Electricity Applied to Meccano

II.—The Dynamo and the Electric Motor

IN last month's article of this series we dealt with the production of electricity by means of primary cells and the storage of energy in accumulators. We must now pass on to the principles that underlie the production of electric current on the large scale required in everyday life.

In order to understand the generating of electric current by dynamos and the utilisation of the current in electric motors and other apparatus, it is necessary to have some knowledge of magnetism. Magnetism probably was known and studied before electricity, as the result of the common occurrence in certain parts of the world of a stone that has the peculiar power of attracting iron. This lodestone, as it is called, is a mineral containing iron, and the name magnet probably was derived from Magnesia in Asia Minor, where the mineral was found in large quantities.

If a piece of lodestone is hung up by a thread it always comes to rest pointing almost due north and south. This fact was known to the Chinese at a very early period and is mentioned by a Norwegian writer who lived a thousand years ago. The end of the stone that points approximately in the direction of the earth's north pole is known as the "north-seeking" pole, or more commonly the "north" pole of the lodestone, while the opposite end is the "south-seeking" or "south" pole. It was from this power of pointing to the north that the lodestone acquired its name, which is derived from the Anglo-Saxon word "laeden," meaning to lead.

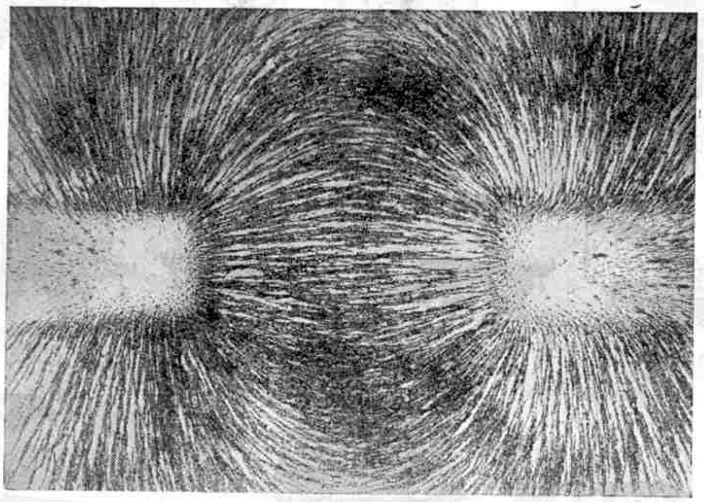

Fig. 1. Lines of Magnetic Force of Two Opposite Poles

At a later period it was found that pieces of steel could be made into artificial magnets that were better in many respects than the natural ones. The simplest method of making a piece of steel into an artificial magnet consists in stroking it repeatedly in one direction from end to end with one pole of a piece of lodestone. If the north pole of the lodestone is used for this purpose then the end of the piece of steel last touched by the lodestone will be the south pole of the new magnet. Soft iron also may be magnetised in this manner and, indeed, much more easily than steel but on the other hand it soon loses its magnetism whereas the hard steel retains it.

Pieces of iron may be magnetised temporarily without actually touching them with a magnet. If, for instance, one end of a bar magnet is brought close to but not touching the end of a piece of soft iron, the latter becomes magnetised and acquires the power of attracting iron filings or another piece of iron. As soon as the magnet is taken away, however, the magnetism of the soft iron disappears. This process is known as magnetisation by induction. It is interesting to repeat this experiment with a piece of glass, paper or wood between the magnet and the piece of iron and it will be found that these substances do not interfere with the action of the magnet. On the other hand if a sheet of iron were interposed the piece of soft iron would remain unmagnetised.

If a small magnet is suspended by a thread we shall find that like the lodestone it takes up a north-and-south position. We shall also find that if we bring near each end of it in turn the ends of another similar magnet the two north poles and the two south poles will repel one another but the north pole will attract the south pole and vice versa. Thus it is evident that whereas both poles of a magnet attract unmagnetised iron or steel the similar poles of two magnets repel one another while the opposite poles attract each other.

If a thin layer of iron filings is spread over a sheet of cardboard and a magnet is moved to and fro beneath the sheet, the filings stand up on their hind legs, as it were, as the magnet approaches them and follow it about as if pulled by invisible strings. Actually the magnet does act by means of invisible strings that are known as lines of magnetic force. These lines proceed from the poles of a magnet in certain definite directions and although we cannot actually see them it is quite easy to show how they work. In order to do this a magnet is placed beneath a sheet of cardboard or glass upon which iron filings are sprinkled thinly and evenly. The sheet is then tapped gently with a pencil. This tapping causes the filings to jump up from the surface of the glass so that they are momentarily freed from friction with it. During that momentary freedom the influence of the magnet is able to re-arrange the filings according to the direction of the lines of the magnetic force that issue from it. The filings thus provide us with a map showing the general direction of the lines of force.

By using different combinations of two or more magnets a great many very interesting maps may be made in this manner. Fig. 1, for instance, shows the lines of force between two opposite and mutually attractive poles of two bar magnets. It will be seen that the lines appear to stream across from one pole to the other. If the experiment is repeated with two similar poles the lines of force do not stream across but after proceeding a certain distance turn aside as if pushing one another away.

Any space containing lines of magnetic force is usually described as a magnetic field.

We are now in a position to understand why a freely suspended magnet always points north and south. The earth itself acts as a huge magnet having one pole in the north of Canada and the other in the antarctic continent, and a magnet points north and south because of the influence of the earth's magnetic poles upon the poles of the magnet. The earth's magnetic pole in Canada must be regarded as the south pole because it attracts the pole of the magnet that we have agreed to call the north pole.

The peculiarity of a magnet of pointing approximately north and south is made use of in the compass. In its simplest form this consists merely of a magnetised needle pivoted so as to swing freely over a card marked with the points of the compass. This form works well on land but for use on ships a more elaborate arrangement is necessary. In the mariner's compass the single needle is replaced by several thin strips of steel magnetised separately and suspended side by side. These are fastened to the underside of a circular card and suspended in a bowl made of copper, which is a non-magnetic metal. In order to keep this bowl in a horizontal position no matter how the ship may be rolling, it is supported by "gimbals," which consist of two concentric rings attached to horizontal pivots and moving in axes at right angles to one another.

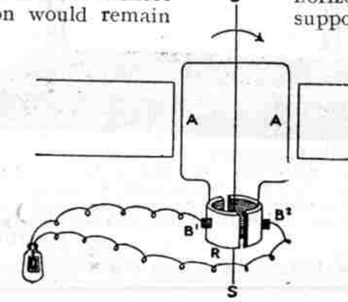

Fig. 2. Dynamo generating continuous current

The compass needle does not point to the true geographical north pole and for practical use it is necessary to know by how many degrees the direction shown by the compass varies from true north. This angle between the magnetic and the geographical meridians is called the "declination," and has been determined by careful survey for places all over the world.

The first indication of the close connection that exists between electricity and magnetism resulted from a discovery made by a Danish scientist named Oersted who found that when he held over a compass needle a wire carrying an electric current, the needle was deflected to one side or the other. Another connection between the two was discovered by Sturgeon, an English investigator, in 1823, who found that a bar of iron becomes a magnet when it is surrounded by a coil of wire through which electric current is passing. The bar regains its magnetic power only during the passage of the current and loses it as soon as the current is cut off. An arrangement of this kind is known as an electro-magnet and it plays a very important part in electrical mechanisms of almost all kinds, ranging from the electric bell to the giant crane that picks up huge masses of iron or steel, and lets them go again in obedience to the movements of a small switch that controls the current.

Another interesting fact is that a spiral of insulated wire through which a current is flowing shows all the powers of a magnet and, in addition, has the peculiar property of drawing or sucking into its interior a rod of iron. Such a spiral is called a "solenoid" and it has many valuable practical applications.

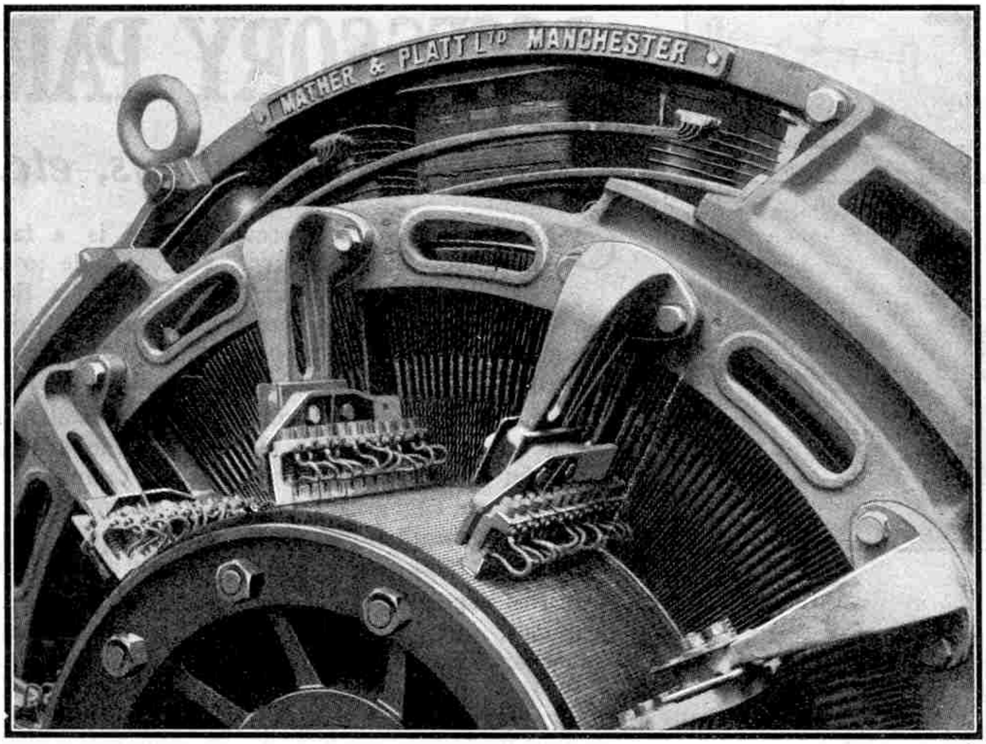

Photo courtesy of] [*Messrs. Mather & Platt Ltd.*

Fig. 3. Close-up view of large dynamo, showing the carbon brushes pressing on the copper segments of the commutator. The poles and their windings are also seen, at the top of the photograph

Sturgeon's investigations led to the even more important discoveries with which the name of the great English scientist Faraday is associated. These discoveries led to the development of the dynamo and the electric motor which to-day play an essential part in industry and transport throughout the world.

Faraday discovered that a current of electricity could be produced, or "induced" to use the correct technical term, in a coil of wire either by moving the coil towards or away from the magnet or by moving the magnet towards or away from the coil. A magnet is surrounded by a field of magnetic force and Faraday found that the current was induced when the lines of force were cut across. Making use of this discovery Faraday constructed the first dynamo. He also discovered that if an electric current is passed through a coil of wire suspended freely between the poles of the magnet, the coil revolves and this discovery led to the development of the electric motor.

Fig. 4 is a diagram of a dynamo in its simplest form. Between the poles of the magnet, N and S revolves a coil of wire A^1 A^2, mounted on a spindle SS. This revolving coil is called the "armature." Two insulated rings R R are each connected to one end of the coil, and the brushes B B made of copper or carbon each press on one ring. The current is conducted away from these brushes into the main circuit, where we will suppose it to be used to light a lamp.

Let us assume the armature to be revolving in a clockwise direction. Then A^1 is descending and cutting the lines of force in front of the north pole of the magnet, and so a current is induced in the coil and, of course, also in the main circuit. Passing on its way, A^1 reaches the lowest point of its circle and begins to rise in front of the south pole, inducing another current, but this time in the opposite direction. The general result is to produce a current that reverses its direction every half-revolution, and such a current is called an "alternating" current.

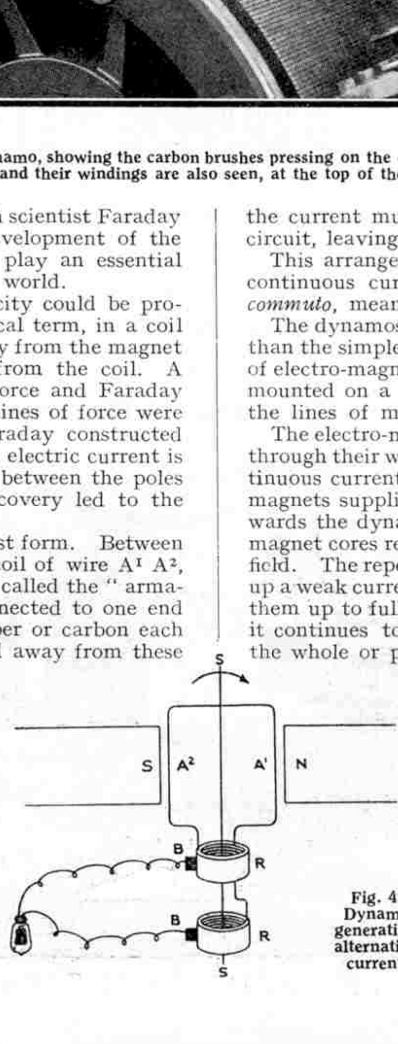

Fig. 4. Dynamo generating alternating current

In a dynamo such as our diagram represents there are only two magnetic poles and the current flows backward and forward once every revolution. By using a number of magnets, however, arranged so that the coil passes in turn the poles of each, the current may be made to flow backward and forward several times.

Alternating current is unsuitable for certain purposes, and by making a small change in the dynamo this current may be converted into "direct" or "continuous" current, which does not reverse its direction.

The difference between a direct and an alternating current dynamo lies in the rings, and the new arrangement is shown in Fig. 2. In place of the two rings in Fig. 4 there is a single ring divided into two parts, each half being connected to one end of the revolving coil. Each brush thus remains on one half of the ring for half a revolution and then passes over to the other half. Thus, during one half revolution the current is flowing from brush B^1 in the direction of the lamp. During the next half revolution the current will reverse its direction, but as brush B^1 has now passed over to the other half of the ring, the current is still leaving by it. A moment's thought, therefore, will show that the current must always flow in the same direction in the main circuit, leaving by brush B^1 and returning by brush B^2.

This arrangement for converting an alternating current into a continuous current is called a "commutator," from the Latin *commuto*, meaning "I exchange."

The dynamos used in actual practice are much more complicated than the simple device we have just described. Each one has a set of electro-magnets, and the armature consists of many coils of wire mounted on a core of iron, which has the effect of concentrating the lines of magnetic force.

The electro-magnets in a dynamo require a current to be flowing through their windings before they acquire magnetic powers. A continuous current dynamo starting for the first time has its electro-magnets supplied with current from an outside source, but afterwards the dynamo will always be able to start again because the magnet cores retain sufficient magnetism to set up a weak magnetic field. The repeated cutting of the feeble lines of magnetic force sets up a weak current which, acting upon the magnets, gradually brings them up to full strength. Once the dynamo is generating current it continues to feed its magnets by sending through them either the whole or part of its current.

What has just been said applies only to continuous current dynamos. An alternating current dynamo cannot feed its own magnets, and these are supplied with current from a separate continuous current dynamo, which may be of quite small size.

Bearing in mind what we have learned about the principle on which the dynamo works, it is quite easy to understand the principle of the electric motor. Suppose, for instance, we wish to use as a motor the dynamo illustrated in Fig. 2. First of all we take away the lamp and substitute for it a second continuous current dynamo. We (*Continued on page* 1097)

Famous Trains—*(continued from page 1059)*

at the inclination mentioned, more particularly between Gretna and Lockerbie. But this is nothing to the "Bank" itself, which rises from Beattock for 10 miles continuously at between 1 in 88 and 1 in 69. For the $39\frac{3}{4}$ miles from Carlisle to Beattock 48 minutes are allowed, but the ensuing 10 miles require 21 minutes and it is quite possible that a minute or two gained between Lockerbie and Beattock may be added to the climbing time.

In the next $2\frac{1}{4}$ miles the railway drops at 1 in 99 into the valley of the Clyde, and remains in it, more or less, all the way to Glasgow. Actually the river is crossed six times—at Elvanfoot, Crawford, Lamington, near Carstairs, Uddingston and then just as the railway enters the Central Station at Glasgow.

After Elvanfoot the fall is gradual for $10\frac{1}{2}$ miles to Lamington, and then there are undulations for 15 miles past Symington and Carstairs to Craigenhill Summit, whence there is a steep and continuous fall for $15\frac{1}{2}$ miles at between 1 in 99 and 1 in 135, to Uddingston. High speeds are seldom attained on these falling grades, going north, as the descent from Beattock Summit to Lamington winds considerably, and down from Craigenhill coalmining country is traversed, which means moderated speed on account of subsidences. So speeds much in excess of 60 m.p.h. are unlikely, and cautious travelling is amply allowed for in the schedule of the train.

Twice between Carlisle and Glasgow it is possible to take water from track-troughs, which a couple of years ago were laid for the first time in Scotland near Floriston, about seven miles from Carlisle, and just south of Carstairs, in preparation for the long West Coast runs since instituted. Eleven sets of track-troughs in all are therefore available over the $401\frac{1}{2}$-miles' journey between Euston and Glasgow.

Mention has been made previously of our departure from Carlisle at 3.50 p.m.; 4.38 p.m. should see us through Beattock and 4.59 p.m. breasting Beattock Summit, at a speed of between 20 and 25 or 30 miles an hour. At 5.17 p.m., having covered with ease the $17\frac{1}{4}$ downhill miles from Summit in 18 minutes, we are drawing up at Symington, under the shadow of the bold Lowland summit known as Tinto Hill. Passengers are not allowed to leave or join the train either here or at Carlisle—the "*Royal Scot*" is, indeed, a strictly "limited" express, conveying passengers for Glasgow and Edinburgh only—but the stop is for the purpose of detaching the Edinburgh portion, for which we shall see waiting, in all probability, a Caledonian 4-4-0 engine.

At 5.20 p.m. we are away again, and as 50 minutes proves all too ample an allowance for the $35\frac{1}{2}$ miles from Symington down to Glasgow, the chances are that, given a clear road, we shall finish our journey before time. Last time I travelled on the train we rolled into Central Station at 6.3 p.m., no less than 12 minutes early by the public arrival time of 6.15 p.m. In the working timetables the scheduled time of arrival is 6.10 p.m.; but so easy is the task of haulage to the new "Royal Scot" engines that a booking of $7\frac{3}{4}$ hours from London or even less, would cause them little concern. Let us hope that, ere long, it will be possible to travel from London to the chief Scottish cities at a throughout average speed of 50 miles an hour and that the "*Royal Scot*" will be one of the trains to do it!

Choose your own Christmas Present!

It is a wonderful sensation to sit down and study illustrations and descriptions, and select your own Christmas present. Try it!

In our pages this month there are advertisers' announcements of all kinds of splendid toys, books, and all manner of articles for giving pleasure to boys at Christmas. We are going to make at least one boy happy by giving him the very thing he wants from amongst the articles advertised in our columns.

Look carefully at *all* the advertisements and decide which article you would like the postman to hand to you on Christmas morning. Write the name of it on the top of your postcard, marking it No. 1. Then write the name of the article that you would like second best and mark it No. 2. Do this with six articles altogether, write your own name and address at the bottom in very plain letters, and send the postcard to "Christmas Presents, *Meccano Magazine*, Binns Road, Liverpool."

To the sender of the list that corresponds most nearly in order of merit with the total voting we will post the article that heads his list, to reach him on Christmas morning.

"Christmas Presents" postcards must reach us not later than 17th December.

Landing Ocean Mails—*(cont. from page 1034)*

designed so that the resulting force passes normally through the base of the tower, thus rendering extensive foundations unnecessary. When not required for use, the conveyor can be raised by the winch, swung clear of the dock by hand, and lowered into any desired position.

While the number of mail bag and parcel-post packages landed at Plymouth from ocean liners already amounts to many thousands monthly, the installation and successful working of this conveyor must tend to increase still further the popularity of Plymouth as a port of call.

Model Building Contests—*(cont. from page 1075)*

a reversing lever, steering gear, and brakes on the rear wheels. The elevation and extension of the escape are controlled by hand wheels and regulated by pawl and ratchet mechanisms.

Robert Whittingham's entry is in the form of a Meccano Orrery. Although simply constructed and using few parts, this forms a most interesting model. The rotation of the Earth and its satellite, the Moon, are reproduced, as well as the progress of both bodies round the Sun. The latter, by the way, is represented by a candle, the light from which serves to illustrate the phenomena of day and night on the Earth.

Readers will observe from the illustration that the First Prize-winning model in Section C represents a tramcar of the type used in Manchester. The method of attaching the trolley arm to the roof of the car is open to criticism, but taken on the whole, I regard this model as an excellent piece of work.

James Yates' entry is in the form of a single-deck motor 'bus. It is fitted with lamps, leaf springs, a door giving admission to the driver's seat, and another at the rear of the coach. The road wheels consist of 3" Pulleys fitted with Dunlop Tyres.

John Warren Davis, the Third Prize-winner in this section, submitted two models. One is a neat model biplane and the other is a pleasing representation of a suspension bridge.

Electricity and Meccano—*(cont. from page 1083)*

know already that when a current is sent through a coil of wire the coil becomes a magnet, having a north pole and a south pole. In the present case the coil in our dynamo becomes a magnet immediately the current from the second dynamo is switched on, and the attraction between its poles and the opposite poles of the magnet causes it to make half a revolution. At this stage the commutator reverses the current, and consequently also the polarity of the coil. There is now repulsion where before there was attraction, and the coil makes another half revolution. This process continues until the armature attains a very high speed. The operation of an electric motor is thus based on the attraction between unlike poles and the repulsion between similar poles.

Having dealt briefly with the more important principles of electricity, we shall proceed next month to describe the construction and use of some simple but essential pieces of electrical mechanism.

Toys for Christmas

Hamley's Branches are now showing a fine selection of toys and games and an interesting afternoon may be spent examining them. A good way to choose what you would like for Christmas is to take a pencil and notebook and make a list of the things you like best, then the choice can be narrowed down later.

Hamley's, by the way, have prepared a fine catalogue and if you send them your name and address, they will send a copy free of charge. This is a great help if you live too far away to visit their Showrooms. The catalogue is packed from cover to cover with hundreds of illustrations and you should be sure to mention the "*M.M.*" when asking for your free copy.