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# Researches on Bell's telephone

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air near the cannon. Evidently a musical sound of low intensity must be used for a correct determination of the velocity of sound. —Silliman's *American Journal*, February 1879.

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RESEARCHES ON BELL'S TELEPHONE. BY HENRI DUFOUR.

The principles on which the construction of Bell's telephone is based are direct consequences of the phenomena of induction and electromagnetism; and from theoretical considerations all that passes in that instrument can be foreseen. When it is employed we are struck, on the one hand, with the minuteness of the vibratory motions necessary to produce magnetic modifications of the magnet and the induction resulting from it, and, on the other, with the relatively great intensity of the sounds produced.

It seemed to me that it would be interesting to verify upon a few instruments the principal phenomena which theory enables us to foresee, and to seek out some of the causes which may modify them.

The instruments employed were constructed by M. J. Cauderay, at Lausanne. The mean length of the magnet was 127 millims., the thickness of the vibrating plate from 0·159 to 0·175 millim. The induction-coil contained 46 metres of wire of 0·3 millim. thickness.

*Intensity of the Currents.*—The maximum intensity observable is obtained by pressing on the vibrating plate so as to bring it into contact with the soft-iron termination of the magnet; the displacement it thus undergoes is about 1 millim., and produced a deflection of 7–8° upon the galvanometer which I used. An equal deflection in the opposite direction is observed when the plate resumes its initial position.

The movement of the plate towards the magnet produced an inverse induced current in the three instruments which I tried, the pole of the magnet being in fact behind the coil through which passed the cylinder of soft iron.

For the purpose of knowing if the two currents, direct and inverse, possess an appreciable difference of intensity, the wires of the telephone were put into communication with two carbon electrodes dipping in water, and which could be connected with the galvanometer by means of a commutator. A great number of vibrations of the plate were produced, so that a series of induced currents, direct and inverse, traversed the liquid; the electrodes connected with the galvanometer gave no polarization-current. From this we may conclude that the difference of intensity of the two currents is very slight. In the construction of the telephone, therefore, no account is to be taken of the action which this difference may in time exert upon the magnetization of the bar.

Two of the instruments employed had poles of opposite names submitted to the action of the coil; and when joined they worked as well as those which are symmetric.

*Intensity of the Magnetism.*—The variations of intensity of the agnetism were ascertained in the following manner:—The north pole of the magnet of a Weber's magnetometer was submitted to the simultaneous action of the south pole (surrounded by the coil) of a telephone A and the south pole of a magnet; these two instruments were placed so that the bar of the magnetometer was in equilibrium between them. A second telephone, B, was in communication with A. The movements of the mirror of the magnetometer were observed by the ordinary method of reflection of the divisions of a rule in the field of a telescope.

A pressure exerted upon the plate of B permitted a slight displacement of the magnet to be ascertained; but the movement was too small to be measured; its direction was always that which the theory caused to be foreseen.

*Vibrations of the Plate.*—Some attempts were made to determine the vibrations of the plate. The first method employed consisted in transmitting the vibrations to a gas-flame. For this purpose the wide-mouthed bell of the telephone was replaced by a cylindrical one of small capacity. A cork, pierced with two holes through which passed two kneed tubes of glass, bounded within the cylinder a sort of little chamber comprised between the front face of the vibrating plate and the hind face of the cork. The illuminating-gas entered through the first tube, and issued, forming a small flame, at the extremity of the tapering second tube; so that the whole constituted something analogous to the manometric capsules which M. König places upon the pipes.

Every vibration of the plate is betrayed by a movement of the flame when the induced currents employed are those produced by a small Dubois-Reymond coil, even when the exterior coil is at 2 centims. from the extremity of the inducing coil. The currents produced by the voice in a second telephone cause no variation in the height of the flame.

The result was equally negative when a small mirror was borne on a kneed lever with its end resting on the vibrating plate. A ray of light reflected by the mirror did not appear to be displaced under the influence of the vibrations produced by the voice.

Finally, I tried to produce coloured rings between the vibrating plate and a lens placed upon it. For this a very thin piece of glass (Deckgläschen) was placed upon the vibrating plate, in contact with the slightly convex lower face of a lens. The sounds were transmitted by the instrument, although weakened. The coloured rings were observed through a telescope furnished with a reticule.

The displacement of a bright ring to the following dark one is produced by a difference in the thickness of the stratum of air equal to a quarter of a wave-length; that is to say, a change in the position of a yellow ring will be ascertained for about 0·000143 millim. displacement of the plate. This displacement is manifested by a diminution in the distinctness of the rings, which oscillate about their normal position. The displacements are observed very distinctly by employing the induced currents of a Dubois-Reymond coil; but it has not been possible to verify them for the currents produced by the voice.

Having heard it said that two telephones the localities of which have very different temperatures do not work well. I desired to put the matter to the test by direct experiment. One of the instruments was left during several hours exposed to a temperature of $-18°$, while the other passed the same time in an enclosure heated to 40° C. The two instruments, put in communication, transmitted speech perfectly.

As soon as the telephone was employed on the telegraph-lines, the action was remarked which is exerted upon the instrument by the currents used to work the Morse apparatus, and passing in wires near that which connects the two telephones. This action is attributable to an induction-phenomenon, to a deflection, or perhaps to both causes combined. I have tried directly at what distance an intermittent current can produce an induced current appreciable with the telephone.

Two copper wires, perfectly insulated, were stretched parallel over a length of 15·2 metres, and at distances varying between 15, 35, and 45 centimetres. One of the wires joined the pile and the manipulator with the receiver of a Morse apparatus; the earth-line was formed by the gas-pipes. The two extremities of the other wire communicated directly with the telephone. The current employed produced a deflection of 60° on a telegraph-compass. Under these conditions all the motions of the manipulator were distinctly perceived; and I am persuaded that a telegraphist would have understood the signs produced by the manipulator, even when the distance between the two wires was 45 centimetres.

It may hence be concluded, therefore, that on telegraph-lines the noise heard in the telephone when a message traverses a neighbouring wire may be attributed, at least in part, to induced currents. This experiment may have a certain interest in the lecture-room, to show at what distance an induced current can be produced. In this respect the telephone is much more sensitive than the galvanometer.—*Bibliothèque Universelle, Archives des Sciences Physiques et Naturelles*, No. 1, 1879, pp. 91–95.

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## HARMONIC ORBITS.

*To the Editors of the Philosophical Magazine and Journal.*

Gentlemen,

M. Th. von Oppolzer's "Vulcan"-orbit (*Comptes Rendus*, Jan. 6, 1879) represents another of my predicted harmonic orbits:—

| | Distance. | Time. |
|---|---|---|
| Von Oppolzer........ | ·123 | 58·8 days. |
| Chase, prediction .... | ·120 | 58·1 „ |

This leaves only one "missing link" in my triple series of principal harmonics, extending from $\alpha$ Centauri to the Sun. There are many secondary harmonics, indicating possible asteroidal positions. One of these has been confirmed by Mouchez's second Watson orbit.

Faithfully yours,

Haverford College, Pennsylvania
February 10, 1879.

Pliny E. Chase.