and it will soon be getting dark. Good-bye, and thank you so much for promising to go to Mrs. Goode. She will be so glad to see you come in."

"Don't be in such a hurry, my little girl. I can't allow you to go till I have looked at your foot, so sit down and let me examine it."

The poor ankle was so swollen with walking that Dr. Black's touch, gentle as it was, almost made Minnie cry out, and she had to shut her lips very tightly together to prevent any sound escaping them.

"It's a bad sprain," was the verdict, "and this little foot mustn't be put to the ground for some time."

"But I must make haste back to mamma," exclaimed Minnie, "and I would rather go at once, please, because I've been away a good while already. It took me such a long time to get here from the place where I tumbled."

"You don't imagine I am going to let you walk home with such a foot as that? I will drive you round as I go to Mrs. Goode's; and we will start as soon as I have bandaged the damaged ankle, and made it a little more comfortable."

"Don't be frightened, mamma, dear," said Minnie, as she hobbled into the room, having refused Dr. Black's offer to carry her in, as she said it would alarm her mother, and make her think something dreadful had happened. "I've only hurt my foot a little, and it will soon be all right again."

It was a long time, however, before Minnie could take any more long walks, and she was confined to the house for some little while.

Early the next morning Ella came in, full of self-reproach at having let Minnie go to Mrs. Goode's alone. "It was very selfish of me!" she exclaimed. "Mamma said so when she came back to the room and found you were gone by yourself; and I see it now. Both Tom and I are ashamed of it. I do so wish I had come with you, for then I could have gone for help when you hurt yourself so; at all events, you wouldn't have had that long walk round by Dr. Black's afterwards, because I could have gone instead; and it was that made the ankle so much worse, Dr. Black says. He says too," she continued, turning to Mrs. Wallace, "that he never knew such a brave, unselfish girl as Minnie. Yes, it is quite true what mamma says; she was only thinking of other people yesterday afternoon, and Tom and I were only thinking of ourselves. But we are going to put off the Christmas-tree till Minnie is well enough to come to it, and Tom is collecting all his new story-books to bring over for her to read. Papa says we shall all love her even better than we did before, if that is possible," and Ella wound up by giving her friend a warm embrace, whilst a happy light shone in Mrs. Wallace's eyes at these praises of her little daughter.

Minnie herself was made still happier by Dr. Black's telling her, when he came to see his little patient in the afternoon, that he hoped Mrs. Goode's son would soon begin to improve. Had more time been lost it would have been more serious, but Minnie might feel that she had perhaps saved his life by fetching him help before another night had gone by.

SOME ELECTRICAL EXPERIMENTS.

By the Author of "How to Make an Electric Machine," &c. &c.

I TRUST that during the time which has elapsed since the publication of my directions how to make an electric machine, many of my readers have succeeded in making one. Some no doubt have failed, and some perhaps have found that they have not been able to devote their attention to the construction of a thing which certainly requires time and trouble. But I hope that both the successful workers and the unsuccessful will study this paper, for it concerns them both. For I now intend to detail some experiments which can be performed with the machine, and some others which can be done without any apparatus at all beyond that which is within the reach of all.

First I must say a few words about what is called the theory of electricity. A theory may be defined as the best means for accounting for certain facts and appearances which seem very difficult of explanation. Sometimes a theory may be accepted, and may remain unquestioned for many years, when some discovery is made which upsets it altogether, and causes another theory to reign in its stead. I will give you an example of such an occurrence which took place only a few months ago. Two or three observers in different places in this country noticed that a fine yellow powder had fallen upon their plants and outhouses apparently from the sky. They wrote letters to the newspapers about the strange phenomenon, and one of them gravely started the theory that this powder was sulphur which had been discharged from some volcano hundreds of miles away, and had been carried by the wind to the places where it was now deposited. So much for theory number one. Some of this powder was then sent to a gentleman for his opinion about it, which he was very careful not to give before he had consulted his microscope. He then pronounced this wonderful powder to be nothing more than the dusty pollen of a plant. So in this case theory No. 1 had to give place to theory No. 2.

You will now understand that in giving you the generally accepted theory of electricity I am merely stating what seems to be the best way of accounting for the various curious effects that it exhibits. Should this theory some day give place to a better one, all the better, but until it does so the best thing that we can do is to acknowledge it, and believe in it.

I have already told you how the early experimentalists found that electricity could be evoked by rubbing amber and other substances, and that the electricity showed itself by attracting little chips of straw, dust, &c. So a theory was established by which substances were divided into what were called *electrics* and *non-electrics.* We now know this definition to be wrong, for all substances are capable of exhibiting electricity by friction, provided that certain conditions are observed. We know that a stick of sealing-wax when rubbed will attract small pieces of straw or paper, and that if we try the same experiment with a rod of metal it will fail. But if the metal be fastened to a glass handle, so that the electricity cannot run away through our bodies to the earth, we shall find that it will readily show symptoms of electric action. Now, therefore, substances are divided into conductors and non-conductors of electricity, while some few, on account of their intermediate action, are called semi-conductors.

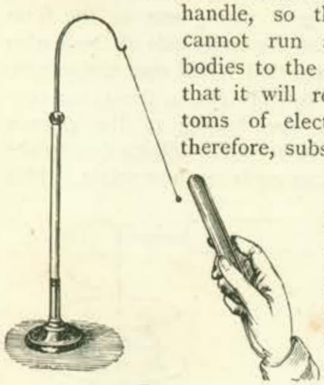

FIG. 1.

Fig. 1 represents a little instrument called an electroscope, which can be easily made, and will assist us greatly in understanding electric action. It may consist of a piece of board six inches square, into which is fastened by cement a bit of glass tubing fifteen inches long. This tube is bent over at the top (which can readily be done with a spirit-lamp), and from its upper end is suspended by very fine silk a pith ball. If now we excite a glass rod by rubbing it with silk, and bring it close to the pith ball, the latter will be attracted towards the rod, but if actual contact be made between the rod and ball, the latter will then be repelled. A stick of sealing-wax rubbed with flannel will have precisely the same effect upon the pith ball. But by using the glass and sealing-wax alternately we shall find that when the ball is repelled by the glass the sealing-wax will attract it, and *vice versa.* So the theory came to be adopted that there were two kinds of electricity, the one called *vitreous* belonging to the glass, and the other *resinous* possessed by the wax. The great Franklin modified this theory. He assumed that electricity pervaded everything in nature. That this electricity consisted of two fluids, the *positive,* answering to vitreous, and *negative,* answering to resinous electricity. These two fluids do not become apparent in a substance until it is subjected to friction, or some other treatment, when they separate. In the case of the pith-ball, the glass or sealing-wax *induces* an opposite kind of electricity in it—it is attracted—but directly contact occurs it is endowed with the same kind of electricity as the rod presented to it, and is repelled. So we see that things charged with the same kind of electricity repel each other, but charged with opposite kinds they attract. This will remind you of the behaviour of two magnets (alluded to in a former article), where opposite poles attract each other, but similar poles have the reverse effect.

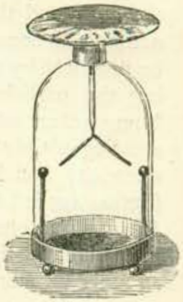

FIG. 2.

A more delicate electroscope than the pith ball arrangement can be easily constructed, and a number of experiments can be made with it. It is shown at Fig. 2. It consists of a clean and perfectly dry bottle having a wide mouth. Into this must be fitted a good cork. A brass wire passes through this cork into the bottle, its lower end having been previously beaten out as flat as possible. On each side of this flattened end is placed a little slip of gold leaf about an inch long. The best way to attach these to the wire is to wet the latter with a little gum—and bring it down on the leaves, which must be previously cut to the proper size. They must be so placed that they will hang together face to face. The other end of the wire outside the bottle is crowned with a little disc of thick card, covered on both sides with tinfoil.

On presenting a stick of rubbed sealing-wax to the disc the gold leaves will fly apart, but by touching it with the flannel that we have just used as a rubber, they will immediately fall to their former position. This experiment will show us that an excited rod and its rubber possess different kinds of electricity, and that the two fluids neutralise one another. Rubbed glass followed by rubbed wax will give the same results. If a stick of wax be broken, and the fractured end be immediately applied to the electroscope the leaves will diverge. Take some ground coffee, fresh from the mill, and drop it upon the disc, and electric action will become apparent; the same effect can be produced by sawing a lump of sugar, and allowing the particles to drop upon the electroscope. Many other substances will give similar effects, showing plainly how universal is the presence of electricity, and how it can be made manifest by friction applied to all kinds of different substances. I may name one more experiment in this connection which is both interesting and amusing. Let an assistant stand on the insulated stool, described on page 141, and let him place one hand upon the plate of the electroscope. No action will take place until he is well beaten with a piece of dry silk or leather, when the gold leaves will instantly diverge; but if he merely stands on the floor without the glass supports, the electricity will pass through his body to the earth, and no effect will be produced.

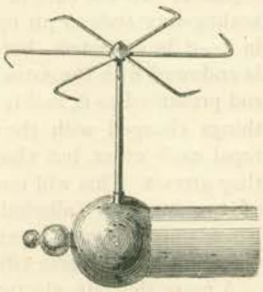

Fig. 3.

And now for an experiment without special apparatus, and which can be accomplished by all of you. Take a common iron tea-tray, and support it on four glass tumblers. Now get a sheet of thick paper just large enough to cover the tray, and warm it at the fire. Remove the paper quickly to a table, and rub it vigorously with a piece of india-rubber. Now take it to the insulated tray, and holding it by two corners drop it upon the iron. You will feel, as you do this, that the metal is strongly attracting it. Upon touching the edge of the tray you can obtain a good spark. Remove the paper, and you can obtain another spark; replace it and the same thing occurs, the sparks getting weaker and weaker until the action ceases. You can vary this experiment, by allowing an assistant to hold the tray, while he stands on the glass stool, when sparks can be drawn from his finger tips as readily as from the glass. Although experiments such as this are readily performed by the means described, they can be much more conveniently done by the use of the electric *machine*; and of course many things can be done with the latter which are impossible without it. Some of these I will now describe.

It will be necessary to have the means of attaching to the prime conductor of the machine several little pieces of apparatus. For this reason it should have a hole at each end, one at the top and another at the back, in which thick wires can be readily placed when desired. In boring these holes, care must be taken that the tinfoil which covers the wood is continued within them, so that the wires afterwards inserted may have a true metallic contact; should this not be the case, the experiments cannot possibly be successful.

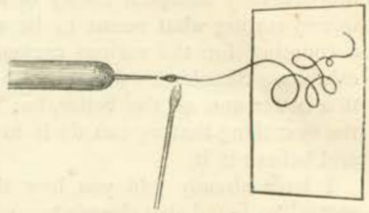

Fig. 4.

Into one of these holes insert a piece of wire about three inches long, which has been filed so that its free end presents a sharp point. Now turn the machine, and place the back of the hand near the point, when a sensation as of a little stream of air will be felt issuing from it. The electric force is quickly discharged from points, hence the use of brass knobs or balls in electrical apparatus, and the avoidance of all sharp corners or projections which might induce leakage. The issue of this force from points may be visibly shown by other methods. Beat a large leaden shot flat, and attach to it copper wires, bent in the form shown in Fig. 3. Let the under side of the leaden centre be so hollowed that it will turn easily upon a pointed wire inserted upright in the prime conductor. Now turn the handle of the electric machine, when the little vanes will revolve by the action of the force moving from their points. This action may be further exemplified by attaching a small button of sealing-wax to a pointed wire inserted in the end of the conductor, and melting it by a lighted taper as the machine is turned. The melted wax will then fly off in a thin stream as fine as a hair, and will describe curious patterns upon a card held near it. The experiment is illustrated in Fig. 4.

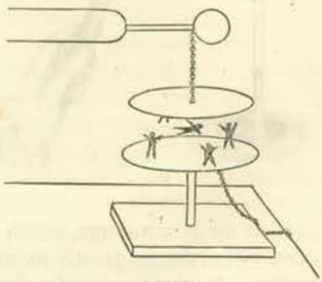

Fig. 5.

A wire furnished with a ball at the end is an almost indispensable attachment to the electric machine, as it is of service in a great number of experiments. A bullet answers the purpose admirably, and if you possess a bullet mould the wire can be readily attached before the metal becomes solid. Otherwise a hole can be readily bored in a cold bullet by means of a gimlet, and the wire can be pointed before it is inserted so as to obtain a firm hold upon the lead. This hint can be taken advantage of in the construction of the Leyden jar, where a ball termination is also required. With this bullet-headed wire inserted in the end of the prime conductor we can now perform many experiments of a very interesting and instructive nature.

Present the inside of a warmed, dry glass tumbler to such a wire fixed on the conductor, and turn the machine for a few seconds. Now remove the tumbler, and invert it on the table over some pith-balls. These balls will now be attracted to the glass, and dance about in a very lively manner, being alternately attracted and repelled as they are charged and discharged by contact with glass and table respectively. The pith balls can be replaced by little pith figures, which can be bought at many of the electrical warehouses, but their dancing can be made much more effective by attaching a metal plate to the conductor of the machine, as shown in Fig. 5, another plate being below which will constitute the dancing platform for the tiny performers. These plates may be made of cardboard, or thin board covered with tinfoil, but care must be taken that the lower one is in connection with the ground either by covering its support with the same metallic coating, or by fastening a brass chain to its under surface, the end of which may trail upon the floor. A few feet of such chain will be found useful in many other experiments.

The repulsion of bodies charged with the same kind of electricity may be amusingly shown by sticking a doll's head with long hair upon a wire inserted above the prime conductor, when the hairs will stand out on end as if the doll were horror stricken at such unceremonious treatment. Of course a good doll must not be decapitated for this purpose, for the commonest wooden-headed subject will do as well as anything.

To show this action—the repulsion of bodies—on a more extended scale a number of light strips of tissue-paper may be attached to the end of a fishing-rod, the last joint of which must be interrupted by a piece of glass rod (see Fig. 6, where A shows how the glass can be bound to the rod). A chain or wire is now fastened from the insulated joint to the prime conductor (B). When the machine is put in action the paper strips will fly away from one another, and stand on end, as did the hair on the doll's head in the former experiment. The same experiment may be made very amusing by using a wig of dry, well-combed hair. An assistant standing on the glass stool, and furnished with head-gear of the kind mentioned, touching the conductor while the machine is in action, will present the most ridiculous appearance owing to the peculiar behaviour of his false crop of hair. Of course sparks can be obtained from the body of any one thus insulated, and connected with the electric machine, and plenty of fun may be obtained by inviting some one not in the secret to shake hands with him. By touching the surface of water he can draw a spark from it, and by applying his finger to a brass ball which has been covered with a piece of tow moistened with ether, the tow will ignite by the spark thus obtained.

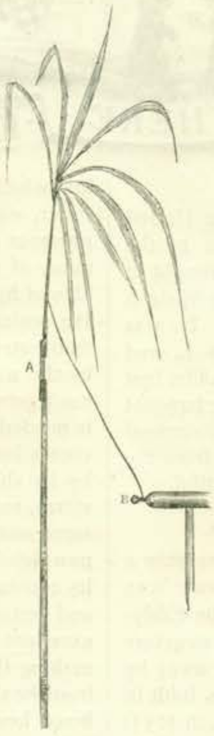

FIG. 6.

By using what is called a battery of Leyden jars (which comprehends a number of jars so connected together that their combined charge can be directed against any object) a number of startling experiments can be made. Model houses can be blown down by artificial lightning, and fine wires can be destroyed by the action of the electricity thus accumulated. All these experiments are accompanied by noise and light—indeed, this circumstance first induced people to believe that thunder and lightning were caused by the passage of electricity from cloud to cloud, and between the clouds and the earth. To test the correctness of these ideas wires were fixed to long poles pointing to the sky, and in stormy weather sparks were by this means drawn from the sky. Dr. Franklin obtained the same result from a kite, an experiment which led to the invention of the lightning conductor, which affords protection to high buildings. This conductor is formed of thick copper wire, one end of which projects above the building it is sought to protect, while the other end is buried some distance in the ground. The lightning passes along the metal conductor in preference to smashing the stone work, which forms a non-conductor.

T. C. H.