The City and Guilds of London Institute are doing work of immense value, and they not only reach the artisan classes and the apprentices, but carefully lay out a programme having some regard for their actual requirements. But they cannot help doing higher work at the same time, and there is a strong temptation to develop this at the expense of the strictly technical teaching. A difficulty of a similar character has been met with in the building of industrial dwellings. Philanthropists, shocked at the dirt, squalor, and overcrowding in the slums, raised large blocks which they imagined to be excellently suited for the poorest classes, who, it was thought, would speedily flock to them. But the so called sub-professional class were more ready to occupy them, and the dwellers in the slums were found not only to be unwilling to change their mode of life, but to be unconscious of some of its worst evils. No one grudged the use of this accommodation by clerks and governesses, but until closer attention and further experience showed how these buildings should be constructed, the misery which originally excited the philanthropy was not touched.

A priori reasoning is as likely to miss the mark in the matter of technical education, as it is in physical science. If the premises be true, and the reasoning be accurate, some real result will be reached; but it may not be the one desired. The method of experiment, nearly always the more costly, is undoubtedly more sure. Such experiments have been made, and a study of their results is very interesting. A most important example is to be found at the Polytechnic in Regent-street, which, begun in 1878, was transferred to its present quarters in 1882. In that year Mr. BESANT's "All Sorts and Conditions of Men" was published, and everyone knows how the ideal People's Palace was soon realised with most of its pleasant details in the Mile End-road. For various reasons, it was soon found that the leading principle of recreation was apparently impracticable, and was probably before its time. A large investment was made in bricks and mortar, and such an investment, instead of yielding interest, entails a considerable cost for up-keep. Endowment was either forgotten or it was imagined that the scheme would pay its own way. When serious difficulties arose, the Drapers' Company and the Charity Commissioners came to the rescue, and it was recognised that, while the East Londoner's "capacity for innocent enjoyment" had not been clearly estimated, there was no doubt that the work-a-day departments in which book-keeping and shorthand were taught, were not only thoroughly appreciated, but were nearly, if not altogether, self-supporting. This result is instructive, and the details of the experience which such important experiments provide have not been lost sight of in the movement for establishing polytechnics and technical institutes in the more crowded parts of London. It is clearly recognised, in the first place, that, as with the highest branches of learning, education cannot be self-supporting, but must receive external assistance. The scope of the work has in several cases, and we hope will in others, be strictly limited to the classes for whom it is intended. Thus, we understand that at the People's Palace a condition for receiving a lad for training as a mechanic is that his parents do not earn more than £200 a year. Many persons will object to such a limitation, but the case is very similar to that of a hospital, which is not intended for, and is justified in rejecting, those who are able to command the services o a doctor. But such limitations are, to a certain extent, artificial, and the true way to reach and to retain the young artisan is to discover, by most careful observation, his exact requirements and those of the class to which he belongs. A scholarship by which, as by a stepping-stone, some exceptionally brilliant student may be passed on to a higher institution, will not necessarily tempt either the teacher or his class to aim too high, and need not in any way introduce the very inexpedient system of payment by results.

Having set on foot a course, or a number of courses, of technical study and training, whether for boys and girls between their schooling and their trade, or for apprentices after their work, recreation naturally follows, and a systematic and well-organised department is to be found in connection with all the polytechnics, though assuming different orders of importance in various localities.

If the complicated difficulties of piece-work could be overcome, and each artisan, after a good training at a technical institution, could, as *The Times* of Monday says, come to love excellence for its own sake, and be proud of his power of producing it, there would be but little difficulty about long hours, and there would, if he desired it, be plenty of time for recreation. By the better training which is now being provided, the quality of the work done should constantly improve, and the revival of the element of personal pride of the worker in his own handiwork may reasonably be looked for; a pride which is stamped on the best workmanship of to-day, but which was far more prevalent and characteristic before the days of trades unions. A more noble ideal than is taught in Hyde Park would be a trades union in which every member must have passed through a technical institute, and must after he has served his time, show, and afterwards maintain, a certain proficiency in his craft.

THE HISTORICAL DEVELOPMENT OF THE INDUCTION COIL AND TRANSFORMER.

BY DR. J. A. FLEMING, M.A.

(Continued from page 302.)

§ 15. **Foucault's Experiments with Two Coils.**—In the *Comtes Rendus* for 1856 (Vol. XLII., p. 215), Foucault describes an interesting experiment which he made with two Ruhmkorff induction coils. He desired to obtain long sparks by adding together the potential of two induction coils. With this object he joined the primary circuits of two similar coils in parallel, and operated them by the current from one and the same battery. Under these circumstances the contact breakers did not vibrate in step, and the secondary spark length, resulting from joining the two secondary circuits in series in the proper way, was not the sum of the lengths of the separate secondary sparks. He discovered an ingenious way of making the contact breakers keep in step. This was effected by joining a piece of wire across from the end of one primary coil to the similar end of the other, this junction being effected between the contact breaker and the beginning of the primary coil. When this was done each hammer kept the other in step with itself, and, on joining up the secondary circuits in series in the proper manner, he obtained a secondary spark double in length (viz., 18 or 20 mm.) of that of each coil separately.

§ 16. **Stöhrer's Induction Coil.**—In 1854 Emil Stöhrer directed his attention to the improvement of the induction coil,* and produced a form of coil which is represented in Fig. 23. The instrument consisted of a primary wire and core of divided soft iron arranged in a vertical position, the iron wires being of 1mm. diameter, and standing loosely in a cylinder of wood so that they could be removed one by one if desired. The iron wires were varnished with shellac. The primary coil consisted of six layers of double covered wire 1mm. in diameter, the height of the whole spiral being 20 centimetres, and its diameter over all 50mm. The secondary coil consisted of three independent coils wound

* See *Poggendorff's Annalen*, May, 1856; also *Phil. Mag.*, 1857, Vol. XIII., 4th series, p. 55.

on separate bobbins made of varnished paper with cheeks of pear-tree wood. The wire was insulated with silk and well varnished, and insulated with a mixture of wax and resin. Stöhrer employed an independent electro-magnetic contact breaker, and a condenser of which the dielectric consisted of waxed cloth. He obtained good secondary sparks 12 or 14 "lines" in length. He tried producing, as Sinsteden had suggested, an arc light between coke points by means of the secondary discharges, but he was not aware of the previous results of Callan or of Page in this respect, and his coil evidently furnished too small a "quantity" of current to enable him to obtain an arc.

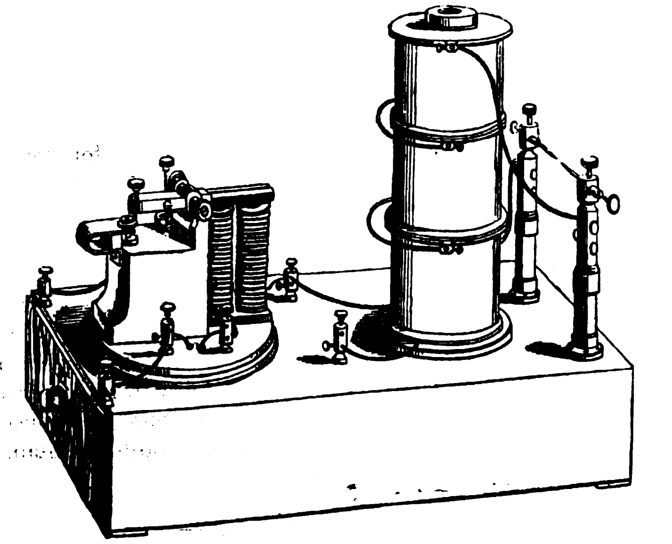


Fig. 23.—Stöhrer's Induction Coil (1856).

§ **17. J. N. Hearder's Induction Coils.**—Mr. J. N. Hearder, of Plymouth, began, in December, 1855, the construction of induction coils, and his Papers describing his work are to be found in the *Philosophical Magazine* for November and December, 1856 (4th series, Vol. XII., p. 377).* Hearder had his attention drawn to the subject by the Paper of Grove in 1855, to which reference has been made already, on the employment of a Leyden jar in connection with the secondary circuit, and this Paper stimulated him to examine the construction of Ruhmkorff's induction coil. After many experiments he was successful in producing a coil for which he obtained a silver medal from the Royal Cornwall Polytechnic. It appears that up to the time of Hearder's experiments he (Hearder) had not, apparently, seen any one of Ruhmkorff's induction coils capable of giving a greater length of secondary spark than three-quarters of an inch. Hearder adopted sheet gutta-percha as his insulating material for the secondary coil, and he describes the chief differences between his own and Ruhmkorff's coil as follows:— He says (*Phil. Mag.*, Vol. XIV., 4th series, 1857) that Ruhmkorff's secondary wire was insulated with cotton, whilst he used silk-covered wire. Ruhmkorff employed shellaced paper between the layers of the secondary coil, whilst he used sheet gutta-percha or thin vulcanised sheet india-rubber. He also claims that he improved the iron core by using smaller iron wires than Ruhmkorff, and that, in place of oiled silk for the condenser dielectric, he substituted vulcanised india-rubber, gutta-percha, or varnished cartridge paper. He also states that he improved the contact breaker by using a stiffer spring, the rate of vibration of which he could alter, within certain limits, at pleasure, by means of a screw.

Hearder noted particularly the limitation imposed by the tendency to discharge from layer to layer of the secondary coil over the ends of the layers of insulator, and he prevented this by extending the sheet gutta-percha placed between the several layers of wire a good way beyond the wire windings, so that the discharge would have to take a longer path through air to get round. A considerable controversy sprang up between Mr. J. N. Hearder and another improver of the induction coil, Mr. C. A. Bentley, as to who was the first to suggest these modifications, and was continued with some bitterness between them (see *Phil. Mag.*, Vol. XIII., 1856, p. 325). Bentley's description of his coil is to be found in the *Philosophical Magazine* for 1856 (Vol. XII., 4th series, p. 319). He constructed a coil capable of giving secondary sparks two inches long in air when the primary current was produced by four or five Grove's cells. Bentley also adopted sheet gutta-percha for the insulation of the various layers of the secondary coil, but whether before or after Hearder it is difficult to say. He employed an electro-magnetic break having a very stiff spring to the hammer, the time of vibration of which he could vary at pleasure. He used also a condenser made of tinfoil and varnished paper.

Hearder constructed about this time a coil some 12 inches in length, in which the secondary circuit had a length of three miles, and from which he obtained secondary sparks about three inches in length. He noted that if the discharge was taken between fine platinum terminals not more than 0·5 inch apart, the negative terminal became white hot very soon, and began to melt. He made many experiments on discharges in air and in vacuo between terminals of different forms.*

Hearder published a Paper in the *Philosophical Magazine* for 1857 (Vol. XIII., p. 325), in which he makes many observations on the heating power of the secondary discharge, both when the terminals were connected to a Leyden jar in the manner described by Grove, and when they were not. He found that whereas the simple secondary current could not, under certain circumstances, heat a few inches of platinum wire red hot, the mere interposition of a Leyden jar across the secondary terminals caused the platinum wire to be heated to redness, or to be fused, thus showing an increase in the quantity of each discharge.

Bentley asserted that he had independently adopted these same improvements as Hearder, and that, by following this mode of construction, Mr. Ladd had obtained sparks 4½ inches long. The points at issue between these inventors are not very important except as showing that several minds had addressed themselves to improving Ruhmkorff's coil, and that the causes limiting the sparking distance were gradually being generally understood.

§ **18. Ritchie's Induction Coils.**—Mr. E. S. Ritchie, of Boston, U.S.A., began apparently to study the construction of the induction coil in or about 1857, and, probably, not knowing what had been done by Poggendorff, he again brought forward the suggestion of insulating the secondary coil vertically instead of horizontally. A Paper by Ritchie is to be found in *Silliman's American Journal of Science* for November, 1857 (Vol. XXIV., p. 45). In this Paper, Ritchie enumerates the causes of the difficulties met with by Stöhrer and Hearder in lengthening the secondary spark beyond three inches, and proceeds to describe his own improvements. Ritchie wound the secondary wire on a glass tube, beginning near one end and winding the wire in a sort of very steep cone (*see* Fig. 24). When this cone of wire was wound on, a *washer* or disc of vulcanised rubber was slipped on and cemented with beeswax and resin, and the end of the wire passed down and insulated with a strip of rubber, and then another cone of wire built up until the whole tube was wound full of coils, insulated from each other with washers or discs of sheet rubber. With a helix so made of 7,000ft. of wire Ritchie obtained a secondary spark of 2½ inches, and with 30,000ft. of wire a spark of six inches. He supplied the above coils with condensers, having respectively 30 and 75ft. of coated surface, the insulator being thin sheet gutta-percha. He found that it was very important to get high insulation between the primary and the secondary coils, and that it was necessary to overlay the glass tube on which the secondary was wound with many sheets of gutta-percha tissue. In 1859 Ritchie sent to France, by MacCulock, a coil made in the above way, which gave secondary sparks 35 centimetres in length, which astonished the French savants, they, as Du Moncel says, not knowing nor caring to know the results of the previous work of M. Jean. A recent coil, made about 1860 by Ritchie, is figured by Du Moncel in

* It is stated in Noad's *Manual of Electricity*, Part II., that Hearder began his work on induction coils in 1846, but this is incorrect.

* See *Phil. Mag.*, Vol. XII., 4th series, 1856, pp. 377 and 443.

his book on the Induction Apparatus of Ruhmkorff, and is shown in Fig. 25. The coil was 120 centimetres in length, and contained 52 kilograms of wire, and weighed in all 112 kilograms. The bobbin was composed of two separable portions, and, in fact, was two distinct coils. The core was a bundle of iron wires each one millimetre in diameter. The primary coil was 60 metres long, and constructed of wire five millimetres in diameter. The secondary coil was 71,200 metres, or nearly 45 miles in length, and constructed of wire ·18 millimetre in diameter. It was made of the purest copper, covered with silk, and wound in a series of flat helices of one thickness of wire, the different spirals being insulated with paraffined paper.

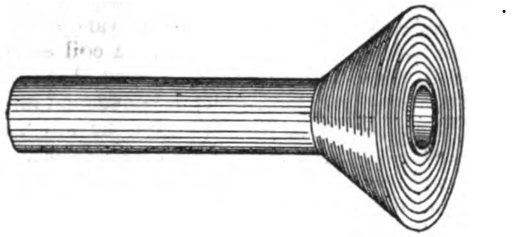


Fig. 24.

The insulation between the primary and secondary coils was separated by a glass tube, and layers of vulcanised caoutchouc placed over it. The condenser consisted of sheets of tinfoil of 30 square decimetres in area, insulated with oiled silk, and arranged so that more or less of the surface could be utilised. The interruptor was a hammer-break, actuated by an electromagnet separate from the coil. The length of each section of the bobbin was 33 centimetres, and the external diameter of the coil 22·8 centimetres. With the currents from three large bichromate cells the secondary sparks were 53 centimetres in length.

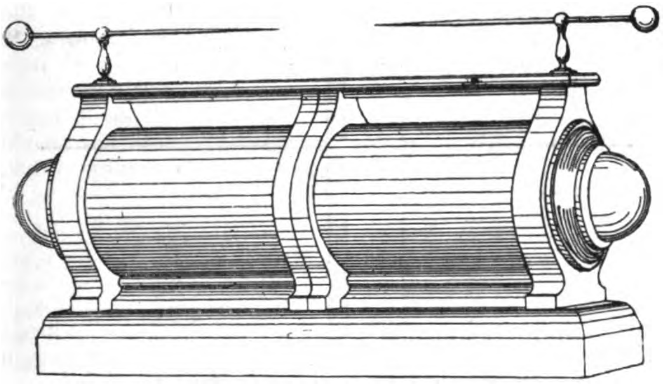


Fig. 25.—Ritchie's Induction Coil (1859).

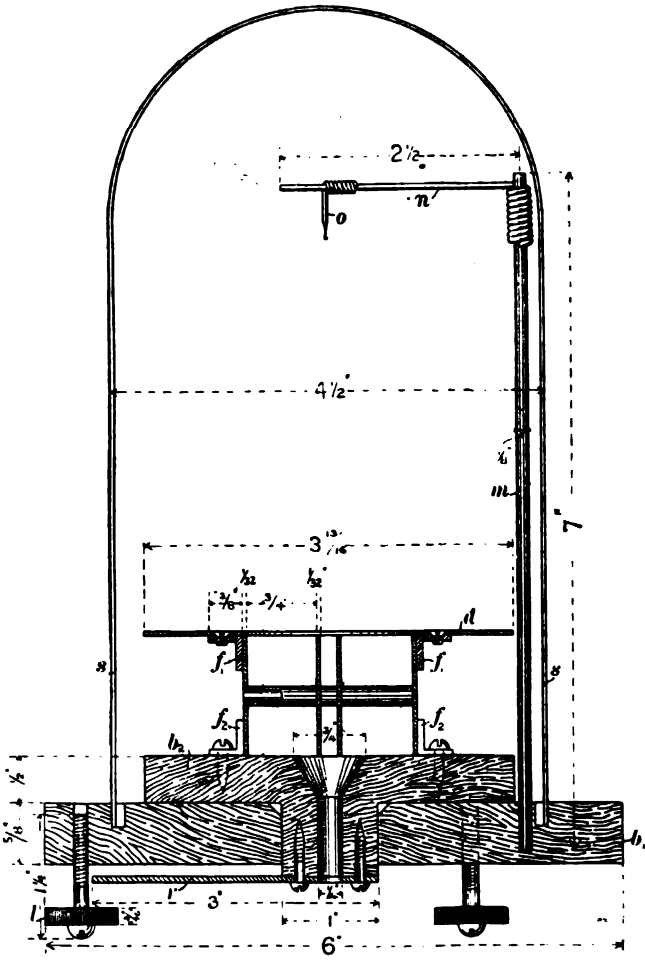
§ 19. **Mr. Gassiott's Large Induction Coil.**—In 1858, Ritchie constructed, to the order of Mr. John P. Gassiott, a large induction coil, which is thus described by Mr. Gassiott in the *Philosophical Magazine* for 1858 (Vol. XV., 4th series, p. 466): "The primary coil is of wire of No. 9 gauge, the helix in three layers and 15in. in length, taking altogether 150ft. of wire. The iron core is 18in. in length and about $1\frac{3}{4}$in. in diameter, of annealed iron wires, No. 16 gauge, annealed with the very greatest care, having been a fortnight in cooling. The primary wire has a cover of gutta-percha, one-tenth of an inch in thickness; over this a glass tube. The secondary helix is divided into three bundles, each five inches in length, wound on cylinders of gutta-percha, the total length of secondary wire being 73,650ft., or 14 miles." The secondary wire was insulated and wound vertically, that is, in separate flat helices. The condenser consisted of varnished tissue paper, three layers of each sheet between every sheet of tinfoil, and there were three condensers which could be employed, of 50, 100, and 150 square feet of coated surface respectively. The coil would give $12\frac{1}{4}$in. sparks. The interruptor was a ratchet break worked by hand, which enabled various rates of interruption to be applied. This coil was used by Mr. Gassiott in his researches on electrical discharge in vacuo, and gave very fine effects.

(*To be continued.*)

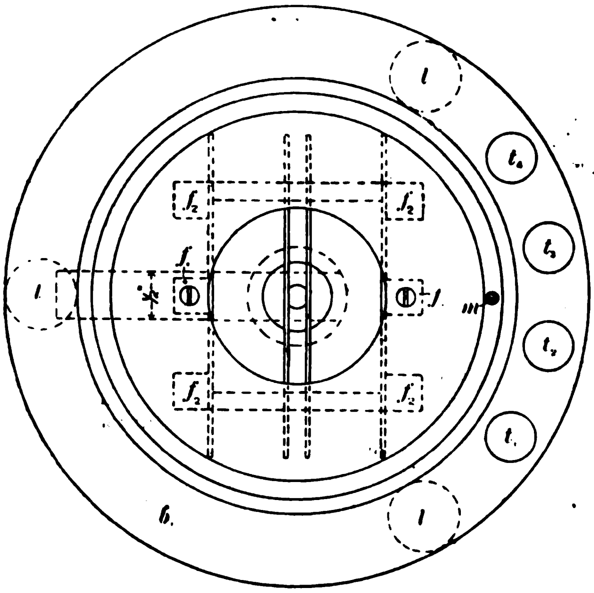
ELECTRICAL INSTRUMENT MAKING.—III.

SUSPENDED NEEDLE GALVANOMETER.

The galvanometer to be described in the present article will be of use in many cases where the extreme delicacy of a reflecting galvanometer is not required, but a mirror may be employed with this instrument in some cases, such as balance tests with a zero method.



Sectional Elevation.



Plan.

Fig. 1.

The base of this instrument is in two parts; the lower part, *b*, is 6in. in diameter and ⅝in. thick; there is a hole through