



## XI. The experimental comparison of coefficients of induction

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standard measure. Therefore, in making the coils, there is no necessity to count the number of turns exactly, or to lay them with the utmost accuracy: they may be wound in the ordinary way, and then a hundred machines or more connected together, with the main circuits in series and with the derived circuits in series, and a current sent from a suitable source through each series; then, if there is one meter which has been standardized by careful experiment, all the rest can be regulated, just as clocks are, by screwing down the weights X X of those that are going fast, or screwing up the weights of those that are going slow.

If in the foregoing paper any of the apparatus is not as fully described as it might be, I must plead as an excuse an endeavour to occupy a reasonable space with an account of what is essentially one invention.

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XI. *The Experimental Comparison of Coefficients of Induction.*  
By HERBERT BARFIELD, B.Sc.\*

OF all electrical investigations, the experimental comparison of coefficients of induction is one of the most difficult to carry out with accuracy; and it is doubtless most desirable that we should be able to compare such quantities much more accurately than has been hitherto possible. The usual methods, as far as their general arrangement is concerned, are in all probability not capable of improvement; but, as carried out, there is one modification applicable to all of them, by which the sensitiveness can be vastly increased. This modification is in the use made of the galvanometer. Hitherto it has been usual to observe the throw of the needle due to the passage of the quantity of electricity in one transient current; but if, instead of doing this, we pass through the galvanometer a number of such quantities in rapid succession and (after the manner of Siemens and others) observe the permanent deflection of the needle, we shall find this far greater than any throw attainable by even the most suitable apparatus.

In fact, the permanent deflection due to a certain number of transient currents per second may be compared with the throw of the needle due to one of them, in the following manner:—Let

H represent the magnetic force acting on the needle,  
G the galvanometer-constant,  
M the magnetic moment of the needle,  
 $\tau$  its time of vibration,

\* Communicated by the Author.

Then

$$Q = \frac{H\tau}{G\pi} 2 \sin \frac{1}{2} \theta,$$

$$nQ = \frac{H}{G} \tan \phi;$$

$$\theta = \frac{G\pi}{H_T} Q, \quad (1)$$

$$\phi = \frac{G}{H} \times n \cdot Q \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\frac{\phi}{\theta} = \frac{n\tau}{\pi}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Now, since  $\frac{\pi}{\tau} = \sqrt{\frac{MH}{A}}$ , equation (1) may be written

$$\theta = Q \cdot G \cdot \sqrt{\frac{M}{HA}} \quad (4)$$

Now, by diminishing  $H$ ,  $\tau$  may readily be made as large as  $2\pi$ , in which case the relative sensitiveness of the two methods would be given by the equation

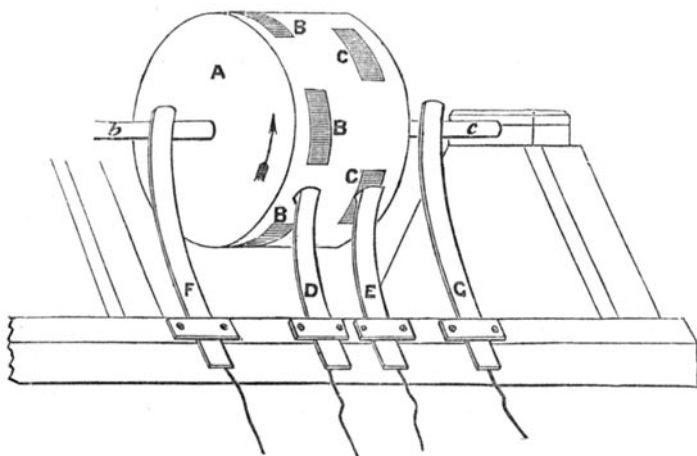
$$\phi = 2n\theta, \quad (5)$$

From this it would appear that the value of  $\phi$  is only limited by that of  $n$ . This latter quantity, again, cannot exceed a limit determined by the duration of the transient current. This duration Blaserna gives as  $\frac{1}{5000}$  second, or thereabouts, in one of the cases investigated by him; but the capabilities of

the apparatus would fix a limit far before any such speed was reached. It does not, however, appear to be beyond the mark to say, that the sensitiveness could be in this method made fifty times as large as that of the ordinary mode of experimenting.

The conclusion expressed in equation (3) has been *experimentally* verified by comparing  $\phi$  and  $\theta$  with the following arrangement:—A single Leclanché cell sends a current through the primary of a certain pair of coils. The secondary is connected up to the galvanometer; and the induced current at breaking is used to deflect the needle.

To obtain a constant succession of transient secondary currents in the same direction, the apparatus shown in the sketch is used:—A is a cylinder of hard dry wood  $5\frac{1}{2}$  inches in diameter, which rotates on its axis  $b c$  in the direction of the arrow. On the surface of A are fixed the brass strips B, C, five in each row: the pieces B are in metallic connexion with each other and also with  $b$ ; similarly the pieces C are con-



nected to the other end of the axis  $c$ . F, G are springs keeping an electrical contact with  $b c$  respectively whilst the axis rotates. D, E are springs pressing firmly on the cylinder, and making contact with the brass strips when they pass underneath. F, D are inserted in the primary circuit; E, G in the secondary. Thus the secondary circuit is only closed between each break and make of the primary; and only the induced current at break flows in it.

It is found that when the cylinder is rotated, a steady deflection of the needle is obtained, which increases with the speed of rotation, as equation (2) leads us to expect.

With the coils mentioned above and with one Lechanché in the primary,  $\theta$  was 13 scale-divisions (the galvanometer being shunted),  $\tau$  was  $7\frac{1}{2}$  seconds, or about  $2\pi$ . When the cylinder was making about 4 revolutions per second (giving 20 breaks per second),  $\phi$  was found to be a little over 500; that is, the light was off the scale.

Now equation (3) gives

$$\phi = 2n\theta = 520.$$

This shows that a value of  $\phi$  enormously in excess of  $\theta$  may be obtained; and though the experiment is only a rough proof of equation (3), it serves to show the greatly increased sensitiveness obtained.

Other experiments of a similar nature were made; but, being merely confirmatory of this, they need no further mention. It is possible that a powerful vibrator might with advantage be substituted for the rotating cylinder; and this would be completely self-acting; but it is doubtful whether it would be easier of manipulation than the cylinder, which can be very conveniently worked by a treadle, thus leaving the hands quite free to adjust the resistances.

In using the rotating cylinder with the bridge, E G would be inserted in the "bridge wire;" and since that is thereby broken whenever the battery is on, the effect due to the induced current is separated from that due to any very slight derangement of the balance—a great advantage when it is remembered how troublesome the presence of this latter effect is liable to be with the ordinary arrangement.

Derby, December 30, 1881.

## XII. *On Sound-Shadows in Water.* By JOHN LECONTE\*.

1. **M**ORE or less perfect sound-shadows thrown by hills, buildings, piers, and other obstacles to the transmission of aerial vibrations, must be within the experience of all. Nevertheless the boundaries of such shadows are so imperfectly defined, that they can hardly be compared, except in a general way, with those of light. Moreover, in some cases the obstacles placed in the route of the sound-waves, being elastic, propagate more or less perfectly the sonorous vibrations of the air through their thickness; so that, under these conditions, it is similar to producing a light-shadow by means of a transparent or translucent body.

2. But even in cases in which the sound-vibrations in air are not sensibly transmitted through the intervening obstacle

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