ELEMENTARY ELECTRICITY

FOR STUDY AND USE WITH

ERECTOR ELECTRICAL SET

FASCINATING AND INSTRUCTIVE FUN FOR BOYS

CONTAINING

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VOL II - **CURRENT ELECTRICITY**

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THE A.C.GILBERT CO., NEW HAVEN, CONN. U.S.A.

My Dear Boys:—

I am very glad indeed to be able to offer you this work on Elementary Electricity which we have prepared for study and use in connection with the Erector Electrical Set.

You will find it, I am sure, the most interesting book you have ever read, for the reason that you are on the threshold of the most fascinating, mysterious and wonderful force that we know of in this world,—Electricity!

This is the Electrical Age, thousands of the greatest scientists are devoting their lives to the investigation of this strange power, and we have harnessed it and made it the Servant of Man, and yet, to-day just as little is known about its origin as long ago at the time when Franklin and Volta were performing their wonderful experiments.

What is it? Where is the source of its power? Somewhere in the World there is a boy who will disclose to the world greater secrets of electricity than are at present known. As a boy I was always intensely interested in electrical experiments, and I know it to be true of almost every boy. There are so many things about it, telegraphy, wireless, electric motors, and strange experiments which can be conducted with the most simple apparatus. I believe that the Erector Electric Set will in a short time become as famous as my other toy, Erector, "the toy like structural steel."

I'm a great believer in boys, I want them to have real good times. I know what's good for them. I know boys need lots of play, entertainment, fun and pleasure, and at the same time I know they want something that requires brain. That is why in every toy that I manufacture it requires "gray matter" to get the most out of playing with them and you will find this true of the Electrical Set. It is one that will keep you right ony our toes, you will never reach the end of it, it is simply the beginning, and it is a great sport, and perhaps, it may become your life work.

Here's good luck to you in your search for Knowledge and Pleasure!

PRIZE CONTEST.

You know, boys, that I've always been a great advocate of PRIZE CONTESTS for boys—in fact I believe I've given bigger prizes and more of them to Boys than any other man in the world.

This year I am giving away $5,000 worth of prizes for the best models of "ERECTOR" (my steel construction toy) and I am also going to have a Big Prize Contest on "BRIK-TOR." I want you to send for my big illustrated folder which tells in full detail about the BRIK-TOR PRIZE CONTESTS. It is too lengthy to print here; don't forget about it—but send today and learn how you can win one of the many prizes which include all sorts of things which boys like to own.

ERECTOR TIPS.

I am going to present you with a year's subscription to the boy's magazine "ERECTOR TIPS!" This is the bulliest boy's paper you ever read. Brimful of good stories and pictures and special articles on athletics, prize contests, etc. Also new wrinkles in model building for ERECTOR TOY ENGINEERS. Now, don't miss this free offer; just send 10c. to pay the postage and you'll get the magazine regularly six times a year.

GILBERT INSTITUTE OF ERECTOR ENGINEERING.

This is the great big feature that appeals to every ambitious boy as well as his parents. Any boy owning "BRIK-TOR," "ERECTOR," or the "ELECTRICAL SET" can qualify for membership in the INSTITUTE and win a diploma certifying to his knowledge the ability in engineering construction, architectural design and electrical engineering. It is the most fascinating and absorbing way of learning the secrets and of mastering these three big subjects.

Boys! I have great plans for you which I want to work out during the coming year in the INSTITUTE and so I want you to know all about them. I can't tell you the details here because of limited space, but if you'll send a 2c. postage stamp I'll be delighted to mail you a book in two colors which gives the full story. Just say "Send me the book: 'How to become an ERECTOR MASTER ENGINEER.'"

A. C. Gilbert
PRESIDENT.

THE A. C. GILBERT CO., New Haven.

Elementary Electricity

FOR STUDY AND USE WITH THE

ERECTOR

ELECTRICAL SET

BY

ALFRED C. GILBERT, M. D., E. M. E.

YALE UNIVERSITY, 1909

GILBERT INSTITUTE OF ERECTOR ENGINEERING, 1916

AND

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Book I

Static Electricity and Magnetism

The Wilson H. Lee Company
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STATIC ELECTRICITY

What is Electricity? Of course, it should be the first question to be decided before we go ahead experimenting with electricity. And you see I am sorry to confess, that neither you nor I, nor anybody who lived, or is living, could answer this question. We do not know what electricity is We cannot define the idea "electricity," but we can turn to advantage the phenomena of electricity. We can, and we do it. We have mastered this mighty force and made it our powerful servant. We can produce it and use it and—are now more the servants of electricity than it is our servant. It is hard to imagine what man's life would be without the use of electricity, and I think the time not very far off when the height of civilization will not be measured by soap, but by the electric meter.

While electricity is still a mystery, much is known about the rules and laws governing its nature. Although it is without doubt one and the same, it is for convenience sometimes classified according to its motion, as:

1. Static Electricity, or Electricity at rest.
2. Magnetism, or Electricity in rotation.
3. Current Electricity, or Electricity in motion.
4. Radiant Electricity, or Electricity in vibration.

You will learn in the following, why we give one and the same electricity different names and also how every one of the named chapters seems to be a special science by itself. But to understand the fundamentals of electricity, to be acquainted with Electrical Engineering, the purpose of this course, you must start with the first elements and advance step by step.

I. FRICTIONAL ELECTRICITY

Did you ever comb your hair with a common black ebony comb? Did you look at the same time in the mirror? What did you observe? Before we study this appearance, let us try an experiment with our hard rubber rod.

1. HARD RUBBER ELECTRICITY.

Tear a piece of paper in very small pieces and lay them on your experimenting table Now, take your piece of flannel cloth and rub the ebonite rod with it until you feel it getting warm. Now, hold it near the small pieces of paper. How they jump! Some of them jump up and stick to the rod, some jump down again, and some lazy fellows just sit up. But the whole company was suddenly changed. Something happened to them.

2. GLASS ELECTRICITY.

Exactly the same thing happens if you rub the glass plate with the flannel cloth, or better still, with a piece of silk. Bring the glass near the paper pieces. You may watch them perform the same evolutions as they did when you approached them with the ebonite rod.

3. FRICTIONAL ELECTRICITY.

It is hard to explain at once what happened, or why this happened so strangely. But we see, it was not the paper which caused the activity; it was the glass plate. We say that through the friction of these objects, electricity was produced. Therefore, we call it **Frictional Electricity.**

4. DR. GILBERT AND ELECTRICITY.

Over 2000 years ago the highly cultivated Greeks already knew that amber would attract light bodies after being rubbed. They called amber—elektron.

For a long, long time, amber and jet were the only two bodies in which the power of electricity had been recognized. About the year 1600, an English professor, bearing a name very familiar to every boy, Dr. Gilbert, of Colchester, discovered by experimenting that not only amber and jet, but a very large number of other substances, such as diamonds, glass, sealing-wax, resin, etc., possessed the same property. He called these bodies—Electrics, and since his time the name—Electricity—has been used to denote the source of all the phenomena which will occupy us.

5. LAW OF ATTRACTION.

We found already the first law of Electricity: it attracts neutral bodies. A neutral body is a body which does not show signs of electricity. And here is the explanation for what you observed when you were combing your hair. The ebonite comb was rubbed by the hair and became electrified by friction. It attracted the hair and the little crackles you heard were the sounds of the electrical sparks which jumped from the electrified comb to the attracted neutral hairs.

6. PAPER ELECTRICITY.

Now, let us try some other experiments. Take a piece of newspaper, about five inches square and lay it on the table and try to lift it. You lift it easily and slide it along the table with a little push. Now, lay it again flat on the table and rub it several times from end to end with your hand. Try to lift it. It acts queerly You can lift it, of course, but it offers a little resistance. Now, lift it against this resistance and try to slide it over the table. At the same moment it touches the table it immediately lays flat on it again. What happened now? Again the mysterious electricity! We rubbed the paper, and it became electrified and tried to attract the neutral body—the table. As the table did not give, the electrified paper attracted itself to the table.

7. HOW TO OBSERVE EXPERIMENTS.

Here is where I have to call your attention to a very important rule. Do not expect too much effect from these experiments, as the quantity of electricity produced by friction is very small. But watch for every little thing which seems unusual. In doing so you will sharpen your wits and be more successful in experimental work, than if you just rush through the experiment to observe simply the final effects.

8. ABOUT APPARATUS.

Now, let's go back to our paper. Put this paper on the radiator, or the stove, so that it gets hot. Now, take your flannel cloth and heat it, also. Rub the paper with the flannel cloth and you will see that it becomes much greatly electrified.

It shows you that the same bodies can produce different results by changing the condition of their substances. This electrified paper will easily stick to the wall and stick to it longer than the cold paper rubbed by your hand.

Bear in mind, that for all experimental work, **your apparatus should be warm and dry to get the best results.**

9. REPULSION.

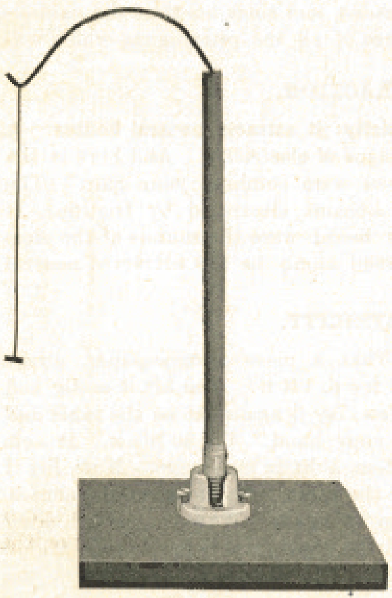


Fig. 1.

So far we have observed Electrical Attraction. We saw that neutral bodies are attracted by electrified objects.

Take an ordinary match and let it burn until it is charred through and through. Break the remaining substance, which is carbon, into small pieces and place them upon the top of your tin disk. Electrify the ebonite rod with the warmed flannel cloth and bring it near the carbon pieces. What do you see? When the paper pieces jumped up to the ebonite rod, they mostly stuck onto it, but now the carbon mostly jumps away as fast as it can. This "jumping away" is called **Electrical Repulsion.** The carbon is first attracted and then repelled.

10. CARBON PENDULUM.

Now, rig up your support for your electrical pendulum and tie a piece of carbon to one end with a silk thread. See fig. 1. Tie the other end to the wire support. Electrify the ebonite rod and bring it near to the carbon pendulum. As soon as you touch the carbon pendulum with your electrified rod, you see it fly away from the rod as far as it can. The carbon is repelled as soon as it becomes electrified through touching the rod.

11. CHARGING BY CONTACT.

We call this kind of electrifying—"charging by contact," in contrast with "charging by friction," when we generate electricity in the ebonite rod, or on the glass sheet, by rubbing it with the flannel cloth.

12. CARBON FLIES.

Put some small carbon pieces in a tin cover and rub the warmed glass plate with a warm piece of silk. Cover the tin with the glass plate and see what happens. Why do the carbon pieces perpetually jump up to the glass and jump down again?

The electrified glass attracts them, charges them with electricity by contact, and repels them instantly. As soon as the carbon touches the tin bottom it loses its charge and becomes neutral again, and, as you know, that neutral bodies are attracted by electrified bodies, the carbon pieces jump up again to the glass plate.

13. ELECTRIC SPIDER.

Take a piece of paper about four inches by two inches, and make a "Spider," as in the picture, by cutting it into small strips, but only up to about one-half an inch from one end. Lay it on your glass plate and rub it with your warmed flannel cloth from the head to the legs, so as to generate electricity in it. See fig. 2.

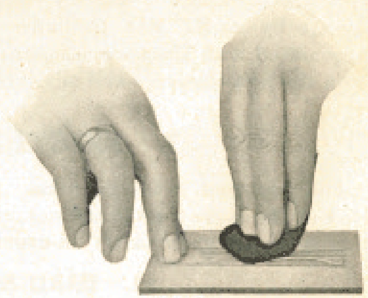


Fig. 2.

Now, lift the spider quickly and see what happens. The spider, which was fast asleep on the glass plate, wakes up quickly and stretches his feet out into the air. Some of them stretch way up and try to reach your hand.

14. UNLIKE ELECTRICITIES.

You know from your experiments that electrified objects attract neutral bodies, and repel them after the attraction. You saw how our spider stretched his legs and how the carbon pieces tried to fly away from our electrified rod, and now let us try one more experiment, which will seem to upset our experiences.

Electrify the ebonite rod and place it on a wire stirrup, made of a piece of wire

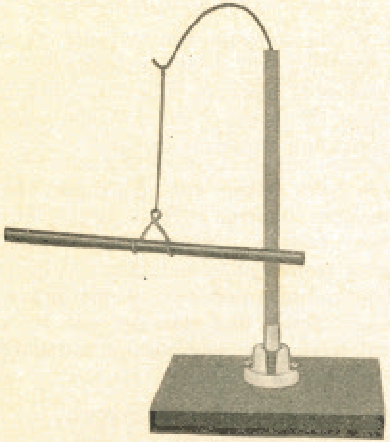


Fig. 3.

or a hair pin. The rod is charged by friction; that means, it is an electrified body. Now, rub the warmed glass plate with silk and bring this electrified body near to the electrified rod.

After all our experiments, we should expect that the two electrified bodies would repel each other. But we see that they attract each other very strongly. And, now, let me explain the mystery of all these experiments.

There are two kinds of electricity. One which we generate through friction of the ebonite rod, and the other which we produce by rubbing glass. It has been agreed for convenience to call the glass electricity—positive, and the ebonite rod electricity—negative.

Positive Electricity is represented by +E.
Negative Electricity, by —E.

15. LAWS OF ELECTRICITY.

As a result from our experiments we deduct the following laws of electricity.

1. **Charges of the same kind of electricity repel each other.**
2. **Charges of unlike kinds of electricity attract each other.**
3. **Either kind of electricity attracts, and is attracted by a neutral body.**

16. CONDUCTOR AND INSULATOR.

It is not often that we have to generate Frictional Electricity in one place and carry it to some other, but it happens sometimes and we have to see how this can be done. We don't know how electricity, itself, acts on our conducting line; we only accept for convenience again the fact that it flows through the conductor, usually a wire, like water through a pipe.

When electricity passes through a conductor, we say that we have an **Electric Current,** or **a Current of Electricity,** but, keep it clear in your mind—electricity is not a fluid. Nor is it a substance which can be moved. We say that it " flows."

When we conduct electricity through a neutral body, we have to be very careful to see that our conductor is entirely insulated from other conducting bodies. When we rubbed our spider, we put it on a glass plate just to prevent the electricity from flowing from the spider to the table. **The glass was the Insulator, or Non-Conductor, and bear this in mind, it is one of the best insulators we know of.**

When we tied the carbon pieces to our pendulum, we used silk thread, because silk prevents the escape of electricity. Silk is an insulator. The ebonite rod is also an insulator.

No conductor is possible without insulators. In nature you will find that two of the most common elements—water and air—act differently. Dr. Gilbert, in his early experiments, observed that presence of moisture spoils the effects of electricity. His experiments prove that water is a good conductor and air a very good insulator. Now you understand more clearly why we want our apparatus to be warm and dry, and why our experiments show the best results on a warm day in a dry atmosphere.

17. POTENTIAL OF ELECTRICITY, (E. M. F.)

When you approached the electrified body with your finger, you saw a little spark jump to the tip of your finger, or knuckle. Your finger acted as conductor and the air around the electrified body as insulator to prevent the electricity from flowing out, as long as some force within the electrified body could overcome the resistance of the insulating air. **We call this inside power of electricity, its Potential or its Electro-Motive Force, (E.M.F.)**

It is something similar to the pressure of water which is kept in a tank on the top of a roof. The water tries to get down to the ground—to reach the surface of all water. The Potential of Electricity acts nearly in the same manner, but not only downwards. It tries to use every conducting body in any direction. This is the reason why the spark jumps over to your finger. You are the neutral body which conducts the electricity down to the earth, because **the Potential of the earth, and of all neutral bodies, is assumed as Zero—0—.**

The electricity passes from the body with the high potential to anyone which has a lower potential. We say that the difference of potentials of two bodies causes an electric current flowing through a conducting line between these two bodies.

18. THE ELECTROPHORUS.

A simple and effective instrument for generating larger quantities of electricity, and more convenient than the glass plate or ebonite rod, is our **Electrophorus.**

This is a small electric machine, the source of our future supply of static-electricity. It consists of the conductor, a tin box and a non-conductor, the resin cake. The tin box is the cover for the cake. The ebonite rod forms the insulating handle for the cover. See fig. 4.

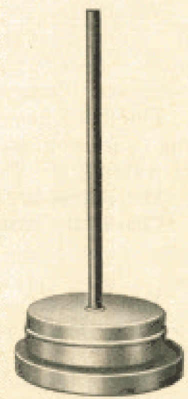


Fig. 4.

19. HOW TO USE THE ELECTROPHORUS.

We will first get acquainted as to how to use it, and later on we will learn how it works.

Fig. 5.

Fit the ebonite rod tightly in the hole of the tin cover by wrapping a small piece of paper around the end of the rod so you can lift the cover by its handle. (a) Place the resin cake upon a wooden table and rub it with a warm flannel cloth for a minute to thoroughly electrify it. (b) Grasp the handle of the cover by its extreme end and place it upon the resin cake, without touching the tin edge of the cake. (c) Touch the cover for an instant with your finger. See fig. 5. (d) After you have removed your finger entirely from the cover, lift it by the end of the ebonite rod.

Bring your left hand near the cover and if you have done everything exactly as directed, you will see a fine spark jump from the cover to your finger through a distance of a half-inch. See fig. 6.

You cannot get a second spark from the cover at the same time. To re-charge it, simply place it upon the resin cake again and let it remain there for a few seconds. Touch it as before and lift it by the handle. You can re-charge your cover many times before you will have to electrify the resin cake again.

The first three or four sparks are usually smaller than those immediately following. As soon as the sparks begin to get too small, charge the resin cake again by rubbing it.

The charge in the cover is +E.
That in the resin cake is —E.

20. EQUAL POTENTIALS.

Now, let us see what we can do with our electric machine. Hang your tin cover by means of a silk thread and one of the clamps to your pendulum. See fig. 7.

The tin is insulated from the table to the earth. The potential of the disk at the start is 0 (zero). It is a neutral body.

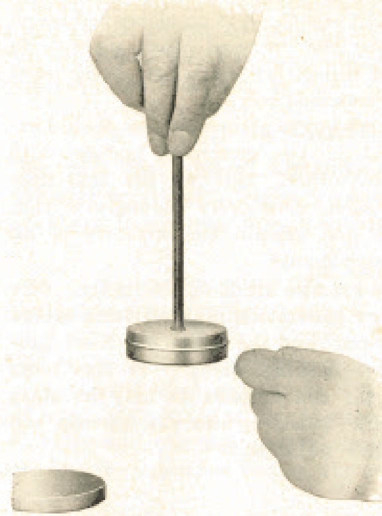


Fig. 6.

21. DISRUPTIVE DISCHARGING.

But, if you approach the tin with your finger slowly, if will move immediately in the direction of your finger until the disk is discharged by bringing the knuckle near enough to allow the spark to pass.

If you have taken out one spark, the disk becomes neutral. This is a very important fact in distinguishing a good conductor from a non-conductor. A good conductor is discharged at once—**disruptive.** A non-conductor, like glass or our resin cake, will have to be discharged many times before it becomes neutral.

22. SILENT DISCHARGING.

Charge the cover again and bring the head of a pin slowly towards it. Watch the many little sparks which follow one another closely with a hissing sound. Again charge the cover and approach it slowly with the point of the pin. You don't see or hear anything. However, you will find that the cover was discharged by a **silent discharge.**

Charge the cover of the electrophorus and bring it near the suspended disk. It will be attracted by the cover and a good spark will jump over. Re-charge the cover and watch the next spark. How is the third one? Sometimes a fourth spark will not pass to the disk, and the disk, itself, will be repelled by the cover. Its potential is raised to the same as that of the cover, and as the cover and the tin are full of the same kind of electricity, they repel each other.

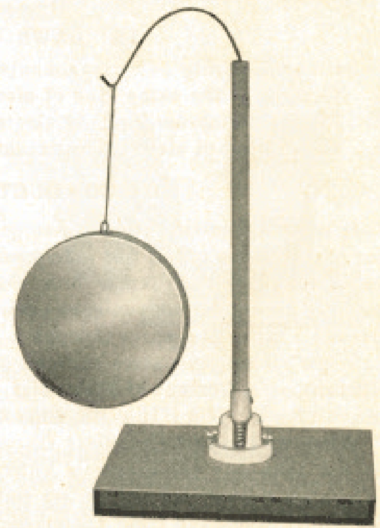


Fig. 7

23. ELECTRIC CLAPPER.

By means of our carbon pendulum we can discharge the electrified cover slowly. If you hold a disk on one side of the pendulum and the charged cover on the other side, the carbon will swing back and forth between the cover and the disk, like a tiny clapper. See fig. 8. It always takes a load of electricity from the electrified cover and brings it to the neutral disk.

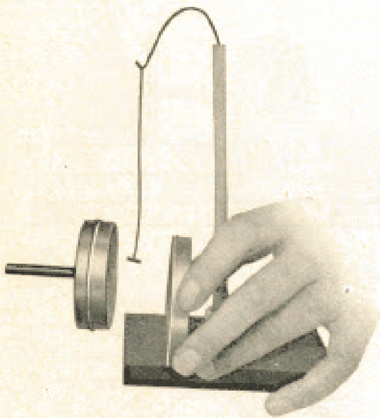


Fig. 8.

As the carbon is a little body it can carry only a small amount of electricity, and as it is a good conductor of electricity, it is quickly charged by the cover and discharged through the "grounded" tin, that is, the tin connected through your body with the ground.

24. ELECTRIC DENSITY.

The charged cover will hardly lose any electricity if you hold it in the air by its insulating handle for some certain time, but if you put a bent pin on the top of the cover, so that its point sticks out in the air as in Fig. 9, you will find it discharged within a few seconds.

Electricity may escape from a point so rapidly that the flame of a candle will be deflected when placed near the point. This current of air is called—Electric Wind.

If you try these experiments in a dark room, you will see that the point of the pin will show a luminous phenomenon—the escaping electricity.

Sharp corners or points are the best means for the electricity of escaping to the air and at such places electricity piles up and is more dense than at others. For this reason, avoid sharp corners and points in your conductor if you want to keep a charge for any length of time.

II. ELECTRIFICATION BY INDUCTION

Up to this time we have studied the effects of electricity, which was either generated by friction or transferred from the electrified object to the neutral body by contact. Now, let us see what happens in the neutral insulated conductor when we approach it with an electrified body, before any spark passes over.

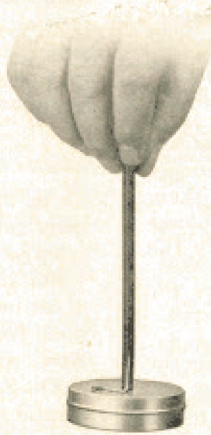


Fig. 9.

25. POLARIZATION BY INDUCTION.

For this experiment let us rig up our stand and put the tin in a position that will prevent it from swinging around by means of silk threads and a few clamps. See fig. 10. A moist cotton thread hangs down from the loop in the top clamp. This thread is our Electroscope.

An Electroscope is an instrument which indicates the presence of electricity. We will learn more about this later on.

Now, charge the disk by touching it with the charged cover. The thread and disk have the same kind of electricity and you will see the thread standing off from the disk. Discharge the disk through your finger and watch the thread. At the moment the charge of electricity leaves the disk, the thread drops flat In this experiment we charged the disk by contact.

But, now bring the charged cover slowly near the neutral disk, keeping them apart about one-half inch so that no spark can pass to the disk. See fig. 10.

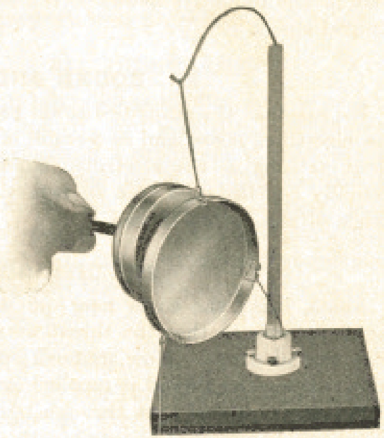


Fig. 10.

Without charging the disk by contact, as we did in our previous experiment, the thread stands off. Take the cover away from the disk and the thread drops. Bring it near again, and the thread stands off as before, showing that it and the disk are electrified without contact, but only while you are holding the cover in place.

26. THEORY OF NEUTRALITY.

To explain this phenomenon, we have to go back to the laws of electricity. If we accept the theory of two kinds of electricity within a neutral body, then we have to take it for granted that both kinds of electricity are equal in power. As they are equal in power, we cannot see their effect, because the laws of electricity teach us that their action neutralizes each other. That is the explanation of why the neutral body does not show any effects of electricity.

If we charge a neutral insulated body with one kind of electricity, this superfluous electricity shows its power in the way we have learned before, attraction and repulsion.

27. THEORY OF INDUCTION.

Our insulated disk with the cotton thread electroscope is neutral. As soon as the positively charged cover is brought near our disk, it destroys the neutrality of the tin by attracting the —E within the neutral body and by repelling its +E as far as it can in the opposite direstion. **The charged cover produces a separation of the two kinds of electricity within the neutral body, by induction.** As soon as the inductive action of the electrified cover is removed, the disk becomes neutral again.

28. BOUND AND FREE ELECTRICITY.

We say that the electrified cover **polarizes** our disk. The —E is drawn towards the electrified cover and as a result of the mutual attraction, it is held, **or bound,** there as long as the electrified cover is within the right distance. The +E is actually repelled and **free** to escape. Its tendency to escape causes the divergence of the cotton thread.

29. CHARGING BY INDUCTION.

Again, bring the cover near our disk and polarize it. Keep the cover at the right distance so that the thread stands off, and touch the disk with your finger. The thread drops. Now, remove your finger and take the cover away rapidly. You will see the thread is repelled again.

We have learned that through induction we create bound and free electricity. When we approached the disk with the plus electrified cover, we bound the —E, and made the +E free at the other end of the disk.

This freed +E escaped through your arm when you touched the tin. The —E could not escape but it became free as soon as the plus electrified cover was taken away. This charge of —E filled the disk and caused the thread to stand out again.

Just a few words more about induction. Insulators and non-conductors are not easily polarized. This is the reason why a conductor is attracted more strongly by a charged body than an insulator, or non-conductor. The neutral body, then, is really no longer neutral when it is brought within the area of the inductive power of an electrified object. We call the area of an electrified body, in which the polarization can be observed—its **Electrical Field.**

30. DIELECTRICS.

Try the experiment of induction again and hold the glass plate between the disk and the cover. The inductive force penetrates and acts through glass, air, paper, etc. These kinds of substances which allow the inductive influence to act through are called—**Dielectrics.**

31. THEORY OF THE ELECTROPHORUS.

If you have entirely grasped the rules of induction, you will easily understand how our little machine, the electrophorus, works.

You generate a charge of —E in the resin cake by rubbing it. See fig. 11. Although its surface and that of the cover, seem to be very smooth, they are uneven and there is a thin layer of air between them, except at a few points of contact. Hence, the cover becomes polarized by induction as shown in Fig. 12. Its +E is bound through the —E of the resin cake and its free minus charge escapes when you touch the cover with your finger. See fig. 13. When the cover is lifted by the insulating handle, the plus charge, which was held bound by the minus charge of the resin cake, becomes distributed throughout the entire surface and is ready for action. See fig. 14. As long as the resin cake retains its charge—under normal conditions for some time—we are able to re-charge the cover by induction.

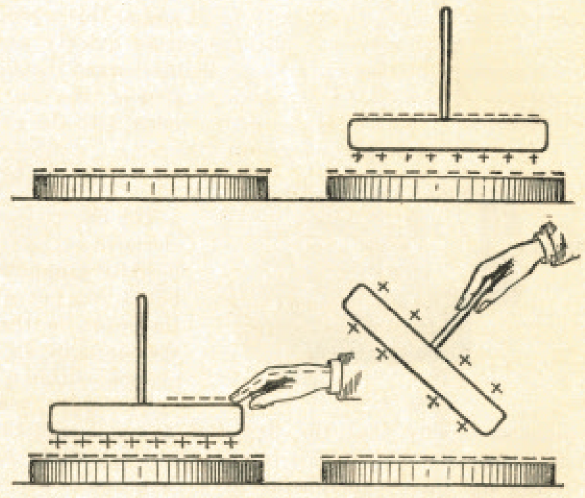


Fig. 11—14.

32. CONDUCTIVE BODIES.

Cut out small figures from paper, about a half inch high. Moisten a few of them and place them on the cover. Charge it and lift the cover. Why do they jump off? Why do the moistened figures jump quicker than the dry ones?

Put little pieces of charcoal, some bread crumbs, and a few small pieces of paper on the cover. Which one will jump first? Try the same experiment with small pieces of cotton thread and silk threads. Moisten one of the cotton threads. Now, what do you see? Which one will jump quicker?

The answer to these questions is to be found in the substances of our experimental objects, as the more conductive they are (charcoal, cotton thread, moist bodies, etc.), the better they will be polarized, charged, and repelled.

33. CONDENSER.

The principle of Induction is used to give a conductor a much greater charge than it would otherwise receive. You remember that our insulated disk in Fig. 7 does not take more than three or four sparks. These sparks fill its **capacity.**

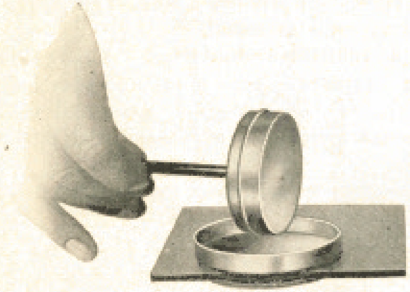


Fig. 15.

Cut out a few pieces of tin foil the same shape and size as your disk and pile them on the table. Place the glass plate between the disk and the tin foil so that it will not completely separate them on one side. See Fig. 15.

Charge your cover and allow the sparks to pass to the center of the disk and see how many sparks it will take. You may charge your disk many times before a big spark passes through the air to the tin foil.

The capacity of the disk has been increased. The body of the disk is the same. As the potential of the electric cover—the charging body—did not increase, the potential of the disk must be the same. Therefore, **the electricity within the disk must have become denser;** it was condensed, and for that reason we call our apparatus a **Condenser.**

34. THEORY OF CONDENSERS.

All condensers consist of two conductors with a dielectric between them. One conductor is insulated from the earth and receives the electricity, and the other conductor is grounded. Every time a spark passes to the insulated conductor from our electrophorus cover the +E in the tin foil is sent to the earth, and the —E is drawn up near the glass.

After several sparks, we have a strong charge of +E in the insulated conductor, and a strong charge of —E in the lower grounded one. The glass keeps the plus and minus electricities apart for some time. The air is not as good an insulator as the glass, so the electricities push their way through the air as soon as the attraction between them becomes strong enough to overcome the resistance of the air.

If you place the glass plate between the two conductors, insulating them entirely, you may fill the condenser much stronger than before.

35. DISCHARGING THE CONDENSER.

To discharge our condenser, lift it by the corner of the glass plate and lay it on your hand. Notice how the tin foil sticks to the glass, attracting and attracted to the disk on top of the glass. Then touch the disk with your other hand. See fig. 16. **Always touch the grounded Conductor first if you wish to feel the shock which is caused by the two electricities that rush together through your body.** If you touch the upper tin first, the electricity, or part of it, passes slowly through your body into the tin foil.

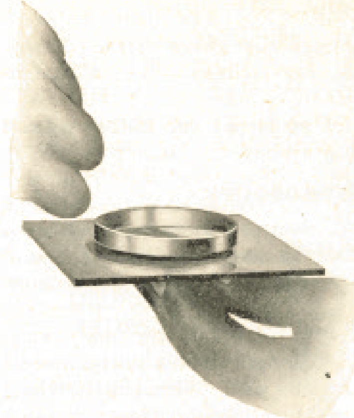


Fig. 16.

36. DISCHARGER.

To discharge the condenser, and to prevent a shock from it, you may use a **Discharger,** which consists of a conductor with an insulating handle. See fig. 17. The electricities pass through the conductor without going through your body, on account of the insulating handle. But always touch the grounded conductor first with one end of the discharger, and then swing it around to the insulated conductor as illustrated in Fig. 17.

37. THE LEYDEN JAR.

The condenser which we used in our experiment is a kind of so-called **Franklin's Plates.** Among the various forms of condensers, the **Leyden Jar** is the best known and is very easy to build.

It consists of a wide-mouthed glass jar, or an ordinary drinking glass, with tin foil pasted around the inside and outside, covering two-thirds of it. A wooden stopper closes the jar on the top, through which passes a metal rod ending on the outside with a metal ball, and touching inside the inner coating of the jar—the tin foil. See fig. 17.

The Leyden Jar is charged by connecting the outer coating through your hand, or in some other way, with the earth, for instance by resting it upon the table, while the electricity is passed through the ball. To discharge it, touch the outside coating first, either with your hand or one end of the discharger, and then touch the ball, or swing the other end of the discharger around the ball. See fig. 17.

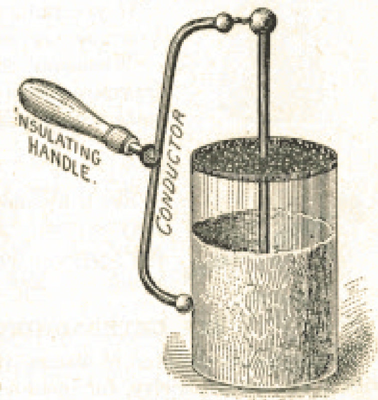


Fig. 17.

38. ELECTROSCOPE.

In our previous experiment we used an insulated disk with cotton threads hanging down on it, to find out when our disk was charged. We called this apparatus—the **Electroscope.**

The electroscope is an instrument by means of which we can determine not only the presence but also the kind of electricity in a body.

39. DR. GILBERT'S ELECTROSCOPE.

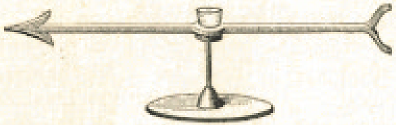


Fig. 18.

The first electroscope was constructed by Dr. Gilbert and consisted of a stiff strip balanced lightly upon a sharp point. See Fig. 18.

A thin strip of wood, straw, or even a goose quill, balanced upon a sewing needle will serve equally well. When the electrified body is held near the electroscope it is attracted and turns around, thus indicating the presence of electric charges far too feeble to attract even bits of paper from a table.

40. GOLD-LEAF ELECTROSCOPE.

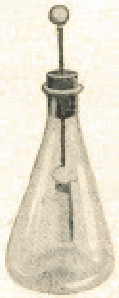


Fig. 19.

The most common form is the Gold Leaf Electroscope, which consists of a glass jar, through the wooden stopper of which passes a metal rod, ending outside in a metal ball, and having two long narrow leaves of some thin metal, like gold leaf, attached to the inner end. See Fig. 19.

If you build yourself an electroscope for your experiments you may use small **tin foil leaves** or moist cotton threads.

Whenever the ball is touched with a charged body the leaves receive a part of the same charge and diverge in accordance with the laws of repulsion.

41. PROOF PLANE.

Fig. 20.

For convenience in using the electroscope, a **Proof Plane** may be used. It consists of a small conductor and an insulating handle. See fig. 20. A ring or a coin may be used as a conductor, and a silk thread for the insulating part.

42. DETERMINING AN ELECTRIC CHARGE.

To determine the kind of electricity in a charged body, charge your electroscope with a known electricity, for instance the —E of your ebonite rod, and make the leaves spread apart. Now, put the proof plane in contact with the charged body, whose electricity you are going to determine, and quickly touch the knob of the electroscope with it. If the leaves diverge still more, they show that the unknown electricity must be the same as that of the ebonite rod—negative electricity. If the leaves fall together, it only shows that the body is probably charged with positive electricity, as a neutral body causes the same collapse of the leaves. **Therefore, an increase of the divergence of the leaves is the only sure test.**

Neutralize the electroscope by touching the knob with your finger. Charge it by means of your proof plane positively from the rubbed glass plate and examine your unknown electrified body again with the help of the proof plane and the electroscope. If the leaves now **spread more apart,** the body is charged with positive electricity.

Experiments of conducting electricity, or charging by induction, can be done and shown with the electroscope very plainly.

43. ELECTRIC MACHINES.

Although the effects of the electrophorus in comparison with the results from the glass plate or ebonite rod are quite large, they are not entirely sufficient. With the electrophorus we can only get one momentary electric charge, and for some certain kinds of experiments this is not enough. There are apparatus constructed called **Electric Machines,** which generate electricity, producing continuously electric charges.

We know of two kinds of electric machines: the one is based on the **principles of Induction,** like the **Toepler-Holtz Machine,** or the **Wimhurst Machine.** See Fig. 21.

These machines produce large quantities of electricity, which are condensed in the Leyden Jars connected with the conductors. The effects of these machines are often dangerous, as the difference of potentials between the two jars is extremely high.

The other kind of electric machine is based on the **principles of Friction.** It is not as effective as the above mentioned machines, but it is more than sufficient for your experimental work at home, and besides it is easily built.

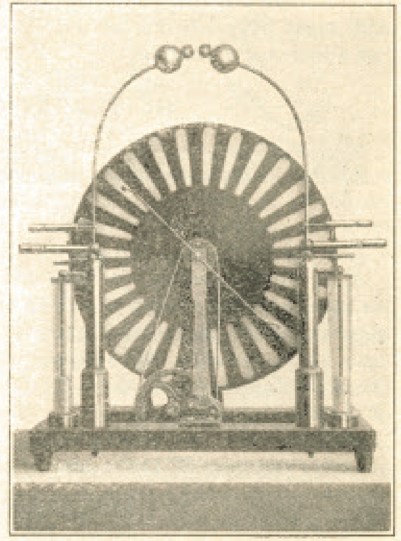


Fig. 21.

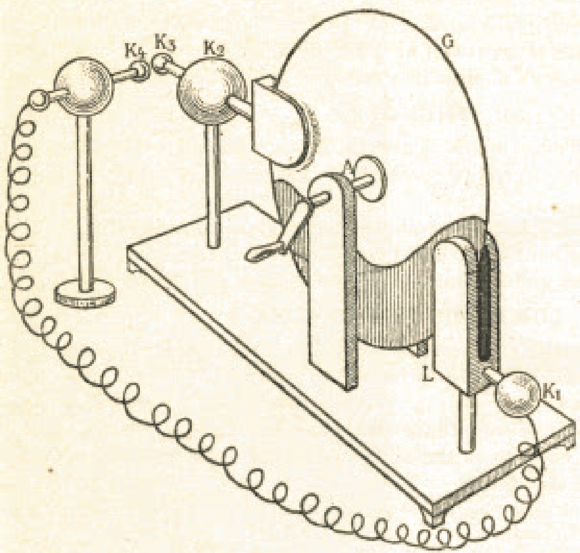


Fig. 22.

The Frictional Electric Machine consists either of a glass plate which is rubbed between two leather cushions, or of a hard rubber plate (for instance a hard rubber talking machine record), which is twirled around between two pieces of catskin. In Fig. 22 A is the axle which carries the plate G. Plate and axle are connected stiffly and mounted in a framework, so that they may revolve easily, by turning the handle, in the manner of a grindstone. L is the insulated carrier of the cushions which are pressed against the plate by means of springs. A piece of hard rubber pen holder insulates L and also K - 1, the metal ball conductor for the electricity generated in the cushions. On the other side of the plate you see an insulated metal ball K - 2, connected with a similar conductor K - 3. Two wooden pieces with needle points on the inside extend from K - 2 on each side of the plate. In order to prevent the escape of electricity between the cushions and the needles, there should be insulated parts, like silk or leather flaps attached to the cushions and partially cover the plate.

45. HOW THE PLATE MACHINE WORKS.

Now, we will suppose we have built our Electric Machine with a hard rubber plate. Through the friction of the ebonite plate on the cat-skin cushions, we generate —E on the plate and +E on the cushions. The +E from the cushions is collected in the conductor K - 1, the —E of the plate is sucked through the needles on the inside of the wooden arms and conducted to K - 3. If you connect K - 1 with the ground—by means of a chain or thick wire its potential becomes Zero, and you can easily pull sparks from K – 3. If you ground K - 3, its potential becomes Zero and the condensed electricity in K - 1 will be glad to rush through your body to the ground.

The best effects can be obtained if you conduct the electricity from K - 1 to the insulated K - 4, and put it up near K - 3. The potential difference between K - 3 and K - 4 is big enough to cause large sparks to pass between these two conductors.

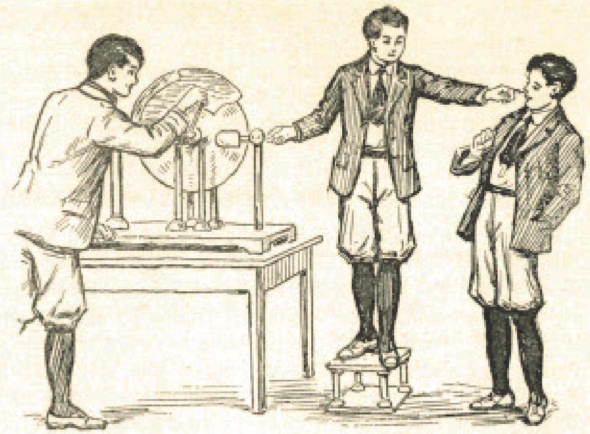


Fig. 23.

46. INSULATING STOOL.

If you have built your electric machine, you will not mind building a little device which is easily made out of a board with four porcelain insulators. See Fig. 23. This is called an **Insulating Stool.**

If you stand on it and hold one hand in connection with one of the conductors of the electric machine, you will act an enlarged conductor and you can perform all the interesting experiments, based on the effects of Static Electricity

47 EFFECTS OF STATIC ELECTRICITY.

The effects of Static Electricity are of different kinds, and you may try them out with your electric machine.

1 **Mechanical Effect:**
Electrical sparks puncture paper, cardboard, glass, etc.
Electric Wind.

2. **Chemical Effect;**
Electric sparks generate ozone by passing through the air.

3. **Heating Effect;**
Gas, powder, etc., can be ignited by an Electric Spark.

4. **Optical Effect:**
Electrical sparks cause luminous phenomena.

5. **Physiological Effect;**
Electric sparks cause a shock in the human body.

ATMOSPHERIC ELECTRICITY

Just as there is electricity in the earth, there is also electricity in the air. Generally the air is electrified and its charge is usually +E. Clouds carry sometimes plus and sometimes minus charges. The cause of Atmospheric Electricity is not perfectly known.

48. BENJ. FRANKLIN'S EXPERIMENT.

It was Benjamin Franklin who proved the identity of the lightning with the discharge of frictional electricity, through an extremely dangerous experiment. What he did was to fly a kite in the face of an advancing thunder storm. A pointed wire was fastened to the top of the kite and a short strip of silk was tied to the end of the kite's string. At the junction between the kite's string and the silk string, a door key was attached. As long as the kite's string was dry no results were obtained, but as soon as it became moist with the rain, making it a better conductor, Franklin found it possible to draw sparks from the key by bringing his finger near it.

Leyden Jars could be charged and all other electrical effects produced by the sparks furnished by the clouds. The proof of the identity was complete.

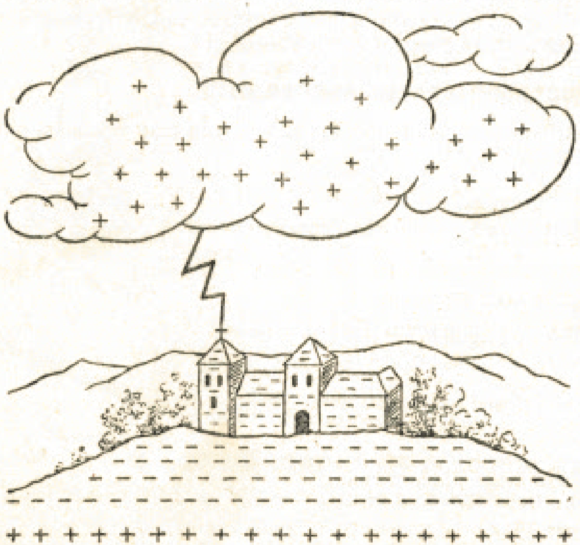


Fig. 24.

49. POTENTIAL OF LIGHTNING.

This experiment was repeated by a man named Romas, who drew from a kite with a metallic string, sparks nine feet long. In 1753, Richman, of St. Petersburg, who was experimenting with a similar apparatus, was struck by a sudden discharge and killed. You see how dangerous this experiment is, as the potential of the lightning spark is beyond all calculation. **It represents millions and millions of volts.**

Lightning may be produced either by the passage of electricity between clouds of different charges, or between a cloud and the earth. See fig. 24. In this case it generally strikes a tree or some other high object. **If you are surprised by a thunder storm in an open field, never stay or walk over the plain. Lie down flat or seek shelter in a thicket—but never under a tree.**

50. THUNDER.

In case of the lightning flash, the air is the dielectric which is broken through and since the velocity of this enormous discharge is very great, a terrific sound is created.

To a person who is near the flash, the sound is that of a mighty single crash, but to one at some distance, the sound produced, with its echoes from the clouds and the earth, is that of the deep rolling thunder.

51. LUMINOUS PHENOMENA.

Heat Lightning is the reflection of a thunder storm from the clouds near the horizon or from the air. The storm is entirely below the horizon and so far away that we cannot hear any sound effects.

St. Elmo's Fire, which you can sometimes observe on the ends of masts of ships, or on any point that sticks up high in the air is the escaping electricity drawn up from the earth to neutralize the clouds.

The Aurora, the light effect in the region of the poles, is an electrical phenomenon of unknown origin.

52. LIGHTNING RODS.

Franklin's experiment with the kite led to his invention of the lightning rod. The purpose of the lightning rod is not so much to attract a stroke of lightning, but to reduce the potential difference between the clouds and the earth at this place, by a quiet discharge. The rod must be pointed at the top, and insulated from the building and have a very good connection with the damp earth below. If a full lightning discharge from the clouds to the earth were to strike the lightning rod, the building could be damaged, although insulated, just as Franklin might have been killed through the silk string, if lightning had struck his kite.

MAGNETISM

53. NATURAL AND ARTIFICIAL MAGNETS.

In nature there are some certain kinds of iron ore (lodestones), which have the property of attracting pieces of iron. See fig. 25. The ancients found lodestones in Magnesia, in Asia Minor, whence arose the name—Magnet. Such magnets are called **Natural Magnets.**

Later, it was discovered that they could impart their power to pieces of steel, when stroked with the lodestone. These **Artificial Magnets** are not only handier to use but acquire the same magnetic quality as the lodestone to a much greater extent.

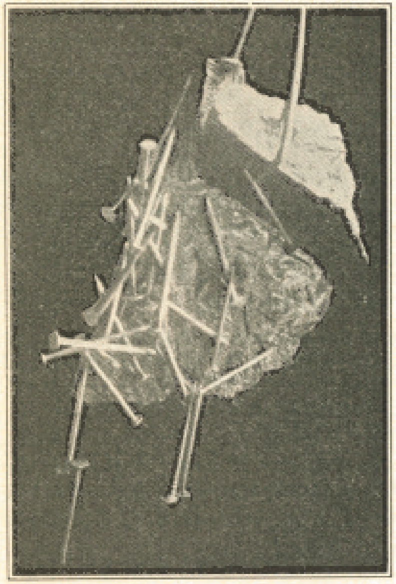


Fig. 25.

54. FORMS OF MAGNETS.

Magnets are made in various forms. The Bar Magnet is a straight magnet. The Horse Shoe Magnet is a Bar Magnet bent into a U shape. See Fig. 26.

A is called the Armature, and should be kept always in place when the magnet is not in use.

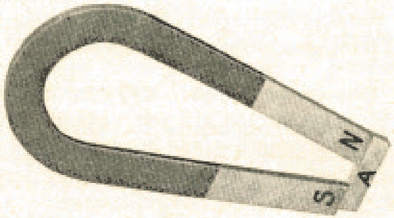


Fig. 26.

55. MAGNETIC POLES.

If you lay your bar magnet on iron filings and then lift it, you will find many of them clinging to both ends, but diminish in numbers towards the center, where there are none. See Fig. 27. Dr. Gilbert, in his famous work "De magneto" published around the year 1600 called the two ends, where the magnetic attraction is greatest, the **Poles,** the middle of the needle, the **neutral point, or equator.**

Fig. 27.

56. PERMANENT MAGNETS.

Pieces of hard steel, like sewing needles, retain their magnetism to a great degree, and hence can be made into **Permanent Magnets.** Pieces of soft iron can be made to act as **Temporary Magnets** under certain conditions, and they hardly retain any magnetism after these conditions are changed.

57. MAGNETIC SUBSTANCES.

Mix needles, tacks, nails, silver, copper and nickel coins, paper and paste-board, all together in a container and approach them with the magnet. You will soon find that some substances are not attracted, although it is thought that all objects are more or less effected by a magnet. These substances which are attracted by a magnet are called **Magnetic Substances;** the others—**Non-magnetic.**

58. POLES.

Suspend the bar magnet by a thread attached exactly to the middle. See fig. 28. After swinging back and forth for a time, it will finally come to rest in a direction that is nearly North-South. It has been agreed to call the end which points to the North, the Plus, or North Pole, and the other—the Minus, or South Pole. The strictly correct names would be the **North Seeking Pole,** and the **South Seeking Pole.** We will soon learn what a mistake we make in calling them the North and South Poles.

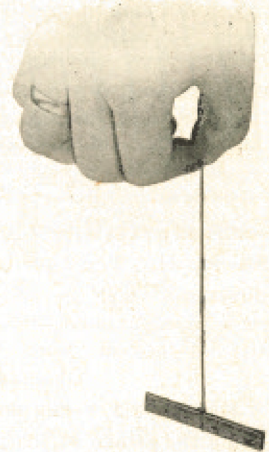


Fig. 28.

59. THE COMPASS.

The most important uses of magnets are in the **Compass,** and in connection with electrical currents, in machines like dynamos and motors.

The biggest of Dr. Gilbert's discoveries was that the magnetic needle points north and south because **the Earth, itself, is a great magnet,** with two poles and therefore causes the freely suspended magnet to turn in a north-south position.

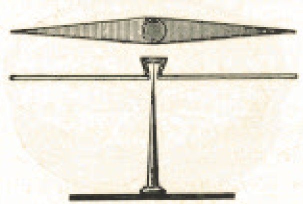


Fig. 29.

The magnetic needle of the compass is a simple bar magnet balanced upon a pivot See Fig. 29. We say this little needle comes to rest in a nearly north-south direction, for if we followed it we would not reach the North Pole of the earth, but the so called North Magnetic Pole. This North Magnetic Pole lies on the north coast of North America, so there is

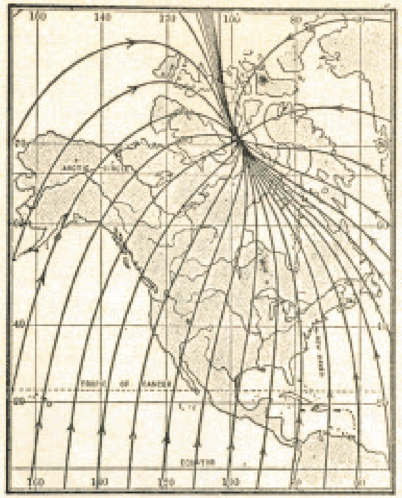


Fig. 30.

some certain divergence between the real north-south direction and the north-south direction of the magnetic needle. See Fig. 30. This divergence, measured by degrees, is called the **Magnetic Declination.**

This declination is different for every meridian of the earth. In some places on the earth, on the meridian of the magnetic North Pole, the needle points to the true north. But, as the Magnetic North Pole itself, for certain not well known reasons, moves westward, the declination at any place changes from year to year. This change for New York, for instance, is about four minutes.

60. HOW TO USE THE COMPASS.

To use the compass, you have to place it in a horizontal position and turn the wind-sail so that the North Pole of the needle covers the "N" on the wind-sail. See fig. 31. You have then found the north-south direction, as well as all other directions which are plainly shown by the wind-sail.

61. ARTIFICIAL MAGNETS.

Magnetize a sewing needle by drawing it across the ends of your bar magnet. Begin the stroke at the middle of the needle and end it at the point, drawing it across the North Pole of the magnet. The North Pole of any magnet is usually indicated by an imprinted "N" or a line. Stroke the needle ten or twelve times. Reverse it and draw it across the South Pole of the magnet, beginning at the middle of the needle and ending at the eye.

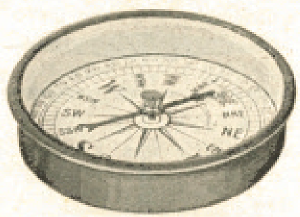


Fig. 31.

If you want to produce a desired pole at a given end of a piece of steel, bear in mind **that the end of a piece of steel which last touched the North Pole of a magnet, becomes the South Pole.**

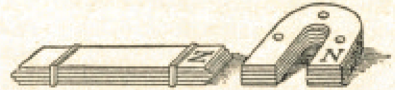


Fig. 32.

62. MAGNETIC SATURATION.

It is of no use to stroke the needle too often, as every piece of steel or iron can only hold a certain amount of magnetism. Then it is saturated, and will not become stronger. As the magnetism does not penetrate deep into the body, thin pieces of steel may be magnetized practically through and through. By riveting these kinds of magnets together, thick magnets of considerable strength are made, and used, especially in motors and dynamos. These magnets are called **laminated or Compound Magnets.** See fig. 32.

63. EFFECT OF HEAT ON MAGNETS.

If a magnet is heated to redness, it will be found on testing it after cooling, as Gilbert showed, that it has lost practically all its magnetism. If the needle is red hot it cannot be picked up by the magnet.

64. LAWS OF MAGNETISM.

Bring the N end of your bar magnet near the plus end of your compass needle and note the result. Bring the minus end of the magnet near the plus end of the needle and observe what happens. Make the same experiment with the minus end of the needle.

From the results of these experiments the following laws are derived:—

1. **Like poles repel each other.**
2. **Unlike poles attract each other.**

Now, take a good size knitting needle. If you find that it is **not** magnetic, which you can determine by the help of your iron filings, approach the North Pole of your compass with one end of it. Repeat this with the other end of the needle. Try the same experiment with the South Pole of the compass needle. If the knitting needle was not magnetic at all, you have found another law of attraction:—

3. **Either pole of a magnetic needle attracts, and is attracted by non-magnetized iron or steel.**

65. PROVE OF MAGNETISM.

As a consequence of this law, attraction, alone, simply indicates that at least one of the objects is magnetized, and only **repulsion proves conclusively that both objects are magnets.**

66. LINES OF FORCE.

Lay the bar magnet upon the table and cover it with a sheet of white paper. Over this put your glass plate and sift iron filings evenly over it. A sieve for this purpose can be easily made by puncturing the bottom of your small pill box. Tap

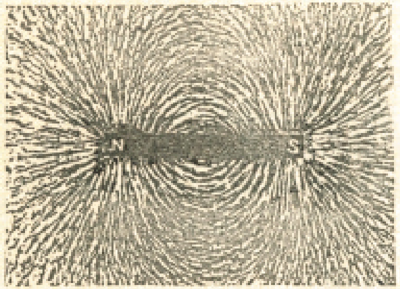


Fig. 33.

the plate gently with your pencil and watch the filings at every blow.

They will arrange themselves in certain magnetic figures, in lines that show clearly the direction of the **Magnetic Force**. See fig. 33.

67. MAGNETIC FIELD.

These **Lines of Force** clearly indicate the area of the **Magnetic Field.** We generally accept the theory that lines of force start from the North Pole of the magnet and pass through the air on all sides of the magnet in curved paths, and finally enter it again at the South Pole.

Every magnet has a certain magnetic field with a certain number of lines of force which pass in the above described directions through the surrounding air. As soon, however, as another magnet is introduced into this magnetic field, it causes a distortion of the lines of force from their previous positions. This fact is a very important one in the construction of Electric Machinery.

68. INCLINATION.

Every suspended magnetic needle indicates the lines of force above a magnet. Let us try this experiment by using a very small magnetic needle and watch the position it takes if we move it along the axle of the bar magnet.

We will soon find that in every position but one, the neutral point or the equator, the needle dips towards the nearer one of the poles. See fig. 34. In a similar way the needle that has been balanced horizontally first, and then magnetized, will not remain horizontal, but will dip towards the nearer pole of the earth.

This angle of dip, or **Inclination**, increases according to the distance from the equator. There is no dip at the equator, while at the magnetic poles, the needle will place itself in a vertical position.

69. NORTH SEEKING POLE.

The laws of magnetism teach us that the plus pole of a magnet repels the plus pole of the needle, and attracts the minus pole. We know that the earth acts as a great magnet, whose lines of force flow from its North Magnetic pole and spread out through the air on all sides before they again reach the earth's South Magnetic pole. As the needle rests in a north-south direction, it is evident that the North Magnetic pole of the earth, and the North Seeking pole of the magnetic needle, must be unlike. In fact, it is the South pole of the needle which points to the Magnetic North pole, and for convenience only we are calling this North Seeking point of the magnet, the North Pole.

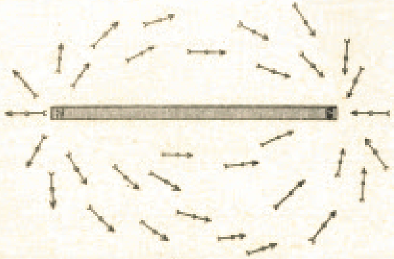


Fig. 34.

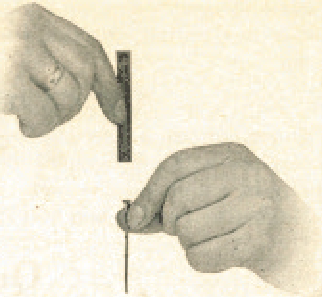


Fig. 35.

70. MAGNETIC INDUCTION.

When a magnet is dipped in iron filings, or nails, it lifts a number of them, attached to one another, because each has become distinctly magnetic through contact with the original magnet. This influence of the magnet over pieces of iron or steel is called **Magnetic Induction.** It reaches over a considerable distance around the magnet.

If you hold a large nail in line with the bar magnet, about one inch away, you can observe that this nail will attract smaller nails and that the end poles of the nail correspond with the poles of the bar magnet. See fig. 35.

This is the reason why the iron filings indicate the lines of force. Each particle of iron becomes a magnet by induction, and, like the magnetic needle, turns so that its two poles are in the lines of force. Its unlike poles attract each other and thus the particles clinging together form the lines of force.

71. TERRESTRIAL INDUCTION.

This is also the reason why you very seldom find any un-magnetic pieces of steel or iron. Already Dr. Gilbert found that the action of the biggest magnet, the earth, converts by induction every piece of iron or steel into a magnet.

Take a piece of iron, a stove poker for instance. As long as you hold it horizontally in an east-west direction, generally both ends will attract each pole of the compass needle, showing that the poker is not polarized. Next hold it in a north-south direction and bring one end to the side of the needle near the north pole. The needle will be repelled at once showing that in this position the poker is polarized. If you bring it back in the first position, east-west, it will again attract both ends of the needle, showing that it is non-magnetic again.

To increase the effects of inductive action of the earth, hold the poker in a north-south direction and give it one or two sharp blows with a hammer. You thereby shake its molecules and enable the inductive force of the earth to turn them more easily in a north-south position. The poker will become permanently magnetized. To make it non-magnetic again, hold it in an east-west line and give it a few sharp blows.

Most steel and iron rods will be found polarized, especially if they have been resting in a vertical position so that the earth's induction could work strongly on them.

72. THEORY OF MAGNETISM.

To explain the magnetic phenomenon, we have to accept the theory that every little piece within a magnet, its molecules, become polarized, and lies partly and wholly in a uniform direction. This can be easily proven by breaking a magnet. Magnetize a needle and note its poles. Break it in the middle and determine the poles of each piece. It became two magnets with the poles of the new magnets corresponding with the poles of the first one. See fig. 36. If you imagine you could break these magnets in half, and then each piece in half again, and so on, indefinitely, until you got molecules from your needle, each molecule would represent a tiny magnet with its poles corresponding with the poles of the original magnet, which you broke first.

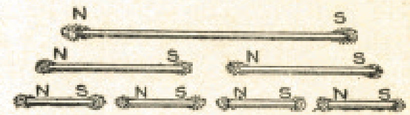


Fig. 36.

Questions to be Answered when Study of Book I is Completed:

1. Classify Electricity.
2. How can you determine the kind of electricity with which a body is charged?
3. Explain the action of the Electrophorus.
4. What are the essential parts of a condenser?
5. Name the most distinct difference between a good conductor and a bad one.
6.. Name the most common appearances of athmospheric electricity.
7. What would you do if surprised by a thunder storm in an open field?
8. Name the laws of Magnetism regarding poles.
9. How do the lines of force run?
10. Is the expression "North Pole" of the compass needle correct?
11. Why are scissors, knives and other steel tools often found to be magnets?
12. How does heat affect magnets?

MEMORANDUM

ELEMENTARY ELECTRICITY

BOOK II

Current Electricity

CURRENT ELECTRICITY

Up to this time we have engaged ourselves in studying the effects which are caused by momentary electric discharges. Even the Electric Machine produced only momentary currents which followed each other at short intervals.

73. ELECTRIC CURRENT.

The most common form of electricity, and the most useful, is the **Electricity in Motion,** or the **Electric Current,** which will occupy us from now on through the book.

74. FLOWING ELECTRICITY.

In order to make the action of this so-called "Current" more intelligible, it is generally compared with the flow of water, but, bear in mind, however, that there is really no such thing as an electric fluid, or substance. The wire carrying electricity does not look any different than the non-charged wire, and the expression "flowing electricity" is only a conventional way of expressing the fact that **the electrified wire, and the space around it, produce some effects which could not be observed** if no electric current was said to be "flowing."

75. VOLTS, AMPERES, OHMS.

The effect of water which flows through a pipe depends upon the pressure of the water and the resistance which the pipe offers to the flow. Similarly, we say that the current must have pressure and overcome the resistance of the conductor to flow along its surface. This pressure is called **"Voltage"** and is measured by **volts.**

The quantity of current that passes along the wire is called **Amperage** and is measured by **amperes.**

The resistance which the conductor offers to the current is called **Electrical Resistance** and is measured by **ohms.** These names were given in honor of three pioneers of current electricity. Volta discovered, about the year 1793, the electric current. He is, in some ways, the father of current electricity. Ampere and Ohm laid down some very important laws of current electricity.

76. ELECTRO-MOTIVE FORCE.

You remember, we spoke of the difference of potentials, or the Electro-Motive Force (E.M.F.) within a body, in the chapter about Static Electricity. This force causes the spark to overcome the resistance of the air and to jump over from the body with the higher potential to the one with the lower potential. Just as the E.M.F. causes the spark to act in this manner, so is the continuous electric current also caused by E.M.F. The greater this force, the greater is its power to push the current through the wires.

77. UNITS OF MEASUREMENTS.

Power, Strength, and Resistance are measured by their units. Their measurement is expressed in figures, for instance: 110 volts, 60 amperes, 25 ohms.

A Volt is that E.M.F. which produces a current of one ampere against the pressure of one ohm. An ordinary dry cell has a E.M.F. of about 1½ volt.

An **Ampere** is the strength of the current produced by the E.M.F. of **one Volt** against the resistance of **one Ohm.**

About 40 feet of No. 24 copper wire will nearly equal the electrical resistance which is called **1 Ohm.**

The **Watt** is the unit of electrical power. It equals a current having the pressure of 1 Volt and the strength of 1 ampere. 746 Watts make one **electrical horse-power.**

78. HOW CURRENT IS GENERATED.

To generate a steady electric current, two conditions are necessary. There must be electric pressure and a conducting path. The necessary E.M.F. may be obtained:—

1. Chemically. 2. Mechanically. 3. Thermally.

79. CHEMICALLY GENERATED CURRENT.

Galvani, an Italian physician, about 1786, in experimenting with frog's legs, produced kicks from the frog's legs when two different metals, like iron and copper, were brought in contact with the nerve and muscle and then made to touch one another. See fig. 1. He thought that the animal generated the electricity, or charged the metals.

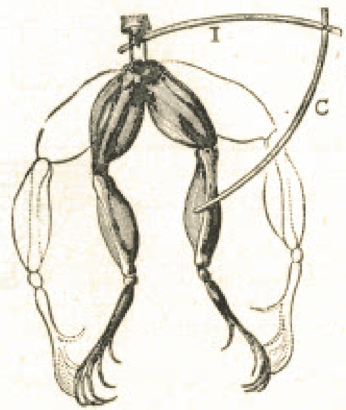


Fig. 1.

80. VOLTAIC PILE.

Volta was the first one who proved that in this experiment the electricity was caused by contact of metals. He constructed what is called a **"Voltaic Pile,"** by placing disks of copper, zinc, and flannel soaked in acid, **on top of one another** in the following manner:—zinc, copper, flannel, zinc, copper, flannel, zinc, etc., etc. See fig. 2. By connecting the first zinc disk with the last copper disk, by means of a wire, he produced the first electric current. In his experiment we see the **fundamentals of Current Electricity.**

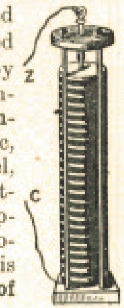


Fig. 2.

81. SIMPLE VOLTAIC CELL.

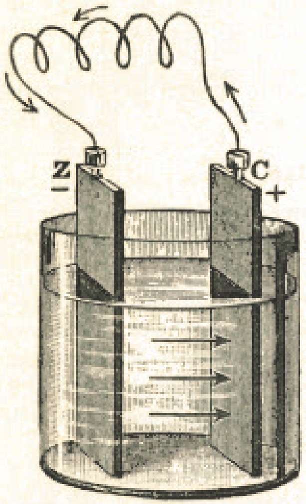


Fig. 3.

Volta soon realized that his pile was not a very practical source of electric current and he next experimented with a glass which was filled with a thin solution of sulphuric acid. Within this solution he put zinc and copper plates so that the plates did not touch one another. This apparatus is called a **Simple Voltaic or Galvanic Cell.** See fig. 3.

82. GALVANIC BATTERY.

A group of these cells connected together in some certain way, is called a **Galvanic Battery.** The terminals of the plates to which the conducting wire is attached, are called the **poles** of the cell, the **copper** being the **positive pole** and the **zinc** the **negative.**

We often speak of a battery when we mean a cell. A battery consists of two or more cells joined together. A single cell can never be a battery.

83. CHEMICAL ACTION.

The chemical action of a cell is not easy to understand and as of no great consequence to us in our experimental work, it may only be said that in the simple cell the solution of sulphuric acid causes chemically a difference of potentials in the two metals. If we connect them externally through a wire, this E.M.F. generates an electric current that flows through the acid from the zinc to the copper plate. In our outside circuit the current flows from the copper plate to the zinc plate. See fig. 3. It is at first quite strong but weakens quickly on account of chemical processes within the cell.

84. POLARIZATION OF THE CELL.

This current carries along bubbles of hydrogen and deposits them on the copper plate, completely covering it in a short time. We call this action of the current—**Polarization of the Cell.**

The hydrogen gradually reduces the surface of the copper plate, and being a non-conductor, it reduces the difference of the potentials between the plates. This tends to lessen the amount of current that can be generated by a cell if the circuit is closed externally. If the circuit is open, no action of importance takes place within the cell.

We have different means of avoiding polarization, but, as they are mostly chemical methods, we will not include an explanation of them.

85. KINDS OF CELLS.

We generally distinguish two kinds of cells:—

1. The **open circuit cell** which is used for intermittent work, as in Electric Bells, etc.
2. The **closed circuit cell** which furnishes current continually, as in Telegraphy, Telephony, etc.

In open circuit cells, polarization does not have much opportunity to occur since the circuit is closed for a short period of time. These cells are always ready to deliver a very strong current when used intermittently.

In closed circuit cells, polarization is prevented by chemical action so that the current is constant and steady until the power of the chemicals is gone.

86. FORMS OF CELLS.

There are many different forms of cells in use and many other substances take the place of the copper, zinc, and sulphuric acid of the Voltaic Cell.

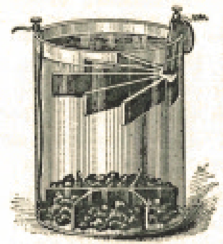


Fig. 4.

The most common closed circuit cell is the **Gravity Cell.** It is a two fluid cell in which the heavier fluid, copper sulphate solution with the copper element, is kept at the bottom of the cell, while the lighter fluid, the diluted sulphuric acid with the zinc element, is floating upon it. See fig. 4. It is mostly used in telegraphy or telephony and by proper care lasts for a very long time.

87. THE DRY CELL.

Of the open circuit cells, the **Leclanche** was best known for durability until it was supplanted by the Dry Cell. See fig. 5

The Dry Cell is composed of two elements, usually zinc and carbon. The zinc forms the containing cup, and one terminal of the cell is attached to it. The other terminal is at the top of the piece of carbon. Instead of a liquid, a paste is used between the elements, composed of carbon and grounded coke, plaster of paris, and moistened with a liquid, generally sal-ammonia. The top of the cell is hermetically closed with pitch to prevent leakage, or evaporation. See fig. 6.

Fig. 5.

The paper box on the outside protects the zinc from coming in contact with any other metal.

The **voltage of a Dry Cell is $1\frac{1}{2}$ volts,** while **the amperage** runs in the neighborhood **of 20 amperes.**

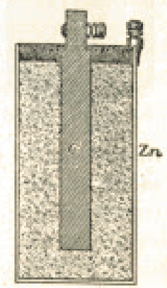


Fig. 6.

As the difference of potential between the zinc and carbon within the dry cell never changes, even a very weak one will show nearly full voltage, so that only **a low amperage will prove its weakness.**

88. ABOUT DRY CELLS.

Dry cells will get weak when the moisture evaporates. In renewing dry cells, the number that was originally required should never be increased because the higher voltage causes more current to flow than is necessary and this increased current flow shortens the life of a battery.

Water should not come in contact with the paper that covers the cells because it forms the insulation and, hence, when moist, current will leak across from one cell to another which would result in weakening the battery.

Weak cells can be somewhat strengthened in case of emergency by removing the paper jacket and punching the zinc cup full of small holes, and then placing it in a weak solution of sal-ammonia, allowing the cell to absorb all it will take up.

89. PLUNGE BATTERY.

A relatively strong cell is the plunging **Bichromate Cell,** the E.M.F. of a single cell being 2 volts. See fig. 7. The cell consists of a glass bottle containing a solution of bichromate of potash, or chromic acid solution. The positive element is zinc and the negative—carbon. These elements are supported from the lid, the zinc plate between the two carbon plates.

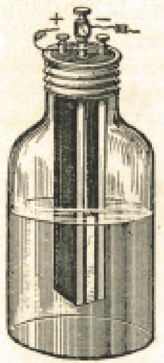


Fig. 7.

The two carbon plates are connected to the same terminal, and the zinc plate is connected to the terminal on the top of the brass rod to which it is attached. This rod slides through a hole in the cover, so that the zinc plate can be lifted out of the the solution when the cell is not in use, thus preventing wasteful consumption of the zinc and the solution. A battery of these cells forms a very strong source of electricity.

90. OHM'S LAW

There are two methods generally used in connecting cells to form a Battery. They are based on the so called "Ohm's Law," formulated by Ohm as the result of his experiments. It says that the strength of the current varies directly as the electro-motive force, and inversely as the resistance.

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}; \quad \text{or } C = \frac{E}{R}.$$

formula we can find any third magnitude if the two others are known.

91. INTERNAL RESISTANCE.

The liquid in the cell offers a resistance to the flowing current, the so-called **Internal Resistance,** which depends on the size of the cell and the material of the liquid. It is the internal resistance that successively causes the weakening of the cell. This internal resistance has to be reckoned with, everywhere resistance at all is mentioned.

92. GROUPING IN SERIES.

For higher voltage, we connect **cells in series,** joining the positive pole of one cell to the negative pole of another. See fig. 8. If every cell shown in this picture has a voltage of 1½ volts, the E. M. F. or the difference of potentials, between the plus and minus poles of the battery, is equal to the product of the voltage of one cell multiplied by the number of cells used. These four cells would be equal to 6 volts. The amperage does not change at all.

Fig. 8.

93. PARALLEL CONNECTION.

By connecting all positive poles of a battery to one terminal, and also all negative poles to another one, we generate between these poles, a current, the strength of which is equal in quantity to the amperage of a single cell multiplied by the number of cells. The voltage is the same as it would be for a single cell.

This connection is called a **Parallel or Multiple** connection. See fig. 9. With dry cells, the amperage of which is 15 for one cell, the result would be 4 x 15 = 60 amperes, at a pressure of 1½ volts.

Fig. 9.

94. KEYS AND PUSH BUTTONS.

When we connect the two end terminals of a battery we form a **circuit.** For opening and closing the circuit, or technically speaking for "making or breaking" the connection of the battery or the circuit, we use various forms of **Keys and Switches.**

The simplest key consists of a springy metal arm fixed at one end so that the other bent up end only makes a circuit with the contact underneath when pressed down. In its normal position, the circuit is broken. See fig. 10.

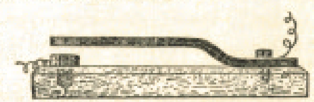


Fig. 10.

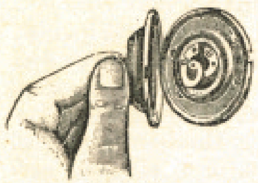


Fig. 11.

In the **push button**, the most common form of key, the connecting metal arm consist of a round spring, which breaks the contact immediately when the button is released. See fig. 11.

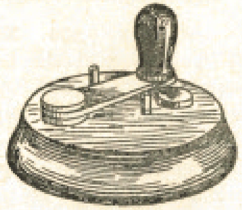


Fig. 12.

95. SWITCHES.

If the connecting arm moves sideways for making and breaking the circuit, we call this devise a **Switch.** See fig. 12. The circuit enters the switch at the pivot and goes through the arm to the other contact. We have switches with two or more contact points by means of which we can send the circuit to different apparatus.

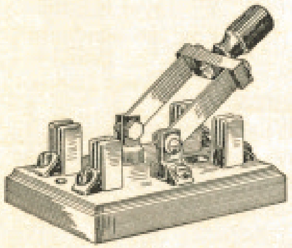


Fig. 13.

For connections of high currents so called **knife switches** are used, where the connecting arm goes between two blades of the other terminal. See fig. 13.

96. CONDUCTORS AND INSULATORS.

All bodies do not possess the same conductive power for electric current. Bodies through which the electric current moves freely are called **Conductors,** and those which offer a high resistance to the flowing current are called **Insulators.** There is, however, no substance so good a conductor as to offer no resistance at all, and no substance of such high resistance as to be a perfect non-conductor.

97. A LIST OF CONDUCTORS.

Metals and alloys are good conductors. Silver and copper head the list of good conductors, while mercury concludes it. The proportion of the conductive power of copper and iron is six to one. To explain this better, you remember that about 40 feet of No. 24 copper wire has the resistance of one Ohm. If you take iron wire of the same size, you will need only the 6th part of 40 feet (about $6\frac{2}{3}$ feet) to obtain the same resistance.

Charcoal, carbon, water, and wood are only fair conductors.

The earth is a good conductor. You will remember the grounding of Conductors, Lightning Rods, etc.

98. INSULATORS.

Dry wood, porcelain, silk, ebonite, glass, dry air, are the best and most often used insulators. The insulation of the wires which carry the current is usually made of wool or silk. For commercial purposes porcelain and glass are the most often used insulators. As water is a conductor, the best insulators become less efficient if their surfaces are moist.

99. DIVIDED CIRCUITS.

If a circuit is divided into different paths, the current will also be divided and flow through each path. If every one of these parts offers the same resistance to the circuit, the amount of current which flows through each division is equally divided.

When two or more conductors are laid side by side from one point of the circuit to another, they are called **Parallel Circuits.**

100. SHORT CIRCUITS.

The current seeks the shortest way between two points of circuit with different potentials. We speak of **Short Circuits** when the current finds, by chance, a short way which was not intended for its regular course, so that practically the whole of the current is "side-tracked" by a "short circuit," generally followed by undesired appearances.

101. LAWS OF RESISTANCE.

The same difference of potentials does not always produce an electric current of the same strength, just as the same pressure of water does not produce currents of water of the same volume or quantity. In both cases the strength, or quantity of the current depends not only upon the pressure, but also upon the amount of friction which the pipe offers to the flow of water on the one hand, and, in the case of electricity, upon the amount of resistance the conducting body offers to the flowing current.

The resistance of the circuit depends upon different conditions.

1. **The longer the conducting wire is, the higher is its resistance.**
2. **The thicker the conducting wire is, the lower is its resistance.**
3. **The better conducting the material is, the less resistance it offers.**
4. **The higher the temperature of the conductor, the higher is its resistance.**

102. CONTROL SWITCH.

In order to study the laws of resistance and to enable us to understand them better, we will use our **Control Switch.** See fig. 14.

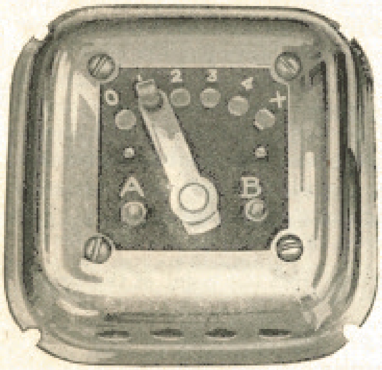


Fig. 14.

The Control Switch is very easy to assemble and I would advise you, in order to comprehend it more clearly, to take it apart. Loosen the four screws in the corner and take off the bottom plate. Be careful not to break the bent metal fingers which are soldered to the resistance coil. This high grade steel wire is wound insulated around a metal frame and arranged so that at the different contacts, different lengths of wires resist the flowing current. This wire is divided by four fingers into equal lengths. The fifth finger is attached to one end of the wire in such a way as to make a connection between the end of the wire and the terminal on top of the controller. See fig. 15.

If the lever is in contact with point O, the current which enters at terminal A, passes by way of the lever over to terminal B, without "flowing" through the wire, and can exhibit its full force. If the lever is moved over to point 1, the current, on its way from A to B, has to pass through 2 parts of the coil of the wire. On point 2, it has to pass through 4 parts, on point 3, 6 parts, and on point 4, it has to pass through the whole length of the resistance wire.

As the full length of the wire offers a resistance of **one ohms, at point 1, it is $\frac{1}{4}$, point 2, $\frac{1}{2}$, point 3, $\frac{3}{4}$, and point 4, 1 ohm.** On point X, the lever is not in contact at all with the wire, nor with the terminal A, so that at this point the current is shut off, or "interrupted." See fig. 15.

In the following we will hear about many interesting experiments that might be performed with this Control Switch.

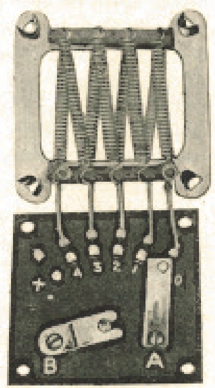


Fig. 15.

103. EFFECTS OF THE CURRENT.

The current, itself, cannot be seen to flow through the wire circuit; its presence is only indicated by the effects which currents can produce. These are of various kinds:

1. **Terminal effects.** 2. **Chemical effects.** 3. **Physiological effects.** 4. **Magnetic effects.**

104. TERMINAL OR HEATING EFFECTS.

If you connect the two terminals of your control switch with your battery or any other source of electricity not over 12 volts, and move the lever over to point 1, you make a circuit which flows through a short piece of the resistance coil. Within a short time, you will notice the heating effect of the current. The wire becomes soon more and more hot until it is red hot, threatening to spoil your control box. By moving the lever over to No. 2, 3, or 4, you can note the same effect but in a little longer time as the current has a longer way to flow and a longer piece of wire has to be heated.

You can even use your control switch as a small toaster, but be careful not to exaggerate the voltage of the current and spoil your box.

All the electric stoves, electric irons, soldering irons, baking ovens, etc., are built on the same principle, using resistance coils as heating appliances.

The heating effect is a waste in many uses of the current. Wherever it is desirable that no part of the electric current be expended in heating the conductor, copper wires of a proper size must be used.

105. IGNITING FROM A DISTANCE.

If the two ends of copper wire are put within a small ball of cotton, soaked in alcohol, and the electric current is sent through the wires, you can easily inflame the cotton. This experiment illustrates one of the methods used to ignite explosives from a distance.

106. ELECTRICAL WELDING.

If two wires, or rods of metal, are held together with sufficient force and a very strong current is passed through, much heat is developed at the junction so that they soften and become welded together. We call this process—**Electric welding.**

107. ELECTRIC LIGHT

The most practical use of the heating effect of the electric current is in its appliance to lighting purposes. The carbon of the arc, or the filaments of the electric bulbs are intensely heated that they may produce light.

108. THE CARBON GLOW LAMP.

It was Thomas A. Edison, who, in 1880, after many experiments, devised the first electric lamp for practical purposes. He used a flat strip of carbonized bamboo in a vacuum lamp, that is a lamp from which all air has been expelled, to prevent the carbon from burning. Without the oxygen of the air, no body can burn, and the heating effects of the electric current only cause a glowing of the carbon filament; we say it becomes **incandescent.** See fig. 16.

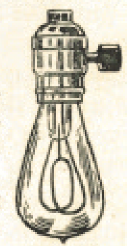


Fig. 16.

109. EDISON'S DISCOVERY.

Edison attached his lamp to a balloon and sent it high up into the air. At first his lamp was mistaken for a star until the switch in Edison's hand, proved the source of that light. The appearance of this new and unusual light caused so much sensation and curiosity that it soon made Edison the most famous man in the whole civilized world.

110. METAL FILAMENT LAMP.

For twenty years Edison's Carbon Glow Lamp held the market until it was superseded by new kinds of lamps having metallic filaments.

The wires used for the filaments of these electric lamps are very expensive as the ores from which they are produced are very rare and difficult to work on. Osmium, Tantalum, and especially Tungsten have come into general use for incadescent lamps.

Fig. 17.

The very fine wires drawn from these metals are able to carry the current that brings them to incadescence without melting them. They are arranged in zigzag upon an insulated frame as they become soft and are easy to bend when heated. See fig. 17.

If one of these wires breaks, you can very often fix the lamp by turning on the current and shaking the lamp slightly, trying by this means, to bring the broken parts together, as they will stick together when in contact, being "electrically welded."

Your **miniature lamp** contains also a metal filament the one end of which, like in all other lamps, is connected to the outside of the metal sockets E. The other end goes through the metal part of the bottom of the socket D, corresponding with the terminals of the receptacle. See fig. 18.

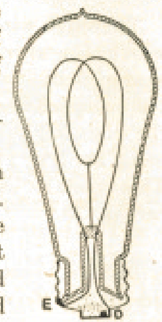


Fig. 18.

The big advantage of these metal filament lamps lies in the saving of the electric current.

A 16 c. p. (candle power) carbon lamp, for instance, for use on 100 v. circuit will take about 0.6 amp., which equals 60 watt. This is at the rate of 4 watts per c. p. On the same circuit we may connect a metallic glow lamp which will give 48 c. p. light, at a value of 1½ watt per c. p. This big advantage can be realized by the fact that the metallic lamp has almost entirely supplanted the use of the carbon glow lamp, even though the price of this lamp is much higher.

111. NITROGEN LAMPS.

Recently, it has been found that if the bulb is filled with very pure nitrogen gas at about one atmospheric pressure, a tungsten lamp will operate at a still lower expense. These lamps are commercially known as ½ **watt lamps,** meaning ½ watt per candle power. As these lamps consume a relatively low amount of current, especially those of larger candle power, combined with very practical handling, they are being substituted, in many instances, for arc lamps.

112. THE ELECTRIC ARC.

When a strong current passes from one pointed piece of carbon to another, the **Electric Arc** is produced. As long as the two ends touch, the current passes from one carbon to the other, and the carbon, being a poor conductor, causes resistance enough to heat the ends red hot. If these ends are drawn apart for a short distance, the current will continue to flow as the intensely heated and consequently thin air reduces the resistance of the air-space between the two points. Furthermore, the current draws with it through the air space very small particles of carbon, which act as conductors. Thus the positive carbon gradually wears away and becomes hollow, forming the so-called "crater." The negative carbon stays pointed and the flying carbon particles from the positive carbon form a ring around its point. See fig. 19.

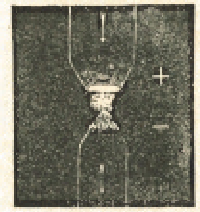


Fig. 19.

The temperature of the arc is extremely high so that flint or diamond will melt in it, and metals, such as gold and platinum, will even evaporate.

As the carbons gradually wear away, the positive one about twice as quick as the negative carbon, some device is necessary for regulating the distance between the carbons so that it will remain the same. These devices are automatic mechanisms controlled generally by the flowing current. In fig. 20 you see the controlling mechanism on an **Inclosed Arc lamp,** in which form of lamp a small globe nearly air-tight surrounds the arc and a few inches of carbon, causing a more slowly burning of the carbons than in the open air.

The carbon candle consists of grounded coke—carbon, combined artificially by chemical process, and pressed into pencil shape under very high pressure. If metallic salts, like calcium salt, are mixed in the carbon substance the hot vapors of these salts become luminous, when heated by the current. The arc is much longer, resembling in appearance a flame, **flaming arc,** so that the golden yellow of the calcium salt for instance makes an exceedingly brilliant effect.

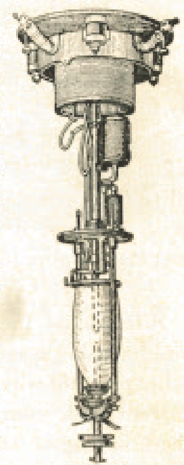


Fig. 20.

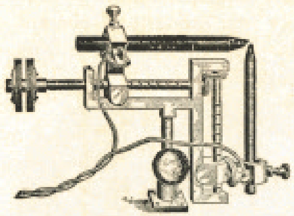


Fig. 21.

In projector lamps, like optical lanterns or search lights, the carbons are usually arranged at right angles so that the crater throws most of its light forward. See fig. 21.

113. ELECTRIC WIRING.

The electric wiring has to be so arranged that the current can perform a complete circuit. It has to carry the current to the lamp or the motor through which it passes and then back again to the generator. If the circuit is broken at any point on its way, there is no current in any part of the circuit.

114. FUSES.

Buildings are wired for use on certain currents and if, from any cause whatsoever, more than the regular amount of electricity should pass through the wires within the house, they would become intensely heated and perhaps start a fire. To prevent this, **Fuses** are used, which act as automatic breaker of the circuit, when the wires are over-loaded, just like steam boilers are protected by safety valves.

Their main part consists of a short piece of a so-called fuse wire, a metal wire of a very low melting temperature, usually lead, the length and thickness of which correspond with the voltage of the current which should pass the circuit. As soon as the wire becomes hot, for any reason whatsoever, possibly a short circuit, the fuse blows out, that is, it melts and breaks the circuit, thus preventing any damage by fire.

In the **Plug Fuses,** see fig. 22, the current passes through a fine wire "F" that is insulated within the fuses and connected to the current like the filament of an incandescent lamp. With this fuse it is impossible to place any except the correct size of plug in the socket.

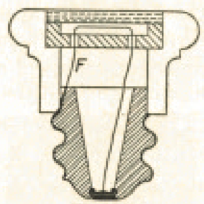


Fig. 22.

115. REPLACING FUSES.

It is against the rules of the Fire Insurance Companies, besides being a very poor policy, to replace a fuse with any other piece of wire, even lead wire. The new wire might be designed for a higher current than your home circuit and will not fuse, thereby causing a fire through the breaking of a wire at some other place and would thus cost you much more than the few cents necessary for a new fuse.

116. SYSTEMS OF ELECTRIC LIGHTING.

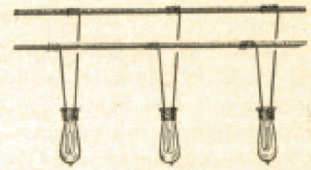


Fig. 23.

For lighting houses there are generally three systems of electric wiring in use.

In the **Parallel System,** the lamps are arranged between two main wires and connected to these by two short lengths of wire. See fig. 23. The current divides in going through each lamp that operates. The potential difference in each path is the same as in the main wires, but the resistance is less as the current has many small paths to travel in going from one main wire to the other.

If we have, for instance, a total voltage of 110 volts in the main wires, every lamp in this system must be of the same voltage. Any lamps of lower voltage would "burn out," that is, its filament would melt.

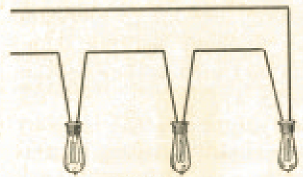


Fig. 24.

In arranging the lamps **In Series,** the same current passes through them one after the other and has to overcome the resistance of all the lamps added together. As the resistance depends directly upon the voltage, we have to insert in the current of 110 volts, for instance, so many small lamps that their voltage multiplied by their number gives the total voltage of the current. For instance, for a current generated by a 12 volt battery, two 6 v. lamps, or 4 3 v. lamps are necessary. See fig. 24.

The **three wires system** is a kind of parallel system in which the current from two sources of electricity is arranged by means of three main wires, the middle one being used as return wire. If the total voltage of the main wires is, for instance, 220 v., one of the wires being neutral, 110 v. lamps can be used for lighting. This system saves in the cost of conductors. See fig. 25.

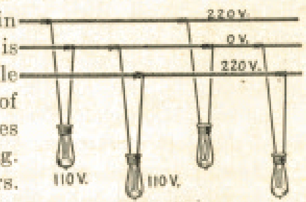


Fig. 25

117. WIRE CONNECTIONS.

The lamps are connected to the main wire by two small wires which are spliced to the main. To make this splice, mark on the main wire where you want to hang the lights. Bare the wire with a penknife and scrape it clean. Then scrape the insulation off the fixture about one-half inch from the end. Bend it around the bare main wire, two or three times very tightly, using a pair of pliers. See fig. 26a.

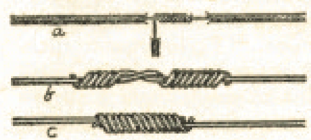


Fig. 26.

In order to conform to the regulations of the

Fire Insurance Companies you have to solder the fixture wire to the main wire and the joints have to be taped, using two kinds of tape, first the pure rubber tape and then the ordinary black tape.

118. DIFFERENT SPLICES.

To connect two wires, use the so-called **wireman's splice,** by twisting the wires together at the center and allowing about two inches on the ends to do the splicing. See fig. 26b.

In the **Telegraph Splice,** the two bare wires are placed side by side and an extra piece of wire is twisted tightly around them by means of a plier. See fig. 26c.

After the twist is made, the ends of the wires have to be cut off as close as possible.

119. EXPERIMENTS WITH YOUR LIGHTING OUTFIT.

Your lamp, a 2.8 v. Flashlight bulb with metal filament, will burn brightly on two dry cells. The terminal of your **receptacles** should be connected with the terminals of the battery and a switch put within the circuit.

For experimental purposes, place your control switch within the circuit and observe how the lamp operates when you offer more or less resistance. See fig. 27

Build yourself an emergency night lamp in your bed-room, using your lighting outfit. Screw your receptacle to the window post and use either the reverse base or the control switch as a key. Do not use a very long conducting wire from the battery to the light as it would consume too much current through the enlarged resistance.

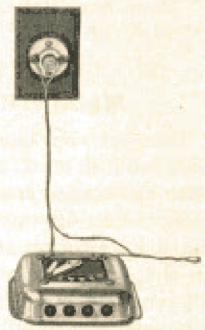


Fig. 27.

120. CHEMICAL EFFECTS.

Inside the cells of the battery the chemical action generates the electric current. In addition to this chemical action inside, there can also be noted chemical effects generated by the electric current outside the battery, when the current passes through certain liquids. The result of this action is usually the decomposing of the liquid into its constituent parts. This process is called **Electrolysis.**

121. DECOMPOSITION OF WATER.

If we pass a current through water, the water will be decomposed into its two constituent gases—**Hydrogen and Oxygen.** These gases appear in the form of bubbles on the ends of the wires which let the current into and out of the liquid.

In arranging the ends of the wires in the manner shown in Fig. 28, we are able to collect the two gases and you will find that there is almost exactly twice as much Hydrogen produced as there is Oxygen. This fact corresponds with the known chemical composition of water which is produced by combining these two gases in the proportion of two volumes of Hydrogen to one of Oxygen, H_2O. As pure water is a bad conductor, it has to be mixed with a few drops of sulphuric acid to reduce its resistance.

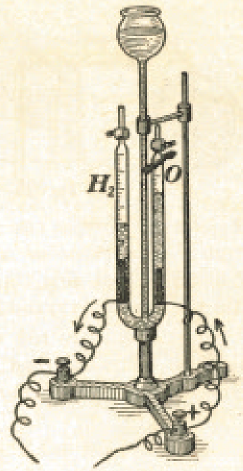


Fig. 28.

122. ANODE; KATHODE.

The ends of the wires leading to and from the battery, are called **Electrodes.** The end by which the circuit enters is called the **Anode.** That by which it leaves, **the Kathode.** The liquid which is being decomposed is called—**Electrolyte.**

The atoms of the constituent parts which are carried along by the flowing current and deposited on the electrodes are called—**Ions.**

123. ELECTROPLATING.

The theory of the electrolysis applies to the process of **Electroplating** and **Electrotyping.** It was observed that the Ions in the Daniel Cell formed an even coating of copper on the Kathode. From this was developed the process of electroplating and electrotyping.

If we wish to electroplate a piece of metal with copper, for instance, we have to use a solution of copper sulphate as electrolyte. For electrodes, we use, as the anode, a plate of copper, and as the kathode, the piece of metal we want to be copper plated. See fig. 29. The electric current will decompose the solution of copper sulphate into copper and sulphuric acid. The ions of copper will be deposited by the current on the kathode, and form there a very thin layer of this metal on the pieces to be plated. The sulphuric acid produces with the copper plate of the anode new copper sulphate until the copper is eaten away.

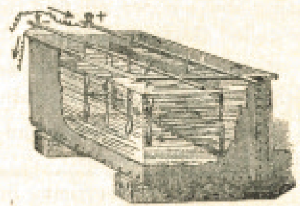


Fig. 29.

For nickel plating, plating with silver and gold, different electrolytes are used.

124. ELECTROTYPING.

Electrotyping is based on the same principles and is the process of reproducing medals, seals or types and wood cuts, etc., in metal. If we want to electrotype a coin,

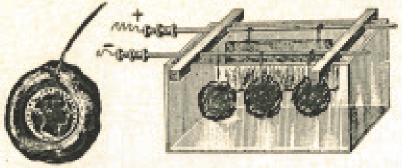


Fig. 30.

for example, we first make a negative impression in wax, plaster paris, or some other suitable material. As these substances are not conductive, we have to coat them with graphite. The chemical action within the solution is the same like in electroplating.

We use this mould as the kathode where the electric current can get to every part of the mold and lay a thin coat of metal from the decomposed solution—either copper, nickel, silver, or gold. See fig. 30. When this coat gets thick enough, the mould is taken out, the wax melted away, and the positive reproduction, consisting of a very thin shell of metal, is obtained.

These shells are too weak to be used, for instance, in the printing process and have to be re-inforced with a layer of metal to make a plate of about ¼ inch thick, which then is mounted on wood. These plates are called **Electrotypes.**

125. PHYSIOLOGICAL EFFECTS.

Just as the electric spark with its high voltage causes a momentary shock within the body, so are we able to observe the effects which the flowing current causes in ourself. We do not have a special sense to note the electricity, but every one of our senses can be stimulated by the electric current.

If we take the two wires of a battery and place one under our tongue and the other above it, we will find that the flowing electric current has a peculiar taste, the so-called **Galvanic Taste.**

By transmitting a very weak current through the eye-ball, the sensation of a bright flash of light is produced.

The senses of hearing and smelling are also stimulated by electricity and produce false impressions.

Quantities of electricity flowing through the human body cause a contraction of the muscles and the fatal action of a strong current depends not only upon the contortion of the muscles, but also of the effects of the electrolysis, as the high voltage makes the blood become coagulated.

From experiments made in America, in connection with the execution of criminals, it was found that the average resistance of the human body is 2500 ohms and that 3000 volts sent through the human body causes instantaneous death. But even much smaller current prove to be very dangerous.

What to do in case of electric accidents, is very important to know. Read and study carefully the Cap. 149, 150, 151 in the Book III.

MAGNETIC EFFECTS.

126. LINES OF FORCE.

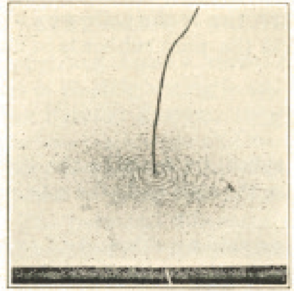


Fig. 31.

The presence of the electric current is indicated by the effects which the current produces. The effects of the current may be observed not only on the conducting body, but also in the space surrounding it.

The magnetic effect of the electric current is of fundamental importance, as most of our electric machines are based on its principles.

Take a smooth thick card and thrust a piece of copper wire through the center of it. Connect the ends of this wire with a battery and sift iron fillings over the card. By slightly tapping the card, if the current is strong enough, the filings will arrange themselves in circular lines with the wire as the center. See fig. 31.

These lines indicate the **Lines of Force** generated by the current which flows through the wire.

127. DEFLECTION OF THE MAGNETIC NEEDLE.

Connect your battery with a straight wire and hold it above and parallel with the magnetic needle of your compass. See fig. 32. The needle will leave its position and try to put itself in the normal direction to the wire. If you hold the wire underneath the compass, the needle will turn in the opposite direction. By reversing the direction of the current in this position the needle will be deflected as at first.

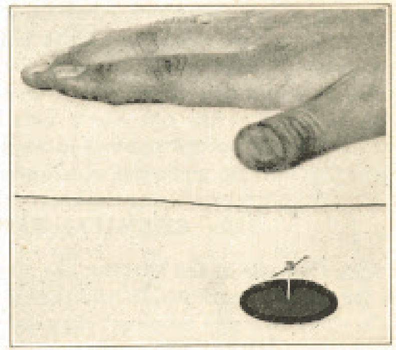


Fig. 32.

128. THE HAND RULE.

The deflection of the needle follows certain laws which can be easily remembered by the following rule, laid down by Ampere.

Place the right hand with the palm towards the needle and on the opposite side of the wire, with the thumb extended and the fingers pointing in the direction of the current. The N. pole of the needle will then be deflected in the direction of which your thumb points. See fig. 32.

By reversing this rule, you can easily find the direction of the current. If you hold your thumb in the direction that the N. pole of the needle points with your palm towards the compass and on the other side of the wire, the current is flowing in the direction of your fingers.

129. GALVANOMETER.

This deflection of the N. point of the needle depends entirely upon the strength of the current, and is used in measuring instruments.

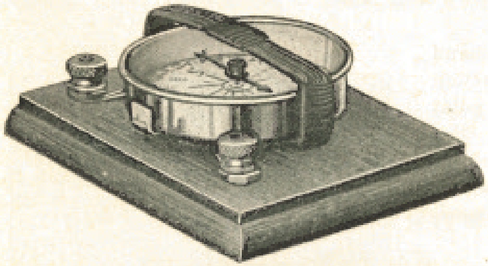


Fig. 33.

Your **Detector Galvanometer** or **Galvanoscope** is a simple form of a galvanometer as you can easily read the angle of the deflection of the needle on the graduated wind sail. See fig. 33.

You have to connect the wires from the battery to the two terminals of your galvanometer to observe the deflection of the needle, which has to be placed just parallel with the wire windings, by turning the wooden base. The wires arranged above and underneath of the compass strengthen, in accordance with the hand rule, the effect of the current.

130. ASTATIC GALVANOMETER.

The galvanometer has usually many layers of wire to increase the effect of a weak current, but very often even the increased strength is not sufficient enough to deflect the magnetic needle as the resistance which the earth's magnetism offers to any deflection of the needle is too big. To overcome this, a form, known as the **Astatic Galvanometer,** is frequently used.

It consists of two magnetic needles connected rigidly to a vertical wire in such a way that the north poles of the needles point in opposite directions. The coil is arranged with one branch between the needles and the other above. See fig. 34.

The astatic needle pair is independent from the earth's magnetism and easily deflected by even a very slight current as the resisting pointing power is nearly nil.

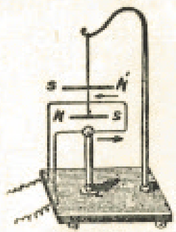


Fig. 34.

131. APPARATUS FOR ELECTRIC MEASUREMENTS.

In order to measure electric units for commercial purposes, we have an instrument based on the effects which we have just studied. This instrument depends for its action on the pull, with which a solenoid of very small resistance draws a soft iron plunger into the coil.

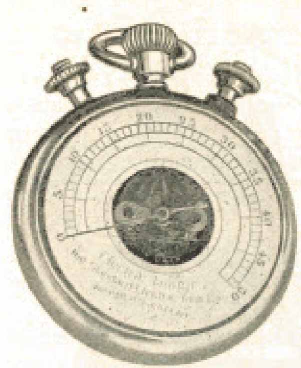


Fig. 35.

Such an instrument used in connection with a scale which indicates the amperes, is called an **Ammeter.** See fig. 35. The stronger the current, the larger will be the pull, expressed by the angle of deflection. This deflection is not indicated in degrees but is read in the number of amperes, registered by a hand on a dial. A fine hair spring swings the hand back if no current flows through the meter.

The same principle can be used in measuring the voltage of a current, with a so-called **Voltmeter.** Very often a counter weight replaces the hair spring like on the diagram, fig. 36, illustrating the principle of this kind of meters.

The effect of the current in the electrolysis can also be used as a measure of its strength. The stronger the current, the greater will be the quantity of metal deposited on the kathode, or the amount of gases generated within a certain time. The apparatus in fig. 30 may be used as a voltmeter, providing the tubes which are to collect the gases are marked off in a graduating scale so as to measure the quantities evolved.

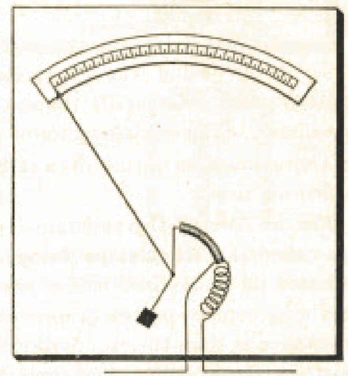


Fig. 36.

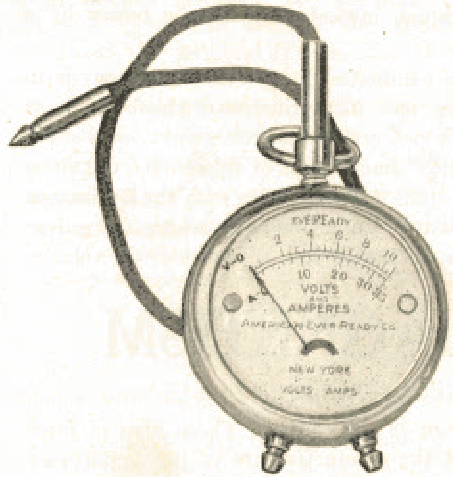


Fig. 37.

The Volt-Ammeter is a combination instrument which is used for measuring volts and amperes of low currents. See fig. 37. This instrument has two scales and three terminals. By connecting two of them either volts (up to 11) or amperes (up to 35) can be measured.

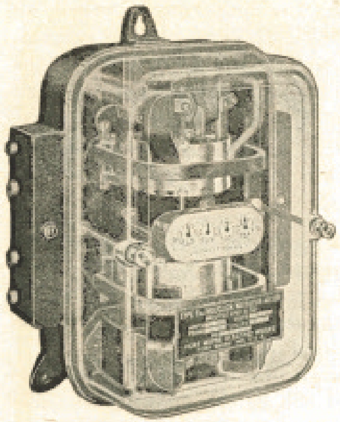


Fig. 38.

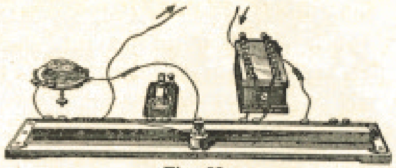


Fig. 39.

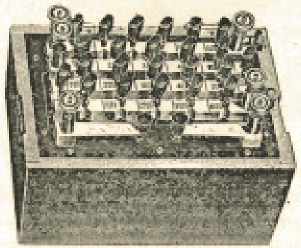


Fig. 40.

To avoid using the Ammeter and Voltmeter simultaneously, a **Wattmeter** is used. Generally the watts are read from a dial like those on the ordinary gas meter. The electric meter in your home is such a wattmeter. See fig. 38.

There are also forms of wattmeters which indicate the electric power by a deflecting needle.

For measuring the resistance within a conducting body, an instrument is in use called the **Wheatstone Bridge.** See fig. 39. The principle of this instrument is based on a standard coil of resistance which serves like the weights of a scale. A sliding contact on the bridge indicates how much larger or smaller the unknown resistance is than the standard resistance coil. In connection with the **Resistance box,** see fig. 40, the wheatstone bridge is used as a balance, where an galvanometer connected in some certain way to the bridge does the work of the tongue.

ELECTRO MAGNETISM

The electric current flowing through the wire generates lines of force which arrange themselves in circles with the wire as the centre. These lines of force generated by the flowing current around the conductor, are of big importance in the study of electrical effects.

132. THE SOLENOID.

If we wind insulated wire around a pencil and then slip it off, we have a so-called **Solenoid.** Place this solenoid upon the table and lay the compass about two inches from one end of it. Connect the ends of the solenoid with the battery and watch the needle. The north point of the compass will be either deflected or attracted. The lines of force which pass around every turn of the wire will change the solenoid into a magnet with two poles—a North pole and a South pole.

If we grasp the solenoid in the right hand with the fingers pointing in the direction of the current, the thumb will then point towards the North pole of the coil. See fig. 41. Such a solenoid, if allowed to swing freely, will finally rest in a position North-South, just exactly like the magnetic needle.

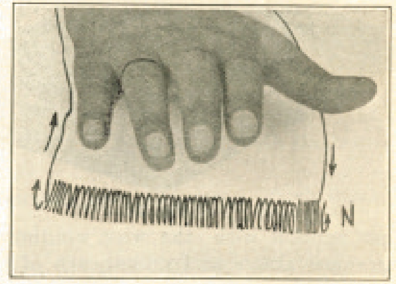


Fig. 41.

133. ELECTRO MAGNETS.

If you connect your solenoid with the battery, you can easily lift iron filings with it, clinging to the outside of the insulating fibre disk. If the solenoid is provided with a soft iron core, it becomes an **Electro Magnet,** as we know that any iron through which lines of force pass shows magnetic effects. The soft iron core put within the solenoid will increase the magnetic strength of the electro-magnet, as the lines of force have less resistance by passing through the iron core and can act with more strength. See fig. 42.

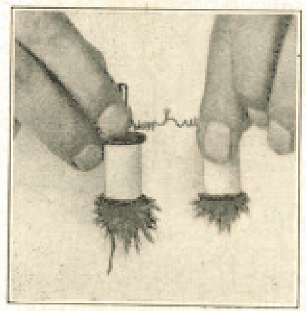


Fig. 42.

As soon as the circuit is broken the iron core becomes demagnetized; a little magnetism, however, will stay in the core, the **residual magnetism.**

Our coil, with the soft iron core, represents a Bar-Magnet and all the experiments we tried with the bar magnet in the Chapter on Magnetism can be repeated with this Bar-Electro-Magnet with even much better success as the strength of these kinds of magnets is greater than that of the artificial magnets.

Try some magnetic figures with your electro-magnet and the iron filings. Repeat the experiments with compass and electro-magnet. Observe the poles of the solenoid by reversing the direction of the flowing current.

134. THE ELECTRO HORSESHOE MAGNET.

The most frequently used and very effective magnet is the Horseshoe Magnet, which consists of a yoke and two solenoids. See fig. 43. The wire is wound on the coils in such a way that if the yoke was straightened into a line, the winding would be all in one direction, that is, the inner ends of the wire have to be connected. Therefore, we have a horseshoe electro magnet with two unlike poles and the lines of force pass through the yoke on their way from one solenoid to the other. As long as the current flows through the coils it causes the yoke to become very strongly magnetized, its strength depending on the strength of the current, and it will lose its magnetism, or become demagnetized, as soon as the current is turned off.

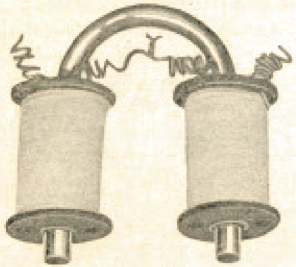


Fig. 43.

135. LIFTING MAGNET.

The Electro Magnet is used practically as a lifting magnet in transferring steel or iron pieces from one place to another. The magnet is placed upon the iron or steel to be lifted, the current is sent through the coil, the magnetically lifted load is shifted to the desired place and finally dropped by breaking the circuit. See fig. 44.

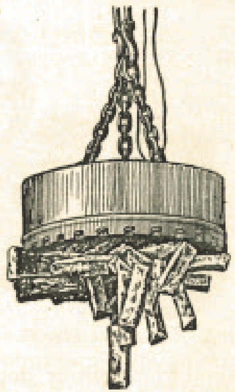


Fig. 44.

Non-magnetic substances can be lifted by attaching them to an armature.

Build a simple lifting magnet with the help of your Erector Set. See fig. 45.

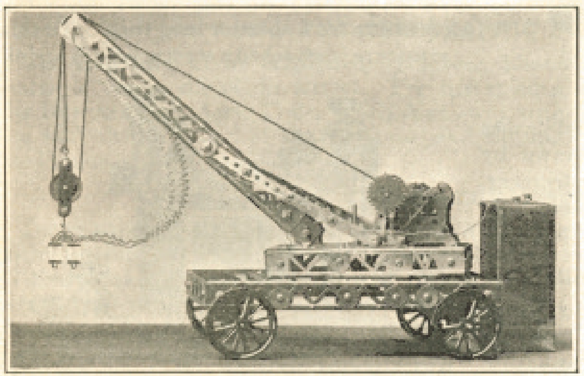


Fig. 45.

136. THE ELECTRIC BELL.

A very common use of the electro magnet lies in its application to the electric bell and electric telegraph.

The electric bell consists principally of an automatic interrupter used in connection with a bell. With the help of your electro horseshoe magnet you can make a cheap yet satisfactory electric bell.

Attach the yoke to a small board, as in fig. 46. A springy piece of steel (B) long enough to reach over both ends of the electro magnet is fastened to another block of wood (A). To one end of the steel (B) attach a small bar of iron as an armature. Extend the spring by means of wire (D) and fasten a knob of iron or brass (E) on the end of it. The bell (F) is held up in place by means of a screw. Thrust a thumb screw (H) through a small wooden support (G) so that its sharpened point just touches the spring (B). From the terminal (I) the wire runs through both solenoids, the inner ends of the wires being connected, to the terminal (K). Another wire passes from the terminal (L) to the thumb screw (H). Now, connect the two terminals to your battery and insert a push button between one wire.

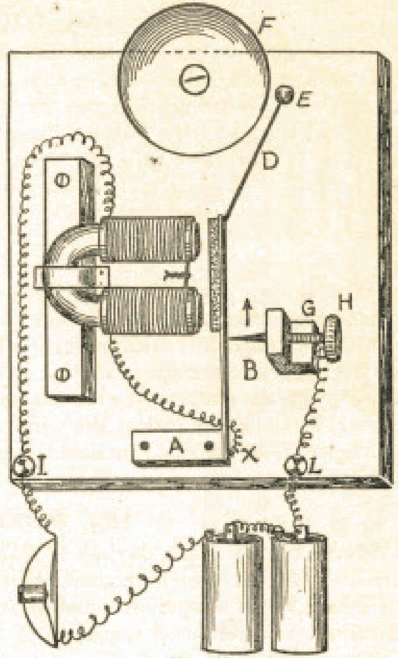


Fig. 46.

137. HOW THE BELL WORKS.

By making the circuit, the current flows from the terminal L through the thumb screw H to the spring B. Then through it and through the wire and the coils back again over the terminal (I) to the push button and the battery. In flowing through the coils, it makes the yoke magnetic. The magnet attracts the armature, thus breaking the circuit between the point of the thumb screw and the spring. By breaking the circuit, the yoke becomes demagnetized, the spring pulls the armature back and gets in contact again with the point of the thumb screw, thereby closing the circuit again.

This causes the bell to ring automatically as long as the push button is pressed in.

If after making the circuit, the bell does not ring loudly, move the thumb screws (H) until you get the right distance between the magnet and the armature.

138. WIRING OF BELLS.

When installing an electric bell in the house, do not forget that the push button acts as a switch, which means that the two ends of the same wire must be connected with its terminals. See fig. 47. This push button could be placed near the front door and the battery down in the cellar, or somewhere out of sight.

When two or more bells are to be rung from a single push button, they should be connected in parallel, like electric lamps. See fig. 25. They will not ring well if connected in series, as they cannot be made to strike at exactly the same rate.

139. TELEGRAPHY.

With the discovery of the electric current there seemed to have been given some means of sending messages through the wires to a distance. As early as the 18th century we find different apparatus which were in use as **telegraphs.** Telegraph is a Greek word and means: writing in the distance. Signals could be sent over wires by means of observing the effects of attraction of small bodies, or of chemical effects, at the other end of the wire.

Ampere built the first practical telegraph by laying out a code which was based on the deflection of the magnetic needle to the right or left of the north pole.

140. MORSE'S INVENTION.

Morse, of New York, devised 1837 the telegraph in which a pencil, attached to the armature of the electric magnet, wrote dots and dashes on a moving paper band by means of the attraction caused by the flowing current. This Morse instrument is the most widely used télegraph at the present date.

The complete telegraph consists in its essential parts of a Morse Key or Transmitter, a Receiver, the line, and the source of electricity.

141. THE TELEGRAPH KEY

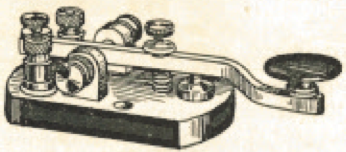


Fig. 47.

The telegraph key, in its simplest form, is an instrument by which, with the help of a spring, the circuit can be rapidly opened and closed. For practical use, the Morse Key serves two purposes,—it makes and breaks the circuit in the sending of the message, and is also used as a switch for receiving messages. See fig. 47.

The key generally used in our country is a key with which, by pressing down the lever, we connect the wires at the front points and make the circuit for sending messages. At the same time we disconnect the circuit on the rear points that serve for receiving messages. The spring pushes the lever back in its original position. In fig. 48 you see three stations and the key of each is in such a position so as to accept messages.

142. THE TELEGRAPH LINE.

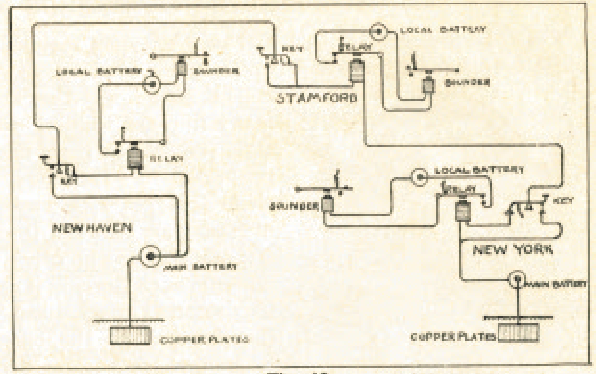


Fig. 48.

The connecting line is usually made of strong copper wire. For economical reasons this wire is blank and insulators of glass, porcelain, or similar material keep it upon the poles. For very short lines, two wires are used, the **sending wire** and the **return** for closing the circuit. But for long lines, the earth is used as the return, the wire on each end being grounded and ending in a large copper plate buried in the earth. See fig. 48.

143. THE TELEGRAPH RECEIVER—EMBOSSER.

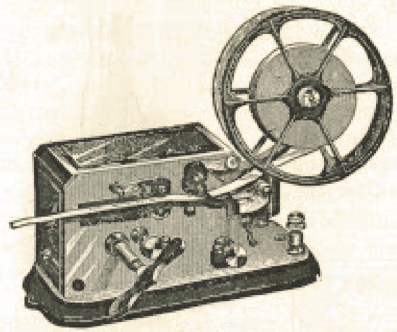


Fig. 49.

The Receiver consists, essentially, of an electro magnet, which, when the current passes through its coil, draws down the armature for a short or long time. To this armature is attached a steel needle or an ink wheel which prints dots and dashes upon a strip of paper, drawn by clock work through the instrument. We call this kind of Receiver—an **Embosser or Printer.** See fig. 49.

144. THE SOUNDER.

The Sounder invented by Henry (New York, 1831) is the receiving instrument by which the armature causes a clicking sound when it is attracted. See fig. 50.

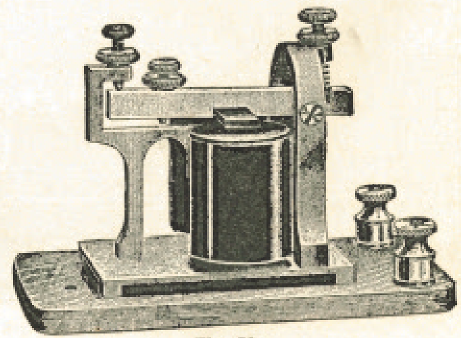


Fig. 50.

When the current ceases, the spring pushes the armature back and causes another click, so that two clicks are heard for one single attraction. The operator listens to the clicks and observes, whether the intervals between them are long or short. A dot causes two clicks immediately after one another. When a dash is signalled the interval between the clicks is longer.

145. SOURCES OF ELECTRICITY FOR TELEGRAPHY.

As the source of the electricity, a battery is generally used, only very seldom do we find a dynamo taking its place.

European telegraphs work on the open circuit, being out of contact when not in use. The American telegraphs are usually operated on a closed circuit plan, and the current always passes through the instrument until interrupted to send a message. The big advantage of the closed circuit plan lies in its facility to discover automatically any faults in the line by the cessation of the current.

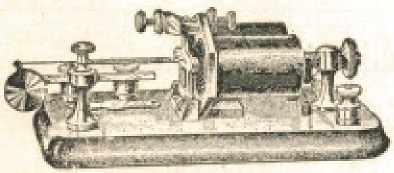


Fig. 51.

146. THE RELAY.

The current which goes through long lines has to overcome a large resistance. This in long telegraph lines is very often so large that the current is too weak to work directly the receiving instrument at the other end. In such a case, a **Relay** is interposed. See fig. 51.

It consists of an electro magnet with a great many turns of fine wire, operated by the main line which attracts a feebly poised armature and thus makes the contact for a strong local current to do the work in the receiving instrument.

147. THE TELEGRAPHIC CODE.

The American Code, originated by Morse, himself, employs more than five marks to form some of the letters. For convenience, this code was changed and the International Morse Code, which does away with this objection, is in general use with the exception of United States and Canada. Below you will find a reproduction of the two alphabets.

148. HOW THE TELEGRAPH WORKS.

Let us suppose that our fig. 48 represents a line from New York to New Haven, with Stamford as the intermediate station. New Haven is going to send a message to New York. When the operator at New Haven presses his key, the connection is made along the entire line and every receiver is apt to do its work.

Our operator begins by sending the New York-Station "call" so that every operator on the whole line will know that they do not need to pay any attention to the message. Our New York operator hears his "call" and responds to New Haven immediately to inform the man there that he is ready to receive the message.

The pressed key makes the connection and causes the electro magnet of the receiver in New York to attract the armature. As soon as the sender releases his key the circuit is broken and the armature is pulled back in its normal position—ready to accept the next signal.

	INTERNATIONAL CODE	AMERICAN MORSE CODE
A	• —	• —
B	— • • •	— • • •
C	— • — •	• • •
D	— • •	— • •
E	•	•
F	• • — •	• — •
G	— — •	— — •
H	• • • •	• • • •
I	• •	• •
J	• — — —	— • — •
K	— • —	— • —
L	• — • •	—— (long dash)
M	— —	— —
N	— •	— •
O	— — —	• •
P	• — — •	• • • • •
Q	— — • —	• • — •
R	• — •	• • •
S	• • •	• • •
T	—	—
U	• • —	• • —
V	• • • —	• • • —
W	• — —	• — —
X	— • • —	• — • •
Y	— • — —	• • • •
Z	— — • •	• • • •
&		• • • •
1	• — — — —	• — — •
2	• • — — —	• • — • •
3	• • • — —	• • • — •
4	• • • • —	• • • • —
5	• • • • •	— — —
6	— • • • •	• • • • • •
7	— — • • •	— — • •
8	— — — • •	— • • • •
9	— — — — •	— • • —
10	— — — — —	—— (long dash)

Questions to be Answered when Study of Book II is Completed:

1. How can cells be connected?
2. How does a push button work?
3. Name good insulators.
4. What is a one-half watt lamp?
5. What is the general rule for replacing fuses?
6. How can you light 3-volt lamps on a 12-volt current?
7. How do you connect wires?
8. Name a few splices.
9. What experiment will show you the direction of the flowing current?
10. How would you build an electro magnet?
11. How does an automatic interrupter work?
12. Why do we use relays in telegraphic work?

MEMORANDUM

ELEMENTARY ELECTRICITY

BOOK III

Electro-Magnetic Induction; Machinery

149. ELECTRIC ACCIDENTS.

For your own benefit and that of your comrades, you should know how to avoid accidents from electricity.

The third rail is always dangerous, so do not touch it. Swinging wires of any kind may somewhere in their course be in contact with live wires, so they should not be touched.

A person in contact with a wire or rail carrying an electric current will transfer the current to the rescuer. Therefore, he must not touch the unfortunate victim unless his own body is thoroughly insulated. The rescuer must act very promptly, for the danger to the person in contact is much increased the longer the electric current is allowed to pass through his body. If possible, the rescuer should insulate himself by covering his hands with a mackintosh, rubber sheeting, several thicknesses of silk, or even dry cloth. In addition, he should, if possible, complete his insulation by standing on a dry board, a thick piece of paper, or even a dry coat. Rubber gloves and rubber shoes or boots are still safer, but they cannot usually be procured quickly.

If a live wire is **under** a person and the ground is dry, it will be perfectly safe to stand on the ground and pull him off the wire with the bare hands, care being taken to touch only his clothing, and this must not be wet.

A live wire lying **on** a patient may be flipped off with safety with a dry board or stick. In removing the live wire from the person, or the person from the wire, do this, with one motion, as rocking him to and fro on the wire will increase shock and burn.

A live wire may be safely cut by an axe or hatchet with dry, wooden handle. The electric current may be short circuited by dropping a crowbar or poker on the wire. These must be dropped on the side from which the current is coming and not on the farther side, as the latter will not short circuit the current before it is passed through the body of the person in contact. **Drop the metal bar**: do not place it on the wire or you will then be made a part of the short circuit and receive the current of electricity through your body.

150. WHAT TO DO FOR ELECTRIC SHOCKS.

Always send for a doctor, but do not wait for him. Treatment should be given even if the man appears to be dead. Loosen the clothing around neck and body. Proceed to restore breathing by artificial respiration.

The patient is laid on the ground, face downward, arms extended above the head, face a little to one side, so as not to prevent the free passage of air. The operator kneels astride or beside the prone figure and lets his hands fall into the spaces between the short ribs. By letting the weight of the upper body fall upon his hands resting on the prone man, the air is forced out of the lungs; by relaxing the pressure, the chest cavity enlarges and air is drawn in to take the place of that forced out. By effecting this change of air—pressing and relaxing, twelve to fifteen times a minute (time it by watch at first, and then count) artificial breathing is performed. Some times it is necessary to work an hour or two before the flicker of an eyelid or a gasp from the patient rewards the life saver's efforts, and then he must carefully "piece in" the breathing until natural breathing is resumed. When breathing starts, then promote circulation by rubbing the legs and body toward the heart. Do not attempt to stimulate by the throat until the patient can swallow. Give a teaspoonful of aromatic spirits of ammonia, in half a glass of water.

151. TREATMENT AFTER RESPIRATION BEGINS.

The after treatment is important. Put the patient to bed, keep quiet and warm. Always get the services of a physician as soon as possible, but do not wait for him to come. Start work instantly. The patient needs oxygen, so keep spectators away. They are robbing the man of the life-giving properties of the air. For this reason, in all but the most severe weather it is well to work on the patient in the open.

ELECTRO-MAGNETIC INDUCTION

In the volume about Static Electricity and Magnetism, we spoke of charging neutral bodies by induction. We found that a charge of electricity electrified neutral bodies by induction. We also observed that magnets induced magnetism in any magnetic masses of iron or other magnetic material by a process of magnetic induction. And here we find again that electric current can be produced in a certain way by the process of Electro Magnetic Induction.

152. THEORY OF INDUCTION.

The cause of this Electro Magnetic Induction, and the theory of it, lies in the lines of force. We know that around every magnet, lines of force are flowing from the North Pole to the South Pole, and we also know that around the wire carrying the electric current, there are lines of force flowing, with the wire as the center. These lines of force are the power, which cause the induction.

153. FARADAY'S DISCOVERY.

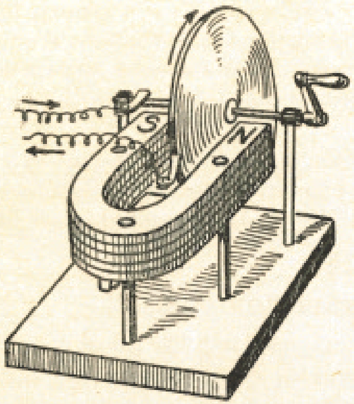


Fig. 1.

It was Faraday's great discovery in 1831 that currents could be produced in a closed circuit, by approaching it with a magnet, or by moving the closed circuit across the magnetic field. He also found that a current the strength of which was changing, induced a secondary current in a closed circuit near it.

Upon his discovery are based the modern dynamos, machines, motors, induction coils, transformers, and other appliances.

In fig. 1 you see his first electric machine with which he proved his discovery, and, that a few years ago, demonstrated before a convention of electricians, found to be in perfect working order.

When the copper plate was rotated between the poles of the horseshoe magnet, a current was generated within the plate, flowing out at the brush on the circumference and returning through the brush on the shaft.

154. INDUCTION THROUGH MAGNETS.

Connect the two ends of one coil with your galvanometer, and bring your bar magnet quickly near it. See fig. 2. If you watch your needle very closely, you will note a slight deflection when you approach the coil with the magnet. As long as the magnet lies motionless near the coil, your needle will show no signs of current effects. However, if you pull the magnet rapidly away, the needle will be deflected in the opposite direction than before. By repeating this experiment with the other pole of your bar magnet, you find the needle deflected in the opposite direction.

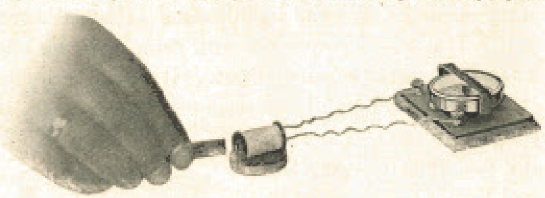


Fig. 2.

The more rapid the motion, the stronger is the induced current.

155. INDUCTION THROUGH CURRENTS.

Connect the second coil with your battery, and try the same experiment as with your bar magnet and you will note the same effects. Instead of approaching the coil, connected with the galvanometer, with the other coil through which the current flows, you will observe the same results if you put the two coils about one-half inch apart, and make and break the circuit, by means of a key or your reverse base. See fig. 3.

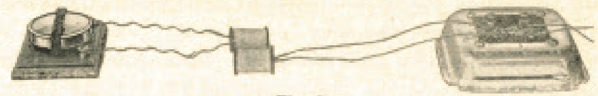


Fig. 3.

156. ALTERNATING CURRENTS.

And here you will note the same effect—that no induced electricity is generated when the battery current flows but only the **making and breaking of the circuit generates induced currents, first in one direction by making the circuit and then in opposite by breaking it.**

Currents that change their direction in this manner are called **alternating currents.**

157. PRIMARY AND SECONDARY COILS AND CURRENTS.

The coil which generates the current is called the **Primary Coil,** and the current in it, the **Primary Current.** The other coil in which the current is induced, is called the **Secondary Coil,** and the momentary currents induced in it, are called **Secondary Currents.** By means of the hand rule, we find that by making the circuit we cause an inverse secondary current, which means this momentary current flows in the opposite direction than the primary current. By breaking the circuit, we generate direct current; which means one which runs the same way through the secondary coil as the battery current flows through the primary. After flowing in both directions the current has performed a **cycle.**

158. THEORY OF INDUCTION.

The cause of the electro magnetic induction is not easily explained. It may be said here that the disturbance of the lines of force cause the induction, and that by increasing or diminishing, or in any way changing them—electric currents are generated.

159. RUHMKORFF'S INDUCTION COILS.

If the two coils are put together in such a way that the secondary coil is wound around the primary coil, we have an apparatus which is known as the **Induction Coil** or the **Ruhmkorff Coil.** See fig. 4.

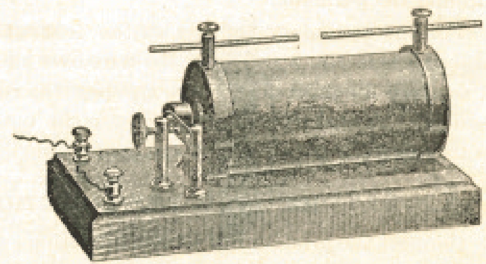


Fig. 4.

The primary coil is wound coarsely, just to accommodate the voltage of the flowing current. The secondary coil is generally wound of very fine wires, because the finer the wire, the more turns can be made around the same surface. As more turns we have, the more lines of force are flowing around them, and the higher will be the voltage of the secondary current. So high, in fact, that a spark may pass many inches between the two wire ends of the secondary coil.

160. HOW TO BUILD A RUHMKORFF COIL.

As experiments with an Induction Coil are very instructive, and it is quite easy to build one, I would advise you to construct one in the following manner:

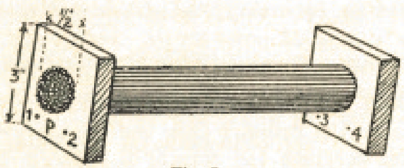


Fig. 5.

Two small wooden parts, about 3 inches square, are used as the frame work. Drill a hole of about ½ inch in diameter in each of them, and besides these, two smaller holes, Nos. 1, 2, 3, and 4. See fig. 5.

Now, take some medium size iron wire and cut it into lengths of about 4 inches and wind as many together as necessary to fit the holes of the frame snugly. Then dip them in hot melted paraffine wax. Drain the superfluous wax off, remove the binding, and the core is ready. You can just as well use an iron bar ½ thick, but the former kind of core is preferable.

Now, take about 2 ounces of No. 24 cotton covered wire, pass one end through the hole No. 1 and wind about six layers around the core. Pass the end through the hole No. 2 and mark this side of the coil P. (Primary current.)

Melt some more paraffine and pour it over the coil until the wire is entirely covered. Then wrap a piece of note paper, about the same width as the winding, around the paraffine.

For the secondary coil use cotton covered wire No. 30. Stick one end of it through hole No. 3 and wind the wire over the primary coil in the same direction. Use about 5 ounces of this wire and pass the end through hole No. 4 and mark this end S. (Secondary current). Cover the outside again with some more melted wax, paste the paper over it and your Induction Coil is complete.

160. HOW THE INDUCTION COIL WORKS.

Connect the primary coil of this induction coil with an automatic interrupter, or build an interrupter, as explained in Cap. 136 of Book II, by using the core of your primary coil as the electro magnet. See fig. 4. The interrupter is necessary, for you will remember that induced currents are generated in the secondary coil only by making and breaking the contact in the primary coil. The automatic interrupter makes and breaks the contract many times a second which causes as many induced alternatic currents.

If you own an **Erector Transformer,** connect the primary coil with the 4 Volt combination and try all the experiment. The current of this transformer being alternating will induce a current in the secondary coil, when flowing through the primary coil without an automatic interrupter.

161. EXPERIMENTS WITH INDUCTION COILS.

This induction coil can be used for numerous experiments. The gas mixture in the engine of every motor car is exploded by the spark of an induction coil. The spark is also applied to ignite mines or blasting from a distance. And airless tubes or such filled with gases might be lightened by it.

If we connect the ends of the secondary coil, to two insulated movable rods, we can repeat, with this induction coil, all the experiments we made with our Electric-Static-Machine and observe the same effects. The two rods act as conductors.

To obtain physiological effects we have to touch both rods. Be careful to try this experiment only with a small coil as the extremely high voltage in the large secondary coil is often dangerous.

By means of a pair of handles each attached to one terminal you feel the current best. If it is too strong for you bring the two ends of the handle together, thus short circuiting the current before it passes through your body. See fig. 6.

The high voltage of the secondary coil enables the current to overcome the resistance of the air between the two ends of the rods and to jump across it in the form of bright sparks. This effect is used in Wireless Telegraphy.

By connecting the two terminals of the secondary coil through pieces of metal the metal can be melted.

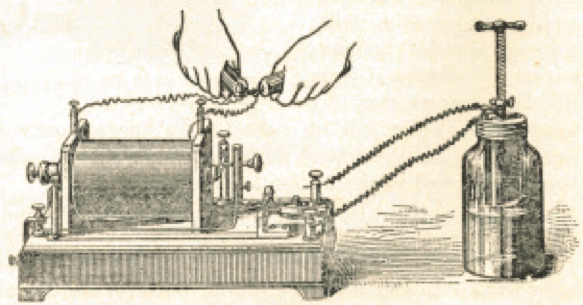


Fig. 6.

162. GEISSLER TUBES.

If we put a glass tube, from which nearly all the air has been removed, and which has a platinum wire on each end, between the two terminals of the secondary coil, a spark will jump across the vacuum but not with the appearance of a spark but in the form of a violet light which fills the entire tube. These, so called Geissler Tubes, may have various forms and being sometimes filled with different gases at different pressures give out many brilliant, luminous effects. See fig. 7.

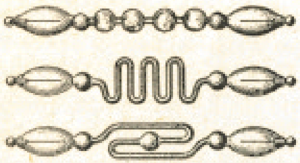


Fig. 7.

163. X-RAYS.

It has been known for some time that invisible rays pass from that end of a vacuum tube by which the current leaves.

Professor Roentgen discovered that these Kathode rays could penetrate, more or less, through bodies which, up to that time, were thought to be untransparent. These rays have the same effect on the photographic dry plate as the regular light rays and produce on them negatives of all the substances which they cannot pass through. Take the human hand for instance. The rays will pass through the flesh and reproduce the bones, through which they cannot pass equally well. See fig. 8.

This wonderful discovery is used in medical work to great advantage.

Fig. 8.

164. TELEPHONY.

The most common use of the induction coil lies in its appliance to telephony.

The first practical instrument for reproducing sounds at a distance, the telephone, or over-distance-talker, was invented by Graham Bell. It was in Boston, in 1876, when he and a friend talked over the first telephone line which led through his experimental rooms from the first to the third floor of a building.

The principle of the telephony is based on Induction. The Transmitter, the part spoken in to, **the line, the receiver,** the part which gives the sound out again, and an **electric bell** for calling up, **are the essential parts of the telephone.**

The transmitter and receiver were in the first telephones changeable, that is, the transmitter could be used as a receiver, and vice versa, as their construction was the same. In modern telephone work the Bell instrument is being used as a receiver, while as a transmitter, an instrument invented by **Reis** is in use.

165. BELL'S TRANSMITTER.

In the Bell, or magneto transmitter, the speaker talks through the mouthpiece, a thin plate of steel, which vibrates through the sound of the voice. You are familiar, I suppose, with the fact that every sound generates air waves. Every consonant and vowel and every sound whatsoever causes some fixed amount of air waves in a second. The steel disk or diaphragm, D, vibrates in accordance with the air waves which touch it. Very near it but not touching it is the magnet, M, as the core of a coil wound of a very fine wire. See fig. 9.

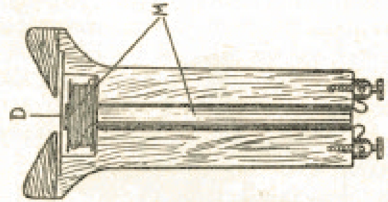


Fig. 9.

The ends of the wire of the coil are connected with the ends of a similar apparatus so that a complete circuit is made. **Every time the diaphragm is pressed near the magnet by the pressure of the air waves of the sound, a feeble current of high voltage is induced within the transmitting coil and conducted over the line to the receiving coil at the other end. It causes there exactly the same variation of the strength of the magnet and thus the same vibration of the diaphragm and, thereby, reproduces exactly the same sound at the other end that was produced on the transmitting diaphragm.**

The induced current is an alternating one and although very small can force its way through a long length of wire on account of its high voltage. **No other current than this induced one passes the line.**

It proved that for practical use, Bell's telephone was not strong enough to transmit sounds over a long distance and an instrument took its place based on the principles of the microphone.

166. THE MICROPHONE.

The Microphone consists of pieces of carbon so fixed that they form only a very loose contact. See fig. 10.

A little carbon rod (C) rests very loosely between the two carbon pieces (A and B) which in connection with the battery and transmitter form the complete telephone line. No receiver is necessary, as the slightest variation of the strength of the current causes the vibration of the carbon rod and thus repeats the vibration on the transmitter.

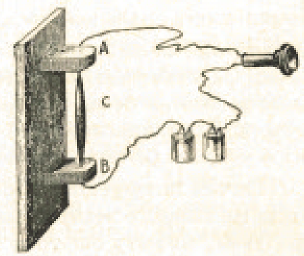


Fig. 10.

167. CARBON TRANSMITTER.

This principle has been made use of in the **Reis carbon transmitter** which are in general use in all telephone lines. See fig. 11.

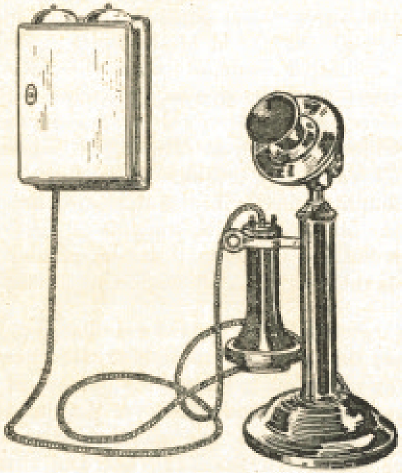


Fig. 11.

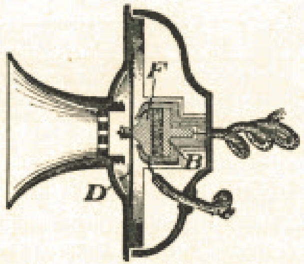


Fig. 12.

Fig. 12 shows a section of this transmitter, in which the diaphragm D, is connected with the front terminal F. Between that and the back terminal B granulated carbon is placed loosely. **These carbon granules offer different resistances to the flowing current depending on the pressure, produced by the vibration of the diaphragm.** This variation of resistance causes a corresponding variation in the currents transmitted through the line, thus producing the same vibration in the diaphragm of the receiver as is produced in the diaphragm of the transmitter by the sound waves of the speaker's voice.

With this line a battery of one or two cells is necessary. As this battery is very often too weak to transmit sounds over very long distances we use induction coils in telephone as we use relays in telegraphy. The primary current of the two cells generates in the secondary coils a current of varying very high voltage which forces its way through very long distances.

Through forty years evolution of the telephone, we have succeeded in speaking from the distance between the first to the third floor of a building like Mr. Bell and his friend, to carry our voice over such enormous distances like from New York to San Francisco.

168. TRANSMISSION OF ELECTRICAL CURRENT.

It is very often necessary to conduct a current from the place where it is generated to some other place where its effects are to be used. Generally copper wire constitutes the conducting line as copper offers a very low resistance to the flowing current. You know that the resistance depends upon the thickness of the conducting body and that some of the strength of the electric current would be lost as a result of a too thin conducting body, chiefly due to the heating of the wire.

A current of 50 amp., for instance, needs a conducting wire with a diameter that is five times as large as one of 10 amp. As copper wire is very expensive, the conducted current has to be brought down to a low amperage so that thin copper wire may be used as conducting lines. The power of a current of 50 amp. and 100 volts is 5000 watts. We obtain the same result if we transform this current to one of 10 amp. and 500 watts for the time the current is to be transmitted.

169. TRANSFORMER.

A transformer is simply an induction coil, having iron cores, usually of laminated iron strips of "U" shape piled together to constitute a closed magnetic circuit. Upon the cores are wound the primary coil, to receive the current, and the secondary coil, to give out the induced current. In fig. 13 the primary coil is wound over the secondary coil in a **Erector Transformer.**

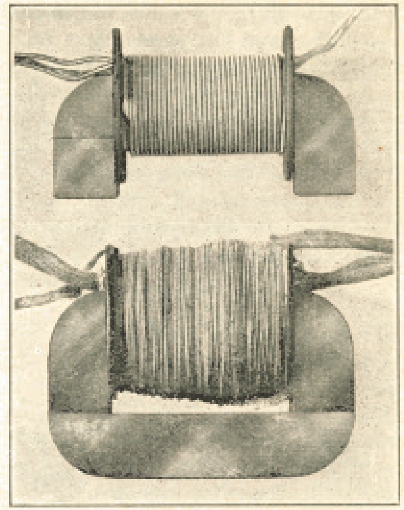


Fig. 13.

In a transformer that is required to change the voltage of a current from high to low, a so-called **step-down transformer,** the primary coil consists of many turns of fine copper wire to receive the small current with high voltage, and the secondary coil consists of a few turns of thick copper wire to give out a much larger current at low pressure. To transform a current from 500 to 100 volts, there has to be five times as many windings on the Primary Coil than on the Secondary Coil.

In a **step-up transformer,** that transforms low voltage into high, the arrangement of the coils is just reversed.

170. THE ERECTOR TRANSFORMER.

The Erector Transformer is constructed for transforming **the alternating lighting current of 105-115 Volts into currents of low voltage.** It will drive your toy motor at a minimum of expense, and pay for itself in a very short time, saving the expenditure for dry cells.

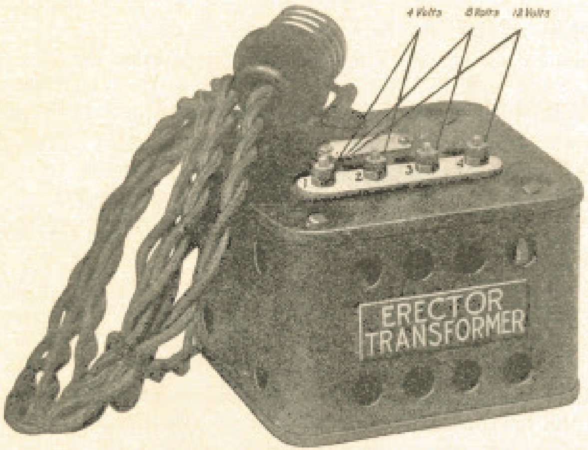


Fig. 14.

In this transformer we have three secondary coils. One is to reduce 110 volts to 4 volts; the second, 110 volts to 8 volts; and the third, 110 volts to 12 volts. The ratio of transformation, i. e., the proportion of windings of the secondary coils in our transformer is 1 : 2 : 3. That means there are twice as many windings in the second secondary coil as there are in the first, and three times as many in the third.

One end of every secondary coil is connected with the terminal No. 1. Between the terminals Nos. 1 and 2 the transformer will reduce the current to 4 volts between Nos. 1 and 3 to 8 volts, and between Nos. 1 and 4 to 12 volts. See fig. 14.

171. DISTRIBUTION OF CURRENT.

For economical purposes we generally produce electricity of a high potential, 1000 to 5000 volts. Such currents can be sent by relatively thin copper wire. As a current of 5000 volts, however, cannot be used commercially, step-down transformers are used to reduce the voltage. They are placed in Sub-Stations in large cities, from which currents of low pressure are distributed to the houses. Sometimes in secluded districts a small transformer is provided for each house.

For lighting and power transmission on railroads large transformers are usually immersed in oil tanks to preserve good insulation and prevent heating. See fig. 15.

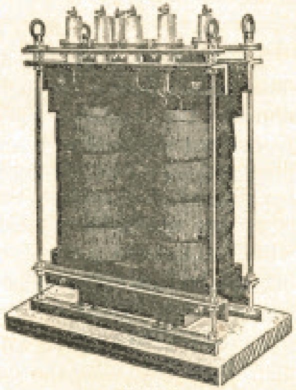


Fig. 15.

172. THE DYNAMO.

The theory of the induction of currents finds its biggest application in the construction of **Dynamos.**

The dynamo is a machine for generating electric current by mechanical forces. When we produced electric currents in a closed circuit, we had to use the power of our hand to bring the bar magnet near the coil, or approach it with the other coil through which the current was flowing. These movements generated feeble currents, the effects of which we could observe on the galvanometer.

The dynamo is based on the same experiment, only in a more practical way. The most essential parts of it are **the magnet, which is arranged as a magnetic field, the closed circuit which moves within the magnetic field, and the force which causes this movement.**

173. THE IDEAL DYNAMO.

In Fig. 16 we have **two permanent magnets,** at the north and at the south pole. Between these two magnets is a **single coil** attached so that it can be moved by a crank within the **lines of force** which flow from the north to the south pole.

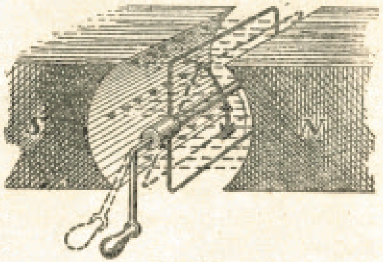


Fig. 16.

Every time the two horizontal parts of the coil perform a movement of 180 degrees up they cut on their way down respectively more lines of force than on their horizontal way, when they are moving nearly parallel with the lines of force With this increasing and decreasing of the lines of force, we generate two currents within the coil, **one inverse** and **one direct.**

The laws of induction prove that both horizontal parts generate the inverse and the direct current at the same time, If we connect this loop of wire with the galvanometer, the needle will prove this by declining to the right and to the left of the north pole.

174. COMMUTATOR.

In order that the current taken from the coil of the dynamo may be in one direction, the ends of the coil are connected to copper terminals that revolve with the shaft and the currents are taken off with brushes. These brushes are placed in such a position that the change from one terminal to the other takes place at the same moment that the direction of the current in the coil changes. **This arrangement will produce, on an external circuit, a current which always flows in one direction. We call this part of the dynamo the commutator.** It consists of as many pieces of insulated copper as there are insulated coil units in the so-called armature.

175. THE ARMATURE.

The armature is the part of the dynamo in which the current is generated. It is generally the rotating part and made of soft iron. Parallel to its axle slots are cut in which the wires of the coils lie.

The ends of each coil are connected with the corresponding commutator bars. The Voltage of the external circuit will be the sum of the E. M. F.'s induced in all the coils of the armature.

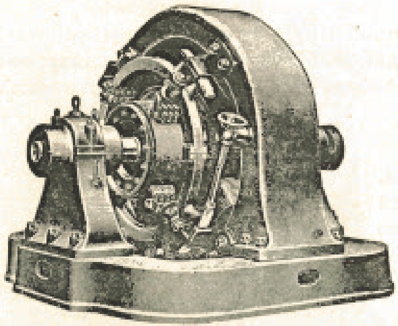


Fig. 17.

176. THE FIELD MAGNET.

To produce the lines of force in the dynamo, there are several methods employed. The frame of the dynamo may consist of more than one pair of poles, a so-called **Multi-Polar Dynamo,** but no dynamo is possible without at least one pair of magnetic poles. We speak of a four pole dynamo, if it has two pairs of poles. See fig. 17. Those with three pairs of poles are called six pole dynamos, and so on.

177. TYPES OF DYNAMOS.

If the dynamo has a magnetic field produced by current from some outside source of electricity, such as a battery or another dynamo, we call it a **Separately Excited Dynamo.**

The **Dynamo in Series** is so arranged that the entire generated current passes around the field magnet's course on its way from the machine, thus increasing the strength of the field magnet.

In the **Shunt Dynamo,** only a part of the current is carried around the field magnet. The combination of the Series Dynamo and the Shunt Dynamo gives the **Compound Dynamo,** generally used for incandescent lighting, as the current produced by this kind of dynamo has the big advantage of practically constant strength.

178. DIRECT AND ALTERNATING CURRENTS.

The dynamo, the coils of which are connected to a commutator, will produce direct current. If the ends are coupled to copper rings instead of to the bars of the commutator, the external current will correspond with the one generated within the armature, that is, it will be an alternating one, changing its direction twice for every rotation of each coil. These two changes represent one cycle.

The advantage of the alternating current over the direct current is mostly economical, as the high voltage of the alternating current reduces the cost of transmission. By means of simple transformers the current is changed from higher to lower voltage and then applicable for commercial purposes.

Its disadvantage lies in its high pressure, which requires more efficient insulation and also makes it dangerous. **Alternating currents, besides, cannot be used for such purposes as electroplating, making permanent artificial magnets, charging storage batteries, etc.**

179. POWER STATIONS.

Mechanical power for generating electric current is supplied either by steam engines or water power. Steam power stations are generally erected on rivers, where coal is accessible. Water turbines are driven by natural cataracts or by the effuse of water-dams.

180. THE ELECTRIC MOTOR.

A dynamo is a machine for producing electric current by mechanical forces The reversal of this effect, that is, **generating mechanical forces by electric current, is the purpose of the Electric Motor.**

The theory of this action is based on the laws of magnetism, that unlike poles attract each other and like poles repel each other, and also on the theory that every solenoid becomes a magnet with two poles if the current flows through it. When you have grasped these two ideas, you can easily understand how the motor works

The most essential parts of the electric motor are the field magnet, the armature, the commutator and the brushes. You see there are nearly the same parts as in the dynamo, and, in fact, an ordinary direct current dynamo will act as a motor if the current is sent through it, entering by one brush and leaving by the other. There are, however, many small differences in the construction of a motor and a dynamo, though, generally speaking, both machines are nearly alike and only the results are different as one is just the reversal of the other.

181. SIMPLE ELECTRIC MOTORS.

A very simple electric motor consists of a bar magnet and a solenoid. See fig. 18. The current flowing through the solenoid should generate a north pole at the end opposite the magnet. The magnet is suspended by two threads with its north pole about one-half inch away from the iron core of the solenoid. If no current flows through the solenoid, the bar magnet will attract the iron core, or, providing the solenoid with the iron core is fixed, the bar magnet will attract itself to the core.

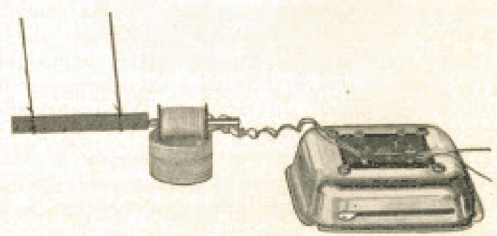


Fig. 18.

As soon as we have, with the help of a key, sent the current through the solenoid and generated a north pole in the attracted end of the iron core, the two north poles will repel each other. After the repulsion, we break the circuit and cause the north pole of the bar magnet to again attract itself to the core. This motion, to and fro, can be considered as the mechanical effect, but of course, it is hardly possible to use this kind of mechanical force to any practical advantage.

In this device the bar magnet represents the magnetic field, the coil the armature and the key the commutator.

182. THE THEORY OF THE ELECTRIC MOTOR.

The electric motor, based on the same principle of attraction and repulsion, produces its mechanical effects through rotation. The poles of the armature are rotating around the axle being attracted and repelled by the field magnet. To increase the effect, the armature consists of an electric magnet and is arranged in such a way that, for instance, in moving towards the north pole of the magnetic field each of its poles remains a south pole until it is opposite the north pole. Then, by means of the commutator, it automatically changes from the south pole to the north pole and will be repelled. The same thing happens at exactly the same time on the south pole of the magnetic field, but just the reverse. This attraction and repulsion of the unlike and like poles causes, with the help of the law of inertia, the rotation of the armature. See fig. 21.

183. THE ERECTOR MOTOR.

This theory will be more clearly understood after you have assembled the different parts of your motor which are contained in your Electrical Set. In fig. 20 you are shown all the parts named and also the manner of their arrangement when the motor is completed. By following these directions carefully, you will be able to build the most powerful toy motor ever brought out. It will be a source of much enjoyment that will more than repay you for the time expended in constructing it.

184. THE FIELD MAGNET.

Your field magnet consists of laminated steel strips of "U" shape, held together by two insulating fibre pieces. Thrust one end of the armature wire through the middle hole on the left side, leaving about two inches of covered wire sticking out for connection with the terminal. Place over the horizontal part of the "U" between the fibres, the field magnet fibre insulation from your part box.

Now, take the field magnet in your left hand, holding it by one branch of the "U" so that the square corners of the fibre pieces are before you and wind six layers of wire around the horizontal part of the "U" between the fibre pieces, winding it in the opposite direction from that which the hands of a clock turn. After the sixth layer leave about two inches of wire hanging down

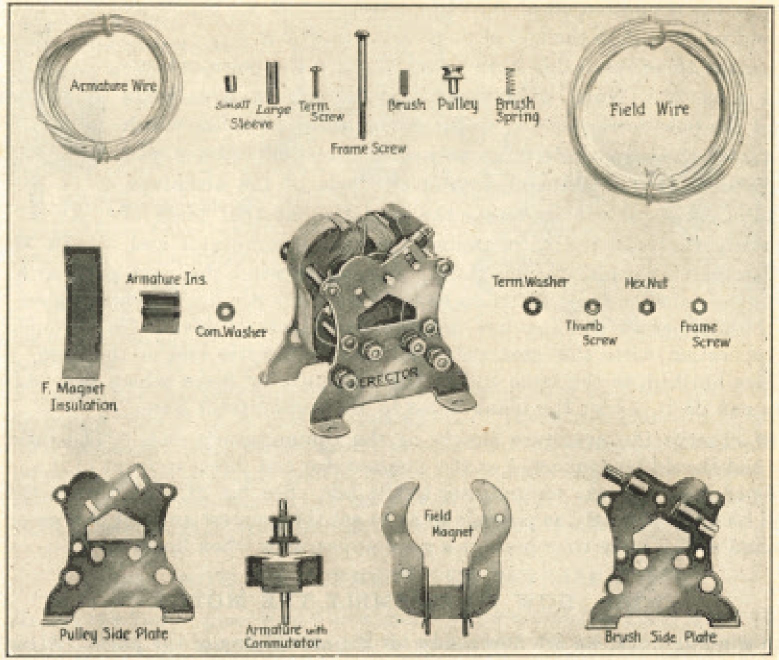


Fig. 20.

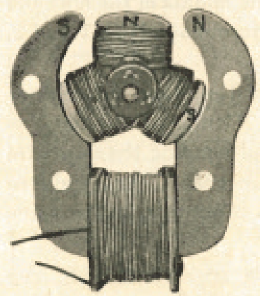


Fig. 21.

for connection with the terminal and thrust this wire through the bottom hole of the fibre at your left. See fig. 21.

185. THE ARMATURE.

Now for the armature. Your armature consists of laminated steel parts of "Y" shape representing three poles which give the motor the advantage of being self-starting. Already mounted on one end of the spindle of the armature is your commutator, consisting, in accordance with the three poles, of three brass pieces held in position by means of fibre disks. The ends of the brass pieces, near the armature, are bent out in such a way as to hold the armature wire.

Scrape the insulation off about one-quarter inch of the armature wire and connect it to the end of one commutator bar.

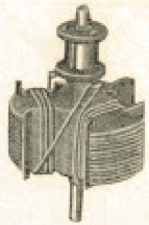


Fig. 22.

Place the three insulating fibre pieces between the poles as illustrated in fig. 22. Now, wind the armature wire in five layers around the pole corresponding to the commutator piece on which you started the wire, again in an anti-clock direction. When you have finished winding the wire around one pole of the armature, instead of cutting it, merely scrape the insulation at that piece of wire where you take the turn around the next commutator end, and after making it fast to this point, proceed to wind the next pole with five layers of wire in the same direction as the first one. See fig. 22 which shows you only the manner of winding but not the five layers of wire, Go through the same operation with the next pole and attach the free end of the wire, when you have finished, to the same end of the commutator piece where you started. If you can do it, solder the blank wires to the commutator bars.

Now observe the armature closely at the commutator's end. The inside of every coil should be connected to the commutator end direct in front of it and the outside ends to the next commutator to the left. See fig. 21. All these windings should be done as neatly as possible so as to get the greatest amount of wire on the poles and at the same time present a good appearance when finished.

186. HOW TO ASSEMBLE THE MOTOR.

The winding done, we are now ready for the assembling of the parts. Attach to the terminal-side-plate the other three terminals as you see it on the one already assembled.

The screw should rest insulated from the motor plate in the middle of the hole and should not touch the metal anywhere. Connect the two terminals, Nos. 1 and 2, on the outside by a thin copper wire.

Cut two pieces of wire—one about two inches long and the other about three inches, and scrape one-half inch on each end of them bare. Connect the longer one of these wires to terminal No. 3, by loosening the screw and bending the bare wire around the screw, between the screwhead and the fibre washer, and tightening then the hex-nut as securely as possible. Connect the other wire, in the same manner with terminal 2.

Then stick the four frame-screws through the holes of the pulley side plate, slip the four small pole sleeves over them, force the screws through the corresponding holes of the field magnet, and then put the long sleeves over the screws. See fig. 23.

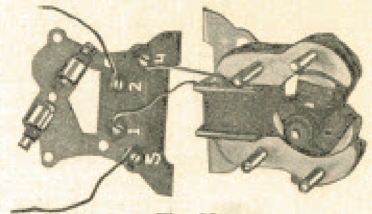


Fig. 23.

Now place the armature in the field magnet, and lay the small fibre washer on top of the commutator. Having done this, connect the terminal No 1 on the inside of the terminal base plate, to the outside end of the field magnet wire, and terminal No. 4 to its inside end, sticking out of the fibre piece. See fig. 23. All these connections with the terminals have to be done very carefully in order to avoid any short circuit in the motor.

Lay your motor with the pulley-side-plate on the end of the table so that the armature is lifted and the commutator stands out.

And, now for the final operation. Pushing back a little the brush-holders thrust the commutator between them. Then stick the four ends of the screws through the corresponding holes, and twist the four frame nuts on the screws, tightening them as securely as you can.

Now move the brush-holders back on their place and put the brushes in. Then place the springs in back of them and thrust the wires from the terminals Nos. 2 and 3 through the holes in the end of the brush-holders, so that they hold the spring in place and make at the same time a good connection.

Drive the pulley on the shaft by a hard whack with a hammer, but be careful not to bend the axle by hammering too roughly.

Compare your work frequently with the illustrations so that you will not make mistakes.

Your finished motor is the most powerful and efficient toy motor anywhere near its size. Owing to its construction it will run on only one Dry Cell, but will develop unexpected power on a stronger current—up to 12 volts, either alternating or direct.

If you should experience any difficulty in assembling this motor, write to Mr. A. C. Gilbert about it, or send the parts by parcel post to The A. C. Gilbert Company, New Haven, Conn, with your remittance of 50c., which will cover the actual cost for labor and return mail charges, and they will assemble it and return it to you, the day it is received.

187. HOW THE MOTOR WORKS.

Now, let us see how your motor works. Connect the two end terminals with the battery and close the circuit by means of the key. Out motor is a direct or alternating motor, mounted in series, and it makes no difference by which of the two lower terminals the current enters.

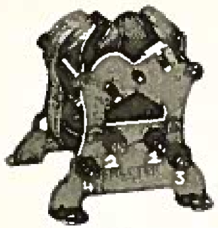


Fig. 24.

We will suppose that a direct current enters by terminal No. 4. Then it has to make its way through the coil of the field magnet, first, and causes the magnetizing and polarizing of the laminated steel pieces. Then it passes to terminal No. 1, through the bare wire to terminal No. 2, and then to the brush A. The commutator brings the current to the three coils of the armature. From the coils, the current flows through the commutator bars to brush B, which is connected with the terminal No. 3, from which the current goes back to the battery, closing the circuit. See figs. 23 and 24.

On its way through the armature, the current flows, by means of one commutator bar, to two poles of the armature at the same time, entering one coil by the outside end of the wire, and the other coil by the inside end. Thus it generates two unlike poles, which again are unlike to the poles of the field magnet. See fig. 21. The unlikeness of the poles causes an attraction and thereby starts the movement of the armature. At exactly the same moment that the poles are attracted to just opposite the ends of the field magnet, the commutator reverses the poles, causing now a repulsion between the poles of the armature and of the **field magnet, which do not change at all.**

If you watch your commutator closely, you will see that the brush jumps across the slit at the same moment that the poles of the armature are just opposite the poles of the field magnet.

188. THE POWER OF THE MOTOR.

This attraction and repulsion causes a constant rotation of the armature, depending on power from the strength of the magnets. As these magnets are electromagnets, their strength increases with that of the current, although limited through the magnetic saturation of the laminated steel plates and also by the conductivity of the wire.

Do not expect to obtain a very powerful motor by connecting it directly to your house wire of 110 or even 220 volts. The result would only be a short circuit in your lightning wire and a blown out fuse, as your motor does not offer resistence enough to a current of 110 volts. You can obtain the best results from this motor by using the Erector Transformer on the 12 volt combination, or running it on four to six dry cells.

189. REVERSE BASE.

If you are now familiar with the theory of the motor, you will easily understand how the Reverse Base acts, the purpose of which is to reverse the movement of the motor by changing the direction of the flowing current within the field magnet **or** in the armature, **but not in both circuits.**

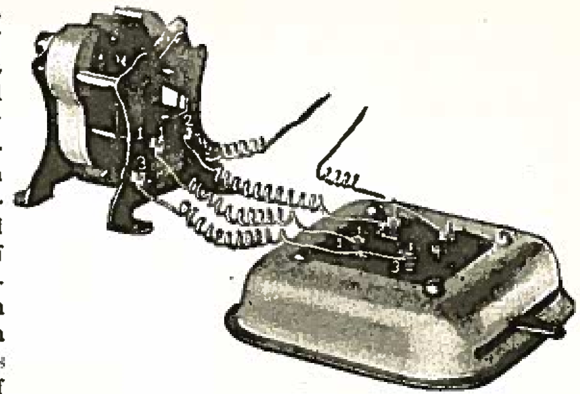


Fig. 25.

I hope you will understand why the changing of the direction of the current within the field magnet **and** the armature would simply result in the same movement as before only with changed poles. By changing the poles of the field magnet only, by means of the reverse base, the current produces a **repulsion** where it was an **attraction** before, and vice versa, thus reversing the direction of the movement.

The reverse base has four terminals on top, corresponding with the four terminals of your motor. Nos. 1, 2, 3, and 4. See fig. 25. These terminals are in contact with two half-round brass pieces, arranged between fibre insulation in such a way that by means of the lever, always two different terminals might be connected when the lever is moved from one end of the slot to the other. If the lever is held in the middle, the current flowing through the reverse base is interrupted.

190. HOW TO CONNECT THE REVERSE BASE.

Take out the bare copper wire which connects terminals No. 1 and No. 2 of your motor. Connect the terminals Nos. 1, 2, and 3, of the motor, with the corresponding terminals of the reverse base, and the terminals No. 4 with the battery. See fig. 25.

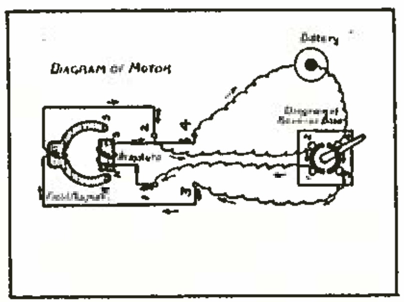


Fig. 26.

When the lever is held in the middle, the reverse base breaks the circuit, and the motor does not work at all. When it is moved over towards terminal No. 4, it forces the current which enters by terminal No. 4 to go to terminal No. 3 and flowing from terminal No. 3 of the motor through the coil of the field magnet, to return through the terminals No. 2—2, flow within the reverse base to terminal No. 1 and enter the armature on Terminal 1. See fig. 26.

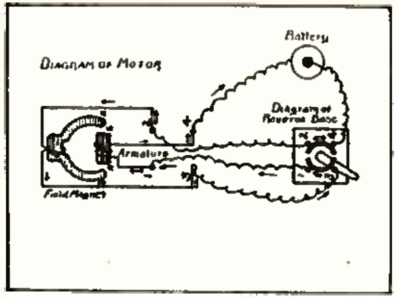


Fig. 27.

If you want to reverse the motor, switch the lever to the other end, and force the current to go from terminal No. 4 to No. 2 of the reverse base and enter the field magnet at terminal No. 2 of the motor, changing, thereby, the direction of the current flowing through the coil of the field magnet. Thus the poles of the magnet are changed and the motion reversed. In both positions the current which flows through the armature enters by terminal No. 1 and leaves by terminal No. 4 This proves that the poles of the armature remain the same—unchanged. See fig. 27.

The hole in the lever will enable you to work your reverse base from a distance, a feature that will help you to perform many interesting experiments.

191. THE USES OF THE ELECTRIC MOTOR.

The uses of the electric motor are so many and varied that it is impossible to enumerate all the things which are done with the help of these motors. From the tool room with the most delicate die work, down to the kitchen with the simplest housework, electric motors are everywhere in use. Individual motors drive machines, such as printing presses, lathes, band saws, drilling instruments for dentists, and even help in the reproduction of music.

192. ELECTRIC RAILWAYS.

A very important use of motors lies in their application to the **electric trolley line and railways.** With the invention of the electric motor, many suggestions were made to propel vehicles by electricity, but only when the dynamo was commercially introduced for generating the electric current, could the problem be solved. In 1879 Edison brought out the first practical working model of an electric-driven car, and since 1890 the great development of electric transportation has started in the United States.

193. ARRANGEMENT OF ELECTRIC RAILWAYS.

The trolley lines or Third Rail Railways are comprised of a **Generating Station, the Trolley Wires** or **the Third Rail, the Cars with the Motors,** and **the Road Bed.** The dynamos, in the power stations, usually produce direct current, at a voltage of about 500 volts. The positive poles of these dynamos are connected with the trolley wires or the third rail, while the negative poles are in connection with the tracks, which serve as return conductors.

The current goes from the trolley wire to the wheel on top of the trolley pole, which is pressed against the wire by means of a spring. From there it goes down to the control switch and through the motor down to the track, and back to the dynamo, closing the circuit. The cars are arranged in parallel, like the glow-lamps in the lighting system, and each takes its own current from the wire, independent of the rest. See fig. 28.

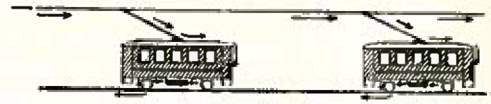


Fig. 28.

The motors, usually two in one car, are about 25 to 30 H.P. Since they are subjected to the severest kind of usage, they are built in water-tight cases.

194. REGULATION OF SPEED.

When the motorman turns his crank to the first notch, he sends the current through a number of resistance coils, before it reaches the motor which will run with very low speed. Your control switch is just the same in miniature as the speed controller in the big electric railways. The further the motorman turns the crank, the less resistance is interposed between the main wire and the motor, so consequently the motor will speed up. As soon as the resistance is all cut out the current simply passes through the motor and drives it at full speed.

195. RAILWAY SYSTEMS.

There are several ways of bringing the electric current to the car. When the live wires are placed over the tracks, we have an **Overhead System.** If the current is picked up by the car from conductors laid in a slip between the tracks, by means of a contact or plough, we speak of an **Underground Conduit.** The **Third Rail System** carries the current in the third rail which extends slightly above the road surface near one track, while a long skate or shoe, fastened beneath the car, slides above it and picks up the current.

196. ELECTRIC LOCOMOTIVES.

For inter-urban purposes, like in the subway of New York, all motor coaches are provided with motors under the floors of the cars, and, when connected together, can be controlled by one motorman standing in the front car.

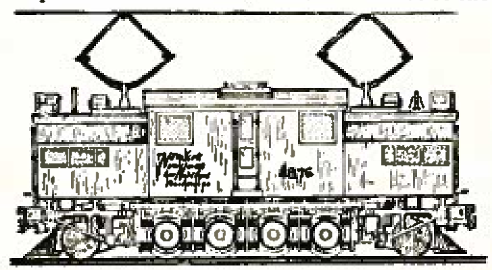


Fig. 29.

For lines where ordinary cars or coaches are used, locomotives are a necessity. The modern electric locomotive of 2,000 H.P. weighs about 80 to 100 tons, and is about 40 ft. long; while the modern steam locomotive, of about 1,500 H.P., with its tender, weighs about 150 tons, and is about 60 ft. long. See fig. 29. Therefore, the running cost of the electric locomotive for a mile is much less than that of the steam locomotive, so it is quite clear that the electric locomotive will supplant every steam locomotive wherever "white coal," the cheap water power, can be used for generating electric current.

The use of electric motors in connection with automobiles or boats depends entirely upon the source of electricity for the motor. This is generally a, so-called, **Secondary Battery** or **Accumulator.**

197. STORAGE BATTERIES.

The problem of accumulators, or storage batteries, keeps our world-famous electrician and inventor busy trying to bring out an accumulator that will be strong, and at the same time light in weight. At the present time the storage batteries are too heavy for general use, and take up too much space. These batteries are not accumulators of electricity, but what they storage is power in the form of chemical action.

We charge the accumulator by reversing the chemical occurences within the simple cell; we increase the difference in potentials between the two poles of the accumulator by connecting it with the dynamo, or other generator of **direct** currents. The direct current flows within the accumulator from one electrode to the other and, figuratively speaking, is stored on the Kathode of the cell. The electrodes consist mostly of lead plates, and the liquid is diluted sulphuric acid. The current causes chemical occurrences of complicated kind, the effect of which appears in a high difference of potential between the lead plates. The current, coming from the accumulator runs in a contrary direction to that in which it was sent through it.

It is evident that by using lead plates in the accumulator it has to be quite heavy. With the solution of the problem of the storage batteries, that is to say, with the invention of one which is light and at the same time efficient, we will come a big step nearer the new evolution in human progress—the electrical era.

198. ABOUT MACHINES.

Machines are devised for the purpose of saving power while obtaining the same results. But the golden rule of Mechanics reads:—**"Wherever we save on power, we lose on time."**

To better explain this, recall how you have tried to lift a heavy stone by means of a lever. You forced one end of this lever under the stone, and pushed the other end, which was sticking up in the air, down until it reached the ground. You moved the end of this lever down about one yard or more, while you lifted the stone only a few inches. The distance which one end of the lever traveled was many times greater than that of the other. Here is the proof of the above mentioned rule: You have lost time by traveling a longer way with a small power where you could have performed the same feat in a shorter way with a stronger power—that is, if you **could** lift the stone directly to the height that you did, with the help of the lever.

199. LAW OF THE LEVER.

The distance that the two ends of a lever travel depends upon their length so that we can find an expression for the law of a lever. The power, P, and the weight, W, are in the same proportion to each other as the weight-arm W.A. is to the power-arm, P.A.

$$P:W = WA:PA$$

Or, in other words, the power necessary on a two-arm lever to lift or overcome the weight on the other end, is equal to the weight, multiplied by the length of the weight-arm, divided by the power-arm.

$$P = \frac{W \times WA}{PA}$$

200. WHEEL AND AXLE.

Applying this rule to the wheel and axle we obtain the same results, if we consider them as a modified lever, the arms being the radii of the wheel and the axle.

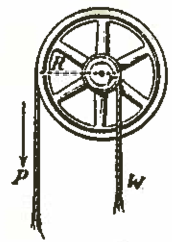


Fig. 30.

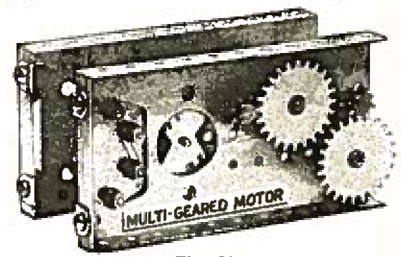


Fig. 31.

The power is easily applied at the circumference of the wheel, and the weight at that of the axle. See fig. 30. The use of this arrangement is very practical.

201. GEAR BOX.

Combinations of the wheel and axle, where the axle of one system is working upon the wheel of the other, are used, not only where the effects of a small source of power has to be increased but also where it is desired to make differences in speed.

202. KINDS OF GEARING.

The two gear wheels we are going to use in our **Gear Box** are of unequal diameter, and, consequently, of unequal circumference, the smaller one, the pinion gear, having eight teeth, and the larger one, the gear wheel, twenty-four. See fig. 31.

Fig. 32.

Every time the gear wheel performs one revolution the smaller one has to make three, and vice versa: every time the pinion gear performs one revolution the gear wheel is only one-third way around. The former kind of gearing we will use to obtain higher speed, and the latter for increasing power.

Our motor turns with about 1800 revolutions a minute: although it is the strongest toy motor on the market its absolute power is not very great. The gear box will overcome this fault and give you a motor which will easily lift any weight you would like to use with your toys. By properly gearing and using a steel shaft to prevent bending, it will lift 200 lbs. See fig. 32. But do not forget: **Every increase of power is made possible at the sacrifice of speed.**

203. HOW TO ASSEMBLE THE GEAR BOX.

To rig up your gear box you must use your motor and four small Erector screws and nuts. The two holes in the small bent end of the gear box sides correspond with the two holes on each end of the motor side plates. You have only to push the screws through these holes and screw the nuts down very firmly. See fig. 31. The terminals of the motor go through the holes of the plate designed for them.

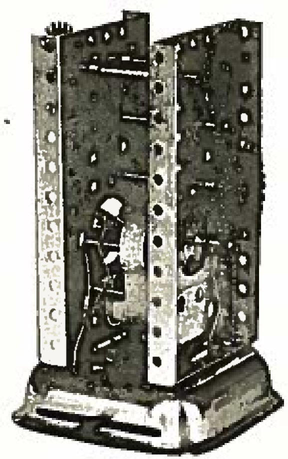


Fig. 33.

204. HOW TO USE THE GEARING.

Attach the pinion gear to the motor pulley and bring it in connection with the large gear wheel mounted on the first axle and held in place by two collars inside.

This large gear wheel and its axle will make about 600 revolutions in a minute, in accordance with the difference in the circumferences of the gear wheels. But, with reduced speed, the axle gains about three times in power, as you can easily feel if you try to stop the motor by the axle.

Putting another pinion gear on the other end of this axle, and connecting it with the gear wheel on a second axle, you reduce the speed again to one-third of the first axle, so that the second axle makes about 200 revolutions a minute, while you increase hereby the strength again about three times.

This gearing will easily lift twenty pounds and run all your models with remarkable speed.

Every gearing combination which follows, will reduce the speed but increase the power in the same proportion.

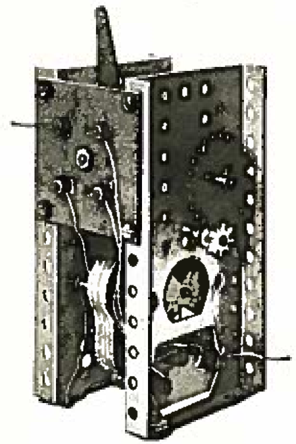


Fig. 34.

Connect your gear box to the top of the reverse base as pictured in fig. 33, by using the four top screws. You will then have a unit of construction that will fit in the Erector Construction Toy or any other toy of similar kind, as the holes on the gear box correspond with the usual distances on the steel parts of these toys.

If you want to mount your multigeared motor on a base, connect the top part of the reverse-base to the side of the gear box. See fig. 34. The wires run between the terminals in the same manner as shown in fig. 25.

The combination of the control-switch and the multigeared motor, connected as in fig. 35, is also a unit around which you may build your models.

Study the illustrations and read the instructions carefully. This is a very important part of your course.

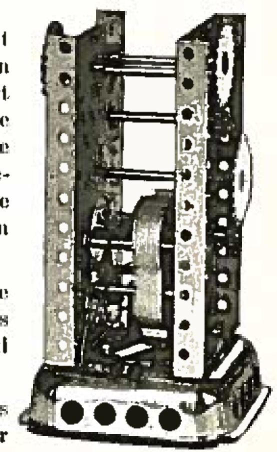


Fig. 35.

Questions to be Answered when Study of Book III is Completed:

1. How could you help a person in contact with a live wire?
2. Describe artificial respiration.
3. How can you prove electro-induction?
4. What is a cycle?
5. Name uses of the Ruhmkorff coil.
6. Describe a telephone transmitter.
7. How does the telephone work?
8. What do you know about the distribution of current?
9. What does the commutator on the dynamo?
10. How can we reverse the direction of the rotation of a motor?
11. How is the speed of an electric street car regulated?
12. How does the gear box prove the "golden rule" of mechanics?

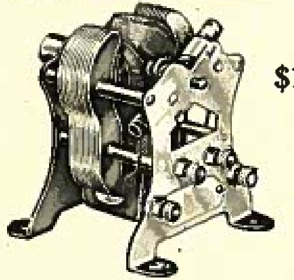
MEMORANDUM

INDEX

The Numbers Refer to the Figures Alongside of the Headings

ERECTOR ELECTRICAL ACCESSORIES

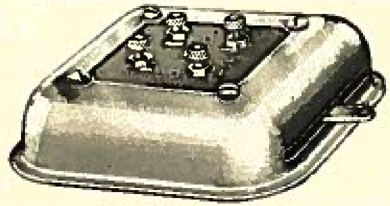
P 58 **$1.50**



No. P-58 Erector Motor. Retails for $1.50.—This is the four terminal motor, which comes in all Erector sets, from $5.00 up. It can be made reversible by attaching to reverse base P-59. It is the most powerful and efficient toy motor for anywhere near the same price. Owing to its efficient construction it requires very little current to operate.

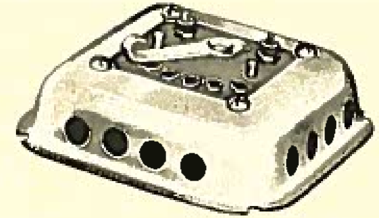
P 56 **$5.00**

No. P-56 Erector Universal Motor. Retail for $5.00.—This is the last word in motor construction. The first highly efficient small motor that can be attached direct to any house current, with either direct or alternating current, 105 to 115 volts. It is well ventilated. The brushes are self-lubricating, and all parts perfectly insulated. Furnished with 5-foot cord and plug attached. This motor saves the expense of transformer or batteries. It gives you an even smooth current at the lowest possible expense.



P 59 **75c.**

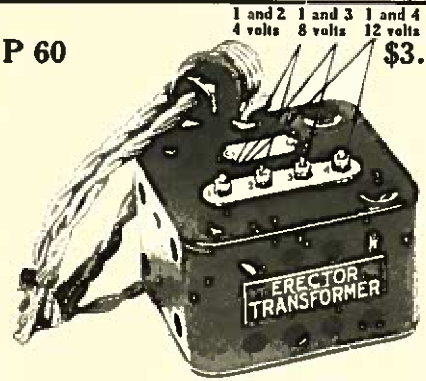
No. P-59 Erector Reverse Base. Retails for 75c.—Is made of pressed steel, reversing mechanism, being well protected. The arm changes the current when turned from left to right. The hole in the arm is for attaching a cord so that the motor can be reversed at long distance, as from one room to another. The base operates with any four terminal battery motor on a current of not more than 25 volts.



P 61 **$1.50**

No. P-61 Erector Control Switch. Retails for $1.50. Strongly constructed. Parts well protected by pressed steel base. It is well ventilated, so that it will keep cool under considerable overload. This switch controls the speed of any toy motor so that models or electric trains can be operated as fast or slow as desired.

P 60 **$3.00**



No. P-60 Erector Transformer Retails for $3.00—This transformer is for alternating current, 105 to 115 volts. Supplied with 5-foot cord, and adjustable plug. Well ventilated, and perfectly insulated. It gives even current to the motor, and operates models at a minimum of expense. It will pay for itself in a very short time.

No. P-64 Erector Transformer Retails for $2.50—This transformer is exactly the same as P-60, except that it is an 8-volt transformer, having terminals one and four.

PRICE LIST

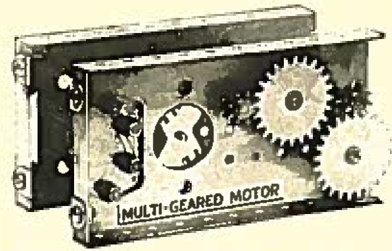
SEPARATE PARTS OF THE ELECTRICAL SET

		Price U. S.	Can.
P-701	Glass Plate	10c.	15
P-702	Cloth piece	5c.	8
P-65-2	Electroph Cover	15c.	22
P-65-3	" Cake	15c.	22
P-709	Ebonite Rod	10c.	15
P-66	Galvanometer	40c.	60
P-67	Compass	20c.	30
P-723	Bar Magnet	10c.	15
P-68	Elect. Horseshoe Magnet	45c.	67
P-69	Solenoid	20c.	30
P-727	Yoke	5c.	8
P-736	Box with Iron-filing	10c.	15

		Price U. S.	Can.
P-729	Miniature Receptacle	10c.	15
P-730	Miniature Elect. Lamp	15c.	22
P-731	Field Magnet Wire	5c.	8
P-732	Armature Wire	5c.	8

We do not fill orders for less than 25c.

P 63 **$2.00**



No. P-63 Multi-geared Motor Retails for $2.00. This is a remarkable electrical combination, the motor mounted between the plates being the Erector Motor P-58 which can be easily detached. There is an endless variety of gearing, to control every type of electrically operated toy. One shafting, one pinion gear, and one gear wheel is furnished. The gears in the illustration shows but a few of the possibilities.

No. P-62 Gear Box Retails for 50c.—A great many boys will receive P-58 motor with their Erector outfit. They can, by purchasing a gear box, turn their motor into a regular multi-geared one. The Gear Box consists of two side plates with one shafting, one pinon gear and one gear wheel.

Hello Boys!

Now if you should have any trouble with your Electrical Set or you find that you cannot accomplish certain of the problems write to me personally and immediately. I will be mighty glad to straighten out your difficulties and explain everything you may wish to know. You are going to have a lot of pleasure with this apparatus but of course Electricity is a big Science and Study and you are likely to encounter problems which will naturally come to the beginner. But remember my promise: I am always ready and willing to help my boys.

A. C. Gilbert
President

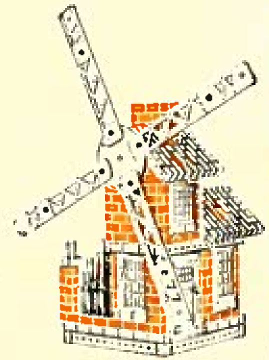
Have you heard about the "Gilbert Institute of Erector Engineering" and the splendid Diplomas I am awarding to Boys who build acceptable models? I've just printed a big illustrated book telling all about it and how you can win. Send for one. Make up your mind now to become an "Erector Engineer." Prove to your parents and friends that you are the type of boy they can be proud of—a boy of ability who likes to *DO* things, and who always "goes in to win."

ERECTOR

TOY ENGINEERING

This is the play for the boy of to-day! Anything mechanical or structural can be duplicated with Erector. This famous toy will interest and instruct every "live wire" boy. Each set is complete with large illustrated Manual of Instruction. Boys never grow tired of building Erector models. The sets are indestructible, and models can be taken down and parts used over and over again. Each set is complete in itself for building a wide range of models, limited only by the ingenuity and skill of the boy Each set contains all essential engineering parts, such as long and short girders, angle irons, shafting, groove and hubbed wheels, pinions, gears, pulleys, nuts and bolts, depending in quantity and variety upon the price of the set. With most of the sets there is included a strong electric motor, which will easily lift 200 pounds when properly geared.

Brik-tor



"The Toy That Completes Construction Toys"

Brik-tor is a remarkable toy. With it a child can construct interesting and attractive models of buildings of every description. Brik-tor is to architecture what Erector is to Mechanical Engineering. Brik-tor can be used in connection not only with Erector but any other construction Toy and contains a generous quantity of steel bricks in many colors, together with fundaments, rods, doors, windows, frames, strips, plates, etc. In fact everything necessary to build with.