Natural Magnet

Artificial

Part II. p.12 - Frictional Electricity - Elektron Electrical Experiments

I

Part I. MAGNETISM

The story of magnetism began long ago with the discovery that a certain kind of iron ore has the power of attracting pieces of iron, and of setting itself in a north and south direction if suspended freely. The Chinese seem to have been familiar with this ore in very early times, and as far back as 1,000 B.C. they made use of it to guide their caravans across the plains of Tartary. A crude form of mariner's compass was certainly used by the navigators of Chinese ships that made voyages to India between A.D. 265 and 419. Indian and Arab seamen probably learned the secret from the Chinese, and through them knowledge spread to the West.

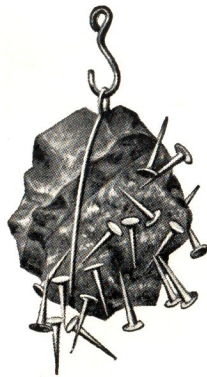


Fig. 1. Lodestone that has been dipped in a heap of tacks.

This remarkable ore, which was called the "LODESTONE" or "STONE THAT GUIDES," was well known in certain parts of Europe long before the compass came into general use in the West. It was found in large quantities in Magnesia in Asia Minor, and the word "magnetism," which is now used to denote its peculiar power, is said to be derived from the name of this province.

The lodestone is a natural magnet, but it is not very convenient for experimental use. Fortunately, artificial magnets more suitable in shape and in other ways may be made without difficulty. If a bar of steel is rubbed several times in the same direction with one end of a piece of lodestone, the steel acquires the lodestone's properties of attracting pieces of iron and steel and turning to the north if free to do so. The steel has thus become an artificial magnet, and as the lodestone does

not lose any of its own magnetism in the process, we are provided with a means of making any number of such artificial magnets. A bar of iron can be magnetised in a similar manner, and is easier to magnetise than steel; but it soon loses its magnetism, whereas steel retains it. The harder the steel the better it retains its magnetism, and so artificial magnets are made of specially hardened steel.

Bar and Horseshoe Magnets

TWO BAR MAGNETS (Part No. 1505), of hard steel are included in the Elektron Electrical Outfit, and with them many interesting experiments may be carried out. If you try to pick up needles, pen nibs, or other small pieces of iron or steel with one of them, you will find that the objects are attracted only at the ends of the magnet, the middle having no effect whatever. The same curious property of the magnet can be shown by rolling it in iron filings poured out on a sheet of card or paper. (A supply of these filings is contained in the glass tube included in the Outfit). The filings cluster thickly at

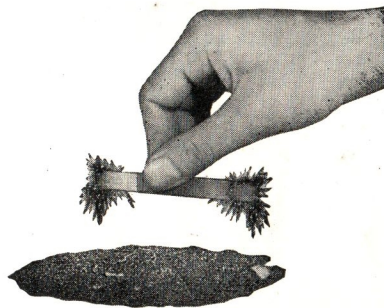


Fig. 2. Attractive power of magnet concentrated at its poles.

the two ends of the Magnet, but few or none are attracted by the middle. The two ends are known as the poles of the Magnet.

There is also another familiar form of magnet made in the shape of a HORSESHOE. If a magnet of this type is tested with iron filings it will be found that these cling thickly round

NB.

BAR.

pick up

ends middle

filings

ends middle

Horseshoe filings

Elektron Electrical Experiments

the ends, none being attracted by the curved portion, showing that the horseshoe magnet resembles the bar magnet in possessing two poles. A Horseshoe Magnet of convenient size is included in the Outfit (Part No. 1507).

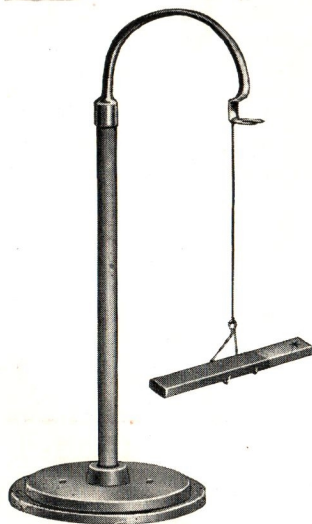


Fig. 3. A suspended magnet points north and south.

An interesting thing about magnetism is that its invisible power can pass through solid substances. This is illustrated in an amusingly simple way by sprinkling iron filings on a sheet of cardboard or glass and moving one end of a Bar Magnet slowly about underneath the card. The filings respond in a comical manner to the magnetic influence and seem to stand up and to march about like a company of soldiers.

Magnets Look to the North

To test the north-pointing properties of one of our Bar Magnets, we suspend it so that it is free to turn, and for this purpose we use the stand shown in the accompanying illustration. The Erinoid Tube (Part No. 1509) is fitted into the central hole of the Circular Base (Part No. 1508), and the Stand Bracket (Part No. 1510) is placed on top of it. The Brass Stirrup (Part No. 1511) is then

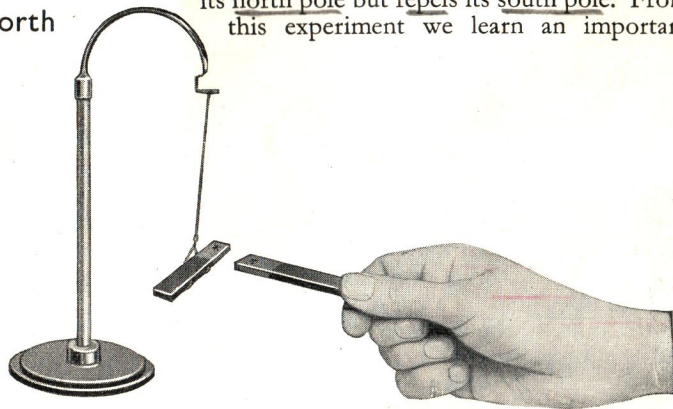


Fig. 4. The north pole of a suspended magnet is repelled when a similar pole of a second magnet is brought towards it.

hung from the end of the Stand Bracket by means of a length of silk thread from the Reel (Part No. 1518).

The Bar Magnet fits comfortably in the Brass Stirrup, and a few trials will enable a balanced position to be found for it (Fig. 3). At first it swings round, but soon it comes to rest with one end pointing to the north. (No matter to which point of the compass the Bar Magnet is turned, it will always return to this north-and-south position when left free. It is always the same end of the Bar Magnet that points to the north; and this end is called the magnet's north pole, the opposite end being its south pole.

"Likes" Repel and "Unlikes" Attract

If we suspend one of the Bar Magnets in the Brass Stirrup as already described, and in turn bring near each end a needle or other piece of unmagnetised iron or steel, we find that both ends of the magnet are attracted. Repeating the experiment, but using the other Bar Magnet instead of unmagnetised steel, the result is surprisingly different. The north pole of the magnet we are holding attracts the south pole of the suspended magnet, but repels its north pole (Fig. 4). If we hold the south pole of our Magnet towards the suspended magnet, it attracts its north pole but repels its south pole. From this experiment we learn an important

NOTE - Erinoid Tube does not acquire electricity! see p. 12.

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principle : that opposite poles—one north and one south—attract one another, and that similar poles—two norths or two souths—repel each other.

Contact

One of the favourite experiments with a magnet is to suspend a chain of needles or Meccano Nuts from one of its poles, adding them slowly and carefully one by one to see how many the magnet will sustain. An interesting variation of this experiment is to make a loop of nuts by suspending a chain of them from each pole of a magnet and gently bringing their ends into contact (Fig. 5). As the nuts used were not previously magnetised, these experiments show that the nut actually brought into contact with the magnet immediately becomes a magnet itself, and that the power of attraction is passed on to each nut added to the chain.

Induced Electricity
P.M.

Induced Magnetism

There is an easy way of testing this by suspending a large nail or a piece of soft iron from one end of the Bar Magnet, and dipping its lower end into a heap of filings, and then lifting it away. It will be found that a bunch of filings clings to it, showing that it has become a magnet. If now we hold the nail in one hand and gently detach the magnet from it with the other, the filings immediately fall off, showing that the nail has lost its magnetic power.

It is not necessary actually to touch a nail or a piece of soft iron with a magnet in order to confer temporary magnetic powers upon it, for it acquires these when a magnet is held near it. This is

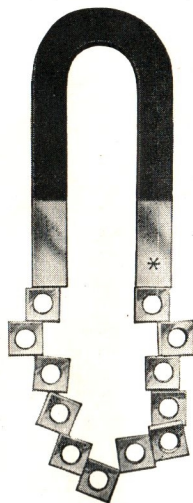


Fig. 5. A loop of Nuts held together by magnetic attraction.

shown by the experiment illustrated in Fig. 6, and the process by which temporary magnetism of this kind is produced is called MAGNETIC INDUCTION.

Near.

If iron filings used in our experiments become scattered, the natural thing to do is to pick them up with the magnet. This is quite easy, but trouble arises in persuading the magnet to part with them, and much scraping and pulling is necessary. This can be obviated by collecting the filings by means of a piece of soft iron hanging from a bar magnet, and therefore temporarily magnetised (Fig. 7). If the collected filings are then held over the container, they will be released and

Hanging From magnet

will fall neatly into it as soon as the magnet is taken away from the iron.

Tapping or opposite Pole!

How to Make Magnets

Exactly as a piece of iron or steel can be turned into an artificial magnet by stroking it with a piece of lodestone, so can magnets be made with one of the Bar Magnets included in the Outfit. A medium-sized sewing needle makes a convenient piece of steel for the purpose, but it should first be tested with filings, to make sure that it is not already magnetic. Next, the needle is laid on the table and the north pole of the Bar Magnet is drawn slowly along it from eye to point (Fig. 8). This operation is repeated several times, care being taken to draw the magnet well beyond the point of the needle before bringing it back to the eye. Another test with filings will show that the needle has become a magnet.

eye to point



Fig. 6. A nail becomes a temporary magnet when held near a pole of a Bar Magnet.

It will be interesting now to find out which is the north and which the

Magnetised Iron filings (undisturbed) will stick to non-magnet, as it can't stick to them.
Non-magnetised will stick to either pole anything magnetic. (See p. 2)

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south pole of the needle, making use of the suspended Brass Stirrup for the purpose.

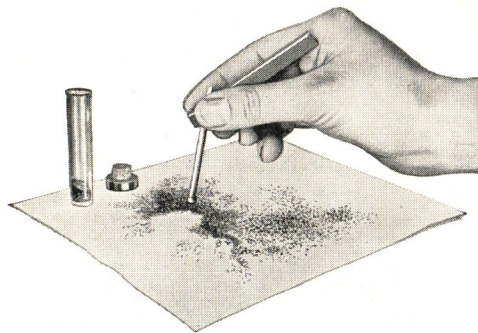


Fig. 7. Collecting scattered iron filings by means of a large nail.

It will be found that the needle sets itself with its point directed to the south, so that the eye end is evidently its north pole. As the needle was stroked with the north pole of the Bar Magnet, it is clear that in making a magnet the pole formed at the end of the needle where the stroke begins is similar to the pole of the magnet used, and that the pole produced at the end of the stroke is of the opposite kind. This is easy to test by magnetising a second needle with the south pole of the Bar Magnet instead of the north. Another way to show the same thing is to use the north pole of the Bar Magnet, drawing it along the needle from point to eye, thus producing a north pole at the pointed end.

Magnetic Screwdrivers

To the beginner it is always very surprising to discover how many iron and steel articles are already magnetic to some extent, and it is interesting to investigate some familiar household articles in this respect. Often it will be found that a pair of scissors, a penknife blade, or a

screwdriver attracts iron filings, but as a rule the attraction is only very feeble, for magnets of this kind are always weak. In most cases such articles are none the worse for being magnetised, and sometimes their efficiency actually is increased. A case in point is the magnetic screwdriver, which is capable of picking up small iron or steel objects such as screws, bolts, or nuts, and of retrieving them from cracks and corners in which they are difficult to reach. Meccano model-builders find a magnetised screwdriver a great help in picking up a nut or a bolt that has dropped into an awkward position.

Any screwdriver can be made into a sufficiently strong magnet by stroking its blade from end to end with a bar magnet in the manner we have already described.

A so-called PERMANENT MAGNET tends to lose its magnetism gradually unless precautions are taken to prevent this. The usual method is to place a piece of soft iron, known as a keeper, in contact with poles of opposite kinds. With bar magnets this involves keeping them in pairs, separated by a piece of thin wood or card, with unlike poles adjoining and a piece of soft iron across the poles at each end (Fig. 9). With a horse-shoe magnet all that is necessary is to place the iron keeper across the two ends (Fig. 10).

See neutralise p. 10 -

Magnets Dislike Rough Treatment

Violent handling of any kind is harmful to magnets, and it is easy to show that this is the case. Magnetise a steel needle by stroking it repeatedly in one direction with one of the

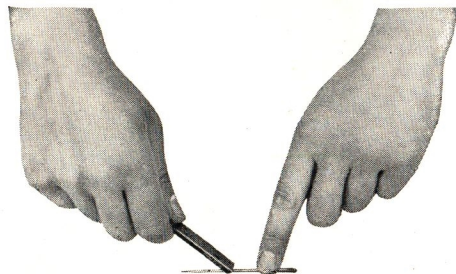


Fig. 8. Magnetising a needle by means of a Bar Magnet.

poles of a Bar Magnet and test its power of attraction by the amount of filings it will pick up. Then throw down the needle violently several times on stone or concrete and test it again. It will be found that the rough treatment has caused

(NB)

Slam on - Weaken.
Pulling suddenly - Helps maintain.

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it to lose some of its power. Allowing a keeper to slam violently on to a magnet will rapidly weaken the magnet, but curiously enough, pulling a keeper off suddenly has just the opposite effect, and actually helps to maintain the powers of the magnet.

Secrets Revealed by Magnetic Maps

Genl. dir. in which forces act = $\angle OMF = \text{field F}$

In order to find more exactly how magnetic forces act, lay a Bar Magnet on the table and over it place a thin sheet of glass, or a card as thick as a postcard. The bottom of the flat box that contains the smaller parts in the Outfit is bored with several small holes. Remove

the contents of the box and pour iron filings into it; then shake the box gently over the card so as to sprinkle the filings evenly and thinly over the whole of its surface (Fig. 11). Now tap the card gently with the end of a pencil, or with one of the Rods included in the Outfit. A remarkable transformation immediately takes place, for the filings arrange themselves in lines radiating outward in all directions from the poles and forming a beautiful regular pattern (Fig. 12).

A pattern formed in this manner is known as a magnetic map, for the filings show the general direction in which the forces act, and the lines marked out by them are spoken of as LINES OF MAGNETIC FORCE. Tapping helps the filings to take up positions in obedience to the magnetic force by causing them to jump up from the card, thus temporarily freeing them from the effect of friction.

- 1/4 Plate or 1/2 Plate -

It is great fun to make a series of photographs of magnetic maps, and this is easily done in a room lighted only by ruby light. The magnet or magnets are laid on the table in the desired arrangement, and a photographic plate is placed over them, film side up. Quarter-plates ($4\frac{1}{4}$ in. by $3\frac{1}{4}$ in.) will do

fairly well for the purpose, but more complete maps may be obtained if half-plates ($6\frac{1}{2}$ in. by $4\frac{3}{4}$ in.) are employed instead.

Filings are sprinkled evenly over the plate, which is then gently tapped to enable the filings to arrange themselves in accordance with the magnetic forces acting on them. A lighted match is then held a few inches above the centre of the plate, where it illuminates the sensitised film evenly, allowed to burn up

brightly, and blown out. The plate is now tilted to allow the filings to fall off, and tapped gently on its lower edge to make sure that none of them cling to it. Develop-

ment in the ordinary way gives a negative from which splendid prints may be made, showing the directions of the lines of force.

Another Method of Map Making

Magnetic maps may be made also with the sensitised paper known as gaslight paper, which does not necessitate working by ruby light. A piece of this is laid on a sheet of thin card resting on the magnet. Iron filings are then sprinkled directly on the sensitised paper (in the manner already described), and are made to arrange themselves along the lines of force by gentle tapping, a single light tap usually being sufficient. A longer exposure to light is required than in the case of a photographic plate. A negative print is obtained in this manner, and a positive may be made from it by placing a second sheet of sensitised paper on it, with

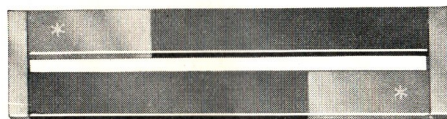


Fig. 9. How keepers are placed on Bar Magnets not in use.

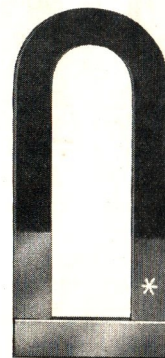


Fig. 10. Horseshoe Magnet

Too light
wt. To
scratch
surface?
Match.

Develop
Print.

No
Ruby
reqd.

(NB)

Fix
Print

evenly
thinly

Ruby

Customary To regard Earth's N. Pole as possessing South Magnetism. —

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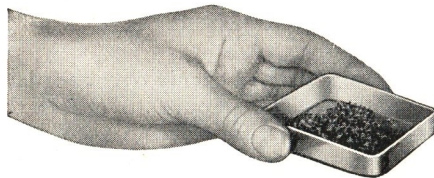
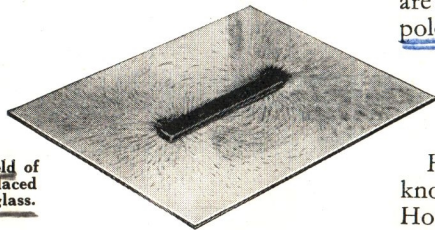


Fig. 11.
Mapping the Field of
a Bar Magnet placed
under a sheet of glass.



the film sides in contact, and repeating the exposure and development. The accompanying illustrations of magnetic maps were made in this manner, using "Velox V.G.3" paper. The exposure was made by means of a flashlamp with a $3\frac{1}{2}$ v. bulb, moved about at a distance of about 12 in. above the paper for a period of 10 seconds.

Fig. 13 shows the direction of the lines of force between two unlike poles, one north and the other south. The lines seem to stream across from one pole to the other, and they help us to understand how it is that two unlike poles attract one another. Fig. 14 shows the result obtained from two similar poles—that is two norths or two souths. Here the lines do not stream across from pole to pole, but turn aside as if pushing each other away, showing us how two similar poles repel one another.

Many other interesting maps may be made with different arrangements of the Bar Magnets, and with the Horseshoe Magnet by itself or in combination with the Bar Magnets. The introduction of pieces of soft iron into various positions near the magnets also gives many curious designs.

The Earth a Giant Magnet

Our experiments have shown us that a suspended magnet always comes to rest in a north and south direction—in fact, it behaves as though it were under the influence of another magnet. This is actually the case, for the Earth itself is a giant magnet (with a north and a south pole that act on our suspended magnet.) The Earth's magnetic poles are not at the same points as its geographical poles, the north magnetic pole being in Northern Canada and the south magnetic pole in Victoria Land, in the Antarctic Continent.

Here we come to a curious problem. We know that similar poles repel one another. How is it, therefore, that the Earth's north magnetic pole attracts, instead of repelling, the north pole of a magnet? [One or other of these poles must actually possess south magnetism, and it is customary to regard this as being the case with the Earth's north magnetic pole.] All confusion disappears if we think of the north pole of a magnet as being a north-seeking pole, and its south pole as a south-seeking pole. N. Pole of mag. does not seek N. Pole of another magnet. of Earth.

Magnets Help Sailors

A bar magnet suspended so that it is free to set itself north and south forms a compass. Many forms of this instrument have been designed, and one of these is included in the Elektron No. 1 Electrical Outfit. It is in

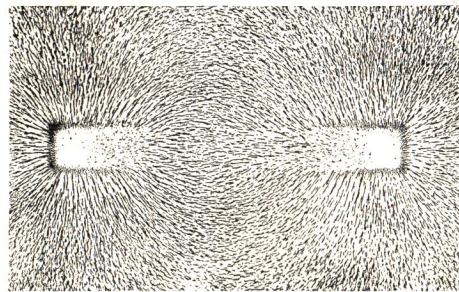


Fig. 12. Lines of Force of Bar Magnet.

med. nails - not large enough apparently. (mag. or illum.?)

Compass Box appears to be non-ferrous metal e.g. Copper (Zinc-Lead?).

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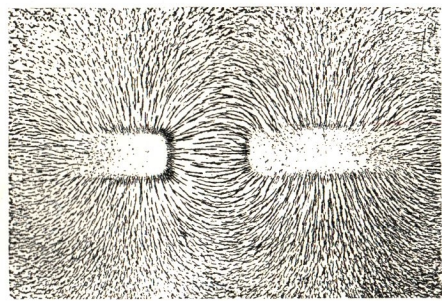


Fig. 13. Lines of force between opposite poles of two magnets.

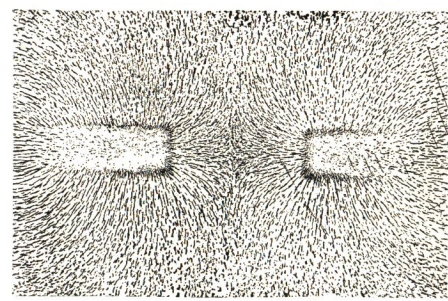


Fig. 14. Lines of force between similar poles seem to push each other away.

Needle Compass.

two parts, a Compass Needle (Part No. 1503) consisting of a small magnet with pointed ends, and a Compass Box (Part No. 1501) at the bottom of which is a Brass Slide fitted into brackets and supporting a finely-pointed pivot. At the centre of the Compass Needle is a tiny cup, and when this is placed over the pivot the needle is balanced and free to set itself north and south. The accompanying illustration shows the Elektron Compass assembled and correctly adjusted (Fig. 15).

Card does not rotate - only needle.

At the bottom of the Compass Box is a card on which the points of the compass are marked, lines being drawn from the centre of the Box to indicate North, South, East, West and other directions. In order to use the Compass as a direction-finder, the Compass Box is turned round slowly until the needle is exactly over the line on the card that has an arrow-head, indicating north, at one end, and the letter S, indicating south, at the other. It is then easy to see in which direction any other point of the Compass is situated.

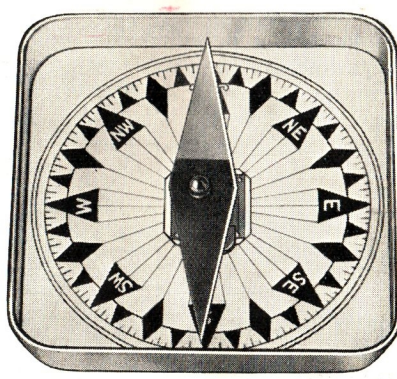


Fig. 15. The Elektron Compass.

Compound Needle Compass

A special kind of compass has been designed for use on ships. Instead of a single needle this has a compound needle consisting of several slender strips of magnetised steel, attached to a circular card of semi-transparent paper mounted on a light aluminium framework (Fig. 16). The card and the compound needle together weigh only a fraction of an ounce, and they are delicately pivoted on a point supported in a copper bowl. In order that this bowl may retain its horizontal position, no matter how the ship may be rolling, it is supported on gimbals consisting of two concentric rings attached to horizontal pivots and swinging on axes that are at right-angles to one another.

There are also liquid compasses, in which the card floats on the surface of some such liquid as (dilute alcohol). 2 pint. b. - 1 alc.

Steering by Compass

Inside the bowl and above the card is a mark known as the "lubber line." This indicates the centre line of the ship, and the steersman must keep the bearing given

Needle
Metal Box
Brass Slide
Brackets
Pivot
Cup

Box
Turned
until
Needle
over N
on Card.

any
other

you could set div. refd. against fore raft line of ship, & then keep needle pointing to N. pt. of Card.

dumb Card.
Metal Box cause آهن.?

Rice
Paper
Fraction
oz. wt.
Defn.
Gimbals
or pitching

?

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to him directly on this mark. For instance, if he is told to steer due West by compass, he must manipulate the steering wheel in such a manner that the point marked W points

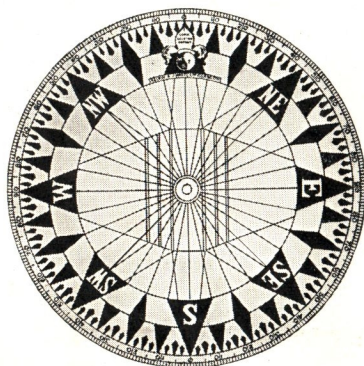


Fig. 16. Card of mariner's compass, which has several strips of steel instead of a single needle.

directly to the lubber line. He then watches carefully to detect any slight swing of the card that would take this mark away from the line, and turns his wheel as may be necessary to bring the mark back again into position.

We have already seen that the Earth's magnetic poles are not at the same points as its geographical poles, and therefore the compass needle does not point exactly to the geographical north and south. A navigator who followed exactly the indications of his compass would therefore be wrong in his geographical direction. For instance, if he were to steer westward by compass across the Atlantic Ocean from Land's End in order to reach the mouth of the St. Lawrence River, he would probably end up as far astray as the West Indies, for on the Atlantic Ocean the compass points west of north. On the west coast of America the opposite is the effect, the compass pointing east of north.

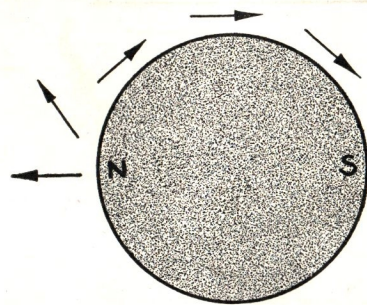
True North and Magnetic North

The difference between true north and magnetic north, called "DECLINATION," varies at different places. If the compass is to be

a reliable guide, this difference must be known accurately at as many places on the Earth's surface as possible, and large numbers of measurements of declination have been made both on land and sea. Magnetic measurements at sea are made in special vessels constructed almost entirely of wood, for the presence of iron or steel would disturb the magnets employed. From the surveys made by these vessels a world magnetic map has been prepared, and from this navigators know exactly how much to allow for declination, wherever they may be.

Magnetic Dip

The suspended Bar Magnets and the Compass Needle are free to swing only in a horizontal direction. If a magnetised needle is suspended so that it can swing vertically as well as horizontally, it not only comes to rest in a north and south position, but at any place north of the Equator it tilts with its north-pointing end downward. If the needle is taken to a place south of the Equator it tilts in the opposite direction with its south-pointing end downward. Exactly at the magnetic equator the needle would not tilt at all, for the influence of the Earth's two magnetic poles would be equal; and if the needle were placed immediately over either magnetic pole, it would take up a vertical position. This tilting, known as "MAGNETIC DIP," is due to the fact that the Earth is a sphere, and Fig. 17 clearly shows how it is caused.



In practice it is the opp. way round - as N. Pole of Earth has South Magneticism.

Fig. 17. Diagram showing why one end of a compass needle balanced on a horizontal axis dips owing to the attraction of the Earth's magnetic poles.

All ferrous metal is made up of particles of iron or steel with N. or S. Poles mixed up - which neutralise ea. other -
 When magnetised they combine & become a magnet till disarranged again.

Elektron Electrical Experiments

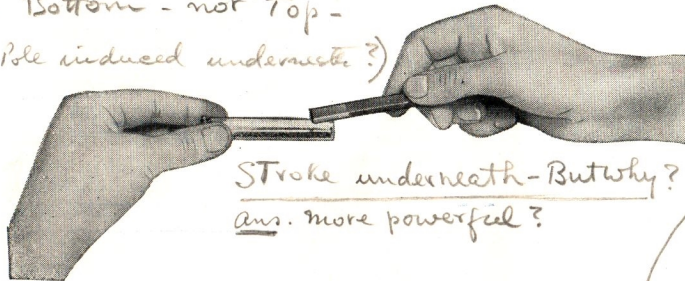
9

#

If a large amount of filings in Tube stroke Bottom - not Top -

— KEY TO whole Thing. —
 Each Small Filing is a Magnet

(Is opp. Pole induced underneath?)



Stroke underneath - But why?
 Ans. more powerful?

Fig. 18. Making a mass of iron filings into a feeble magnet.

Re-arranging Particles

When a needle is magnetised by stroking with a magnet nothing is added to it or taken away from it, and yet a great change has come about, as our tests with filings have shown. This change is due to an actual re-arrangement of the particles of which the needle is composed, and the following experiment will give us a good idea of what takes place.

Take the Glass Tube containing filings, shake it, and test its ends in turn with the north and the south pole of the Compass Needle. Both poles of the Needle are attracted equally, which shows us that the filings as a whole are not magnetic. Now hold the tube horizontally and slowly draw the north pole of a Bar Magnet along the outside from the cork towards the sealed end (Fig. 18). The filings appear to follow the magnet, re-arranging themselves so as to take up the line it traces. Taking care not to shake the filings, test the sealed end of the tube with the south pole of the Compass Needle, and this time it will be found that the Needle swings away, showing that this end of the tube of filings is now a south pole. As the glass plays no part in the magnetic action, it is evident that the mass of filings forms a magnet. If now we shake the tube so as to upset the arrangement of the filings, we find that all magnetic power has disappeared.

The explanation of these interesting experiments is that each small filing is itself a feeble magnet, but the mass in the tube is not magnetic as a whole because the filings are mixed up with their poles pointing in all directions (Fig. 19A). The effect of drawing the Bar Magnet along the tube is to cause the filings to re-arrange themselves so that their north poles all point in the same direction (Fig. 19B). Their magnetic effects are thus combined instead of opposing each other, and the whole mass of filings then acts as if it were a magnetised rod of iron of similar size.

A similar change takes place in a piece of iron or steel when it is magnetised, for the metal consists of tiny particles that are themselves magnets. In this case, however, the particles are very much smaller than the filings we have just used; they are indeed too small to be seen even with the aid of the most powerful microscope. In an unmagnetised piece of iron the particles are arranged unsymmetrically, so that they neutralise one another's effects. When the iron is stroked

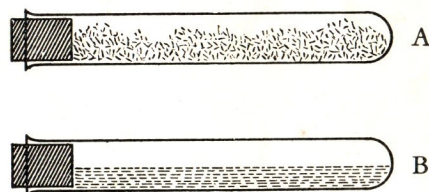


Fig. 19. (a) Iron filings before magnetising, with their north poles pointing in various directions.

(b) Filings after magnetising, arranged with their north poles all pointing in the same direction.

↓
 (Take out Metal Top Cork.)
 Compared with a Bar magnet.

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 Note - The Keepers fall off in experiment "Z", but needles only if Bars Tapped? Magnets not same strength?

10

Elektron Electrical Experiments

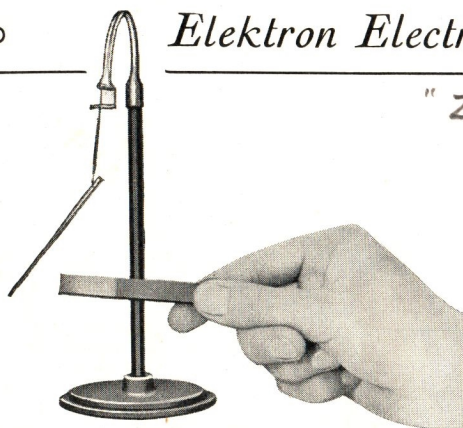


Fig. 20. Magnetic repulsion causes a needle to take up an unusual position.

with a magnet, however, the particles rearrange themselves with their north poles all in the same direction, and as a result of their combined magnetism the whole piece of iron acquires magnetic powers. *N. & S. Poles.*

We have seen that shaking the tube of iron filings after it has been magnetised disarranges the filings and destroys the magnetic effect of the whole. In a similar manner violent treatment of a piece of magnetised iron causes its particles to lose their symmetrical arrangement, so that the iron is no longer a magnet. This explains why magnets should be handled gently, and never knocked or allowed to fall.

Fun With Magnets

A great deal of fun may be had with the Bar Magnets and a few needles that have been magnetised in the manner already described.

A magnetised needle suspended by a thread from the stand made from the Erinoid Tube (Part No. 1509), the Circular Base (Part No. 1508) and the Stand Bracket (Part No. 1510) as shown in Fig. 20, may be made to perform surprising antics by bringing near it the poles of a Bar Magnet.

"Z"

Support one or two needles from the south pole of one of the Bar Magnets; then slide the second Bar Magnet along the top of the first in such a manner as to bring its north pole above the south pole from which the needles hang (Fig. 21). As soon as the second pole reaches the end of the first magnet the needles fall off, for the two poles neutralise each other's effects.

P. 9.

Repulsion "Effects"

Interesting and curious repulsion effects may be obtained with vertical floating magnets made by piercing small corks with magnetised needles. The needles used must be magnetised by stroking them from the eye to the point with the north pole of a Bar Magnet, and must be pushed through the corks in such a manner that their eyes, that is their north poles, are uppermost. (Fig. 22).

Place four of these floating needles in water in a basin. As their poles are similar they repel each other and become widely

separated; but if the south pole of a Bar Magnet is brought above them they will move towards it, only to stop a short distance away from it on account of their dislike for each other's company. They form the corners of a square, and are in positions where the pole of the Bar Magnet and the mutual repulsion of the needles themselves balance one another (Fig. 23). It is interesting to add more magnetic needles to the group and to see how these arrange themselves to produce different regular patterns.



Fig. 22. Magnetised needle and cork for experiments with floating magnet.

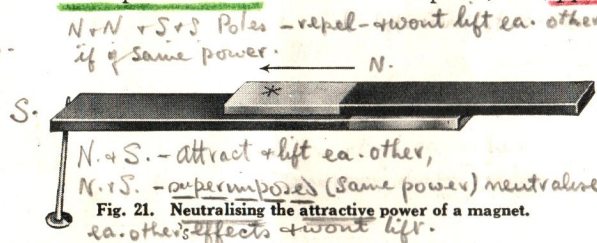


Fig. 21. Neutralising the attractive power of a magnet.

Hanging down

See p. 4.

Elektron Electrical Experiments

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For instance, if seven needles are used, one settles immediately below the south pole of the Bar Magnet and the remaining six form a ring around it (Fig. 24).

A surprising result follows the use of more than seven magnetised needles, for a third ring is then formed. Thus if 18 floating magnets are employed the formation already obtained is surrounded by an outer circle of 11 magnets. It is attractive to bring in the additional magnetised needles one at a time in order to see how their introduction affects the patterns.

Patience is required in all these experiments, for the balance of attractions and repulsions is

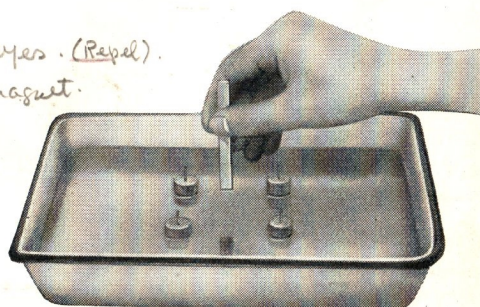


Fig. 23. How four floating magnets arrange themselves beneath pole of a bar magnet.

easily upset. Special care must be taken to keep the basin steady, for slight movements in the water may upset the arrangements.

A Magnetic Fishing Game

A magnetic fishing game that will provide great amusement may be easily arranged. First obtain some small celluloid fishes from almost any toy shop. Next magnetise a number of small sewing needles, half with the north pole at the eye end and half with the



Fig. 25. Fishing with magnets for bait! The fish have magnetised needles inserted in their heads which are attracted or repelled by the poles.

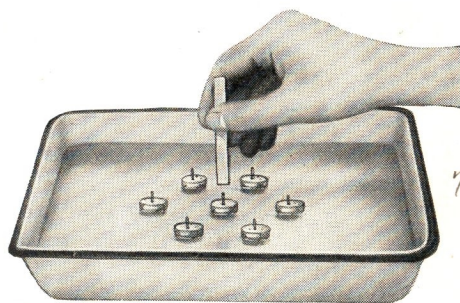


Fig. 24. The addition of three floating magnets to the four shown in Fig. 23, gives rise to a new arrangement.

north pole at the point. Insert one of these needles in the nose of each fish, in such a manner that the eye projects very slightly. There should be no difficulty in arranging that the hole is above the waterline. Short needles should be used in order that their insertion may not disturb the balance of the celluloid fish.

The fishing is done by two "anglers" each provided with a Bar Magnet suspended at the end of a piece of string (Fig. 25). If matters have been properly arranged, some of the fishes will be attracted by the "bait" whilst others will be repelled by it, and considerable dexterity is required to hook them, especially if the water is disturbed in order to keep them moving. If several anglers wish to take part in the game, strongly magnetised darning needles may be used as bait instead of the Bar Magnets, although in this case the magnetic effects will not be as strong.

so as not
to water =
log fish.

all N. eyes. (Repel).
S. Bar Magnet.

Part I. 12
 p.1. - Magnetism.

Elektron Electrical Experiments

Part II. FRICTIONAL ELECTRICITY

Amber
 !
 About 600 years B.C. a Greek philosopher named Thales became interested in Amber, a transparent yellow substance that when rubbed acquires the power of attracting bits of straw, feathers, and other light bodies. We now know that amber is fossilised resin, but the Greeks, in accordance with their custom, provided it with a legendary origin. They said that Phaeton, son of the Sun god, one day in a spirit of daring decided to drive his father's chariot, and quickly met with difficulties. The chariot got beyond his control and came so near the Earth that the heat radiated from it caused the land to become scorched and the oceans and rivers dried up. Zeus, the lord of the heavens, was so angry with Phaeton that he hurled a thunderbolt at him and struck him to Earth. The boy's sorrowing sisters, the Heliades, were changed into poplar trees, and their tears into amber. Among the names given to the Sun god was Alektor, meaning "the shining one"; and so amber, the tears of the Heliades, came to be named elektron or "the shining thing," from which word we get our word electricity. This name was first used by Dr. Gilbert, a famous scientist whose experiments in magnetism and electricity, carried out during the reign of Queen Elizabeth, were the foundation of these sciences.

Glass and Ebonite Acquire Electricity

giving Power of attraction.
 P.17
 light substance - ces.
 Flannel
 In addition to amber there are many other materials that when rubbed acquire the power of attracting light substances—ebonite is one. Take the Ebonite Rod (Part No. 1514), rub it smartly with the Flannel Square (Part No. 1516), as shown in Fig. 26, and test its powers

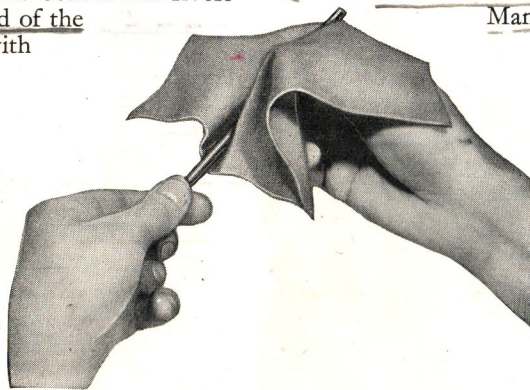


Fig. 26. An ebonite rod electrified by rubbing with flannel.

of attraction with small pieces of thin paper. It will be seen that these leap towards the rod and cling to it. Now try the experiment with the Glass Rod (Part No. 1515) rubbed with the Silk Square (Part No. 1517) and the same result will be obtained. In a similar manner a glass vase may be given this power of attraction by polishing it vigorously with a silk handkerchief. A postcard rubbed with flannel, or a sheet of brown paper brushed with a clothes brush, also become attractive. The power of attraction in each of these experiments is due to the presence of a small charge of electricity produced by friction.

(In these and all other experiments in frictional electricity dealt with in the

Manual it is necessary to have all our material perfectly dry, for the least damp will cause failure. For this reason the best results are obtained by carrying out operations in a well-warmed room.

Two Kinds of Electricity

In our experiments in magnetism we saw that although both poles of a bar magnet will attract pieces of iron and steel, actually they are quite different for one has north magnetism and the other south magnetism. We shall now see that a similar state of affairs exists in regard to these electrical charges. Using the stand already described in the section on magnetism, we electrify one of the Ebonite Rods by rubbing it with the Flannel Square. Laying it in the Brass Stirrup, we then rub the second Ebonite Rod with the Flannel Square and bring this towards the electrified end of the suspended rod. The latter is repelled by it for it immediately swings away from the rod held in the hand (Fig. 27). We know that the charges of electricity on the two rods

© P.13.

Silk

Brush

NP

DRY

+

unmay

N. Mag.
 S. Mag.

Repelled

Ebonite Rod attracts more than glass Rod

Erinoid Tube see p.2.

Elektron Electrical Experiments

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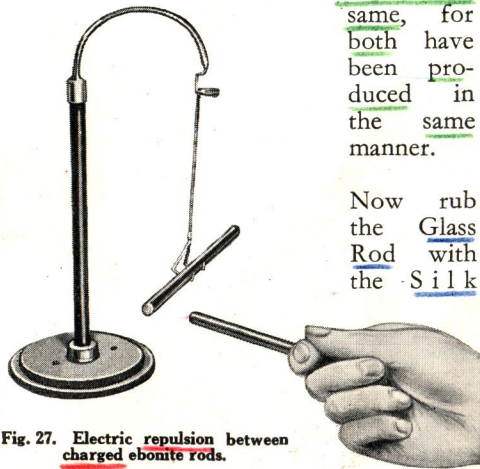


Fig. 27. Electric repulsion between charged ebonite rods.

Square and try its effect on the suspended Ebonite Rod. This time the latter rod is attracted by it, for it swings round to meet the Glass Rod. ✓

Positive and Negative Electricity

These experiments show that the charge of electricity on the Glass Rod must be different in some way from that on the Ebonite Rod, for it produces an opposite effect. The electricity produced on the Glass Rod is said to be "positive," and that of the opposite kind on the Ebonite Rod "negative." ✓

Our experiments show us also that there is a further similarity between electricity and magnetism. Similar magnetic poles repel, and unlike poles attract one another; and here we find that substances

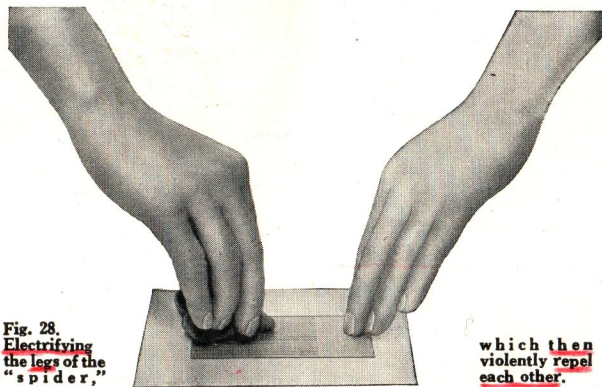


Fig. 28. Electrifying the legs of the "spider,"

which then violently repel each other.

In carrying out the experiments in attracting small pieces of paper to the glass or ebonite rods, it may have been noticed that some of the pieces stick to the rod whereas others soon fall off. This effect is "more

© P. 12

Opposite Charge?

Similar Charge.

N. Magnetism } Similar Poles - repel.
S. Magnetism } Unlike " - attract.
+ electricity } Substances charged similar electricity - repel.
- " } " " " " - attract.

} N. Pole.
} S. Pole.
} + or Pos. Pole.
} - or Neg. " .

must be the same, for both have been produced in the same manner.

Now rub the Glass Rod with the Silk

charged with similar kinds of electricity repel, and those charged with opposite kinds attract each other.

It is easy to find whether the kind of electricity produced by friction on a card, a sheet of paper, a stick of sealing wax, or any other material is positive or negative. All that is necessary is to bring the electrified material near the suspended Ebonite Rod. If the rod swings away the charge on the substance brought near it is negative, whilst if it is attracted the charge is positive.

To Find whether + or - .

The Electric Spider Charged By Friction.

An interesting experiment that will help us to remember that objects charged with similar kinds of electricity repel one another, may be carried out with an "electric spider" made from a sheet of paper about 4 in. in length and 2 in. in width. The paper should be cut for about 3 in. of its length into eight narrow strips, which represent the legs of the spider, the uncut end representing the head. Lay the spider on a glass plate, hold it down by the head, and stroke its legs smartly with the Flannel Square (Fig. 28). Now lift the spider quickly, and its legs will immediately spread out from one another. The reason for this behaviour is that the legs have been given similar charges by friction and therefore they try to get as far away from one another as possible. ✓

4 x 2

Why not all fly off?

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Elektron Electrical Experiments

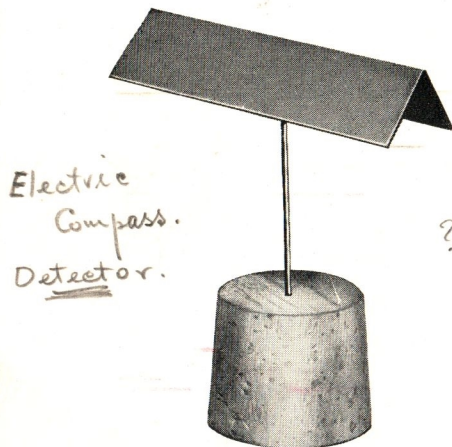


Fig. 29. The electric compass, used to detect electric charges.

noticeable if small pieces of tinfoil—or so-called “silver paper”—are laid on a metal tray, for then the pieces are first attracted by the electrified rod and violently repelled almost immediately they touch

it. What happens is that when the pieces come in contact with the rod, some of the electricity on the rod is transferred to them, and they are then repelled because their charges are similar to that on the rod. Some stick, fly.

Electric Detectives at Work

Sometimes we may wish to test a piece of ebonite, glass, or other material in order to see if it is electrified. It is not always convenient to make use of

1. small pieces of paper or
2. of a suspended rod for this purpose, and a useful
3. substitute is a device that may be described as an electric compass or pointer. This is made by cutting a piece of stiff paper or thin card $1\frac{1}{2}$ in. by $\frac{3}{8}$ in., folding it in two along its length, and balancing it on the point of a needle passing through a cork (Fig. 29). If desired it may be balanced instead on the Pivot (Part No. 1502) removed from the Compass Box. When an electrified rod is brought near

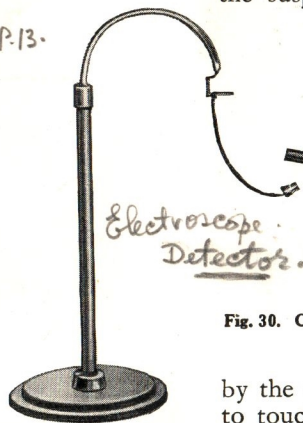


Fig. 30. Cork made to dance in air by electrical attraction.

one end of the balanced pointer, it swings round towards the rod.

Glass or Ebonite, as paper pointer not magnetised.

4. A more useful device for detecting the presence of electricity can be made by hanging from the stand by means of a length of silk thread one of the small Corks (Part No. 1519), all of which are pierced for the passage of the thread, which may be readily inserted by means of a fine needle. (If desired a feather or a strip of thin paper could be used instead of the Cork.) The paper might be cut to the shape of a butterfly (Fig. 33) or a small bird, and painted in suitable colours to add to the effect when it swings about.

A. Simple Electroscope

or Strip Thin Paper

Hang a Cork from the stand and bring near it a glass or ebonite rod that has been electrified by rubbing. The Cork is strongly attracted (Fig. 30) and as it is extremely light it may be lifted above the stand to the full extent of the thread by raising the charged rod. (Similar effects are produced if a feather or a strip of paper is used.) This apparatus is a simple form of electroscope, which is the name given to an instrument for detecting the presence of small charges of electricity.

In the experiment we have just described, the suspended Cork was strongly attracted

by the electrified rod, but was not allowed to touch it. A great change occurs if the Cork is allowed to touch the rod, for then, instead of being attracted, it is violently

Electroscope - name given to Instr. for detecting small charges of electricity.

+ + - Rod held together appear To ^{mechanical} touching one or both?
 + + - Paper or Rods will lift Paper on Touching as long as forces equal?

Elektron Electrical Experiments

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But can still be lifted if Touching, except when foil covered.

repelled (Fig. 31). As in the case of the pieces of paper that adhere to the rod, this remarkable difference in behaviour is caused by electricity having been transferred from the rod to the Cork, so that the two repel one another because both are charged with the same kind of electricity. The best results in this experiment are obtained by wrapping the suspended Cork in tinfoil, or in a small strip of the Aluminium Foil provided in the Outfit.

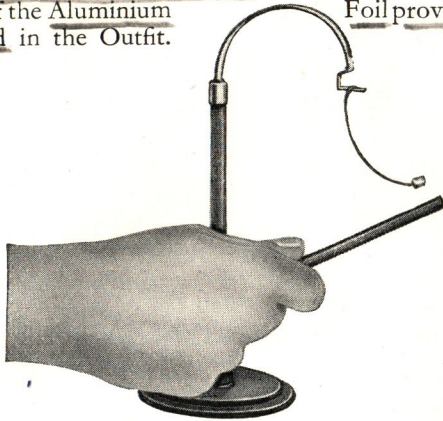


Fig. 31. Repelling a charged cork upward by means of a rod possessing an electrical charge of the same kind.

The Earth a Gigantic Electrical Reservoir

To Earth - Glean - Ebonite -
 Before the Cork can be attracted again after being repelled in this manner, it is necessary to take away from it the charge of electricity it received from the rod. This is done by brushing its surface with the hand, an action known as "earthing" because the electricity on the Cork passes through the hand and the body to earth. Apparently the Earth is a gigantic reservoir, into which both kinds of electricity pass whenever they have the opportunity, and there neutralise each other. (There is no doubt that the Cork has lost its electricity, for on bringing the charged rod near it, it is again attracted.)

An Amusing Electrical Game

An amusing experiment may be carried out with a suspended Cork wrapped in tin or aluminium foil. A

charged rod is held on one side of the Cork at a distance of about an inch, and on the opposite side of it is placed the Electro-scope Plate (Part No. 1520), as shown in Fig. 32. The Cork is first attracted to the rod, but as soon as it touches it, it is repelled to the Plate, after which it swings backward and forward between the rod and the disc, forming an electrical pendulum. What happens is that the Cork is first attracted by the rod, then repelled immediately it touches it, and attracted once more after having touched the Plate, because this earths it and deprives it of the charge that caused repulsion.

This alternate attraction and repulsion is made use of in an interesting toy or game. Obtain a shallow cardboard box, with a lining of tinfoil, and divide the bottom of the box into numbered sections. Place a paper arrow in the box, and cover the box with transparent celluloid. When the celluloid is electrified, by rubbing it gently with the finger, the arrow jumps up to it, and drops back again on its becoming electrified. It is earthed when it touches the tinfoil lining, and can then be attracted once more. In the game the players score by means of the numbers on which the arrow falls, after it has been attracted and repelled by the electrified cover. An alternative device tell fortunes or in which case humorous descriptions are the numbers in the

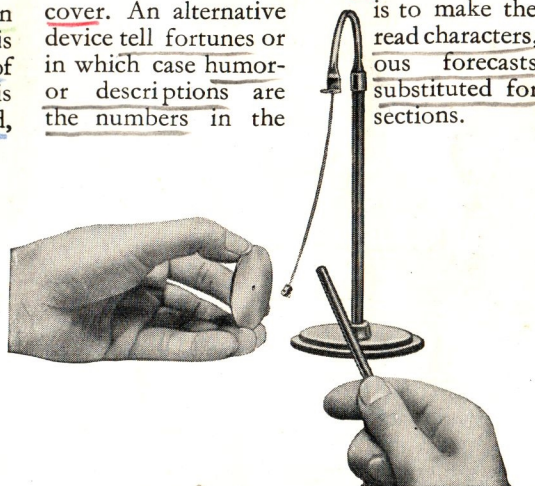


Fig. 32. An electric pendulum

Neutralised
P18?

Tin foil
Alum.
Foil

X

Game.

Touch.

NB.

Elektron Electrical Experiments

"ELEKTRON" Making a Useful Electroscope

An ELECTROSCOPE that is more attractive and useful than the suspended Cork may be made from parts included in the Outfit, with the addition of a glass tumbler (see Fig. 34). The Circular Base (Part No. 1508) forms a cover for the tumbler, the flange with which it is provided resting on the glass rim. The Ebonite Bush (Part No. 1524) is placed in the central hole of the cover, and through it is passed the Electroscopie Rod with screwed ends (Part No. 1521). The $\frac{1}{4}$ in. Erinoid Sleeve (Part No. 1522) is slipped over the rod above the Ebonite Bush, and the Electroscopie Plate (Part No. 1520) is screwed on the upper end of the rod, where it is held in position by a lock nut. The sleeve on which the Plate rests thus prevents the Rod from slipping through the Ebonite Bush, and also holds the Plate at a convenient distance above the cover.

The indicator that is to show the presence of electricity consists of two narrow strips of aluminium foil, each about 1 in. in length and $\frac{1}{4}$ in. in width, cut from the piece of Foil (Part

other, and a tiny hole is pierced through the pair at one end. They are then hung side by side on the Electroscope Hook (Part No. 1523), which is screwed on the lower threaded end of the Electroscopie Rod.

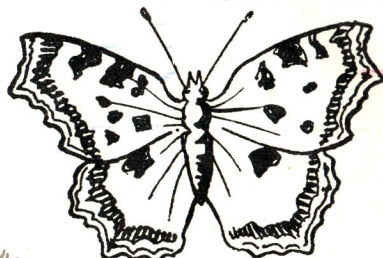


Fig. 33. This butterfly drawing may be traced on this paper for use in interesting electrical experiments.

The aluminium strips are usually referred to as the "leaves" of the electroscope. They are protected from draughts by the tumbler, and in their normal position they are in contact with each other. When they are electrified, however, they swing

apart, owing to the repulsive action of similar charges. This may be shown by charging a Glass or Ebonite Rod and touching the Plate of the electroscope with it. The leaves immediately open out and remain wide apart even after the Rod has been removed, for both are charged with the same kind of electricity. Touch the Plate with the hand, and the leaves immediately fall together again, because the electricity in them has leaked away to earth.

4 PARTIAL - - Conductors and Insulators

The possession of an electroscope enables us to test other materials to find out whether they allow electricity to leak through them, as it does through the hand during earthing. All that is necessary is to take the substance to be tested in the hand, and touch with it the disc of a "charged" electroscope. If the material under test allows electricity to pass through it, the leaves of the electroscope fall together; on the other hand, the leaves remain unaffected if the substance resists the passage of electricity. For instance, if the disc of a charged electroscope is touched with an iron nail held in the hand, the leaves collapse; but if a piece of dry silk thread is used, nothing happens. From this we see that iron allows electricity to pass freely through it, but silk does not behave in this manner.

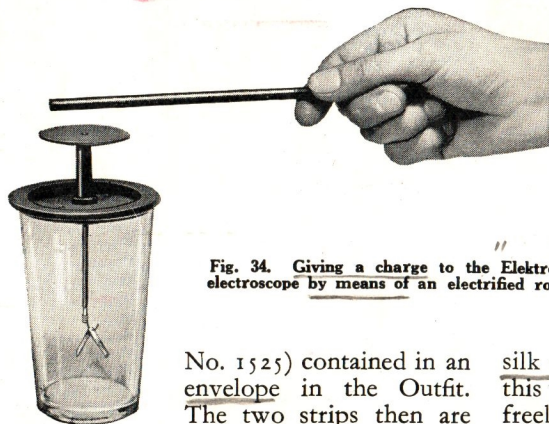


Fig. 34. Giving a charge to the Elektron electroscope by means of an electrified rod.

No. 1525) contained in an envelope in the Outfit. The two strips then are placed on top of each

+ + - Should neutralise if of same power? Temp. or Permanent?

Elektron Electrical Experiments

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Substances such as iron, through which electricity passes easily, are known as CONDUCTORS; and those like the silk thread, that resist the passage of electricity, as NON-CONDUCTORS. In between these extremes are many substances that allow electricity to pass to some extent, and are known as PARTIAL CONDUCTORS.

Good and Bad Conductors

Among conductors are metals, acids, water (impure) and the human body; cotton, linen and paper may be regarded as partial conductors; and dry air, ebonite, glass, silk, resin, sealing wax and gutta-percha are non-conductors. When a conductor is surrounded by a non-conductor in such a manner that its electricity cannot escape, it is said to be insulated, from the Latin *insula*, an island, and non-conductors are known also as INSULATORS.

We have already seen two practical applications of the respective properties of conductors and insulators. In making our cork electroscope it was necessary to insulate the Cork, and this was done by hanging it by a silk thread. In the more elaborate electroscope the leaves are suspended from the brass Rod, which is a conductor, so that electricity can reach them from the brass Plate. On the other hand the Rod, the Plate and the leaves must be insulated, for otherwise they could not be charged with electricity. The non-conducting Ebonite Bush is used for this purpose.

Damp Substances cannot be Electrified

We have already drawn attention to the fact that experiments in frictional electricity must be carried out with dry apparatus and in

a dry room. In a cold damp atmosphere it will be found that the leaves of a charged electroscope slowly come together, showing that their charge is leaking away, in spite of the insulating Ebonite Bush. The leakage is due to the presence of a film of moisture on the surface of the Bush, which—as water is a conductor—enables the electricity to leak away. It is for the same reason that it is difficult to electrify glass or ebonite rods in a damp atmosphere.

It will have been noticed that so far the rods we have used for producing charges of electricity have all been non-conductors, and the reason for this will now be clear. When we rub a rod of a non-conducting material, the part rubbed becomes charged, and the electricity remains there because the rod will

not allow it to pass away. If we try the same experiment with a rod of metal or other conducting substance, however, we get no result. Electricity is produced,

but it immediately spreads along the rod to the hand and so escapes to earth. If we wish to electrify a rod of a conducting material we must insulate it to prevent the charge from escaping. For example, a metal rod may be electrified quite easily by rubbing it with fur, if it is provided with a handle of glass or some other insulating material.

The Mysteries of "Electrical Induction"

We have already seen in several experiments that a cork receives a charge of electricity when it is touched by an electrified body. It is not necessary that actual contact should take place, however, for one body may be charged from another by what is known as "ELECTROSTATIC INDUCTION." A simple experiment will illustrate this.

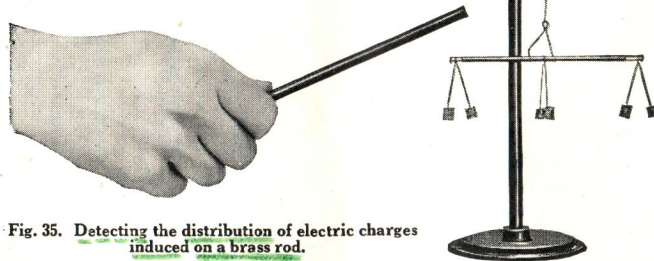
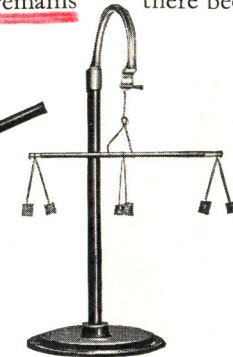


Fig. 35. Detecting the distribution of electric charges induced on a brass rod.



Electrical

Induction

Temporary

N.B.

(impure)

P.3.

Charge
TouchedCharge
Induction

(Compare Brass Rod To Magnet with + & - Poles.)

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Elektron Electrical Experiments

(Unattractive)

Same with magnets + non-mags?

↑ Important

Place the ^{Brass} Electroscopie Rod in the Stirrup of the stand, using a shorter piece of silk thread than in previous experiments. Suspend a pair of Corks from one end of the Rod, and hang similar pairs at the opposite end and on the middle of the Rod, as shown in Fig. 35. Now bring a charged Ebonite Rod near one end of the brass Rod. The Corks at the two ends immediately repel one another, showing that the ends are electrified, but no repulsion takes place between the Corks in the middle, indicating that this part of the Rod is not electrified. Tests show that the charges at the ends are of opposite kinds, that nearest the Ebonite Rod being positive and the other

electrified, such as the cork employed in our earlier experiments. The electrified rod induces a charge of the opposite kind on the side of the cork nearer to it, and one of the same kind on the side farther away. One half of the cork is therefore attracted and the other half repelled, but as the attracted half is nearer, the attraction is stronger than the repulsion, and the effect is to make the cork move towards the electrified rod. When the cork touches the rod, the charge on the near side is neutralised, leaving only that on the far side. This is similar to the charge on the rod, and repulsion takes place.

induce

By Transference P.15?

An Electroscopie Puzzle Solved

In making experiments with the electroscopie it probably will have been noticed that the leaves begin to open out as soon as a charged rod is brought near the disc. This effect is not permanent, however, for if the rod is removed without touching the disc, the leaves immediately collapse. The explanation is simple. Let us suppose the charged rod to be one of ebonite, rubbed with flannel. The rod is negatively electrified, and therefore it attracts positive electricity to the disc of the electroscopie and repels negative electricity to the leaves, (which then repel one another). When the rod is removed the attraction and repulsion disappear, and the leaves therefore lose their negative electricity and fall together.

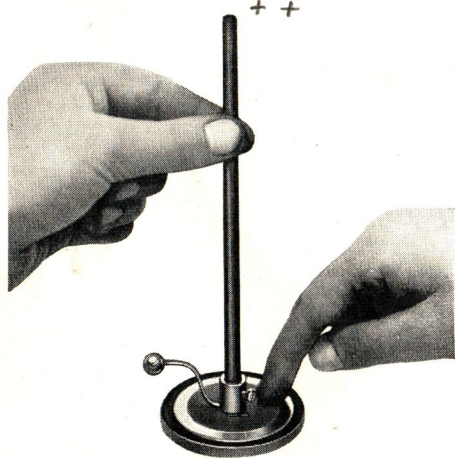


Fig. 36. Charging the Electroscopie.

one negative. Thus the negative charge on the Ebonite Rod has attracted positive electricity towards it, and has repelled negative electricity to the farther end of the Brass Rod.

Induction "Acts through" Glass

When the charged Rod is taken away the Corks are no longer repelled, for the opposite charges on the Rod unite and neutralise each other. In this experiment, electrical charges are said to be "induced" on the brass Rod. Induction takes place across a considerable distance, and is not stopped by the presence of a sheet of glass or other similar obstacle.

We can now understand why an electrified rod or other body attracts one that is not

A surprising result follows if the brass disc of the electroscopie is touched "momentarily" with the finger while the charged Ebonite Rod is held near it. The leaves immediately fall together, because the negative electricity in them finds its way through the finger to earth; but when the charged Ebonite Rod also is removed the leaves again open out.

What has happened is that as there is now no negative electricity left to neutralise the positive charge, this makes its way throughout the whole of the metallic parts of the electroscopie. The leaves, which previously were negatively charged, are now positively charged, and therefore again repel each other.

P.16

Silk? Wire?

of Brass Rod.

Why?

Tests?

P.13.

P.14.

Touch.

+ Charge on Glass Rod?

Brass

Charges produced greater than obtained by rubbing Ebonite or Glass Rods.

Elektron Electrical Experiments

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The Elektron Electrophorus

Good use is made of induction in a simple form of electrical machine known as the electrophorus, and the Elektron Electrophorus is illustrated in Figs. 36 and 37. It consists of two parts. One of these is the Ebonite Disc in Holder (Part No. 1592); the other is built up by passing the shank of the Brass Holder for Ebonite Rod (Part No. 1594) through the hole at the forked end of the Sparking Rod (Part No. 1593), and into

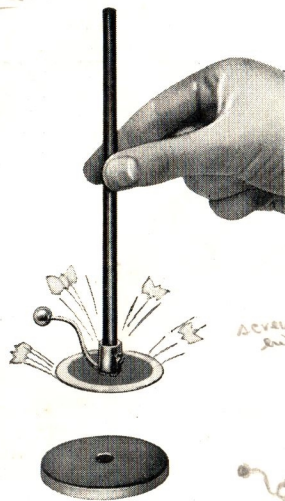


Fig. 37. The Dancing Butterflies.

the threaded hole in the centre of the Electro-scope Plate. On screwing down tightly the Electro-scope Plate is held firmly in the position illustrated. An Ebonite Rod (Part No. 1514) is then fitted into the Brass Holder and secured by means of the set screw.

In order to charge the Electrophorus the surface of the Ebonite Disc is 'lightly' rubbed with the Flannel Square (Part No. 1516). The Electro-scope Plate is then placed on the charged ebonite, the projecting portion beneath fitting into the central hole in the Ebonite Disc, and is momentarily touched with the finger (Fig. 36). The Electro-scope Plate is then lifted away by its insulating handle, and the sharp crack of an electric discharge is heard when the knuckle is brought near the ball at the end of the Sparking Rod. If the experiment is carried out in the dark an electric spark is seen, and the presence of the charge can be shown also by means of the Elektron Electroscope illustrated in Figs. 30 and 34.

In this experiment the negative electricity generated on the Ebonite Disc induces an equal positive charge on the lower side of the Electro-scope Plate and an equal negative charge on the upper side. When the upper surface is touched with the finger, the negative charge there is repelled to earth, leaving only the positive charge on the Electro-scope Plate.

The great advantage of the Electrophorus is that the Electro-scope Plate can be repeatedly charged without diminishing the charge on the Ebonite Disc. This charge leaks away slowly, however, and eventually the Ebonite Disc has to be re-charged by rubbing.

The Jumping Frogs

The charges produced by the Elektron Electrophorus are greater than those obtained by rubbing ebonite or glass rods. The device therefore offers a convenient means of producing the electrification required for practically all the electrical experiments described in this Manual, and also for other interesting and amusing experiments.

Cut 12 or more small pieces of thin paper about $\frac{1}{8}$ in. square and distribute these on the upper side of the Electro-scope Plate. Charge this by induction in the manner already described, and on lifting it up from the Ebonite Disc the tiny pieces of paper shoot upward and outward from it in all directions. They do this because they share the positive charge given to it and therefore are repelled by it. This repulsion is shown in a very amusing

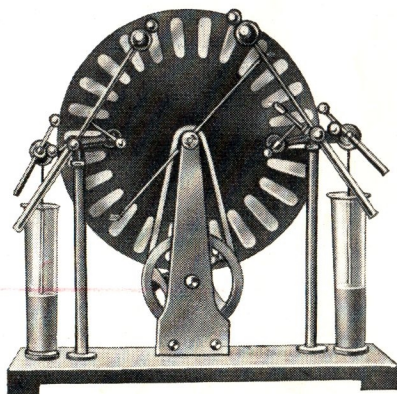


Fig. 38. Wimshurst Electrical Machine.

Wont it recharge after finger away? <

influence or induction manner by cutting larger pieces of light thin paper to the shapes of butterflies, which in the experiment fly through the air, or of frogs, which leap up in a life-like manner.

The principle of influence or induction is employed in machines for producing much larger quantities of electricity than can be obtained by the means already described. The best known of these appliances is the Wimshurst machine (Fig. 38). The actual operation of this machine is somewhat complicated. But in principle it consists in accumulating small charges of electricity of opposite kinds produced by induction, until they reach a large total.

We have already mentioned that a postcard becomes electrified when briskly rubbed with flannel, as is shown by its power of attracting light substances. The presence of electricity may be shown also in another way. If the rubbed card is brought to the tip of the ear, a very slight tingling sensation is felt, accompanied by a faint crackling sound. If the experiment is carried out in complete darkness in front of a mirror, a tiny spark is seen at the same moment. These effects are characteristic of the discharge of a highly electrified substance.

Real and Artificial Lightning

Much more striking results of this kind can be obtained from a Wimshurst machine, even a small machine being capable of producing brilliant sparks 3 in. or 4 in. in length between the balls at the ends of its discharging rods. These sparks do not flash straight across between the balls, but take a zig-zag course, and are accompanied by sharp cracks. Their resemblance to a flash of forked lightning



Fig. 39. Flashes of forked lightning, photographed at night.

(Fig. 39) is very noticeable, and actually they are lightning in miniature. As the machine is operated, the balls become charged with opposite kinds of electricity, which try to reach one another across the intervening air gap.

Air is a bad conductor of electricity and therefore it opposes this passage; but when the charges reach a certain strength the electricity forces its way

across. The particles of air along the line of the discharge are rendered incandescent by the heat produced by the violent passage of the electricity, thus giving rise to the spark, which is accompanied by a sharp crackling sound.

Thunder and Lightning

A lightning flash is produced in a similar manner. The clouds are liable to become strongly charged with electricity, sometimes positive and sometimes negative; and at a certain strength the electricity is discharged in the form of a gigantic spark, which may be several miles in length, between two clouds or between a cloud and the earth, as shown in Fig. 39.

Thunder is the noise that accompanies the discharge. It is very loud and is probably caused



William Gilbert (1540-1603).

influence or induction

Dry Air - non-conductor p. 17.

Wimshurst - rst.

sensation sound.

sight.

Wimshurst - rst
3" + 4"



Elektron Electrical Experiments

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by the sudden expansion of the heated air along the path of the discharge. This expansion produces a partial vacuum, into which the surrounding air rushes with great violence. The sounds thus produced at different points along the track of the flash reach us in succession in a sharp rattle, followed by a more or less prolonged rumbling resulting from echoes from other clouds.

186,000 Miles Per Second

The distance from us ^{to} of the seat of the lightning discharge can be roughly estimated in a very easy but interesting manner. Light travels at a speed of 186,000 miles per second, and therefore the flash reaches our eyes practically instantaneously. Sound, however, travels only at a speed of about 1,115 feet per second, so that an appreciable time elapses before we hear the thunder. If therefore we multiply the number of seconds between the flash and the thunder by 1,115, we obtain an approximation of the distance in feet of the discharge.



Benjamin Franklin (1706-1790).

What is Electricity?

Why should such a simple action as rubbing with a piece of silk or flannel make amber, glass or ebonite capable of attracting light objects? Apparently nothing is added to or taken away from the material rubbed, and this is unaltered in appearance. The cause of the change remained a complete mystery for more than 2,000 years. The Greeks thought that the attractive power was due to a living principle or soul that was roused to action by friction. Later it was thought that each kind of electricity was an indestructible fluid. The two fluids were supposed to be present in equal quantities in an uncharged substance, and one that was electrified was thought to contain an excess of either the positive or the negative fluid. A simpler

idea was suggested by BENJAMIN FRANKLIN (see below), the famous American experimenter, who in 1747 suggested the existence of one electrical fluid. He called this the positive fluid, and supposed it to be attracted by amber. He believed that everything contained a store of it, and that forcing more into a body produced a positive charge, while taking some away produced a negative charge.

Electricity Not a Fluid!

We no longer believe in the existence of electrical fluids of this kind, for we now know that electricity is actually a part of every material thing. Matter is built up of minute particles named ATOMS. These atoms are far too small to be seen even with the aid of the most powerful microscope, and yet they are made up of even smaller particles, a positively charged nucleus or centre, and lighter particles known as ELECTRONS, which are actually tiny particles of negative electricity. The electrons in an atom are kept in position

by the attraction of the appropriately charged nucleus, around which they rotate at high speeds, but they are easily dislodged by any disturbance, so that they may move from one atom to another. A substance that contains more than its share of electrons, due to a transference of this kind, is charged negatively; and similarly one with a shortage of electrons is charged positively. When a glass rod is rubbed with silk or an ebonite rod with flannel, disturbances take place within the "atoms", with the result that the rods either gain or lose electrons, and thus become charged either positively or negatively. Electrons are very active and flow readily through conductors. When in movement they form electric currents and fascinating experiments with these may be carried out with the No. 2 Elektron Outfit referred to on the back cover of this Manual.

Electrons in movement form electric currents.

Surplus
-
Deficiency
+
Gain or
Loss of
electrons?



1501
1502
1503
1504

Now that you have experienced the fun and excitement of carrying out electrical experiments you will be keen on proceeding further with this wonderful hobby. You may do this by purchasing a No. 2 Elektron Outfit, with the contents of which you can perform experiments revealing the mysteries of current electricity.

Elektron Outfit are the Coils and Yokes and other apparatus required for the construction of Electro-Magnets that can be used in building an Electric Bell and a Buzzer for use in an electric telegraph system. A specially-wound coil and other necessary parts are supplied for assembling into a Shocking Coil that will give hours of fun. Two working Electric Motors also can be built.