E STUDY OF
ECTRIC MOTORS
EXPERIMENT

M. ST. JOHN

Robert E Hopkins.
Tarrytown
New York

The Study of Electric Motors by Experiment

CONTAINING

Sixty Experiments that Bear Directly upon the Construction, Operation and Explanation of Electric Motors; together with Much Helpful Information upon the Experimental Apparatus Required

By

THOMAS M. ST. JOHN, Met. E.

Author of "Fun with Electricity," "The Study of Elementary Electricity and Magnetism by Experiment," "Wireless Telegraphy for Amateurs and Students," "Electrical Handicraft," "Things a Boy Should Know About Electricity," Etc., Etc.

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THOMAS M. ST. JOHN

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THE STUDY OF ELECTRIC MOTORS BY EXPERIMENT

CHAPTER I

MATERIALS OF CONSTRUCTION

1. Laboratory Motors and Dynamos. When the student gets to the point where he begins his experiments with motors, he feels that he is doing something, for things begin to move and he can see that he is producing results right from the start. There are many things that can be done with a properly-constructed motor, and a motor that will merely go around is a very poor sort of a thing for the student; in fact, it isn't worth anything to use in the laboratory. What the student needs is a motor that can be taken apart and used for experiments, one that is so constructed that it shows how the big machines work, and one that is under perfect control. Motors should be easily controlled as to speed, as well as to the direction of rotation.

The advantage of the laboratory motors described in this book is that they will do all that other motors will do, and much besides; for they are designed especially for those who want to use them for experimental purposes as a part of the general study of electricity.

As the main features and parts of small dynamos and motors are the same—in fact, most small dynamos can be used as motors—we shall first take up a few experiments that will aid in understanding both machines. The student will find it to his advantage to perform the experiments that are herein suggested, unless he has already done so, for it will make things clear as he goes along.

2. Materials of Construction. It would seem that big motors or dynamos should be built of many different things and be very complicated in order to be able to do what is expected of them; but when you examine them you see, on the contrary, that they are very simple in construction and that they are made up chiefly of but two metals, iron and copper. Of course, there are other things on them, such as insulating materials, nickel-plating, etc., but these are there chiefly for looks and for keeping the iron and copper in place so that they can do their proper work.

There must be some reason for this choice of materials and for this simplicity of construction, and that is what we want to find out by experiment. If the student will keep these two things in mind, when doing the experiments, he will see why these special experiments and explanations have been given.

3. Iron is an element, from a chemical standpoint, but we seldom see pure iron. About all of the iron we use and that is sold in the market for wagons, machinery, bridges, etc., is far from being pure, as it contains other things, too, such as carbon, phosphorus, silicon, sulphur, etc. These impurities, as the chemist calls them, are the very things that make it possible to so modify the iron that it becomes suitable for electrical purposes; for, if we had only the absolutely pure iron, we could not have steel and other forms of iron that are really more important than the pure iron. We shall see how iron is used in the construction of these wonderful electrical machines, and find out why certain kinds of iron are better than others for the purpose.

4. **Copper** is also an element used in electrical machines, but in this case we try to get it as pure as possible. The copper used for the wire and other parts of motors and dynamos must be pure, and a great deal of care is used in making it for these purposes. The experiments that follow will show how the copper wire and iron act together to make the motor or dynamo a success.

5. **Permanent Magnets.** About the first thing we think of when the magnet is suggested, is the ordinary horseshoe magnet. These have been made for centuries, but it took a long time before the connection between electricity and magnetism was discovered. The horseshoe magnet is a permanent magnet, for it holds its magnetism for years if handled properly.

6. **Electromagnets** are those produced with the aid of the electric current, and it is these with which we shall spend most of our time in the experiments. If it were not for the electromagnets, which are made with iron and copper, we could not have motors and dynamos.

CHAPTER II

PERMANENT MAGNETISM

TWENTY EXPERIMENTS IN PERMANENT MAGNETISM THAT BEAR DIRECTLY UPON THE CONSTRUCTION AND EXPLANATION OF MOTORS AND DYNAMOS.

7. Note. While most of the twenty above-mentioned experiments will be found in Part I of "The Study of Elementary Electricity and Magnetism by Experiment," they are repeated herein because they have a direct bearing upon motors and dynamos. A review of these will aid the student, and, if he has never actually performed experiments along this line himself, he should not fail to follow out the suggested experimental work.

EXPERIMENT 1. To study the horseshoe magnet.

8. Directions. If you remove the soft iron "armature" or "keeper" from the end of the horseshoe magnet and then move it about over the whole magnet, you will find that the attraction for the armature is greatest at the ends of the magnet. There does not seem to be any pull upon the small piece of iron at the curved part of the magnet, but this part is silently doing its part of the work just the same, as you will find by one of the future experiments.

9. Discussion. The ends of the magnet are called its "poles," and the central part that seems to have no magnetism is called the "equator." Electromagnets have poles, also, and the location of these poles becomes quite an important matter in dealing with motors and dynamos.

EXPERIMENT 2. To see what ordinary things are acted upon by a magnet.

10. Directions. With your horseshoe magnet, try all of the different metals that you can find, to see which are affected by the magnet. Try iron, copper, tin, zinc, lead, wood, glass, and any other things you have at hand.

11. Discussion. Most bodies, when placed near a magnet, do not seem to pay the slightest attention to the magnet, and when removed from the magnet they do not seem to have taken any magnetism with them. In the case of iron and steel, however—and a few other things might be mentioned—we have substances that are really affected and which, in certain cases, take something from the magnet. Steel, which is a modified form of iron, has the property of holding quite a little of the magnetism when removed from the magnet, and it is this property that makes it possible for the horseshoe magnet to hold its magnetism at all.

Substances that are attracted by a magnet are called "magnetic" substances, even if they do not hold the magnetism afterwards; but a magnetic body is not necessarily a magnet.

12. Magnetism is that queer something or other that magnets have and give out freely to surrounding bodies. For the student who is working with motors and dynamos, it isn't necessary to stop and think about the ether-whirls and other theoretical discussions. This matter has been taken up in some of the author's other books, but it does not need to be discussed here.

When we take up the subject of "lines of force" and the "magnetic field," we shall find that the space about the magnet is filled with "magnetic lines of force" and that objects placed in this field are bathed with invisible power of some sort called magnetism. Experiment 2 proved that all substances are not affected by this queer bath, and this is a good thing; for we must have some inactive parts in the motors and dynamos.

EXPERIMENT 3. To find through what substances magnetism will act.

13. Directions. If you put a small piece of iron wire or a little heap of iron filings upon a sheet of stiff paper and then move your horseshoe magnet about immediately under the paper, you will see that the paper does not hold the magnetism back.

If you try thin pieces of wood, cardboard, glass, and various other things, you will also see that these are likewise unable to keep the magnetism from reaching the iron. Now, if you try a sheet of tin in place of the paper, you will find that the magnetism is not so strong as in the case of the other things and that, if the tin be thick enough, almost no magnetism will get through to attract the iron.

14. Discussion. We say that paper, wood and the other things through which magnetism can act are "transparent to magnetism," for the power of the magnet can pass through them. In the case of the tin, which is really nothing more than sheet iron covered with tin, the magnetism, or most of it, is held back. We shall see, further on, what becomes of the magnetism and why iron acts like a "screen" to magnetism.

The fact that magnetism can act through cotton and silk cloth is a very important one, as the covering on the copper wires used on motors and dynamos is either cotton or silk.

15. Note. As it will be impossible to give herein all of the elementary experiments on magnetism in connection with the work on motors, the student is referred to any good text-book on the subject, and if he is not thoroughly familiar with such experiments, he should take up the subject and get at the bottom of it.

EXPERIMENT 4. Making magnets from a magnet.

16. Directions. When a piece of steel is rubbed properly upon a horseshoe magnet, magnetism is given to the steel, which also becomes a magnet. The steel has the power of holding the magnetism, and it can even pass some of it along to other pieces of steel.

EXPERIMENT 5. To see what is meant by the north pole of a magnet.

17. Directions. If we rub a sewing-needle upon one of the poles of a permanent magnet, we shall have a small straight magnet, and this is called a "bar magnet." It is an easy matter to float this small bar magnet upon a cork in a dish of water to see if it will turn to any particular direction. One end of it will always turn to the north.

18. Discussion. The end of a magnet that points to the north when it is floated or otherwise suspended is called its "north pole," and the other end is its "south pole." The north pole is also called the "north-seeking" pole, and, as the little magnet has the power to point, we say that it has "pointing-power." The "magnetic needle" and the "compass" work upon this principle and depend upon a small pivoted bar magnet for their action. The student should be provided with a small magnetic needle for testing the poles of his motors and dynamos.

EXPERIMENT 6. Attractions and repulsions of magnets.

19. Directions. After you have made a small bar magnet with a needle, or you can use your compass instead, you should experiment with them to find out the laws of magnetism. If you try to touch the north pole of the horseshoe magnet, which should be marked with a line or with an N, to the end of the little floating bar magnet that points to the north, you will find that they actually repel each other. If you try the opposite poles, that is, a north with a south, you will find that they attract each other.

20. Discussion. The attractions and repulsions of these little magnets are strong enough to move a freely-suspended magnet, and to show that real motion can be produced by the action of one magnet upon the other. As will be seen when we come to the experiments upon electromagnets, it is this action of attraction or repulsion that causes the armature of the electric motor to revolve.

EXPERIMENT 7. To see if we can make more than two poles in a bar magnet.

21. Directions. Place a sewing-needle upon the table, and hold it down with your finger while you touch its point with the south pole of your magnet. Lift the magnet straight from the needle, touch the middle part with the north pole, and, finally, the head of the needle with the south pole again. Now if you dip the needle into iron filings you will find that you have made three poles, for the filings will stick to it in three places.

You should test these three places with your compass to find out whether the poles are north or south.

22. Discussion. It seems rather strange that we can have a bar magnet with three or more poles, and that we can make them north or south as we desire, but such is the case, and we can have as many poles as there are places touched with the magnet.

Such poles are called "consequent poles," and they are made use of in the construction of motors and dynamos. They will be studied again when we take up experiments with the motor.

EXPERIMENT 8. To study the theory of magnetism.

23. Directions. If we place a little pile of iron filings upon a piece of paper and then draw a pencil or other unmagnetized thing lightly over it, we shall find that the pencil has made some little furrows through the filings, and there will be nothing else that can be seen. Now, if, in place of the pencil, we draw one end of a bar magnet through the filings, we shall see that something has happened besides the making of the grooves.

24. Discussion. Whenever a magnet acts by contact upon the pile of filings, as explained above, we find that the filings have been brought into line and that they point in the same direction. Most of the particles of filings have been made to change their first positions and take up new lines. Each little piece of iron has been magnetized, and, although it could not follow the magnet bodily, it has at least turned upon a pivot, like the compass-needle, to watch the magnet disappear.

Every bar of steel is composed of very small particles, which are called molecules, and it is supposed that these molecules have the power to turn upon their axes when the magnet is rubbed over the steel. Of course they are too small to be seen, but the experiment with the filings should aid in understanding how they act under the influence of the magnet. In this case, the pile of filings takes the place of the piece of steel, while each piece of filing takes the place of a molecule. There are experiments that show that the pile of filings becomes magnetized and gets poles like any piece of iron.

When as many as possible of the particles of a piece of steel have been brought into line, we say that the steel has been "saturated" with magnetism. We shall see, later, that we can magnetize a piece of steel by using the electric current instead of a permanent magnet. Each little molecule of the steel is supposed to be a very small magnet, even before we try to bring it into line, so that all that is really necessary is to have the magnet or the electricity swing the molecules around so that they will all point in the same direction.

EXPERIMENT 9. To find whether soft iron will permanently retain magnetism.

25. Directions. Rub a short length of soft annealed iron wire upon your horseshoe magnet to magnetize it as you did the needle, and then test it by seeing how many iron filings it will lift. Try a needle again and compare the strength of this with that of the wire.

26. Discussion. We find that, although the soft iron wire is strongly attracted by the magnet, it does not carry away much magnetism when removed from the magnet. In the case of the steel, however, we find that this holds the magnetism very well, and that it will lift quite a load of the filings.

This power to retain the magnetism is called "retentivity," or "coercive force." From this we see the difference between iron and steel at once, and can understand how one might be better than the other for certain electrical purposes. The fact that soft iron loses most of its magnetism as soon as it is removed from the action of a magnet makes it suitable for many electrical machines in which it is absolutely necessary to have it act in this way.

EXPERIMENT 10. Hard steel and soft steel.

27. Directions. Take a needle that has been thoroughly magnetized, test its lifting-power with filings, then place it upon a piece of iron and hammer it several times to jar its molecules out of line. Testing it again, you will find that it has very little magnetism.

Now take an ordinary wire nail, which is made of what is called soft steel, try the same thing with this and you will find that you can hammer out part of the magnetism; that is, its retentivity is less than that of steel. Again, try the same thing with a piece of soft iron wire and you will find that the wire has almost no retentivity.

28. Discussion. It should now be clear that, when we want to make a permanent magnet, we should use good hard steel that has the proper retentivity, and that, for places where we do not want magnetism to last, we should use the softest of iron. There are times where it is necessary to use soft steel or cast iron in order to get a medium retentivity. The choice of iron for making motors and dynamos depends largely upon the amount of "carbon" in it, as it is this element—when combined with the iron—which determines the hardness of the steel.

EXPERIMENT 11. About residual magnetism.

29. Directions. When we magnetized the soft iron wire and then pounded it with a hammer, we found that it lost all of its magnetism, or practically all of it. Now try again, and, before you strike it with the hammer, see if the magnetized wire will lift a few iron filings; that is, does it really hold some of the magnetism after it has been taken from the magnet?

30. Discussion. Even soft iron will show some indications of magnetism when it is first taken from the magnet, and, even if it does lose the greater part of it when pounded, there is a slight tendency towards retentivity. This magnetism that iron holds is called "residual magnetism," and it is this magnetism that is made use of in the dynamo to start the production of electricity, as will be explained later. The principal thing for the student to remember now is that it is important, in the case of dynamos, for some magnetism to remain in the iron after the dynamo has been stopped. This is certainly one practical use of residual magnetism.

EXPERIMENT 12. About induced magnetism.

31. Directions. Place an unmagnetized sewing-needle upon a piece of stiff paper, then move your horseshoe magnet around under the paper. Test the needle for magnetism by seeing if it will lift any filings.

32. Discussion. We learned in Experiment 3 that magnetism will pass through paper, and so we expected that the needle would move around by the pulling-effect of the magnet. As the steel of the needle has considerable retentivity, it held the magnetism very well and was strong enough to lift almost as many filings as it did when it was magnetized directly upon the magnet.

We see from this that we can magnetize steel without even touching it directly with a magnet. This needle is said to have been "magnetized by induction"; that is, it was magnetized at a distance, without actual contact. This effect is brought into play in every electromagnet when it is energized by the electric current flowing through the coil of wire. If magnetism did not act through the air and at a distance, many of the effects that we now get would be impossible. Induction-coils, dynamos, motors, telegraph instruments and numberless other electrical machines depend upon this simple thing for their action and usefulness.

EXPERIMENT 13. About polarization and pole-pieces.

33. Directions. If you place a soft iron wire about an inch long upon one pole of your horseshoe magnet so that it will point away from the magnet, you will find that the end of the wire will lift filings, also. With your swinging needle test the end of the wire for poles, when placed upon the north and then upon the south pole of the magnet. Try the same thing with a piece of paper between the magnet and the wire, to see if you can lift filings.

34. Discussion. A piece of iron, when placed upon the pole of a magnet, becomes magnetized by induction, even if it does not touch the magnet at the end. The effect is the same as for the needle, when it was magnetized through the paper, and, as the wire could lift iron, we know that it had poles at the end. By means of the compass-needle we find that the pole at the lower end of the wire is the same as that of the magnet to which it is attached; that is, if the wire hangs upon the north pole of the magnet, the lower end of the wire will also be a north pole.

This wire is said to have been "polarized," and the pieces of iron which take up these poles by being in contact with a magnet are called "pole-pieces." As will be seen when we look more thoroughly into the construction of motors and dynamos, pole-pieces are used on most every machine of this kind to lead the lines of force where they are most needed.

EXPERIMENT 14. To study combinations of pole-pieces.

35. Directions. If you put two short lengths of soft iron wire upon the same pole of a magnet, as suggested in Fig. 1, you will find that both of the lower ends of the wires will lift filings and that they are of the same polarity. This will be evident, as they will repel each other if they are near enough to act.

If you now hammer the wires a little to remove the residual magnetism and then place them upon the opposite poles, as in Fig. 2, they will still be able to lift filings, but they will attract each other when near enough.

This might be expected from the information derived from Experiment 13.

36. Discussion. From the latter part of this experiment we see that the two movable poles tend to rush toward each other, and that there must be a pull upon the poles of the regular horseshoe magnet in their attempt to get nearer each other to shorten the distance the lines of force have to travel in getting from one pole to the other. This shows the necessity of having rigid pole-pieces on motors and dynamos so that they will keep the proper distance apart.

Fig. 1

Fig. 2

EXPERIMENT 15. To study the effect of a continuous pole-piece.

37. Directions. In place of the two wires used in Experiment 14, bend one piece as shown in Fig. 3, place the two ends upon the poles of the magnet, then test the curved part for magnetism to see if it will lift any filings.

38. Discussion. In this continuous pole-piece there was no tendency to lift iron, showing that there was no pole at the bend of the wire. If we consider the wire a small horseshoe magnet that is magnetized by induction, we can understand that its poles are at the ends and that it has no power to attract near its equator. (Exp. 1.)

If the wire be bent a little more, as in Fig. 4, a consequent pole will be made at the bend and we shall be able to lift small pieces of iron, as indicated.

In the case of motors and dynamos with two poles, we want the lines of force to pass in great quantities between the poles or pole-pieces, so we do not want the pole-pieces to touch each other. We shall see that the lines of force on their way from one pole to the other pass through certain coils of wire, and that this is necessary to produce motion in the motor or electricity in the dynamo. Whenever the poles are joined by a metal strip, as in the case of many small motors, this strip is made of brass and not of iron; for iron would sidetrack some of the lines of force, as did the bent wire of Fig. 3.

Fig. 3

Fig. 4

EXPERIMENT 16. To study the magnetic field of the horseshoe magnet.

39. Directions. Remove the armature of the horseshoe magnet, place the magnet upon a table, put a piece of stiff paper over it, then sprinkle some fine iron filings upon the paper. Tap the paper gently to assist the particles of filings as they try to swing around.

40. Discussion. If you have the proper filings, you will see that they arrange themselves in lines and curves about the poles of the magnet, and that they indicate roughly how far out the force of the magnet reaches.

If you place your compass-needle in various positions about the magnet, you will find that this is more delicate than the filings and that the "magnetic field" reaches out into space on all sides of the magnet. The picture made by the filings is called a "magnetic figure," and we shall use these to study the magnetic fields of the motors described in this book.

We see from this experiment that the little particles of filings become magnets, by induction, and that, when they are assisted by the tapping, they get into the same lines as those taken by the compass-needle when it is moved about in the field. The magnetism travels from one pole to the other in curved lines, and, for convenience, we agree that they start from the north pole of the magnet and pass through the air to the south pole. They seem strongest near the poles, and from the magnetic figures we see that there is quite a space about the ends of the magnet from which these lines pour in their wild rush to get to the south pole.

EXPERIMENT 17. Magnetic field with armature in place.

41. Directions. Lay the horseshoe magnet upon the table as before, but with its soft-iron armature in place upon the poles, then make its magnetic figure with the filings. Study the space near the poles and armature and note whether the lines of force are as strong as when the armature was removed.

42. Discussion. From this it is evident that the lines of force go through the iron armature instead of passing out through the air. Of course, many of them leak out of the sides of the poles and get past the armature; but the greater part of them take the easy path through iron instead of the path through the air, which offers a high resistance.

There were no well-marked curves directly over the armature, and this indicates that at this point the lines of force do not leak out into the air; on the contrary, they are only too glad to hide themselves in the iron as they swiftly pass around and around the circuit.

This experiment should now make it clear why there was no pull upon the armature when it was placed at the equator of the horseshoe magnet in Experiment 1. We do not get poles and a pulling-effect unless the lines of force come out into the air on their way from the north pole to the south pole. Wherever there is a leakage of lines of force we have poles.

EXPERIMENT 18. Lines of force and air-gaps.

43. Directions. Lay the horseshoe magnet upon the table, as before, place a couple of matches against its poles, and then put the armature so that it will press against the matches while trying to get to the poles. Make the magnetic figure of this arrangement and note especially what the filings do over the spaces occupied by the matches.

44. Discussion. Magnetic lines of force will go out of their way to get to a piece of iron on their way around the circuit between the poles if the distance to travel in the air is thus shortened. If we want to carry the magnetism across any space without losing very much in power, we can fill the space with soft iron, and if air-gaps have to be left, as in the case of the armatures of motors and dynamos, the air-gaps are made as small as practicable, thus making the resistance to the lines of force as small as possible.

EXPERIMENT 19. Hollow armatures.

45. Directions. Place the horseshoe magnet upon the table again, but this time lay an iron ring against the poles, as in Fig. 5. An ordinary iron washer will do for this experiment. Sprinkle iron filings upon the paper placed over this arrangement and note especially how the lines of force act over the hole in the ring. Do they seem prominent, or are they few and indistinct?

46. Discussion. The iron ring in this experiment acts very much like the regular armature, inasmuch as it seems to take most of the lines of force and to make an easy path for them. The field seems to be particularly weak over the hole in the ring, and this indicates that the lines of force bend around the hole to follow the iron, and so they do not leak out into the air to attract the filings.

We have, here, the same thing on a small scale as in the round armatures of dynamos and motors, which are

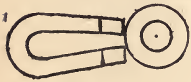

Fig. 5

Fig. 6

also made hollow. In large machines it is important to have the rapidly revolving armatures hollow to give them the required ventilation and to allow the proper wiring. Besides, on large machines, a solid armature would be too heavy.

EXPERIMENT 20. To study a certain combination of two magnets.

47. Directions. Place two horseshoe magnets upon the table with their like poles together, as indicated in Fig. 6, then make the magnetic figure of the combination as described before.

Note especially whether the lines of force pass across the space between the poles or whether the field seems weak there.

48. Discussion. It might seem to the student that the lines of force should pass around through the curved parts of the magnets and not rush across the air-space at the middle of the combination. But if you consider the fact that these lines are streaming out of both north poles in their endeavor to get to the south poles, you can see why they are only too willing to rush across the short air-gap to the desired pole.

Many of the larger motors and dynamos are somewhat similar in construction to the plan given in these two magnets. Diagrams will be given later to show the route of the lines of force in such combinations.

CHAPTER III

EXPERIMENTAL APPARATUS

EXPLAINING APPARATUS USED IN CONNECTION WITH MOTOR AND DYNAMO EXPERIMENTS.

49. Experimental Apparatus. While it is taken for granted that the student is familiar with all of the simple apparatus that is required for doing experiments with motors and dynamos, a short discussion of them will be given herein, however, as some of the pieces used by the author are of special design. In case the reader wishes to make his own apparatus for these and other experiments, he is referred to the author's book on "Electrical Handicraft." All of the apparatus needed for the experiments can be purchased in case the student does

Fig. 7

not wish to make it. (See list at the back of this book.) Do not get the idea from the numerous pieces described that all of them are needed. A variety is given so that the student can more easily find out what he wants for his special work.

50. Strap Key, Style A. Fig. 7 illustrates the use of a simple strap key, a dry battery being shown at the right and an electromagnet at the left. When the finger-piece of the key is depressed, the current can flow, because two of the metal parts are forced together, and, as

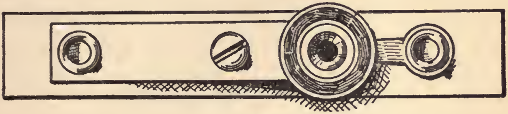

Fig. 8

soon as the pressure is removed, the spring of the strap separates the two parts and the circuit is broken again.

Fig. 8 is a top view of a very handy strap key, which is made of nickel-plated brass straps, with black finger-

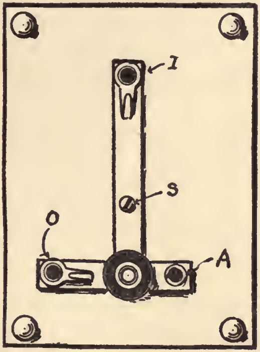

Fig. 9

piece, all being mounted upon a narrow, bright red base. The holes at the right and left are eyelet holes, the eyelets also being nickel-plated. The whole is to be screwed to the table or to the wall by wood screws that are to pass through the two holes, the wires from the battery or small dynamo being fastened under the heads of the screws. The screw-head shown at the center is the head of the adjusting-screw, which is used to adjust the height of the brass key-strap above the lower contact.

51. Strap Key, Style B. Fig. 9 shows a different form

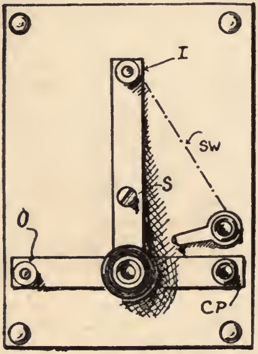

Fig. 10

of key (Apparatus No. 84 in "Electrical Handicraft") made with nickel-plated brass straps, black finger-piece, and spring binding-posts, all mounted upon a black base having red cleats at the bottom and nickel-plated corner nails. The current enters the key at I and leaves at O, when the key-strap is depressed. This has no side switch.

52. Strap Key, with Side Switch. In some experiments you want to send intermittent currents, and then, perhaps, you would like to have the current flow for some time without holding the key down. Fig. 10 shows a form of key with which this can be done. Wire SW connects the underside of the nickel-plated screw binding-post, I, with the underside of the pivot of the small switch-arm. Now, when the switch is turned so as to rest upon the contact-point, CP, current will pass out through O, even if the key does not touch the lower strap. This is the sort of key that is used in telegraph work, and it is a very handy form for many experiments.

53. Double-Key Current-Reverser. In Fig. 11 we have the top view of a current-reverser (Apparatus

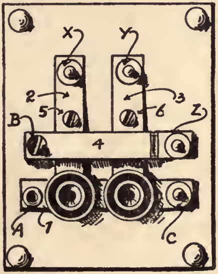

Fig. 11

No. 128 in "Electrical Handicraft"), which is suggested here as it is very useful in motor experiments, and because it is so constructed that it can be used in many ways. This reverser is made of nickel-plated brass straps, nickel-plated screw binding-posts, and black finger-pieces, all being mounted upon a dead-black base with bright red cleats. Both of the key-straps press up against the upper strap unless depressed to touch the lower strap marked 1. This little reverser is so made that it can be used also for a key, push-button, and two-point switch. It really consists of two or three pieces of apparatus, and is extremely handy.

54. How this reverser works. Fig. 12 shows how this piece of apparatus can be used to reverse the direction of the current in an electromagnet or other coil of wire. A dry cell is shown at the right of the figure, with wires leading from it to the two binding-posts C and Z of the reverser, C standing for the carbon and Z for the zinc of the cell. When the current comes from the carbon of the cell, it can go no farther than Strap 1, because the other straps are above it.

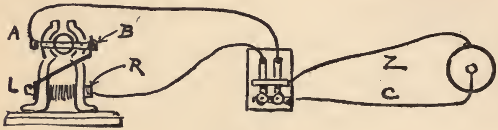

Fig. 12

If Key 2 be pressed far enough to strike the lower strap, the current will pass along Key 2, which does not now touch 4, and out through X to the coil and back to the reverser at Y. It will then pass from 3 to 4, and then back to the cell.

When Key 3 is pressed, the current, which still enters the reverser at C, will pass to 3 and out at Y. It is evident, then, that by this simple arrangement the current can be made to pass through the coil in either direction by pressing the proper key.

We shall see that with the aid of this reverser and with motors of the proper design, we can reverse motors and do various interesting experiments.

55. Two-Point Switch. Fig. 13 shows the full-size top view of a two-point switch (Apparatus No. 62 in "Electrical Handicraft") that can be used to advantage in some of the motor experiments. The five holes show the location of the nickel-plated eyelets, the switch-arm being at the middle. Dotted lines WA and WB represent wires under the bright-red base, and these connect the two eyelets at the ends with those upon which the switch-arm is turned. Connections are made by means of screws put into the two end eyelets and the middle

Fig. 13

one, the wires being held under the screw-heads when the switch is screwed to the table.

Fig. 14 shows one use for this switch, in which the current from a dry cell may be turned to either of two things as, for example, a bell or motor. This may also be used to switch the current from a small dynamo, the battery being replaced by the dynamo. In either case, the

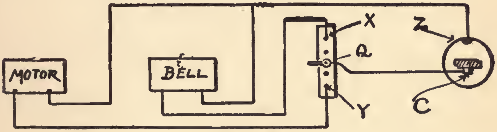

Fig. 14

current enters the switch at Q, from which it will pass to the desired instrument by turning the switch-arm to the proper contact-point.

56. **Rheostats** are adjustable resistances that are so arranged that different lengths of resistance-wire can be thrown into the circuit by merely turning a switch-arm to the desired point. Numerous kinds of rheostats are

made, but the ones herein described have been designed for students' use. With these rheostats we can regulate the speed of motors, vary the brilliancy of the electric lamps and do a number of things. Some of the small rheostats are so made that they so gradually increase or decrease the speed of a motor that there are no distinct changes or jumps. It is much more interesting to have the motor leap ahead a little as each contact-point is

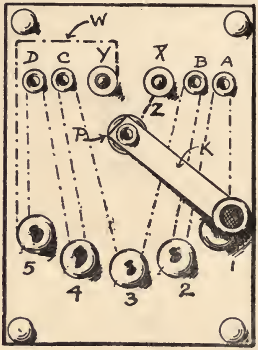

Fig. 15

reached than to have no such changes, and it is more fun to have the motor sing a different tune as each distinct speed is reached. This is the plan used on trolley-cars and in other commercial power-plants, and that is why this sort of rheostat is used in these experiments.

57. Five-Point Rheostat. Fig. 15 shows the top of a neat and useful five-point rheostat, the resistance-wires under the base being shown by dotted lines (Apparatus No. 124 in "Electrical Handicraft"). This instrument can be placed in the battery or small dynamo circuit by joining the wires to the nickel-plated screw binding-posts X and Y. If the current enters at X when the switch-arm is in the position shown in the figure, it will be obliged to pass through the entire length of the re-

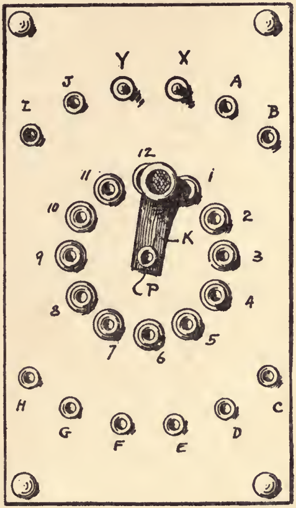

Fig. 16

sistance-wire and out through wire W before it can leave the instrument by way of binding-post Y.

If we now move K to the second nickel-plated contact-point 2, two parts of the resistance-wire will be cut out of the circuit, thus reducing the resistance. By moving K to contact-point 3, about one-half of the resistance will have been cut out, and when K rests upon contact-point 5, the current will pass from X to Y with almost no resistance. This is the general action of most rheostats, and we shall see how the two kinds described herein can be used in the experiments. They are mounted upon dead-black bases and have a fine appearance. The five-point rheostat is designed to regulate the current from two dry cells when they are used to run small motors, as, for example, the "St. J. Motor No. 1." When current is derived from small dynamos, the "Eleven-point Rheostat" should be used.

58. Eleven-Point Rheostat. Fig. 16. Although this rheostat is built in a way that is a little different from that used for the five-point rheostat just described, the general principle of the two is the same (Apparatus

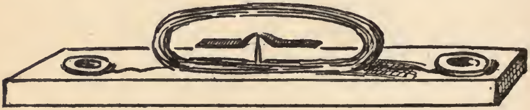

Fig. 17

No. 125 in "Electrical Handicraft"). The resistance of this instrument is quite a little more than that of the other, as it has been designed to work with three dry cells in connection with small motors and for experimental work with miniature incandescent lamps. In connection with small lighting-plants run on the current from small dynamos, this rheostat can be used to regulate the brilliancy of the lamps, and it is also useful in protecting lamps and other apparatus from too much current.

This instrument looks very well when mounted upon a switchboard, as the contact-points and other parts are nickel-plated.

59. Current Detectors. We shall see by the experiments upon this subject that an ordinary coil of wire acts like a magnet when a current of electricity passes through it, and that the electromagnetism produced by the coil acts upon the pivoted needle-magnet and causes it to move. We really have two magnets acting upon each other, when the current is turned on. Uses for these detectors will be given under the proper experiments.

60. Simple Current Detector. Fig. 17 shows a form of current detector that will do for many experiments, and it is very inexpensive. The coil is mounted upon a

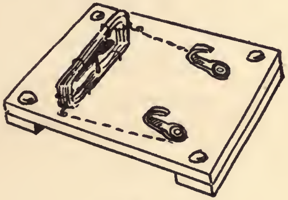

Fig. 18

narrow base, the ends of the wire being fastened to eyelets which also act as binding-posts. Screws are used to fasten the detector to the table, the circuit-wires being held under the heads of the screws. The needle is made of narrow spring steel and is pivoted at the center, as shown.

61. Handy Current Detector. Fig. 18 shows a handy form of detector that has the coil and nickel-plated spring binding-posts mounted upon a black base (Apparatus No. 22 in "Electrical Handicraft"). This can be set anywhere, as it does not have to be screwed to the table. (For the construction of galvanoscopes and delicate detectors see Chap. 3 in "Electrical Handicraft.")

CHAPTER IV

ELECTROMAGNETISM

TEN EXPERIMENTS ON ELECTROMAGNETISM THAT AID IN UNDERSTANDING THE CONSTRUCTION AND OPERATION OF MOTORS AND DYNAMOS.

62. Electromagnetism is the name given to magnetism that is produced by electricity. In Experiment 16, we saw that a magnetic needle was affected, when placed in the field of a permanent magnet, and that its north pole always pointed in the direction in which the lines of force pass on their way from the north to the south pole of the magnet. We must now try some experiments that will show how magnetism and electricity work together in motors and dynamos.

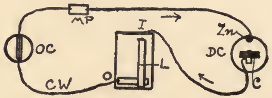

Fig. 19

EXPERIMENT 21. Electric current and magnetic needle.

63. Directions. If you make up a circuit similar to that shown in Fig. 19 consisting of a battery DC, a key, and one of the current detectors OC, just described, you will find that the needle of the detector will swing rapidly each time you close the circuit at the key, and that it will go back to its original position as soon as you open the circuit again. The needle, of course, should be directly under the coil when it is at rest; that is, the coil should be placed in a north and south line.

64. Discussion. From this we see that the coil of the detector becomes a small electromagnet the instant the current passes through it and that, best of all, it loses its magnetism as soon as the circuit is opened. We have here the two magnetic fields acting upon each other like the two fields of two permanent magnets.

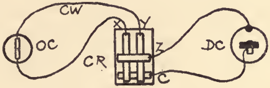

Fig. 20

EXPERIMENT 22. Reversing the current in the detector.

65. Directions. If we now put a current-reverser in the circuit in place of the key, as suggested in Fig. 20, we shall find that the needle will turn in a direction depending upon the particular lever that is pressed.

66. Discussion. We have, then, in this simple coil of wire on the detector, a plan by which we can tell the direction of the current. If the current passes through the coil in one direction, magnetism is built up in it in just the opposite way from that in which it is built when the current flows in the opposite direction.

EXPERIMENT 23. Magnetism from hollow coils of wire.

67. Directions. Fig. 21. If you arrange a battery, reverser, and a hollow coil of wire as shown, you will be able to reverse the current in the coil at will, and if this coil be placed in an east and west line, with your compass-needle a short distance away, you can study the change of magnetism in the coil as it reverses. See how far from the coil the needle will be affected.

68. Discussion. Here we have merely a coil of copper wire without any iron, and still we get poles with attractions and repulsions for the compass-needle every time the current passes. It is this property that coils of wire have that makes them so valuable in all electrical apparatus.

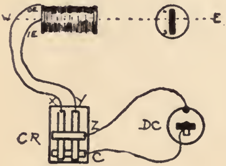

Fig. 21

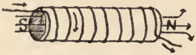

Fig. 22

EXPERIMENT 24. About coils of wire with cores.

69. Directions. Slip an iron core through the hollow coil used in the last experiment and see whether the action upon the compass-needle is more or less than before.

70. Discussion. When we place an iron core through a coil of wire, we get what is commonly called an electromagnet, and we find that the core adds greatly to the strength of the magnet.

We have already seen that air does not readily conduct the lines of force, and so we may expect that when the lines of force have to push their way through long air-spaces, the strength of the magnet is lessened. Soft iron is a splendid conductor of these lines of force, so when the core is in place the "magnetic flux," as these lines are also called, can rush through the core on their way from the south to the north pole of the electromagnet. This reduces the air-trip about one-half and thus greatly increases the strength of the electromagnet.

EXPERIMENT 25. Polarity of coils.

71. Directions. If we notice the direction of the current as it passes around the coil to see whether it goes in the same direction as that taken by the hands of a clock or in the opposite direction, we shall find that a

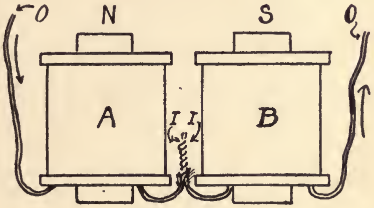

Fig. 23

certain direction of current always produces a certain pole. If you take the trouble to follow this up, as suggested in Fig. 22, you will find that when the current passes in a right-handed manner, as in the figure, the left-hand end of the coil will be a south pole. If you face the right-hand end of the coil, the current is seen (see direction of the arrows) to pass around it in an anti-clockwise direction, and this produces a north pole.

We shall want to know what pole we are expected to find when we experiment with the electromagnets on motors, so the student should fix this rule thoroughly in his mind.

EXPERIMENT 26. About horseshoe electromagnets.

72. Directions. If you have a pair of electromagnets already wound and joined, test the poles with a compass-needle to see if one pole is north and the other south. Also note the way in which the current enters each of the magnets.

73. Discussion. Fig. 23 shows a side view of two electromagnets with the wires properly joined to get the best results; that is, they are so wound that one will be north and the other south when the current passes, as shown by the arrow. (See "Electrical Handicraft" for full details for making different kinds of electromagnets.)

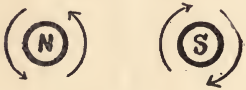

Fig. 24

If you notice the way the coils are wound, and also the way the current enters the coils, you will find that when looking down upon them, as in Fig. 24, a north pole is produced when the current flows through the wire in an anti-clockwise direction, and that the pole will be south when it flows in a clockwise direction. This was mentioned in one of the previous experiments.

EXPERIMENT 27. Regarding the joining of electromagnets.

74. Directions. If you have an experimental electromagnet of the right design, you can try the strength of the two when arranged as suggested in Fig. 23, and then again with a piece of iron joined to the lower ends of the cores, as shown in Fig. 25. Why is there such a difference in the strength?

75. Discussion. The strips of iron shown in Fig. 25 are held firmly between the base and the ends of the cores, thus making a good contact. You have seen that lines of force find it much easier to travel through iron than through the air, so this iron, called a "yoke," makes a complete path for the magnetic flux as it passes from the south pole to the north pole. At this point the lines of force pass out into the air on all sides of the magnet and find their way to the south pole near by, making the

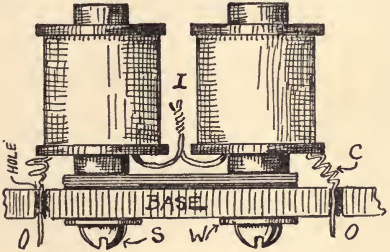

Fig. 25

field of force very strong between the poles. If it were not for the yoke, the combination would be much weaker. This fact is considered in the construction of motors and dynamos, as we shall soon see. The yokes should be made of soft iron, and for students' use the author prefers yokes that are made up of a number of strips. Fig. 25 shows a useful size for experimental magnets, full size, and these are shown mounted in Fig. 26 (Apparatus No. 115 in "Electrical Handicraft"). A careful study of ordinary electromagnets will aid you in seeing how things work when you take up the motors. Fig. 27 shows a larger pair of mounted magnets arranged especially for experimental work (Apparatus No. 116 in "Electrical Handicraft").

EXPERIMENT 28. Magnetic figure of electromagnets.

76. Directions. If you have a pair of electromagnets like those shown and discussed in the last experiment, arrange a sheet of glass over the poles by laying it upon books; then sprinkle iron filings upon the glass and tap it, as previously explained.

77. Discussion. You will find that there is a much stronger field between the poles of this magnet than you

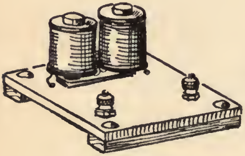

Fig. 26

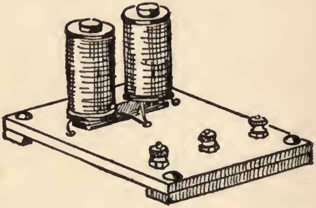

Fig. 27

had in the case of the permanent horseshoe magnet, provided you have any kind of a current, and that you have perfect control of this field by the use of a key placed anywhere in the circuit. Notice how you can make the field disappear when you open the circuit, and how the lines of force appear the instant you close the circuit.

EXPERIMENT 29. Magnetic figure of single electromagnet.

78. Directions. If you will arrange your apparatus as suggested in Fig. 28, which includes a battery, or dynamo, to give the current, a key and a single magnet placed on its side, you will be able to make an interesting magnetic figure.

79. Discussion. This shows us that the field is strong at the poles of the electromagnet and that, without pole-pieces or other additional parts, we get a figure much like that produced by a straight bar magnet. If you compare this figure with that of the pair of electromagnets, you will see what part the yoke plays in saving the resistance to the lines of force.

EXPERIMENT 30. Magnetic figure of two like poles.

80. Directions. If you have a pair of mounted electromagnets so arranged that you can change the wiring

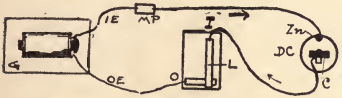

Fig. 28

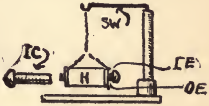

Fig. 29

(Fig. 27), it will pay you to join them up so that the current will pass around them in the same direction; that is, so that they will both be north or south poles. Do this, then make the magnetic figure of this combination and see whether the field is strong or weak between the poles.

81. Discussion. When the two poles are the same, the lines of force repel each other, thus weakening the attraction for outside pieces of iron. This arrangement is not adapted for use in motors and dynamos, as there we want as strong a field as is possible. The stronger the field between the poles on a motor, the stronger the attractions and repulsions of the armature-magnets for the poles.

CHAPTER V

MOTION AND CURRENTS

EIGHT EXPERIMENTS SHOWING HOW MOTION CAN BE PRODUCED BY ELECTRIC CURRENTS.

EXPERIMENT 31. Motion produced with a hollow coil of wire and a piece of soft iron.

82. Directions. Arrange a hollow coil of wire, as shown in Fig. 21, then suspend a short length of soft iron wire by means of a piece of thread directly in front of the opening. Close the circuit for an instant and see what happens to the wire.

83. Discussion. We have here what might be called a sucking effect, for the iron wire will be drawn into the coil instantly. We have a polarizing effect upon the iron wire as soon as the current flows; then, as soon as the wire gets poles, it becomes a magnet and is attracted strongly by the electromagnetism of the coil. Even by this simple arrangement we can produce motion.

EXPERIMENT 32. Motion produced with a hollow coil of wire and a bar magnet.

84. Directions. In place of the iron wire of the last experiment, use a magnetized sewing-needle and see the effect when the poles are brought near the hole in the coil. Try both poles.

85. Discussion. We have a stronger effect than in the case of the iron wire, because the magnetic field of the small permanent magnet is stronger than that of the wire, which was magnetized by induction, and which, as has been explained, has but little retentivity. The fact that one end of the needle is attracted and the other repelled by the coil, shows that the coil has a particular pole at the end used.

EXPERIMENT 33. Motion produced with an electromagnet and a piece of iron.

86. Directions. Fig. 29 suggests a method of supporting your electromagnet H, the wires IE and OE being connected to a key and battery. IC represents a

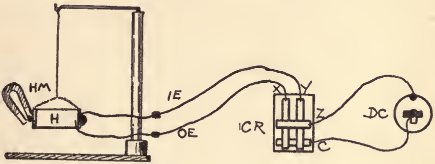

Fig. 30

piece of iron, which should be held a short distance from H. Try the effect of turning the current on and off at the key.

EXPERIMENT 34. Motion produced with an electromagnet and a bar magnet.

87. Directions. In place of the piece of iron used in the last experiment, try a good permanent magnet. See if you can show both attractions and repulsions.

EXPERIMENT 35. Motion produced with an electromagnet and a horseshoe magnet.

88. Directions. Fig. 30 shows an arrangement by which, with the reverser, and the other parts, you can get some interesting results. Try reversing the current in the coil until you get the best results.

89. Discussion. We have, in this experiment, both attractions and repulsions in rapid succession, and this shows what takes place in the motor. The attractions and repulsions follow each other very rapidly in the revolving armatures, but of course the motion is always in one direction instead of in opposite directions, as in the experiment.

EXPERIMENT 36. Motion produced with two electromagnets.

90. Directions. In Fig. 31 we have two electromagnets, one of them being supported in such a manner that it will swing easily. The current that comes from the

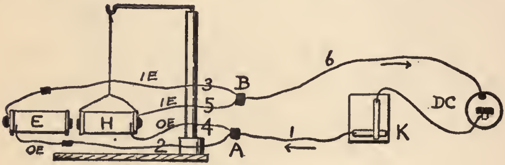

Fig. 31

battery branches at A and B, so as to magnetize both coils at the same time. Try this in different ways, with the poles of E and H alike and unlike, holding E in the hand.

91. Discussion. In the case of the two electromagnets, we have the main parts of an electric motor or dynamo. We see from this that we can get an attraction or a repulsion at will, depending upon the poles that are near each other, and this is exactly what happens in the motor. The only thing lacking here is some plan by which we can automatically turn the current on and off.

EXPERIMENT 37. Rotary motion produced with a hollow coil and a permanent magnet.

92. Directions. If you will now refer to Fig. 21 again, you will find that by this plan you can get rotary motion in the magnetic needle by properly turning on and off the current at the reverser.

93. Discussion. In all of the other experiments in this chapter we produced motion, but in this we really have a rotary motion, and it is this that we want in the regular motor.

EXPERIMENT 38. Rotary motion produced with a permanent magnet and an electromagnet.

94. Directions. If we arrange our apparatus as suggested in Fig. 32, a small nail wound with insulated wire will do for the electromagnet, and have a key, battery

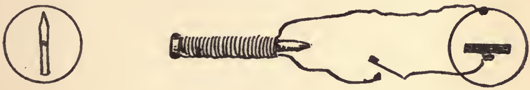

Fig. 32

and a compass-needle, we can get rotary motion and regulate it pretty well by turning on the current at the right time.

95. Discussion. We might say that we have in this apparatus a very small motor, but it still lacks the one important feature of being able to regulate its own current.

CHAPTER VI

ELECTRIC MOTORS IN GENERAL

96. Simple Action of Motors. We have seen, in the numerous experiments that have been suggested, that motion can be produced in many ways by the attractions and repulsions of magnets—no matter whether they be permanent magnets or electromagnets. As electromagnets can be made much stronger than permanent magnets, their magnetism being under perfect control, it is evident that to get the best results, we need a current of electricity to energize the coils of wire. In this way we can get powerful magnets, and with the aid of pole-pieces we can lead the magnetism to just the proper point. Then, by a plan to regulate the poles, we can get either attractions or repulsions to produce a constant rotary motion.

Now that we have mentioned the broad principle upon which motors work, let us take up the parts of a simple motor in detail to learn just how they do work.

97. The Field-Magnets on all ordinary motors do not move, as they are generally a part of the base of the machine. There are many forms in which these field-magnets are made, depending upon the design of the machine, and still they are very similar to each other after all. When we speak of field-magnets, we really mean the whole thing, including the cores, the coils and the pole-pieces.

When a current passes through the coils of the field-magnets, these become strong electromagnets and they either attract or repel the electromagnets produced in the armature by the same current or by a part of the same supplied current. Figs. 33, 34 and 35 show three shapes of field-magnets that are commonly used on small motors, and although the second looks different from the first, it is really the same as the first, but tipped upon its side.

In Fig. 35, however, we have a different form, in which the lines of force have two paths to travel on their way from the south pole through the two yokes Y to the north pole. This form of field is like that discussed in Experiment 20, in which two horseshoe magnets were

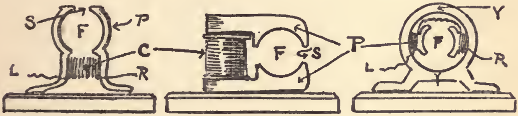

Fig. 33 Fig. 34 Fig. 35

used, and it is a common form for the field-magnets of large motors and dynamos, several coils and pole-pieces being used.

In the three illustrations the lettering has been made the same, for convenience, in which C stands for the coil of wire, P for the pole-pieces, R and L for the ends of the coils, F for the field (where the lines of force pass through the armature when it is in place), S for the space between the ends of the poles, and Y for the yokes. In these drawings all parts are omitted for clearness, except the field-magnets.

98. Armatures are made in many ways with as many kinds of windings, but the general principle is the same; that is, coils of wire magnetize the cores, and in this way we get electromagnets that attract and repel the field-magnets. The coils of wire must be well insulated from the iron of the armature, and the connections must be made in the proper way to give the desired poles. We shall take up one or two special forms of armatures when we discuss the special motors.

99. Commutators are devices for changing the direction of the current in the armature-coils as they revolve, so that the desired poles will be made. These consist of bars of copper, called commutator bars, which are insulated from each other and from the shaft of the machine, but so fastened that they will turn with the shaft. The ends of the armature-coils are joined to the commutator bars in such a manner as to allow the current to enter a coil from one bar and leave it by way of one of the other bars. If the armature did not revolve, it would be an easy matter to get the current in and out of the coils, but, as we must have a constant rotary motion, this device is necessary.

100. The Brushes lead the current to the commutator bars and thus to the coils. The brushes are stationary and gently press upon the commutator as it revolves with the shaft. Most small machines have but two brushes, which feed all of the commutator bars as they revolve, current entering the motor through one brush and leaving by the other. The brushes should make a firm contact with the commutator, but they should not press too hard upon it, as this would retard the motion of small motors on account of too much friction.

101. Methods of Winding. As we shall see in some of the experiments that follow, there are two principal ways in which small motors are wound, and these are called the "series" and the "shunt" windings. Most of the smaller motors are wound by the series method, but some of those that are a little larger are shunt-wound. The smaller motors that are described in this book are so designed that they can be used either series-wound or shunt-wound, and this is a great advantage to the student when it comes to really understanding how things work; in fact, these motors have been arranged in this way by the author for the special use of students. (See experiments for discussions of these two methods.)

102. Reversing Motors. It would seem, upon first thought, that if we reverse the current entering a small motor, the motor should reverse at once. This is not the case, however, as we shall see when we take up one of the small motors in detail. This is just the trouble with all of the ordinary small motors—for they are not designed so that they can be reversed—and when we reverse the current we change all of the poles in both the armature and field-magnets, and so we have the same effects of attractions and repulsions as before. Wherever we have an attraction with the current flowing in one direction, we again get an attraction with the current reversed, and this makes a constant rotation in the one direction.

To get the motors to reverse, we must have them so constructed that we can reverse the current in the field, for example, without reversing it in the armature. This requires some form of reverser, of course, so connected with the motor that all of this can be done. When we reverse the current in one part and not in the other, we get a repulsion where we previously had an attraction, and in this way the motor has to turn in the opposite direction. (See experiments with Motor No. 1.)

103. Coils in "Series." If we have two coils of wire arranged as indicated in Fig. 37 so that the current which passes through one of them has to also go on through the other before it can return to the battery, we say that these coils are in series. When two or more coils are arranged in series, the resistance of all of them taken together is equal to the sum of their separate resistances, for the same current has to go through all of them, one after the other.

104. Coils in "Shunt." In Fig. 38 we have two coils so arranged that the current coming from any source branches into two different parts at C, one part return-

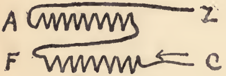

Fig. 37

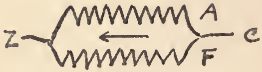

Fig. 38

ing to Z through coil F, and the other part through coil A. We say that these two coils are in "parallel," or that one of them is a "shunt" of the other. A shunt is, really, a branch, and when a wire branches into two or more parts, each branch gets a part of the current and the resistance of all of the branches together is less than that of any of the branches alone. When the branches are all carrying current, the electricity has more than one path, or, in other words, there is more copper to carry it.

CHAPTER VII

PRACTICAL EXPERIMENTS WITH MOTORS

105. Small Motors. There are many good motors upon the market, but space will not permit of a description of all of them, and as the general principles are the same in all of them, so many details will not be necessary. In the experiments which follow, the author has chosen small motors that seem to him to be best adapted to the use of students, some of the motors being those already upon the market, and some being of special design to make them more useful to the student; for it is not enough to have a motor that will simply go around, when it comes to experimental work.

All of the motors described herein are made of the best materials by skilled workmen, thus giving us something upon which we can depend, and where special designs have been given, we have something that will do all that ordinary motors will do, and more besides.

As the motors used for these experiments differ somewhat in shape and construction, and as we shall have to refer to them frequently, it has been thought best to give them numbers and to refer to them by these numbers. Some of the motors can be used as dynamos, and this is a great advantage for the student; for he then really has two machines in one. (See Chap. 9.)

106. Motor No. 1. This motor (Fig. 39) is designed for students and others who want a small motor for experimental purposes, as well as for all of the regular work that any small motor can do. After considerable experimenting, the author decided that this would be the best form and construction for an all-around small motor, and he believes that it can be used in more ways than any other motor of equal cost. It is an efficient motor for its size, and it gives a very good idea of the general construction and action of large motors. One of the special features of this motor is that it is so designed that it can be used on a circuit with a current-reverser, rheostat, etc., thus making it possible to regulate the direction of rotation and, besides, to control the speed while running in either direction.

This change of direction and regulation of speed is of the greatest value when you want to run small toys and various mechanical effects. The four nickel-plated binding-posts are mounted upon the framework of the motor, and not upon the wooden base, as is usually the case, so that the motor itself can be removed from the base and used in different ways, remounting it upon toys, etc. In this way it will still retain the ability to reverse.

As it has a three-pole armature, it will start promptly as soon as the current is turned on. The armature-shaft carries a pulley, and it is so arranged that a fan can be put on without removing the pulley. One cell of battery will run this motor at high speed, but it will be found best, especially where you want to run toys or the fan, to arrange the batteries according to the requirements, thus reducing the strain on the cells and increasing their life considerably. (See Chap. 10.)

Motor No. 1 stands three and one-half inches high. It is finished in black enamel with nickel-plated trimmings, and it is well made and strong. With it are furnished one long and two short nickel-plated brass connecting-straps, with which various connections can be conveniently made for the experiments.

107. Taking Motor No. 1 Apart. In order to make a study of this motor, all that is necessary is to remove the armature; and to do this simply take out the two small screws that hold the strap-bearing at the pulley-end of the shaft, this being called the back bearing-strap. Carefully pull the armature out and put the screws back in place so as not to lose them. In replacing the armature,

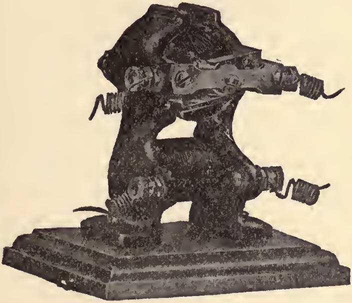

Fig. 39

be very careful not to bend the brushes and to so center the armature when putting in the screws that it will turn freely. This must be done with care or the armature can not revolve as it should, and it may even hit upon the field-magnets as it turns.

EXPERIMENT 39. To test for poles of the field-magnets.

108. Directions. Following the directions in paragraph 107, remove the armature of Motor No. 1 and arrange it in circuit with a reverser and a dry battery, as in Fig. 40, being careful to have your connections as shown. As previously explained, the current coming from the carbon of the cell cannot get beyond the reverser until one of the keys is pressed.

Hold a compass-needle near one of the pole-pieces and then near the other as you press the left-hand key of the reverser for a moment, and note which pole-piece attracts the north pole of the compass-needle. When you have decided which pole-piece is a north pole, repeat the experiment and press the right-hand key of the reverser.

109. Discussion. The student should note that when the current enters the left-hand binding-post it passes through the coil in a clockwise direction as you face the left-hand end of the coil, and in an anti-clockwise direc-

Fig. 40

tion when you reverse it. From the results a comparison should be made with Experiment 25. We have here a good example of pole-pieces, which lead the lines of force up from the ends of the coil to a place where they can stream through the armature-core when it is in place.

EXPERIMENT 40. To test for residual magnetism in the pole-pieces.

110. Directions. Having performed Experiment 39, test the poles for magnetism without passing any current through the coil.

111. Discussion. The iron used in the construction of motors and dynamos holds some of the magnetism after the current ceases to flow, as is shown by this experiment; in fact, if this were not the case, the dynamo could not start to generate a current as soon as it is revolved. This will be taken up more fully in "The Study of Dynamos by Experiment."

EXPERIMENT 41. To test the lifting-power of the field-magnets.

112. Directions. With the armature removed, as in the above experiments, and as shown in Fig. 41, see if you can lift the armature when you press one of the keys of the reverser. Try other pieces of iron, letting the current pass for a moment only, so as not to overwork the cell.

EXPERIMENT 42. To test the lifting-power of the field-magnets when the armature is in place.

113. Directions. Slip the armature back into place without screwing on the bearing, and again test the lifting power, comparing it with the results of Experiment 41.

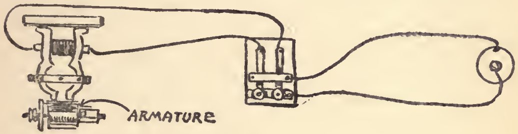

Fig. 41

114. Discussion. It is evident that when the armature is in place the lifting-power is small, and from the previous discussions, we come to the conclusion that there are not so many lines of force leaking into the air now as there were when the armature was out of the field. Let us study this more fully in the next experiment.

EXPERIMENT 43. To study the magnetic field of the field-magnets with the armature in place.

115. Directions. Arrange your apparatus as shown in Fig. 42, holding the base of the motor in a small vise. In this way the pole-pieces can be used to hold a piece of cardboard in a horizontal position, and all can be held firmly if the two little screws that usually fasten the bearing-strap be put through small holes in the cardboard and screwed into place. A small slit will be necessary to allow the cardboard to be pushed beyond the shaft between the pulley and the nickel-plated bearing-strap. A small piece of paper can be pasted over the slot when the cardboard is in place, to keep the filings from falling through, and the bearing-strap may be turned out of the way. Make the magnetic figure of the field with iron filings, tapping the cardboard as previously explained.

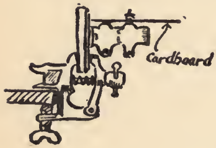

Fig. 42

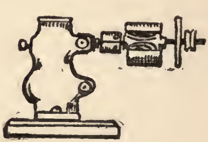

Fig. 43

EXPERIMENT 44. To test the magnetic field of the field-magnets with the armature removed.

116. Directions. Arrange as for the last experiment, but with the armature removed, and again make the magnetic figure with filings.

117. Discussion. From the last two experiments it is evident that the magnetic field of a pair of field-magnets like that on Motor No. 1 is more evident when the armature is removed, because the lines of force pass through the iron of the armature more easily than through the air; and, when the armature is there, the lines of force merely have to jump across the small air-gaps.

When the armature stands still, the lines of force pass nearly straight through the iron core, following the easiest path. When the armature is revolving and the motor is running regularly, these lines of force are slightly changed in their course, but this need not be taken into account in these small motors.

The chief thing to keep in mind is that the thousands of lines of force are threading through the armature and its coils when they revolve, and that if this were not the case the motor would not revolve and the dynamo would not generate a current.

EXPERIMENT 45. Making permanent magnets with the motor.

118. Directions. With the field-magnets you can make small permanent magnets out of pieces of steel, needles, etc., if you allow the current to pass through the coil, the armature being removed.

Various other experiments can be done with these electromagnets, but some sort of a key should be in the circuit so that the current can be regulated, leaving it on but for a moment each time to save the battery.

EXPERIMENT 46. To test the armature for magnetism.

119. Directions. Remove the armature of Motor No. 1 and slip the pulley-end of the shaft into the hole in the front bearing-strap, as shown in Fig. 43. With books or blocks build up a little platform under the core of the armature so that you can place nails or other small pieces of iron near the core. Hold one of the wires from a battery upon one of the commutator bars, and with the other hand touch the remaining wire to the other two bars in succession to see if the electromagnets of the armature can lift iron.

120. Discussion. From this it is evident that the electromagnets produced by a current passing through the armature-coils are quite strong, and that they are capable of creating a decided pull upon pieces of iron. It must also be evident that if the field-magnets are properly magnetized, the pull will be still greater.

EXPERIMENT 47. To test the armature-magnets for poles.

121. Directions. Arrange your apparatus as directed for the above experiment, but instead of trying to lift iron when the current is turned on, make the little platform tall enough to hold your compass-needle near the poles.

Part 1. Place the armature, as shown in Fig. 44, which gives merely the end view, so that the pole con-

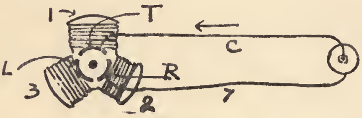

Fig. 44

taining the small screw will be on top. This should be done for convenience, as the screw will act as a guide and enable you to keep the facts clear. In this a battery is shown to the right, the wire from the zinc being marked Z and that from the carbon C. The current coming from the cell by way of wire C, called the positive wire, will enter the commutator bar at the top, marked T, and return to the cell through the right bar, marked R. Test each pole of the armature, following the current in your mind, and see if the law given in Experiment 25 holds true, remembering that the current does not pass around all of the cores in a clockwise direction. Make a diagram and mark your results.

Part 2. Turn the armature to the right through one-third of a revolution, which will bring pole 1 over to the former position of pole 2, and so on around. Test again, still touching wire C to the top bar, and note that changes have been made in two of the poles, although the relative positions of the north and south poles have remained the same.

Part 3. Repeat Part 2, again turning the armature one-third of a revolution. Do the same relative positions remain?

Part 4. Repeat the above, reversing the current; that is, let the wire from Z touch the top bar, and that from C the right bar. Make a diagram of the new poles and compare the results with those above.

122. Discussion. If the student will take the trouble to do the above experiment carefully and fix the results in his mind, he will have no chance to forget the general principles upon which the current reverses each half revolution through the coils of the little armature of Motor No. 1. As the current is supposed to pass through the motor in one direction, when it is running under ordinary conditions, it must be clear that while the pole-pieces of the field-magnets have constant polarity, the three poles of the armature are rapidly changing.

CHAPTER VIII

SPEED REGULATION AND DIRECTION OF ROTATION

EXPERIMENT 48. Direction of rotation.

123. Directions. Part 1. Assemble the motor again, being careful not to bend the brushes and to have the armature run easily without hitting the field-magnets. This is important, and it is best to put a small drop of machine oil on each bearing, placing it with a toothpick or a match. With the apparatus arranged as in Fig. 40, but without connecting the field-coils to those of the armature, press the right-hand key of the reverser to

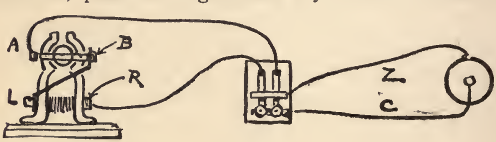

Fig. 45

allow the current to enter the coil at the right end; that is, allow the current to pass through the coil in a clockwise direction as you look at it from the right. Test the pole again and satisfy yourself with the compass-needle that the right-hand pole is south. You may even omit the reverser and touch the wire from the carbon to the right-hand binding-post of the field, with the wire from the zinc to the other post on the field.

Part 2. With the long connecting-strap join the left-hand post of the field across to the right-hand post of the armature, as shown in Fig. 45, but before you turn on the current, try to figure out which way the motor should run if the wire from the carbon (the positive wire) should let the current in at R, from which it would go through the field-coil to L, across to B, thence through the armature-coils to A and back to the battery. When you have decided, see if you were right by trying with the current.

124. Discussion. Keeping in mind the fact that the right-hand pole-piece of the field should be south, and that as the current enters the top commutator bar, as in Experiment 47, Part 1, making the top pole-piece of the armature also south, there will be a repulsion between these two parts, and the motor will turn forwards; that is, away from the brushes, giving it an anti-clockwise direction when you face the armature.

We have already mentioned the fact that the motor will run in the same direction as before if we reverse the current in the whole motor, as we shall do if we simply change the wires leading from the battery. The reason should now be clear, for in this case the right pole of the field will be north, and so will the top pole-piece of the armature. The poles being the same, that is, north, we get a repulsion as before. The previous experiments showed that the poles are reversed when the current reverses.

125. Attractions and Repulsions in Motor No. 1. We have just shown that, with certain connections, we have a south pole at the right of the motor and also a south pole at the top of the armature, thus causing a repulsion. The student must not get the idea from this that we have only repulsions. We arrived at the conclusions about the repulsion by considering, for convenience, but one pole of the armature. In Experiment 47 we found that the two side poles of the armature were north when the top pole was south, and so we have quite a number of attractions and repulsions.

As will be seen by referring to Fig. 46, the top pole of the armature is repelled by the right field-pole, and it is at the same time attracted by the left field-pole. Again, the left and right poles of the armature are repelled by the left pole of the field, and both are attracted by the right field-pole. With the numerous attractions and repulsions, we get a steady pull and push in the same direction.

Now, of course, if the poles of the armature remained the same during the entire revolution, the armature would soon find a position in which its poles would have the

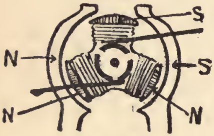

Fig. 46

Fig. 47

greatest attraction for the poles of the field, and there it would remain. Here is where the commutator does its work, by reversing the current as the brushes change to other commutator bars, thus keeping up the motion. If you look carefully at the commutator-end of the armature, you will see that this change is made just as the right pole of the armature reaches the middle point of the south field-piece. This instantly changes the attraction to a repulsion. If you slowly turn the armature and watch for this, you will see that all of the changes are made at this point, for the lower brush then slides from the right commutator bar to the left one. The above applies, of course, when the experiment is performed as described above.

EXPERIMENT 49. Backward motion for Motor No. 1.

126. Directions. Put on one of the short connecting-straps, CS, so that it will join binding-posts R and B, as shown in Fig. 47, then connect the positive wire, from a battery to L and the negative wire to A. The current will now pass through the field in the opposite and through the armature in the same direction as in the last experiment; that is, we have reversed the current in the field without reversing it in the armature, and this makes the motor revolve in a clockwise direction.

127. Discussion. This plan of reversing the motor is

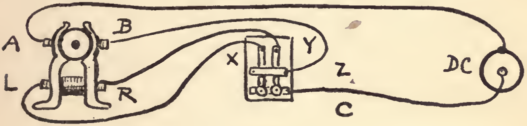

Fig. 48

rather unhandy, as it is not convenient to change the wiring every time we want to reverse the motor; so we make use of the current-reverser to do this for us, as directed below.

EXPERIMENT 50. Reversing Motor No. 1 with the current-reverser.

128. Directions. Arrange the motor, a battery and a current-reverser, as shown in Fig. 48. Press the right-hand key first and see if the motor turns in the same direction as in Experiment 48; that is, anti-clockwise. Follow the current in your mind to make sure that this is correct, then press the left-hand key for a moment to see if the motor reverses.

129. Discussion. We have, in this case, a method of easily accomplishing the results shown in the previous experiment, and this explains the general method used, even in large motors. The main point to be remembered is, that in reversing the motor we have to reverse the current in either the field or the armature without reversing it in the other.

EXPERIMENT 51. Reversing Motor No. 1 by a second method.

130. Directions. Arrange the wiring as shown in Fig. 49, in which the reversing will take place in the armature-coils, connecting the field-coil up as you did the

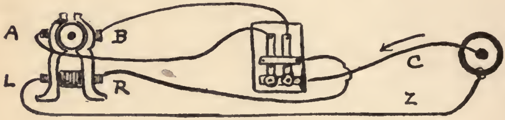

Fig. 49

armature in the previous experiment. See if you still get the same reversing as before.

131. Discussion. We see from this that the motor reverses by this plan as well as by the other. Now that we have succeeded in changing the direction of rotation of this little motor, let us see how we can regulate its speed.

EXPERIMENT 52. Regulation of speed for Motor No. 1, coils in series.

132. Directions. Arrange the motor, rheostat and batteries, as shown in Fig. 50, then try the speed at various points on the rheostat.

133. Discussion. In this case, we see that the current goes through the rheostat, the field-coil, the connecting-strap, and then through the armature-coils and back to the batteries. There are no branches here to divide the current, so we say that we have a series-wound motor. In this experiment we can use the five-point rheostat, as shown with two batteries, or the eleven-point rheostat with three batteries. These instruments are described in Chapter 3.

EXPERIMENT 53. Controlling speed and direction of rotation of Motor No. 1, series-wound.

134. Directions. Fig. 51 shows how to connect the reverser with the other things used in the last experiment. Be sure that you get the connections right and

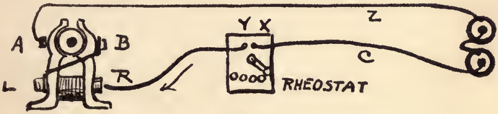

Fig. 50

then try to vary the speed with the rheostat and the direction of rotation with the reverser. (See Sec. 137 on Series-wound Motors.)

135. Discussion. It will be seen here that the coils are still in series, even if the reverser be used, and that we can change the speed of the motor when it is running in either direction. This arrangement is a very handy one for running toys, as we have the motor under perfect control. (See the author's "Real Electric Toy-Making for Boys" for various toys that are to be run with small motors.)

136. Load on Motors. When a motor is running without doing work and simply has to turn itself, we say that it has no load. Although the motor has no outside work to do in this case, it really has something to do, for it must overcome the friction of its bearings and the resistance of the air to its rapidly revolving armature.

As soon as we attach it to some machine and make it do outside work, we say that the motor is running with a load, and it would seem perfectly natural for a motor to slow down a little when its load is increased. From this we should also expect that the current would have to be increased to keep up the proper speed with the larger load.

Small motors do not run well at slow speed, and so we have to gear them down to get to the proper speed for toys and other things. (See "Real Electric Toy-Making For Boys," Chaps. 10, 11, 12, for full direc-

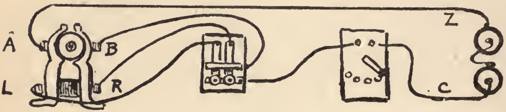

Fig. 51

tions for making shafting, bearings, pulleys, winding-drums, etc., for small motors.)

137. Series-Wound Motors. As has just been mentioned, it is natural to expect that a motor should run faster as soon as its load is decreased, and still faster when the load is entirely thrown off. In the case of the series-wound motor, this would become a serious thing if it were not watched and its speed regulated, for these motors have a tendency to keep on running faster and faster, or to "race," as it is called, and such motors have been known to actually tear themselves to pieces by the excessive speed under no load.

In places where it might be possible for the belts to break or come off, thus allowing a series-wound motor to race, or where a variable speed is not wanted, series-wound motors are not generally used. There are many places, however, where a variable speed is really wanted, as, for example, on electric cars, pumps, hoists, etc., and in these cases the speed is under the control of a rheostat placed in the main circuit, as in one of the previous experiments. For work like this, the operator is on hand to attend to the rheostat. In the case of ordinary electric fans, for example, the load is constant, and there is no chance for the fan to race, and so many of these motors are series-wound. They will race, however, if you remove the fan and let them run.

In series-wound motors, the same current passes through both armature and field, so when the strength of current in either of these two parts is changed, it is also changed in the other part. For example, if we increase the load on the motor, the armature will naturally slow down a little, and from the experiments on counter-electromotive force, we know that the resistance of the armature will be decreased. This will allow more current to pass through the armature, and we should expect that more power would be the result; but, as mentioned above, the field also feels the effect of this increased current, and the magnetic flux of the field is increased. The counter-electromotive force in the armature increases with the additional magnetic flux, and so the motor has to slow down.

The thing may be summed up, in a general way, by saying that the strength of the field is not constant in series-wound motors. Every change in load makes a corresponding change in the strength of the field and in the pressure of the counter-electromotive force.

This trouble is overcome in shunt-wound motors, as will be explained below. Series-wound motors have a very strong pulling power or "torque" when they start, and this is an advantage in starting electric cars and other machinery for which they are adapted.

EXPERIMENT 54. Motor No. 1, shunt-wound.

138. Directions. Place the two short connecting-straps upon the motor, as shown in Fig. 52, then hold the ends of the wires from a battery against the straps to see if the motor will turn.

139. Discussion. By this method of wiring, the current which passes to strap 1 will divide, part of it going through the field-coil and the rest through the armature-coils to strap 2 and back to the battery. While Motor No. 1 is not wired for a shunt-wound motor, it works well enough for experimental purposes. Some of the larger motors to be described later are so wound that they really work better as shunt-wound motors than they would if connected up as series-wound motors.

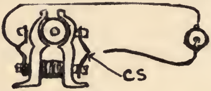

Fig. 52

EXPERIMENT 55. Motor No. 1, shunt-wound and reversible, with one method of speed regulation.

140. Directions. Fig. 53 shows one way to wire your apparatus to get the results secured in large motors; that is, to have them shunt-wound, and at the same time to have them reversible and under control as to speed. In this diagram are shown the motor without any connecting-straps, a three-cell battery, the reverser, and the eleven-point rheostat, all of which have been described in Chapter 3.

With this wiring, care must be taken not to short-circuit the batteries through the armature and rheostat, for the current can go this way without producing motion in the motor. If care be used, there will be no trouble from this, but it is best to put a one-point switch in wire 1 and to open this every time the motor is to be stopped; and the switch-arm of the rheostat should be turned to the dead-point, as shown. The keys of the reverser will prevent a short circuit through the field-coil, as the current can not pass unless one of the keys is pressed. Work out the diagram in your mind before doing the actual experiment.

141. Discussion. The above arrangement is what we may have in large motors, although there are certain disadvantages. The student should thoroughly fix in his

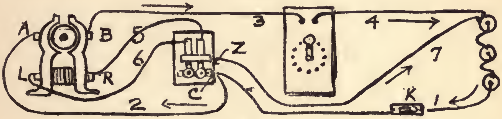

Fig. 53

mind that we are reversing on the field and regulating the speed by means of resistance in the armature-circuit.

If we follow the diagram, we shall see that when the current gets from the carbon of the batteries or from one of the small dynamos—if that be used to furnish the supply—it divides at C, part of it going through wire 2, through the armature-coils to the rheostat, at which point it can not go farther unless the switch-arm be moved to one of the contact-points. From the rheostat it returns to the batteries. This shows why it is necessary to be careful and not let this current pass when you do not want to run the motor. In regular work, the current should be turned through the field before it is admitted to the armature.

The other part of the current will rush through the field-coil as soon as one of the keys is pressed, the direction of this part depending upon which key is used; but in either case, this part will leave the reverser at Z and return to the batteries through wire 7.

The rheostat, in this arrangement, takes the part of the usual "starting-box," which allows the current to enter the armature through resistance until it gets a speed and is capable of protecting itself with the current it makes while running.

EXPERIMENT 56. Motor No. 1, shunt-wound and reversible, with a second method of speed control.

142. Directions. Fig. 54 shows this second plan, and it will be noted that in this case we have the rheostat

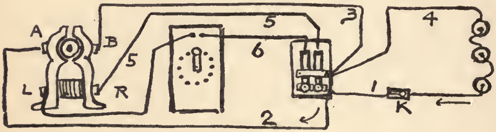

Fig. 54

placed in the field-shunt and that we also reverse the current in the same shunt. The armature-current will be one that we must look out for so as not to short-circuit it, as this would soon weaken the batteries. The one-point switch, K, will protect the batteries if it be opened as soon as you want to stop the motor.

Try the effect of pressing one of the keys of the reverser, then closing switch K, and finally turning the arm of the rheostat to different positions. You will find that you can reverse the motor and regulate its speed, but take particular notice whether it runs faster with much or little resistance put into the field-circuit.

143. Discussion. If the proper connections be made in the above experiment, the student will find that, contrary to all of the other experiments, the motor runs slower as we cut out resistance in the field-shunt by turning the rheostat-arm around in a clockwise direction, as usual. In all of the experiments with the series-wound motor, as well as with the previous shunt-wound arrangement, the less the resistance, the more the speed.

We still have some troubles to overcome, as you will see by the wiring that lets the current to the armature, for it is evident that the whole force of the current is allowed to pass into the armature when it is standing still. This will not make any trouble in the little experimental motors, but it would be a serious thing in the motors used for regular work.

144. Direct-Current Shunt-Wound Motors. We have already seen what is meant by coils in "shunt," so, when we have the field-coil and the armature-coils arranged in this manner, we say that we have a shunt-wound machine, whether it be a motor or a dynamo.

In some of the experiments we have practical wiring on the small motors, and see how these motors are regulated as to direction of rotation and speed.

The series-wound motors, as explained in the last section, tend to "run away" when the load is removed, and this trouble the shunt-wound motors overcome; in fact, a well-made shunt-wound motor will run at almost a constant speed, even if the load be changed, provided it receives a direct current of constant voltage. In these motors, the resistance of the armature-coils is small in comparison to that of the field; in fact, when a large shunt-wound motor is started, the whole force of the current is turned through the field-coils to create a strong magnetic field before any is allowed to enter the armature. This is all accomplished by the "starting-box," the connections of which are designed to do this. As will be explained in another section, it is very important to have the armature come up to speed gradually to give it a chance to generate current like a dynamo to hold the regular current back. If it were not for this, the armature could not stand the heavy current.

Generally speaking, the field of shunt-wound motors is of constant strength, no matter what is happening to the current in the armature, for the field-coils are connected to the mains leading the current to the motor. In this winding, then, we do not have the counter-electromotive force in the armature affected to any great extent by the magnetic flux of the field.

Now, when the load is increased on a shunt-wound motor and it tends to slow down, thus reducing the counter-electromotive force in the armature, in rushes more current through the armature, for the path is easier than before. This increased current through the armature brings it back to speed at once; and we have very little effect from the field, as this has remained practically constant in strength. Small motors are not quite so self-regulating as the large ones, as in these there is not so much difference in resistance between the field and armature.

145. Regulation of Field-Magnetism. As just suggested, the resistances of the two circuits of regular shunt-wound motors are very different. The field-magnet is wound with many turns of wire, thus giving it enough resistance to allow the full force of the current, for a time, without too much heating; at least, this coil will stand this current until the armature gets under way, and then the whirling of the armature fans the field-coils and tends to keep them cool.

The armature has a small resistance, as compared with that of the field-coils, so care must be taken to keep the full force of the current from entering it until it gets almost to full speed. This applies to large motors, of course, the small ones, say up to and including one-sixth horse-power, being so designed that they may be started with full current.

In Experiment 55 we regulated the speed by placing the rheostat in the armature-circuit, but this wastes much power. As the armature-resistance is much smaller than that of the field-coil, the armature will take most of the current and we shall have to arrange to handle all of this current through the rheostat. In this arrangement, the rheostat has to be large to stand the heating effects when the current is held back, and so, if we want the

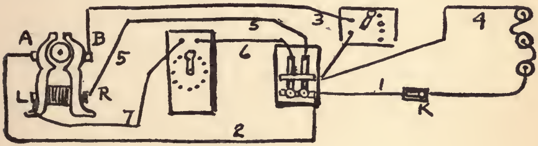

Fig. 55

motor to run at only half speed, we shall have to waste a great deal of power in the form of heat that is lost at the rheostat.

When the magnetism of the field is regulated to control the speed, we have but a small part of the whole current to handle in the field-rheostat, and so it does not make so much difference if a part of this is lost.

EXPERIMENT 57. Motor No. 1, shunt-wound and reversible, with speed control by regulation of field-magnetism, together with starting-box.

146. Directions. Fig. 55 shows a method, for experimental purposes, of letting the current into the armature slowly. The connections are about the same as for Experiment 56, a small rheostat being placed in the armature-circuit, as shown. The one-point switch, K, takes the place of the "main switch" on regular motors, and this should be opened when the motor is to be stopped, to make sure that no current passes through the armature when the motor is not running, thus wasting the batteries.

After you have made the desired connections, see that the starting-box, that is, the rheostat in the armature-circuit, is so arranged with the lever at the right-hand side that no current can pass through it, and that the switch-arm of the field-rheostat is placed as shown, with all resistance cut out. Close the main switch, press the left-hand key of the reverser, then turn the lever of the starting-box to the left upon the first contact-point. The motor should start up slowly with the three-cell battery, its speed gradually increasing as the resistance is cut out by turning the starting-box lever to the left. To get more speed, turn the arm on the field-rheostat to the left so as to add resistance and lessen the strength of the field-magnet.

In stopping the motor, open the main switch first, then bring the other parts to the original starting-points.

147. Discussion. We have here a very good example of the two effects of resistance. In the armature we get more speed by cutting out resistance, while in the field-magnet coils we add resistance to get more speed. This will be spoken of again under Section 151 on "counter-electromotive force."

148. Starting-Boxes. If we wish to use a motor for regular work and do not care to reverse it, and if the motor is simply to run at a certain speed for which it was designed, we have a much easier thing to accomplish than the numerous requirements just studied. As the shunt-wound motor is the one generally used for such work, it will only be necessary to explain this special motor here.

We have already discussed the relative resistances in the field- and armature-coils, and have seen the necessity of letting the current into the armature slowly, thus allowing it to come up to speed gradually. This can all be done with one instrument, called a starting-box, a simple plan of which is shown in Fig. 56. In this, the parts are shown in the position taken before the motor is started, the switch-arm resting upon a dead-point. If

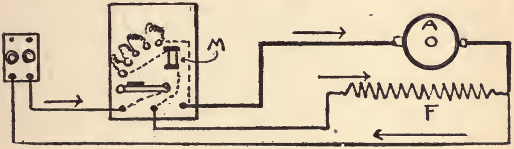

Fig. 56

you imagine this arm turned to the first contact-point, you will see that the current can pass along in the direction shown by the arrow to the pivot of the switch-arm and then through the arm to the contact-point, at which place it divides, part of it going through an electromagnet, M, and so on through the field and out at the main switch. The other part goes through all of the resistance-coils and then through the armature. The wires leading to the armature are represented as being large to show that this resistance is small in comparison to that of the field, and because the armature takes most of the current. The drawing shows that the motor under consideration is a plain shunt-wound motor.

If the switch-arm be now turned to the second and third contact-points, etc., resistance will be cut out of the armature-circuit, thus allowing more current to go through the armature, as it increases in speed. Here is where the counter-electromotive force helps; for the armature generates a current of higher and higher voltage as it goes faster and faster, and so we can let in more and more current and still not burn out the armature, which, we have seen, has very little resistance, and which would, therefore, take too much current if it were not for this extra resistance to be overcome as it gains in speed.

When all of the resistance has been cut out of the armature and it is getting the full force of the current like the field, the switch-arm has reached a point at which an iron plate on it touches the poles of the electromagnet, M, where it will be attracted so long as the current flows and the motor is running. The arm is really under two pulls, as a spring is trying to pull it away from the magnet. In case the current is shut off at the central station for any purpose, the motor will stop; and as this magnet can no longer hold the switch-arm, it is quickly pulled back to the starting-point again. This "release-magnet" is a splendid thing, as it keeps the full current from rushing through the armature when they turn the current on again at the central station.

By this simple plan, then, the field-magnet is energized first, and then the current is gradually increased in the armature as the speed increases. The coils in the usual starting-box are not large enough to take the full current for any length of time without too much heating, as they are designed to carry the current for a few seconds only, while the armature is getting up to speed. The spring that pulls the switch-arm back really protects the coils, for the current can not be left partly on. If you let go of the switch-arm before it reaches the release-magnet, the arm will fly back again and open the circuit. As the magnet lets go of the arm as soon as there is no current in the line, it is called a "no-voltage release."

EXPERIMENT 58. Counter-electromotive force of motors.

149. Directions. Arrange a three-cell battery, Motor No. 1, a key, and a three and one-half volt electric lamp, as shown in Fig. 57. As will be seen by the wiring, the motor is series-wound and the lamp forms a shunt to the motor-circuit.

Press the key to allow the current to start the motor

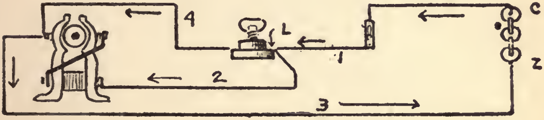

Fig. 57

and note the action of the lamp. When the motor has its full speed, gradually stop it by holding the armature-shaft, watching the lamp.

150. Discussion. We have in this arrangement two paths for the current as it leaves the batteries and reaches the lamp at L, one path being along wire 2 through the motor and back to the batteries through wire 3. The other part goes through the lamp and then through wires 4 and 3 to the batteries. From this it will be seen that the lamp is a shunt of fairly uniform resistance, if we neglect the change in resistance due to its change in brilliancy, and that the motor is a resistance that changes with the speed.

When the motor is held so that it can not turn, its resistance is merely that of the wires in its coils, and as this resistance is small, the motor takes most of the current, leaving very little for the lamp.

As soon as the motor gains speed, it generates a counter-electromotive force which holds back the battery current, thus adding resistance to that of the wires. We know from previous experiments that when we increase the resistance of one shunt, the other shunt has to carry more current, and this is made clear by the lamp, which brightens as the motor goes faster and faster.

151. Counter-Electromotive Force. The last experiment showed that a motor has a much greater resistance when running than when still. The armature-resistance is the one that is affected by the increasing speed, and that is why it is necessary to put a starting-box in the armature-circuit of shunt-wound motors. The field can take care of itself on account of its high resistance, but the armature would burn out at once on large motors if the whole current were allowed to pass through its coils of small resistance. As mentioned, when speaking of the starting-box, the little coils of resistance-wire hold the full force of the current back until the speed is such as to create the counter-electromotive force. This represents a current flowing in the opposite direction to that which makes the motor go.

We have already mentioned the fact that motors will generate a current if rapidly turned by a steam-engine or by some other power as, for example, water-power. In the case of the motor just used, the motor was run by the electrical energy supplied by the batteries; that is, the batteries represent the engine. If we look at it in this way we can easily see that the motor should generate a current, even if run by electricity. In "The Study of Dynamos by Experiment" we shall see what generates this current.

If a motor be well made, it will generate a current having a voltage that is nearly as high as that of the current which enters the armature and runs it. This shows that the armature gets very little current from the supply, when it is running at full speed, compared with what it would get if the armature stood still.

From this we see that, in order to make the motor go, the current that enters it from the supply must be of a greater voltage than that of the counter-electromotive force. There is a constant struggle between the applied electromotive force and the counter-electromotive force, and it is just this struggle in overcoming the counter-electromotive force which changes the electrical energy supplied to the motor to the mechanical energy which

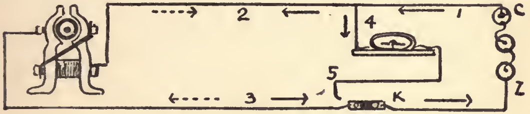

Fig. 58

the motor has as it turns. If it were not for this forcing back of the counter-current, the motor would not go any more than a water-wheel would turn without the pressure of the water against the resisting buckets.

EXPERIMENT 59. To show in which direction the counter-current flows in a motor.

152. Directions. In Fig. 58 we have Motor No. 1, a key, and a current detector arranged so that the detector will be a shunt of the motor. Place the motor about three feet from the detector so that its magnetic needle will not be affected by the electromagnets of the motor. The motor may be at one end of the table, away from the other apparatus.

Press the key for a moment, at the same time noting in which direction the north pole of the compass-needle turns when wire 5 touches the key, K. If arranged as in the figure, current will enter the detector through wire 4, shown by the full-line arrow, causing a certain deflection of the north pole, and as this detector-shunt is of low resistance, the motor will not turn rapidly. Now disconnect wire 5, press the key to allow the motor to get a high speed, raise the key to disconnect the batteries, and quickly touch wire 5 to wire 3 or to the contact on the key that is attached to wire 3. Note that the detector-needle is deflected in the same direction as before.

153. Discussion. From the second part of the experiment we see that, as the needle is deflected in the same

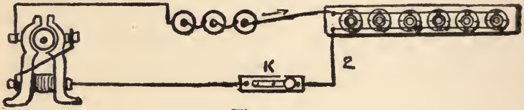

Fig. 59

way as before, the current must enter the detector from wire 4 again. It is evident that when the current came from the batteries, it followed the direction through wire 2 shown by the full-line arrow, and that when the counter-current came from the motor to deflect the needle, it must have passed through wire 2 in the direction shown by the dotted arrow. This shows that the counter-electromotive force pushes against the applied current, as discussed in some of the other sections. This experiment must be done quickly and before the motor has slowed down much.

EXPERIMENT 60. Regulation of speed with lamps in parallel.

154. Directions. Arrange six three and one-half volt lamps in parallel, as shown in Fig. 59, placing the "bank of lamps" in series with Motor No. 1, a three-cell battery and a key. Try the effect on the speed of the motor of turning on more or less lamps.

155. Discussion. As these lamps are so joined that each can let some current through from wire 1 to wire 2, it is evident that, when several lamps are screwed in, more current will pass than when one or two are used. If the cells are strong, two lamps will run the motor slowly, and it will be seen that these light up brighter than when more are used. The faster the motor runs, the greater the counter-electromotive force and the less each lamp has to carry.

CHAPTER IX

VARIOUS ELECTRIC MOTORS

156. Small Motors and Large Motors are names that do not mean as much as they seem to at first, when we consider that a small motor may be so wound as to take a large current, and, in the same way, a large motor may be so arranged as to need a current of small voltage.

A more useful classification would be to put the motors that are to be run with batteries and other small currents together and call them low-voltage motors, then the ones that are to be run from the 110- or 115-volt currents would be called high-voltage motors. This point of classification does not amount to much, although it might prove to be a serious thing to try to run a low-voltage motor upon a high-voltage circuit; that is, it might be serious for the motor. Chapter 10 will give information upon this part of the subject.

All that need be said here is that motors intended for use with battery currents and currents from low-voltage dynamos are so wired that their resistance is low. High-resistance motors would hold the current from a few batteries back to such an extent that there would not be enough electromagnetism produced to turn the armature. We can, by proper apparatus (see Chap. 10), run low-voltage motors upon high-voltage currents; but, if we were to do this without modifying the current, we should ruin the motor by burning out its coils and doing other damage.

157. Compound-Wound Motors. In discussing the series-wound machine, we saw that the coils of the field and armature were in series, and that in the shunt-wound machine the coils are in parallel, each taking a part of the current.

In the compound-wound motor we have a cross between these two methods, as the field is provided with a series-coil and a shunt-coil. Fig. 60 gives an idea as to how this is arranged, and how the starting-box is placed in the circuits to allow the motor to start up slowly so as not to burn out the armature.

The two coils on the field are wound so that the current which flows through them magnetizes the field in the same direction; that is, so that both coils aid each other

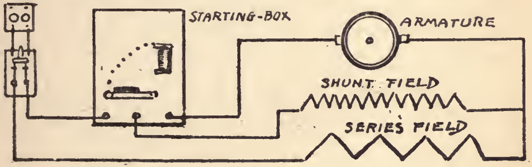

Fig. 60

in making a north pole at the same pole-piece. We have in this winding the best part of both the series and shunt machines, for by this combination we get, in a degree, the powerful starting-torque of the series machine and the steady speed of the shunt-wound motor.

158. Comparison of Series, Shunt and Compound Motors. Compound-wound motors start more promptly than shunt-wound motors, and they will stand overloads better than the shunt-wound machines. Under changes of load the compound-wound motors will vary in speed more than the shunt motors, but they will not vary nearly so much as the series motors. Compound-wound motors are advised for the small sizes that are to be started without starting-boxes.

The speed of series-wound motors varies greatly with the load, and when the load is entirely thrown off, they will race unless proper resistance be thrown into the circuit.

Shunt-wound motors are more or less self-regulating, the large sizes being able to run at almost constant speed, no matter whether the load be large or small, provided the load is within the capacity of the machine. The smaller sizes of this variety are not so self-regulating as the large ones, and so their speed will vary slightly with the load. They will not race, for, as soon as the speed begins to increase, the increasing counter-electromotive force will decrease the current supplied to the armature, and this keeps the speed within limits.

159. Differentially-Wound Motors. This is similar to the compound-wound motor, as just described, except in the arrangement of the two coils that are placed on the field. In this case we have a series-coil and a shunt-coil, but the two are so wound that they work against each other. By this plan the strength of the field is due to the difference in the magnetizing effects of the two coils, hence the name, differential.

A motor of this winding will run at a very constant speed, but the shunt-wound motor will give a speed that is constant enough, and, besides, there are some drawbacks to the differential winding in case the motor is overloaded. The student will not meet this winding under ordinary circumstances.

160. Alternating-Current Motors are made in many ways, and as the average student will not have a chance to take up this part of the subject experimentally, this branch of the work will be omitted. The subject of alternating currents is a large one; in fact, it is too large to be considered in this small book of experiments.

161. Railway Motors. We have already mentioned the series-wound motors as being adapted for use on electric cars on account of the powerful starting-torque. When a loaded car is started, the power needed to get it under way is many times that needed to keep it in motion when once started, especially if the car is stopped on a grade. These motors are easily regulated as to speed and load, and so the direct-current series-wound motors are most commonly used for this purpose. Controllers are used for starting and regulating the speed, and these may be so arranged that the two motors on the car can be joined in series or in parallel, with or without resistance.

Motors used for this class of work are made in special ways for special purposes and have to be very strong and well protected to stand the constant pounding and abuse given them.

162. Special Motors. Electric motors are used for so many things nowadays that it would take a very large book to mention even a small part of the various applications of these wonderful machines. The shapes and sizes have been ingeniously adapted to the numerous requirements, and we find motors working silently in all kinds of places and for all kinds of power. Large manufacturers of motors will design special motors for special purposes and arrange their various parts to do the work required.

163. Protection of Motors. As an electric motor is a machine, at least as much care should be given to it as to any machine; in fact, even more care should be given to electric motors than is given to most machines, as they are very apt to be abused with overloads. A well-made motor runs so quietly and makes so little fuss in doing its work that we are liable to get the idea that it has no limit to its powers and that it can do no end of work. This is a great mistake, and so all motors to be used on regular commercial circuits should be well protected with fuses or other safety devices. As has been stated in the various discussions, a motor takes more current as its load is increased and its speed decreased; so it must be evident that, if the load be increased sufficiently, the motor will turn very slowly, or even stop. As soon as the counter-electromotive force decreases, the resistance of the armature is so small that we get more current through it than it can carry; and so the wires would be melted if they were not protected. This protection is given by using fuses in the circuit that will melt at some stated number of amperes, or by other automatic devices that will open the circuit before the current gets near the danger point.

Motors larger than one-sixth horse-power should be protected with a starting-box having a "no-voltage release" (see Sec. 148).

164. Motor No. 2. While Motor No. 2 is similar in construction to Motor No. 1, it is larger and stronger than No. 1, and it is furnished in either of two windings. It may be had as a plain series-wound motor, as shown in Fig. 61, this style being listed as No. 2205, the price being $2.00. In order to do the experimental work that can be done with Motor No. 1, however, it has to be provided with four binding-posts and some changes have to be made in the wiring in order that it may be run as either a series-wound or a shunt-wound motor. This motor, with the changes made for experimental work, is listed as No. 2206 and costs $2.25. In either winding the binding-posts for the field are mounted upon the wooden base, and the brushes are adjustable while running at full speed. This feature is valuable, as it is necessary to get the proper pressure of the brushes upon the commutator for best results.

Motor No. 2 stands four and one-half inches high. It is finished in black enamel with nickeled trimmings, and the field-magnets are strong, plenty of iron being used in their construction.

165. Dynamo-Motor No. 3. This machine is also furnished to students in two styles of winding in order to adapt it exactly to the requirements. Fig. 62 shows the dynamo-motor as plain shunt-wound, this style being advised when it is to be used as a plain motor or dynamo,

Fig. 61

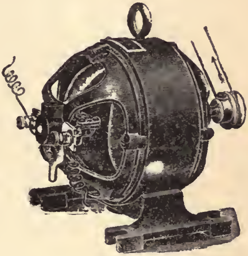

Fig. 62

no changes being needed in direction of rotation. This winding is listed as No. 2209, and it is shown in Fig. 62. Price, $3.75.

When it is necessary to change the direction of rotation as, for example, in running certain toys, this dynamo-motor may be purchased with an extra attachment which gives the machine four binding-posts. In this form it may be connected to the rheostat, current reverser, etc., explained in connection with Motor No. 1. With the extra binding-posts and other attachments not found upon any other small dynamos, this machine is especially adapted for experimental and general purposes. It can be used as a series-wound or shunt-wound motor and as a shunt-wound dynamo, and is listed as No. 2210. Price, $4.00.

As a motor, it will run with the current from batteries or with the current generated by a twin machine turned by some power. Two No. 3 dynamo-motors make a complete electrical power plant if you have some method of turning the dynamo, which will generate current for the other machine to run as a motor. Motors No. 1 and No. 2 run well on the current from one of these machines; in fact, you can furnish current for all kinds of experimental work, including bells, telephone lines, induction-coils, plating outfits, miniature lighting outfits, electric cars, charging storage batteries, etc.

The construction of this machine is mechanical. The field is cast solid, the coils being form-wound and connected in multiple. The armature is of the drum type, one and three-fourths inches in diameter, built up of punchings; that is, it is laminated, with six slots. The brushes are adjustable. The pulley, one inch in diameter, is grooved for a small round belt. Oil cups, black enamel finish. When run at 3,000 r.p.m., gives good current. Safe maximum load, 6 volts 4 amperes. If run as a power motor, from 4 to 6 volts give the best results. The very best way to run this as a dynamo is to use a one-eighth horse-power motor in connection with the bank of lamps explained in Section 180.

166. 110-Volt Motors, as has been explained, are properly wound to take the commercial current, and they develop a counter-electromotive force sufficient to protect the armature when it gets up to speed. For the small sizes up to and including the one-sixth horse-power a starting-box is not generally used except for special reasons. Small motors, if well made, will start off very quickly without endangering the coils unless the load be excessive. A few sizes are illustrated to give the student an idea as to their construction and appearance.

All motors heat up when they are running under a load, but of course the heat must not get too great. The small motors shown in the following cuts are of the standard ventilated protected type, and are guaranteed to carry their full rated load continuously without attaining a temperature greater than 40 degrees Cent. in excess of that of the surrounding air in all parts except commutator, and 45 degrees Cent. on the commutator.

Machines up to 1 horse-power will carry 25 per cent overload for one hour with temperature rise not to exceed 55 degrees Cent. for all parts except commutator, and 60 degrees Cent. on the commutator. Machines of 1 horse-power and above will carry 25 per cent overload for two hours with rise of 55 degrees Cent. for all parts except commutator, and 60 degrees Cent. on the commutator. Machines are not guaranteed to carry continuous overloads. All types of these machines will carry 50 per cent overload momentarily without injury. These ratings are based on condition that the motors are so placed as to receive free circulation of air.

For use in places where they require protection from dust and dirt, chips, flying particles, or protection from mechanical injury, motors may be furnished with either brass wire gauze or solid iron enclosures, and as all motors generate heat while running, and as this heat is not radiated as rapidly in closed as in open motors, the ratings for enclosed motors are somewhat lower than for open motors.

167. Motors for Intermittent Duty. For many classes of service, such as the running of elevators and hoists, motors have such intermittent duty that there is little or no trouble from the accumulation of heat, the load-limit in these cases being reached when sparking at the brushes becomes serious. Motors for strictly intermittent service are therefore rated higher than for constant service.

168. 110-Volt Laboratory Motors. If you have the 110-volt current in your laboratory, you will find that a small motor will be of the greatest help in running small dynamos and other things. The sizes, from one-eighth horse-power to and including one-quarter horse-power, will be as large as are usually found for experimental purposes. A one-eighth horse-power motor will do a great deal, and even run light machinery, such as jig-saws and other small things.

If these motors are run in connection with a bank of lamps, as explained in Section 180, the speed will be under perfect control and there will be no danger of burning out any fuses in the house even if you happen to get a short circuit while experimenting.

The following descriptions of motors are taken from the manufacturer's catalogues, and they are herein reproduced for the guidance of those who are interested in the matter. Such descriptions are instructive, for they explain the special points of each motor illustrated. The author does not wish the term "laboratory motors" to be misleading. He has chosen the name simply because these motors are so useful and so well adapted for laboratory purposes. The motors described below are all commercial motors intended for hard work, and they are suggested because the author is familiar with them, having personally used all of the illustrated sizes for various purposes. Compound windings are advised for these small motors.

169. A One-Eighth Horse-Power Motor. For the amateur and student a motor of this size will be large enough to do most of the work needed. It will run the small dynamos that are shown, run jig-saws and other light machinery. Fig. 63 shows a one-eighth horse-power motor, called "Frame 40," that is well suited for laboratory work, as it will stand constant hard usage. It is of handsome and artistic outline, and, while being well ventilated, it is perfectly protected and satisfies the requirements of a motor having no external current-carrying parts. It is especially adapted for use in positions where the motor is in easy reach of the operator, as it avoids the possibility of touching moving or electrified

Fig. 63

parts. The author has used a number of these motors and has found them very satisfactory. The latest design of the one-eighth horse-power motors differs slightly from that shown in the cut, an improvement having been made in the brush-holder. These motors run at 2,000 revolutions per minute (2,000 r.p.m.) with full load. A motor of this size weighs about 16 pounds and is provided with a 2-inch grooved pulley.

170. A One-Seventh Horse-Power Motor. Fig. 64 shows this size, and although there does not seem to be much difference between the fractions ⅛ and 1-7, this motor will meet more severe conditions of service than the one just described. The frame of this motor is about the same size as that for the one-eighth motor, but it is heavier and more solid, mechanically, stands more overload, and can be wound for higher speeds than the former. Weight, 18 pounds; runs at 2,000 r.p.m.

To illustrate what can be done in changing these motors, using the same frame, this motor can be so wound that it will give one-sixth horse-power at 2,300 r.p.m. This speed is rather high, however, for laboratory

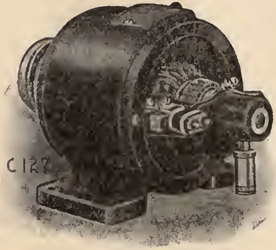

Fig. 64

purposes, but it illustrates how the speed and power can be varied at will by changing the wiring of a motor.

171. Another One-Seventh Horse-Power Motor that is very useful and efficient is shown in Fig. 65. This is styled "Frame 1/7-P," and it was designed specially for driving automatic-playing musical instruments. Its principal qualities, which especially fit it for this class of service, are extreme durability, noiselessness, cleanliness, ability to run for long periods locked up in the instrument case without attention, powerful starting-torque, small dimensions in the direction where space is usually limited —*i.e.*, over the shaft and pulley—and the general convenience and ease of its installation. These qualities have been found valuable in many other kinds of service, and although designed for a piano motor, it is finding extended sale outside of the musical instrument trade. The frame No. 1/7-P is furnished either with or without enclosing covers, the enclosure being recommended only where necessary for the protection of the working parts of the motor, as the motors will run cooler without the

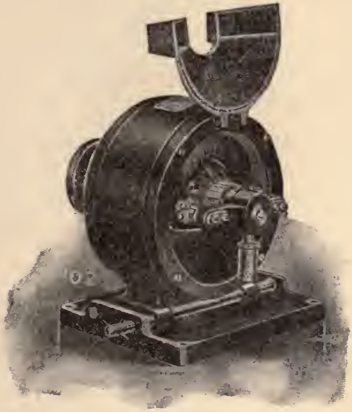

Fig. 65

cover, especially under heavy loads. Whether with or without covers, the motors are ventilated by perforations in the lower halves of the heads. This frame will be furnished with sliding base when ordered. This feature is often very valuable in a motor desired for driving automatic-playing musical instruments, as it allows the belt to be kept at the proper tension without the necessity of cutting and resplicing it. Sliding bases can not be furnished with any other of the small motor frames.

172. A One-Quarter Horse-Power Motor. Fig. 66 shows a very practical design for a motor of this power, and although the illustration is about the same size as that for the other motors shown, the motor itself is much larger and heavier than the others. This is of the ventilated protected type with bi-polar frame, and these are generally shunt-wound with flat pulley, as shown. Each

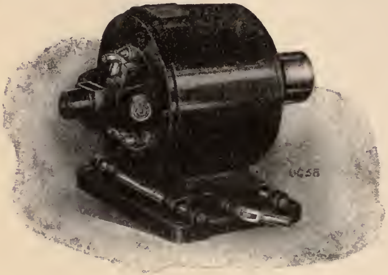

Fig. 66

motor is furnished with sliding base with belt-tightening attachment and with a starting-box having a no-voltage release.

A motor of this rating is, really, a powerful motor, and it will do a great deal of work. The author has used them for running very large static machines, like those used by doctors for medical purposes, and with a proper rheostat, the speed is under perfect control. A motor of this size will run quite a little light machinery.

173. A One-Tenth Horse-Power Motor. This is another small motor that should be added to the above list to make it complete and to show another kind of construction. This is shown in Fig. 67 and can be made to run on alternating current as well as upon direct current.

This is a practical small motor costing a little less than the one-eighth, but of course it is not so powerful as the one-eighth, which, however, will not run on the alternating current. When furnished for running on alternating current, the field-cores are laminated. When supplied for direct current, the field-cores are cast solid.

The winding can be arranged to give one-thirtieth, one-twentieth, one-sixteenth or one-tenth horse-power, according to the speed required. The relative speeds for

Fig. 67

these powers are 1,000, 1,500, 2,000 and 3,000 r.p.m. These motors are furnished with three grooved pulleys, their diameters being three-quarters, nine-sixteenths and seven-sixteenths inches, and the motor weighs four and one-half pounds.

One point the student must consider when thinking of such a motor is that it is series-wound, thus adapting it for a fairly uniform load. These small motors are made to run for long periods without attention and are just the thing when adapted to the work they have to do. For laboratory work they are not so good as the one-eighth, which are compound-wound, but where alternating current is supplied they can be used instead of the other forms described above.

It should be stated, however, that while this little motor will run well on either direct or alternating current where but little power is required, it is not strong enough to properly run Dynamo-Motor No. 3 up to speed for generating a good current. If the student has only alternating current in his laboratory and wants to run one of these dynamo-motors, he will need a one-eighth horsepower alternating-current motor. The author can recommend Motor No. 2254 for this purpose.

CHAPTER X

ELECTRIC CURRENT FOR RUNNING MOTORS

174. Various Methods. The current needed to run your motors will be determined by the particular motors you have, for the current should be of the proper voltage required to get the best results.

The current-supply for laboratory purposes will be either from batteries or from dynamos. In the latter case, the dynamos may be in the room and under control of the student or they may be at the power-house where the commercial current is generated. The following sections will give suggestions as to the various methods that may be used to run the motors described in this book.

175. Battery Currents are sufficient for all of the experiments given, and where it is not possible to generate your own current or get it from the street, this will be the plan to adopt. There are many kinds of batteries on the market, some being adapted for long runs and others being sufficient where short runs for experimental work only are required. For the usual work required in the laboratory, ordinary dry batteries of good quality do very nicely. They are comparatively cheap and there are no dangers from acids or fumes; besides, they can be readily replaced when they get too weak.

176. Forcing Dry Batteries is a very poor plan, as it shortens their life very rapidly. A dry battery is really intended for intermittent work, and if run too long at a time or forced too hard, it will not give the best results. The best plan is to use two or three times as many cells as are needed to get the desired voltage, arranging them as suggested below to increase the amperes.

177. Arrangement of Cells. Fig. 68 shows three cells arranged in series, this combination giving about four and one-half volts. This three-cell set will light small lamps and run Motor No. 1 at a high rate of speed, and should be used when combined with the eleven-point rheostat and other things mentioned in the experiments.

Fig. 69 shows two sets of three cells each, the two being joined in multiple; that is, the whole is arranged in "multiple series." By this plan the voltage of the

Fig. 68

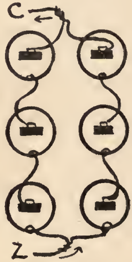

Fig. 69

combined cells remains the same as that of the three cells, while the amperes are doubled in quantity. In other words, by this plan we have more quantity to draw upon at the same pressure as before, so each cell does not get the work that it otherwise would.

If you wish to run your motors for any length of time for fans or other purposes, it will pay you to arrange the batteries as shown; for, by this plan, you will be able to get much more out of them before they give out.

178. Storage-Batteries are very satisfactory for running motors and for other laboratory purposes, especially if you have means of charging them yourself. This can be done very easily if you have the 110-volt direct current, using a bank of lamps. Even if you do not have a complete bank of lamps, as explained in Section 180, you can get the proper attachments at small expense for this work.

For running induction-coils and other things that need a strong current, good storage batteries are fine; for they give results that dry batteries can not duplicate. Storage batteries can be bought for $1.00, $2.00, etc., per cell, according to size.

179. Running Small Motors from Small Dynamos. If you have a dynamo that will generate the right cur-

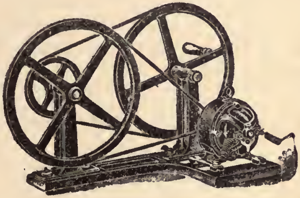

Fig. 70

rent for your small motors and some way of turning the dynamo, you have a complete electric plant. There are several methods of operating the dynamo: by hand-power, by means of a steam- or a gas-engine, by water-power, by an electric motor, etc. For those who have water-power, this is a very satisfactory method, although it would not pay to arrange a water-power plant for running one of the small dynamos like the No. 3 described above. At his country laboratory the author has a fine water-power running a 3-k.w. dynamo which furnishes current for all lighting and experimental work, and so the matter of running small dynamos is a very simple one, as it is in the city where the commercial 110-volt current is to be had.

Fig. 70 shows a handy form of hand-power for running the Dynamo-Motor No. 3 (Sec. 165). This will do for short runs for experimental purposes.

The best way for those who have the 110-volt direct current is to run a one-eighth horse-power motor through a bank of lamps to regulate the speed, and then belt the dynamo to this. By this plan, as has been mentioned, the dynamo can be made to deliver all voltages within its capacity, as the speed is so easily controlled.

Fig. 71 shows such a plan, the current from the small

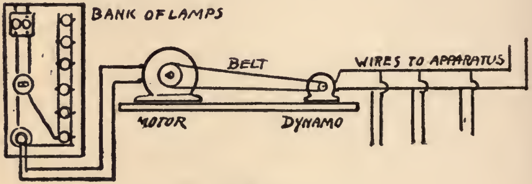

Fig. 71

dynamo being passed to switches or to a switch-board. This matter of switch-boards and handling the current from the dynamos for small plants will be taken up in "The Study of Dynamos by Experiment."

180. Bank of Lamps. This is a very useful piece of laboratory apparatus, especially as it adds greatly to the safety of things. In all experimental work, one is apt to make short circuits by accident, and this causes trouble by blowing out the fuses in the house. The only thing that happens when a short circuit is made in the circuit leading from the lamps, if arranged as in Fig. 71, is that the lights will come up to full candle-power. By putting a fuse-plug in place of one of the lamps, of course, the full current will be passed through the bank of lamps and then the fuses will blow if a short circuit be made.

One should be very careful to think out what will take place in the circuit before closing any switches on 110-volt currents.

These lamps should be thoroughly insulated and carefully arranged, and if they are to be used in the city, they should be on a slate base to comply with the regulations of the National Board of Fire Underwriters. For a six-lamp bank, the slate base should be from 20 inches to 2 feet long, 8 or 9 inches wide and about 1 inch thick. Holes must be drilled and plugged with lead tubing to hold the screws for the various parts. The author has made a number of these for general purposes with six lamps, mounting them on slate painted dead black, and he finds them very useful for regulating the speed of 110-volt motors that are used for running jig-saws, small dynamos, and other light machinery.

In charging storage batteries, and, in fact, for regulating the current, there is nothing better. By using assorted lamps of 8, 16 and 32 candle-power, a very fine adjustment can be made. Each 16 c.p. lamp, screwed in, allows one-half an ampere of current to pass through the apparatus. The 8 c.p. lamp passes one-quarter ampere, and a 32 c.p. one ampere. By proper combinations, you can get just what you need. Such an outfit, with flexible cords, fuses, switch, receptacles, etc., mounted upon a slate base, costs about $5.00, not including the lamps. It can be attached to any socket.

181. Battery Regulator for 110-Volt Currents. Fig. 72 shows a method of regulating the 110-volt current so that it can be used for running small motors, etc., without danger and without too much sparking. The author has used lead plates in sulphuric acid for this purpose, but they are decidedly unpleasant to handle, to say nothing of the troubles that come if they tip over. The method now employed and the cleanest method, is to use dry batteries, the number depending upon the work to be done. These can be joined in multiple so as to get the desired number of amperes. As will be seen by referring to Fig. 72, the current passes from the bank of lamps through the batteries and back—the wires leading to your apparatus being connected to the batteries, as shown; that is, the current you use is merely a shunt of the high-voltage current.

The batteries should be properly joined to the commercial current; that is, they should be considered as

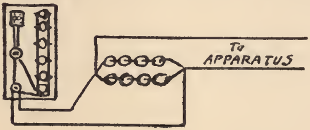

Fig. 72

storage batteries that are being charged. Test the wires leading from the bank of lamps by putting them in a tumbler of water into which you have dissolved a little ordinary salt. The negative wire will give off large quantities of hydrogen bubbles. Tie a knot in this wire to mark it, connect this to the zinc end of the battery regulator and the other wire to the carbon end; that is, place negative to negative and positive to positive, as in the case of charging storage batteries.

With proper switches so that you can vary the number of batteries and by using more or less lamps on your bank of lamps, you can get all of the variations in current that will be needed.

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NOTE—We cannot accept orders for less than 50c.

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1312	Round Bar Magnet...........	..	..	.18	.05
1505	Pocket Compass (Brass).....	..	..	.20	.02
1501	Simple Current Detector.....	60	17	.10	.02
1502	Handy Current Detector.....	61	18	.15	.03
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1084	Strap Key	51	9	.15	.03
1085	Strap Key with side switch...	52	10	.20	.03
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1415	Experimental Electromagnets.	75	26	.35	.08
1451	Hollow Coil on Spool........	..	..	.20	.04
1452	Soft Iron Core for No. 1451...	..	..	.02	.02
1312	Round Bar Magnet...........	..	..	.18	.05
2201	Motor No. 1, complete.......	106	39	1.00	.15
2205	Motor No. 2 series, wound...	164	61	2.00	.38
2206	Motor No. 2 series or shunt..	164	61	2.25	.38
2209	Dynamo-Motor No. 3........	165	62	3.75	6½ lbs.
2210	Dynamo-Motor No. 3.........	165	..	4.00	6½ lbs.
2212	Hand-Power for No. 2210....	179	70	3.75	21 lbs.
2253	One-Eighth H.P. Motor (D.C.).	169	63	11.70	20 lbs.
2254	One-Eighth H.P. Motor (A.C.).	..	..	25.00	25 lbs.
2175	Bank of Lamps (slate base, no lamps)	180	72	5.00	
1101	St. J. Dry Battery, small......	..	..	.12	.06
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No wonder shadow-making has been popular for several centuries! What could give keener delight than comical shadow-pictures, pantomimes, entertainments, etc.? Professional shadowists use wires, forms, and various devices to aid them, and that is why they get such wonderful results on the stage. Do you want to do the same thing right in your own home and entertain your friends with all kinds of fancy shadows? You can do it with this outfit, for the book contains 100 illustrations and diagrams with

directions for using the numerous articles included in the box. You will be surprised to see how easily you can make these funny shadows with the aid of the outfit. Better get one now and make shadows like a professional.

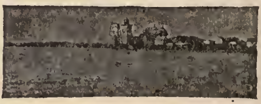
The Outfit contains everything necessary for all ordinary shadow pictures, shadow entertainments, shadow plays, etc. The following articles are included: One book of Instructions called "Fun with Shadows"; 1 Shadow Screen; 2 Sheets of Tracing Paper; 1 Coil of Wire for Movable Figures; 1 Cardboard Frame for Circular Screen; 1 Cardboard House for Stage Scenery; 1 Jointed Wire Fish-pole and Line; 2 Bent Wire Scenery Holders; 4 Clamps for Screen; 1 Wire Figure Support; 1 Wire for Oar; 2 Spring Wire Table Clamps; 1 Wire Candlestick Holder; 5 Cardboard Plates containing the following printed figures that should be cut out with shears; 12 Character Hats; 1 Boat; 1 Oar-blade; 1 Fish; 1 Candlestick; 1 Cardboard Plate containing printed parts for making movable figures.

No. R5.—Complete outfit "Fun with Shadows".................. **$0.25**
If sent by mail, postage extra........................ **.07**

FUN WITH PHOTOGRAPHY

Popular Pastimes are numerous, but to many there is nothing more fascinating than photography. The magic of sunshine, the wonders of nature, and the beauties of art are tools in the hands of the amateur photographer. If you want to get a start in this up-to-date hobby, this outfit will help you. You will enjoy the work and be delighted with the beautiful pictures you can make.

The Outfit contains everything necessary for making prints—together with other articles to be used in various ways. The following things are included: One Illustrated Book of Instructions, called "Fun With Photography"; 1 Package of Sensitized Paper; 1 Printing Frame, including Glass, Back, and Spring; 1 Set of Masks for Printing Frame; 1 Set of Patterns for Fancy Shapes; 1 Book of Negatives (Patented) Ready for Use; 6 Sheets of Blank Negative Paper; 1 Alphabet Sheet; 1 Package of Card Mounts; 1 Package of Folding Mounts; 1 Package of "Fixo."



Contents of Book: Chapter I. Introduction.—Photography.—Magic Sunshine.—The Outfit.—II. General Instructions.—The Sensitized Paper.—How the Effects are Produced.—Negatives.—Prints.—Printing Frames.—Our Printing Frame.—Putting Negatives in Printing Frame.—Printing.—Developing.—Fixing.—Drying.—Trimming.—Fancy Shapes.—Mounting. — III. Negatives and How to Make Them.—The Paper.—Making Transparent Paper.—Making the Negatives.—Printed Negatives.—Perforated Negatives. —Negatives Made from Magazine Pictures.—Ground Glass Negatives.—IV. Nature Photography.—Aids to Nature Study.—Ferns and Leaves.—Photographing Leaves.—Perforating Leaves.—Drying Leaves, Ferns, etc., for Negatives.—Flowers.—V. Miscellaneous Photographs.—Magnetic Photographs.—Combination Pictures.—Initial Pictures.—Name Plates.—Christmas, Easter and Birthday Cards.

No. R6.—Complete outfit "Fun with Photography"................ **$0.50**
If sent by mail, postage extra........................ **.10**

FUN WITH CHEMISTRY

Chemistry is universally considered to be an interesting subject, even in school, and it is certainly an important one in these days of scientific progress. This outfit starts you at the right place and presents the elements of the subject in a most interesting fashion. The experiments are so enjoyable that you will take pleasure in doing them over and over again, and you will want to do them for your friends. You can have a lot of fun

with this set, and even if you have taken advanced courses in the subject you will find something new in these experiments. The more you know about chemistry the more you will enjoy it, for then you can more easily appreciate what a splendid outfit this is for the money.

The Outfit contains over 20 different articles, including chemicals, test-tubes, adjustable ring-stand, litmus paper, filter paper, glass tubing, etc.; in fact, everything needed for the forty-one experiments. The Book of Instructions is fully illustrated, and measures 5x7½ inches.

Fun Found Here: From White to Black, or the Phantom Ship.—Yellow Tears.—Smoke Pearls.—An Ocean of Smoke.—A Tiny Whirlwind.—A Smoke Cascade.—An Explosion in a Teacup.—A Gas Factory in a Test-Tube—Making Charcoal.—Flame Goes Over a Bridge.—A Smoke Toboggan-Slide.—Fountains of Flame.—Making an Acid.—Making an Alkali.—A Chemical Fight.—Through Walls of Flame.—An Artificial Gas Well.—A Lampblack Factory.—Steam from a Flame.—The Flame that Committed Suicide.—Chemical Soup.—A Baby Skating-Rink.—A Magic Milk-Shake.—The Wizard's Breath.—A Chemical Curtain.—Scrambled Chemicals.—And Many Other Experiments.

No. R7.—Complete outfit "Fun with Chemistry"................... $0.50
If sent by mail, postage extra......................... .10

ELECTRIC SHOOTING GAME

Shooting Animals by electricity is certainly a most original game, and it will furnish a vast amount of amusement to all. The game is patented and copyrighted—because it is really a brand-new idea in games—and it brings into use that most mysterious something called electricity. While the electricity is perfectly harmless, there being no batteries, acids or liquids, it is very active and you will have plenty to laugh at. It is so simple that the smallest child can play it and so fascinating that grandpa will want to try it.

The "game-preserve" is neatly printed in colors, and the birds and wild animals are well worth hunting. Each has a fixed value —and some of them must not be shot at all —so there is ample chance for skill. Tissue-paper bullets are actually shot from the "electric gun" by electricity, and it is truly a weird sight to see them shoot through the air impelled by this unseen force.

The Outfit contains the "Game-Preserve," the "Electric Gun," the "Shooting-Box," and the "Electric Bullets," together with complete illustrated directions, all placed in a neat box.

No. R41.—Complete "Electric Shooting Game," postpaid.......... $0.50

NEW IDEA TIT-TAT-TOE

Splendid game for two, three, or four players; great improvement upon the good old game; fascinating game instantly learned; nothing better for children's parties and progressive birthday parties; box with game-board, 12 men, directions; discount for party orders.

No. R21—New Idea Tit-Tat-Toe, sample, postpaid $0.15

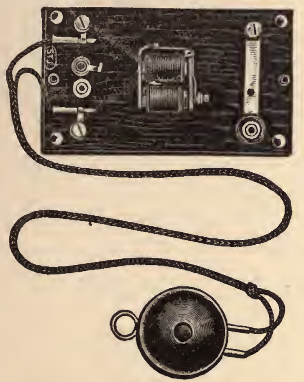
St. J. SEMI-WIRELESS

[PATENT APPLIED FOR]

A SYSTEM THAT TELEGRAPHS AND TELEPHONES

To avoid all misunderstandings we wish to state right here in the first sentence that by the name "Semi-Wireless" we do not mean "wireless," for one tiny wire must join all of the stations on any line, and two wires are still better than one.

Semi-Wireless is a new system that solves the telegraphic problem for amateurs and students. It is simpler and cheaper than the old-fashioned way, with its slow-moving telegraph sounders and relays, its heavy line-wire and its mess of bluestone batteries; it is simpler, cheaper and more reliable than wireless with its coils and condensers, its tuning-coils and transformers. In short, it is the ideal system no matter whether there are to be two or a dozen stations on the line; for every station can telegraph and telephone to every other station. Think what it means to have these two great things combined in one simple system!



No. 2550

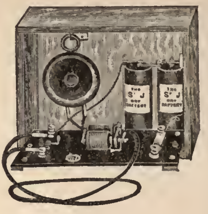
In wireless work a great deal of energy is wasted,—because it has to radiate in all directions in order to radiate at all,—and so the receiving-station gets only the smallest part of that energy. Semi-Wireless does not waste energy; it directs it, and so the messages simply have to go where they are wanted, right into every ear on the line; and that is why so little power gives such remarkable results. One dry battery will do wonders in telegraphing over a ten-mile Semi-Wireless line. The reason? No waste of energy; no horse-power needed to get a flea-power to the right spot; no dynamo wanted to get a dry-battery effect. Everything is economized, ether-waves are directed, power is concentrated and results are absolutely certain. No matter what other systems you have, you need a Semi-Wireless.

Semi-Wireless is a brand-new system that satisfies, for it telegraphs and telephones; it is the best thing ever invented for students of telegraphy and wireless, and it is best for hard service over long lines. We guarantee that Semi-Wireless will do every thing we say it will.

The instruments are strong and well made, and when once set up all expense ceases, an occasional dry battery being all that will be needed to keep it going. The "directing wire" can be strung up in a little while by the method fully explained in the book on telegraphy which is given with each instrument. This illustrated book gives full details for building and operating Semi-Wireless lines, and it also includes codes and numerous aids to learning telegraphy.

The Standard Instrument, No. 2550, is for sending and receiving Semi-Wireless telegrams with any code; and, when used with two or three good dry batteries, we absolutely guarantee that it will send and receive Semi-Wireless messages loud and clear over any properly-built line, up to 1,000 miles in length. For short lines—up to, say, 500 feet—this may also be used to telephone, but two wires should be used for the line and the words should be spoken loud and clear directly into the receiving-transmitter.

The Standard Cabinet, No. 2552, includes the Standard Instrument, No. 2550, and two batteries, all ingeniously mounted in a special stained box with sliding cover. The base of the instrument swings in and out of the box upon pivots, and the outfit is wired and ready for immediate use. This makes a splendid outfit for those who do not care for the telephone part of the system, and we guarantee that the two batteries will furnish power enough to telegraph loud and clear over the longest line you will ever want to build.



No. 2552

The Loud-Talking Long-Distance Transmitter, No. 2554, may be added to either No. 2550 or No. 2552 at any time to make a complete long-distance station for telegraphing and telephoning, connections being made as shown in the Book of Instructions. The peculiar construction of this transmitter makes the results very unusual on all ordinary lines. This transmitter is shown near the top of the Portable Set, No. 2557, mounted upon a frame-work; when sold as No. 2554, however, it is neatly mounted in a separate stained box that can be fastened up just above the Standard Instrument or the Standard Cabinet. As we absolutely guarantee this transmitter to give perfect satisfaction over all properly-constructed lines up to 500 miles in length, you will understand that for all of the ordinary lines that will be put up by amateurs the results will be more than satisfactory; in fact, you will be astonished at the way these peculiar instruments respond to the slightest whisper.

The Standard Cabinet and Transmitter Outfit, No. 2556, provides the same instruments as are furnished in the Portable Outfit, only the telegraph and telephone parts are mounted in separate boxes and not in one large box.

Our Portable Set, No. 2557, is making a great hit—and no wonder. This set is put up in a special stained box with handle and sliding cover, and it stands over 13 inches high. It includes the standard instrument, No. 2550, and the loud-talking transmitter, No. 2554, all neatly mounted and ready for use. You can connect your station to any Semi-Wireless line in one minute by passing the line-wires through the eyeletted holes to the binding-posts at the left. When you consider that we have here a complete telegraph and telephone station in one—you will see its possibilities.

When we tell you that Semi-Wireless messages can be sent loud and clear over lines 1,000 miles in length, we are only hinting at the capabilities of this wonderful invention; so you need not fear that the line you think of building may be too long. We have had official tests made of Semi-Wireless apparatus—the hardest tests that any apparatus could have—and we stand ready to prove every claim we make. With its ability to telephone and telegraph loud and clear over the same wire—and a small cheap wire at that—without the use of dynamos or other expensive current-supply, we believe that we have the greatest combined system of communication ever invented. You can't blame our customers who already have lines for being enthusiastic. One reports that he can hear conversation distinctly six feet from the receivers, and another says that messages are readable fifty feet away. We could tell you greater things than this about Semi-Wireless, but we would much rather confine ourselves to things that can be done by any-one having an outfit.

Learning Wireless.—There are thousands of young men and boys who want to learn wireless and general telegraphy and who can not afford to buy the rather expensive outfits that are needed for such work; and, on the other hand, many young men do buy complete wireless outfits and then find, to their surprise, that they cannot read the messages because they are sent so fast that it requires a great deal of practise to make them out. Semi-Wireless is the great teacher that will help just such amateurs. By having several students on the same line—and there can be fifty as well as a dozen—and by having one good operator to teach them, the whole line can be instructed at the same time and rapid progress can be made by all. The messages can be sent at any desired speed and, if the operator

No. 2557

ST. J. SEMI-WIRELESS—*Cont'd*

is provided with the loud-talking transmitter, verbal instructions can be given to all at the same time; talks can be illustrated by actual messages; the work can be made most practical. Think what a blessing such instruction will be to those just learning! A skilled operator can be found in almost every town who will be glad to give this instruction at a fixed price per hour, and when several share the expense it will be very little for each.

As the messages come flying through every receiver on the line they sound just the same as wireless, and where the line isn't over a few miles long, they can be heard without placing the receivers to the ears. This system is a great help to students of wireless because it gives just the training that is needed; and to crown the whole thing, Semi-Wireless talks as well as it telegraphs. You may be getting code one second and talk the next, so what more could be desired? On two-wire or belt lines the "calls" come in so loud that they can be heard all over a large room.

The Greatest Opportunity Ever Offered to Students.

MISCELLANEOUS SEMI-WIRELESS GOODS

List No.	Name of Article	Price	Postage Extra
2501	Coil of Insulated Copper Wire, size No. 24, for inside lines; 200 feet with 50 double-pointed tacks.	$0.25	$0.06
2505	Special Galvanized Steel Line-Wire for outdoor lines. Put up in 1, 2, 3½ and 12-pound coils. Lengths given are approximate.		
	1-lb. coil, 308 feet	.15	Express
	2-lb. coil, 616 feet	.29	"
	3½-lb. coil, 1,078 feet	.50	"
	5½ pounds, 1,694 feet	.79	"
	7 pounds, 2,156 feet	1.00	"
	9 pounds, 2,772 feet	1.25	"
	12-lb. coil, 3,696 feet	1.50	"
	17½ pounds, 5,390 feet	2.25	"
2511	Insulators, made of hard fibre; allow one for each 50 ft. of line, and 5 or 6 for each station.		
	Semi-Wireless Insulators, per dozen	.06	.01
2514	Semi-Wireless Testing-Switches for testing and grounding stations to locate breaks, etc., prepaid	.25	
2515	Clamp for grounding wires to gas or water pipes	.10	.04
1102	Two-Cell Battery-Sets	.25	.10
1103	Three-Cell Battery-Sets	.35	.15
	Cutting-Pliers for line-wires, etc	.15	.05
2550	Standard Instrument, as per cut, each station	2.00	.15
2552	Standard Cabinet, as per cut, each station	2.50	.25
2554	Loud-Talking, Long Distance Transmitter	1.50	.15
2555	Includes one each No. 2550 and No. 2554	3.50	.30
2556	Includes one each No. 2552 and No. 2554	4.00	.40
2557	Portable Set, as per cut, each station. Must be sent by express; weight, 5 lbs.	4.50	

HANDICRAFT TOOL SETS

HANDICRAFT TOOL SETS. We've had a lot of inquiries about tools to go with these new ideas in apparatus making; and as the methods of construction are quite unusual—in fact, absolutely original—we have decided to make up sets of tools that have been found to be most useful. While ordinary tools are needed for the most part, a few special tools are essential.

Time and energy are precious; don't waste either by trying to make apparatus with poor tools or with tools unsuited to the work. You will get the best value if you buy the tools in sets.

Note: We can not pay express charges on these sets, owing to the special prices given, but we shall be glad to give you an estimate of the charges to your city upon application.

TOOL SET NO. 2. PRICE $2.00. One **Steel Punch**; polished, flat end.—One light **Hammer**; polished, iron, nickel-plated; hardwood handle.—One **Iron Clamp**; japanned, 2¼-in. opening.—One **Screw-Driver**; tempered and polished blade, stained hardwood handle, nickel ferrule. —One **Vise**; full malleable, nicely retinned, 1⅜-in. jaws, full malleable screw with spring.—One **File**; triangular, good steel.—One **File Handle**; good wood, brass ferrule.—One **Foot Rule**; varnished woor, with English and metric systems.—One **Soldering Set**; contains soldering iron, solder, resin and directions.—One **Center-Punch**; finely tempered steel, and of the proper size.—One **"St. J." Special Eyeletting-Tool**; does fine work and is invaluable.—One **"St. J." Special Combination Hand-Drill and Winding-Machine**; takes drills up to and including three-sixteenths inch; finely nickeled and finished in every way; strong chuck and hollow handle for holding drills..—One **Special Threaded Spindle** for Winding-Machine.—One **Three-Sixteenths-Inch Twist Drill.**—One **Drill-Point** for small holes. These straight-shank drills are made of the best steel, properly tempered.—One **Pair of Compasses**; for marking circles on wooden bases, etc.—This set contains **16 tools.**

TOOL SET NO. 2¾; PRICE $2.75. This set contains all that is in No. 1¾ set, together with the following: One **Pair of Pliers**; 6 in. long, bright steel, flat nose, with two wire-cutters; practically unbreakable and very useful.—One **Pair of Tinner's Shears**; cut 2¾ in., hardened iron, suitable for light work.—One **Try-Square**; 6 in. blued steel blade, marked in one-eighth-in. spaces.—One **Anvil**; polished top with japanned body; very necessary for rivetting and eyeletting. This set contains **20 tools.**

TOOL SET NO. 3¾; PRICE, $3.75. This set contains the same number of tools as Set No. 2¾, the difference in price being due to the superior quality of five of the tools which replace those in the cheaper set. These five tools are: (1) Soldering Set, (2) Vise, (3) Tinner's Shears, (4) Compasses, (5) Hammer. The **Soldering Set** is larger, so the soldering iron holds the heat better than the smaller one, and this is a great help. The **Vise** is much larger and heavier than the tinned vise, and it is of superior quality, with strong polished jaws and steel screw; body nicely japanned. The **Tinner's Shears** are made of fine steel, properly tempered; cutting-blades polished, thoroughly reliable. Steel shears can be sharpened when they get dull. The **Compasses** are adjustable with screw and they lock in place; nickel-plated and of superior quality, with pen, pencil and two sharp points.—The **Hammer** is made of cast steel, weight about one pound. **20 tools.**

Handicraft Tool Sets—(*Continued*)

TOOL SET NO. 4¾; PRICE, $4.75. This set is most complete, containing nearly everything that is in the other sets, together with a number of very useful tools.—One **Steel Punch**; polished, flat end.—One **Steel Punch**, for punching larger holes.—One **Light Hammer**, polished, nickel-plated; hardwood handle; proper weight for nailing bases. —One **Cast Steel Machinist's Hammer**; ball pein and of fine quality; proper weight for punching metal straps, etc.—One **Iron Clamp**; japanned, 2¼ in. opening.—One **Large Iron Clamp**.—One **Screw-Driver**; tempered and polished blade, stained hardwood handle, nickel ferrule.—One **Ratchet Screw-Driver**; great help and saves time on some work.—One **Small Vise**; full malleable, nicely retinned, 1⅜-in. jaws, full malleable screw with spring.—One **Large Vise**, of superior quality for larger work; strong polished jaws and steel screw; body nicely japanned.—One **File**; triangular, good steel.—One **File Handle**; good wood, brass ferrule.—One **Foot Rule**; varnished wood, with English and Metric Systems.—One **Soldering Set**, same as in Set No. 3¾. —One **Center-Punch**; finely tempered steel and of the proper size.—One **"St. J." Special Eyeletting-Tool**; does fine work and is invaluable—One **"St. J." Special Combination Hand-Drill and Winding-Machine**; takes drills up to and including three-sixteenths in.; finely nickeled and finished in every way; strong chuck and hollow handle for holding drills.—One **Special Threaded Spindle** for winding-machine; greatest possible help in winding cores.—One **Three-Sixteenths-Inch Twist Drill**.—One **Drill-Point** for small holes.—One **Pair of Pliers**; 6 in. long, bright steel, flat nose, with two wire-cutters; practically unbreakable and very useful.—One **Pair of Tinner's Shears**; made of fine steel and properly tempered; cutting blades polished, thoroughly reliable, sometimes called steel "snips."—One **Try-Square**; 6-in. blued steel blade, marked in one-eighth-in. spaces.—One **Pair of Compasses**; same as in Set No. 3¾, with adjusting-screw, etc.—One **Anvil**; polished top with japanned body; very necessary for rivetting and eyeletting.—One **Hollow-Handle Tool Set**; the polished hardwood handle holds 10 tools, including gimlet, chisel, brad-awls, etc.—One **Saw**; steel frame, polished steel blade; useful for sawing off small pieces of wood.—One **Pair of Shears** for cutting paper and cloth for electromagnets, etc.—This set contains 28 **tools** besides those in the hollow-handle tool set.

SPECIAL SIX-TOOL SET; PRICE, $1.35; PREPAID, $1.80. In case you are well supplied with ordinary tools and want only the special tools needed for this work, the following outfit will be a great help. This special set contains: One **"St. J." Special Eyeletting-Tool**; this tool was devised by Mr. St. John after considerable experimenting to produce a good tool that would be cheap; it positively does as good work as an expensive foot-power machine; simply invaluable.—One **"St. J." Special Combination Hand-Drill and Winding-Machine**; takes drills up to and including three-sixteenths in.; finely nickeled and finished in every way; winds electromagnets splendidly.—One **Vise** for clamping the **"St. J."** winding-machine to the table; this is the tinned vise with 1⅜-in. jaws.—One **Special Threaded Spindle**, for winding-machine; used in winding threaded cores.—One **Three-Sixteenths-Inch Twist Drill**, the size mostly used for handicraft bases.—One **Drill-Point** for small holes.—This special six-tool set will be a splendid addition to any laboratory or workshop, and it is well worth the price, **$1.35. We will send this set by mail or express, prepaid to any point in the United States for $1.80.**

PLEASE SEE DIRECTIONS FOR SENDING MONEY

A MOTOR THAT CAN DO THINGS

The "St. J. Motor No. 1" (List No. 2201) is designed for students and others who want a small motor for experimental purposes as well as for all of the work that any small motor can do. We believe this to be the best small motor made, and we know that it can be used in more ways than any other motor of equal cost ever built. It has four binding-posts,—making it possible to energize the field or armature separately,—and so it can be used in circuits with reversers and rheostats for experiments. The speed and direction of rotation can be changed at will, thus adapting it for running toys, etc. As the binding-posts are mounted upon the frame, this motor can be taken from the base for remounting and using in many ways, and as it has a three-pole armature it will start promptly in any position. The shaft carries a pulley, and a fan can be added at any time. One cell will give a high speed, and more cells may be added, according to the work it has to do.

Motor No. 1 stands 3½ inches high. It is finished in black enamel with nickel-plated trimmings,—strong and well made. With it are furnished three nickel-plated connecting-straps, which are to be used for connecting the

No. 2201

field and armature in "series" or "shunt." So much can be done with this motor that it is simply impossible to tell it here; in fact, it is used as the basis for a whole book of 60 experiments called "The Study of Electric Motors by Experiment," and, when used in connection with the other parts of the Motor Outfits, it will give a practical knowledge of motors that no other plan can give.

These motors and motor outfits have been highly praised by electrical experts and educators as being invaluable to students. They can do everything the big motors can do, and if used with the rheostats, reversers and other apparatus in the outfits, the student will have a whole motor laboratory.

Why not get a motor that has brains and that can do tricks and experiments? Any good motor will go when you turn on the power; but that doesn't mean much when it comes to understanding things.

No. 2201—"St. J. Motor No. 1," with Wiring-Diagrams, $1.00
If sent by mail, postage extra.......................... .15

RHEOSTATS AND REVERSERS

These ingenious rheostats are made in two sizes for experimental purposes, and they are most useful for regulating the speed of motors, the brilliancy of lamps, etc., etc. Some small rheostats are so made that they change the current too gradually. It is much more fun to have the motors leap ahead a little and sing a different tune at each change of speed,—just like the big motors that are used on trolley cars and for power purposes. These instruments are made with nickel-plated brass straps, binding-posts, contact-points, etc., and they make a splendid addition to any electrical laboratory.

No. 1724

No. 1725

No. 1728

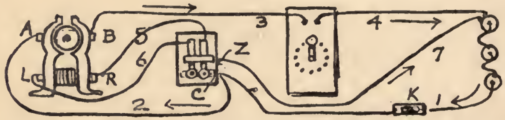
The Five-Point Rheostat, No. 1724, measures 3¼x4½ in. It is designed to regulate the speed of our "St. J. Motor No. 1" when running with two dry batteries.

The Eleven-Point Rheostat, No. 1725, measures 3¾x6½ in. It has more resistance than No. 1724, and it is so designed that it can be used with three cells for our small motors, and also for experimental work with miniature electric lamp outfits. In connection with our small lighting-plants in which the current is generated by one of our Dynamo-Motors, No. 2209, this rheostat is invaluable.

No. 1724—Five-Point Rheostat (Postage extra, 4c.)..**$0.25**
No. 1725—Eleven-Point Rheostat (Postage extra, 5c.) **.35**

This **double-key reverser** is very useful for experiments with motors, etc., because it is so constructed that it can be used in various ways. It is, really, a key, push-botton, two-point switch and a reverser combined, so it is extremely handy. No. 1728 reverser is made with nickel-plated brass straps, binding-posts, etc., all parts being mounted upon a neat base measuring 2¾x3½ in.

No. 1728—Double-Key Current Reverser (Postage extra, 3c.) **$0.25**



This diagram is one of many contained in the book on motors, and shows Motor No. 1 shunt-wound and reversible, using rheostat and reverser to secure one method of speed control.