be a break in that portion of the circuit between the bell and battery which is common to both branches, we lose the control of the bell from both pushes. If there is a break, other than that at the push, in either branch outside the bell and battery, we lose the control of the bell from the push belonging to that branch.

Even a break in the circuit itself acts strictly in accordance with Ohm's law. If no current passes, it is because the resistance *interposed by the break is infinitely large, compared with* the E.M.F. available. If the E.M.F. were increased very much, a current might still pass, as in the case of the electric spark, the arc lamp, and in a lightning discharge, the strength of the current in each case being strictly proportional to the E.M.F. divided by the resistance; but it is always necessary to be sure that we have *all* the resistance of the circuit included in our calculation. Not infrequently the resistance of the generator itself, of the body from which the current proceeds, is of very great importance. Often, too, matter which we do not want, such as dust or dirt, interposes itself in the circuit, and before we can apply the law correctly, we must know this resistance, and it must take its place in our calculations.

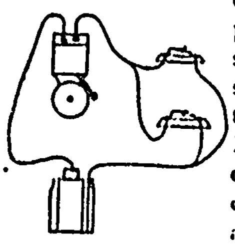

Fig. 7.

It may perhaps be as well here to give the rule for determining the joint resistance of two or more derived or branch circuits. Supposing that we have a source of electricity, with a certain E.M.F. available at a certain point, from which branch out several derived circuits, as they are called. The current in each branch is determined strictly by reference to Ohm's law; that is, the E.M.F. being the same, all we have to do is to divide it by the resistance in each case. A dynamo feeding a number of incandescent lamps is a familiar instance, and easily understood. Suppose that the E.M.F. is the same at the terminals of all the lamps; then, if the resistance of each lamp is the same, the current passing through each *will* be the same, but if their resistances be different, as when they are of different candle-powers, or different patterns, then we calculate the current in each case by the formula, and having obtained all the currents, add them together, and apply the formula $R=\frac{E}{C}$ to the whole, and we have the joint resistance of the group.

To take an example, suppose we have a dynamo, or an electric light service with 100 volts difference of potential, and that we have lamps whose resistances when burning are respectively 400 Ohms, 200 Ohms, 100 Ohms, 50 Ohms, 10 Ohms. These lamps will take ¼ Ampere, ½ Ampere, 1 Ampere, 2 Amperes, and 10 Amperes. The sum of these $10+2+1+5+{\cdot}25=13.75$ Amperes, and their joint resistance$=\frac{100}{13.75}=7{\cdot}57$ Ohms.

The joint resistance of a number of branch circuits, whose resistance is equal, as, say, a number of incandescent lamps, all of the same pattern and of the same candle power, is found by simply dividing the resistance of one branch by the number of branches, thus, if we have 20 lamps, each of 200 Ohms resistance, their joint resistance is equal to $\frac{200}{20}=10$ ohms, when they are arranged as branch circuits emanating from the same points. Of course, in actual work, you do not always have all the branches emanating from the same points, and it is therefore generally more convenient to calculate the currents than the resistances.

For two branch circuits of unequal resistance, the joint resistance may be found by multiplying their resistances together, and dividing the product by their sum. Thus, if we have two resistances 10 and 2, their joint resistance$=\frac{10\times2}{10+2}=\frac{20}{12}=1{\cdot}6$ Ohms. For any number of branch circuits greater than two, the formula becomes somewhat complicated, and the method given above, of finding the current strength in each case, will be found simpler

This matter will be explained more fully when dealing with electric lighting circuits. It may be mentioned, however, that the rule applies to such branch circuits as the insulation of telegraph or telephone lines, and to that of cables for electric lighting or transmission of power; each unit of length, say a mile, or a hundred yards, and each pole, being considered as a separate branch. Thus, if the insulation resistance of a telegraph or telephone line that is to say, the resistance between it and the earth be 1,000,000 Ohms for 1 mile, for 1,000 miles it would only be 1,000 Ohms, and the leakage path, as will be explained later, would be very serious, as, with ordinary telegraph wire, it would be less than that of the proper conducting path.

The Earth. In connection with the electric circuit, the Earth, or Ground, as the Americans term it, often plays a very important part.

It has been explained that the electric circuit consists of a path, from the generator, through the apparatus that is to be worked and that which is to work it, back to and through the generator itself. It will be seen that the apparatus to be worked the bell, lamp, or whatever it may be and that which is to control it say the push, key, or switch may be some distance apart. This requirement would necessitate two wires or conductors between the two places, unless some other path could be found that would perform the office of one wire, and carry the returning current.

The crust of the earth a river or stream, the metals of a railway, the water and mud of a dock, the gas or water service of a town, may each form this path, and thus save one wire or cable. But it must be distinctly borne in mind that "earth," or "ground," as anything which answers this purpose is technically called, is subject to Ohm's law, exactly as the wire or cable which forms the other part of the circuit is. If the resistance of any part of the earth circuit is high, it will weaken the current, exactly as a bad joint would, or a small wire. Thus, if you make connection to the gas-pipe, and there happens to be a *good gas* joint; but, as often happens, a bad electrical joint; between one of the feed pipes and the main you get what is technically known as "bad earth;" or, in other words, you have a resistance in the circuit that you had not bargained for, and which must be avoided if possible. So also with reference to the rails; if the connections between the rails at the fish-plates are not electrically good, a like result will follow.

It must be borne in mind, too, that the resistance of the earth circuit must be proportionate to the current that is to pass. Thus, what would be good earth for a telephone current may be very bad earth for an electric lighting current. Very large iron water pipes, even, might offer so much resistance at their joints as to be quite unsuitable for electric-lighting currents of even moderate strength.

Another important point in connection with earth is its variability under different physical conditions. If the crust of the earth be used, for instance, in very dry weather, or in frosty weather, the resistance may be almost infinite, as the conducting path consists of the moisture in the pores of the earth. Again, a dock with 20 feet of water in it would afford a good conducting path, whereas the dock empty might not.

It will be easily understood, too, from what has been said on the laws of resistance, that it is of importance to have a large surface in contact with the earth, or whatever may be used for a return, as the resistance offered by the earth will vary directly as the distance between the two surfaces, and inversely as their sectional area. It is also of importance that the earth-plate should be proportioned to the current that is to pass, and that it should be subject to as little chemical action as possible. Under the very best conditions there will be some resistance at the surface of the plate, where it is in contact with earth; and that resistance will generally increase, owing to chemical action. It is therefore wise, in laying down electrical apparatus, when using earth, to allow for this, and to make your earth connections very much larger than they otherwise would have to be, or than a consideration of theory simply would dictate; that is to say, the theory that would apparently apply at the time the plate was laid down.

The earth is, of course, subject to the same laws of derived circuits as other conductors; and we may expect that if a portion of the earth's crust, or a stream, gas or water service, form part of several circuits, portions of current from one circuit will occasionally find their way into other circuits; and accordingly we find this the case with telephone circuits, it being most difficult to prevent messages being heard in wires not intended for them, owing to their passage by earth. This is always more marked where earth is bad, or of high resistance.

(To be Continued.)