A PHOTOGRAPHIC FOUCAULT-PENDULUM.

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THE following notes have unavoidably been put together somewhat hastily, but I thought nevertheless that a brief account of some trial experiments with a new apparatus might be of interest to the Society, even before more precise results were obtained.

It was in the small hours of the morning of January 8th, 1851, in Paris, that Leon Foucault obtained the first successful result of his classical pendulum-experiment, demonstrating the rotation of our planet on its axis. The progressive apparent change in azimuth of the plane of vibration of a long heavy pendulum had, without his knowledge, been observed two centuries before by Viviani, at Florence; but the honour rests with Foucault of having discovered, from theory, the physical law governing this movement (as a close approximation at least), and of having verified it by actual experiment.

In order to thoroughly investigate the truth of his now well-known "sine-law," his pendulum experiment was repeated, especially in 1851 and 1852, in many countries of the world,—in France (5 cities), England and Ireland (5), Holland (4), Germany (3), Switzerland (2), Italy, Denmark, Canada, United States, Ceylon, and Brazil (1 each), and in many cases with extreme care. Of course I am not to be understood as referring now to the experiment as doubtless frequently performed merely for lecture-demonstration purposes, but as carried out with the rigorous attention to detail demanded by scientific research. In all these various

places, the investigation was carried out by a visual method of some kind or other, which in certain cases at least, lays itself open to criticism.

During November of last year, while planning details for a quantitative repetition in Sydney, with all the precision possible, of Foucault's experiment, with a view to the verification of his law in the Southern Hemisphere (the observations at Rio Janeiro in 1851 having given unsatisfactory results), it occurred to me that it would be interesting to endeavour to obtain also a photographic record of the apparent variation in azimuth of the oscillation-plane of the pendulum. This appeared to have certain advantages from several points of view, not as supplanting, but as supplementing the time-honoured visual method, which alone I intended following in the first instance. It appeared to me that a small glow-lamp and short-focus lens could be enclosed within the heavy leaden "bob" of the pendulum, and thus a well-defined spot of light could be made to record the change of azimuth of the latter on a sheet of bromide-paper placed below. Professor Pollock, F.R.S., to whom I spoke about the idea, encouraged me to attempt to realise it, which I did. The results so far are, I hope, such as to justify further experiments, to be begun soon. Various difficulties of course soon presented themselves, but they were eventually overcome. Among them was the question of feeding the glow-lamp. Several alternative plans were considered, but finally I decided to adopt an 8-volt supply, derived from four storage-cells symmetrically disposed within the bob itself. The latter was originally designed as a pair of brass hemispheres with bayonet-joint coupling, and filled with lead, except for a cubical space in the centre for the cells and lamp, and two vertical cylindrical spaces, one below, for a draw-tube holding the lens, the other above, to maintain symmetry of mass. This plan was

afterwards partially modified, and the whole weight of the bob is carried by the tube T (fig. 1), which also serves to contain the lamp and draw-tube for the lens,—the enveloping brass hemispheres being thus rendered unnecessary. This modification was suggested to me by Mr. T. J. Murday, to whom I am also indebted for several other improvements which I have much pleasure in acknowledging. He has, at my request, supplied the following details of the method adopted in making the large heavy hemispheres. These are made of stereo-metal, instead of lead, so as to be workable in the lathe.

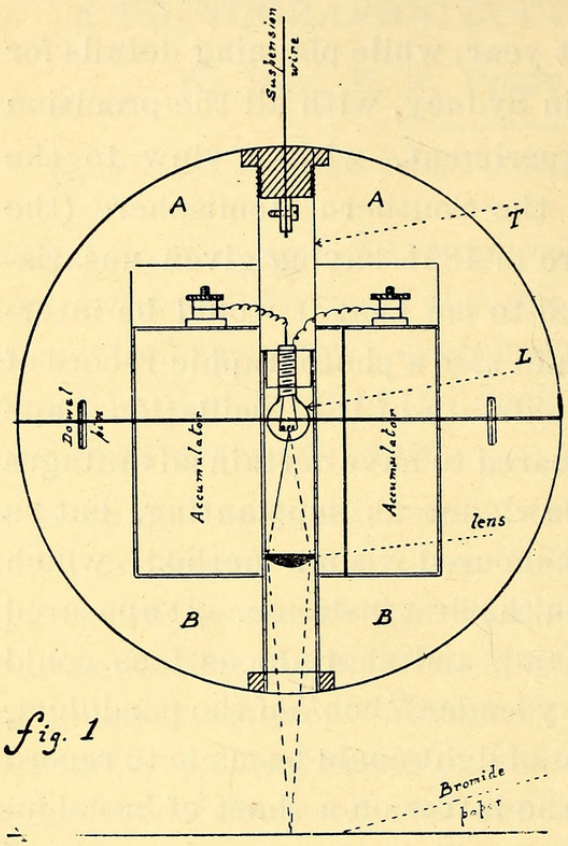


fig. 1

Vertical Section of Pendulum-bob: *A, A*, upper hemisphere; *B, B*, lower hemisphere; *T*, central supporting tube; *L*, glow-lamp.

"The production of a true sphere of relatively small size is a fairly easy task in the hands of a skilled mechanic equipped with proper tools; but when the mass weighs 60 lbs. and measures about 7½ inches in diameter, other methods are called for, and the following brief details of the means adopted in this particular case may not be out of place. From a hemispherical wood pattern two castings in stereo metal were obtained, with the recess for the accumulators cast in. Each section was carefully centred and drilled and afterwards mounted on a rigid steel mandrel, and the face turned flat. The hemispheres were then mounted together on the mandrel,—dowel pins having been inserted to keep them from turning independently,—and the globe thus formed roughed into shape.

"To carry the cutting tool, one end of an L-shaped lever was bolted and pivotted to the bed of the lathe centrally beneath the equator of the ball, the other end carrying the cutting tool at the exact height necessary to sweep out a meridian accurately from the poles. With the ball slowly revolving, this tool was used until the rough surface was removed, and the ball became an approximately true sphere. The final shaping was given by the use of a piece of five inch diameter tube, having the end ground sharp, pressed against the revolving ball until the edge was in contact with the ball surface at all points, and in all positions. A template cut out of flat brass to the exact radius was used to verify the work from time to time.

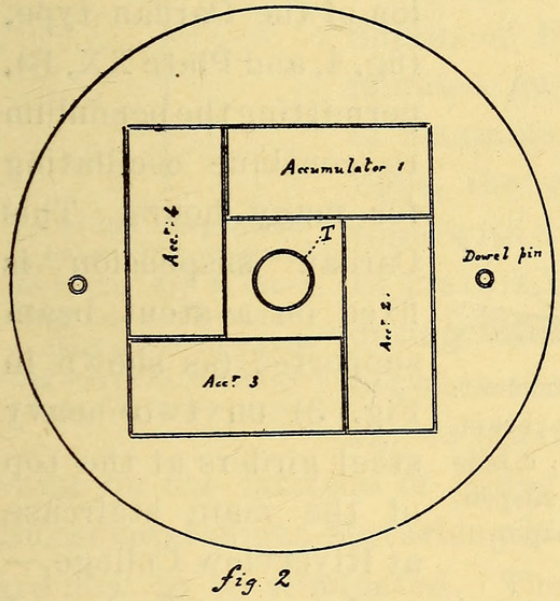


fig. 2

Plan of Pendulum-bob (through equator).

"With the accumulators and central tube in position, the geometrical centre of the ball was determined, and a disc with a conical depression in its centre, was fixed at this point in the tube. A long steel rod fixed to a pedestal and pointed at the top was introduced into the tube, and the ball was balanced on this point, holes being drilled in the heaviest sides, from the interior, until the ball hung on the point without tendency to tilt or rock in any way."[1]

The ball and its contents, as well as the knife-edge suspension for the whole pendulum, have been carefully prepared under Mr. Murday's supervision, and some of the more delicate electrical connections for the glow-lamp

[1] As an additional precaution, with the kind assistance of Professor Vonwiller, the ball was floated in a basin of mercury, at the Physics Laboratory, University of Sydney, and further trimmed till equilibrium was obtained.

have been made by himself. The lamp-circuit is capable of being closed or opened at will, by a screw-switch placed near the upper pole of the ball. The lens (plano-convex) is stopped down to a very small aperture, and its focussing-tube, when the pendulum is in position, can be easily adjusted from the lower end of the supporting tube in which it slides. The sustaining wire is of phosphor-bronze (diam. 1·5 mm.) attached above to a specially constructed knife-edge suspension of the Cardan type, (fig. 4, and Plate XX, B), permitting the pendulum to continue oscillating for many hours. This Cardan suspension is fixed on a stout beam supported (as shown in Fig. 3) on two heavy steel girders at the top of the main staircase at Riverview College,—a spot well suited for a Foucault-pendulum, and where I had for many years contemplated erecting one, as suggested to me as far back as 1891 by the late Father Charles O'Connell, S.J. These girders are two out of a series, about 1 metre apart, designed to support a very large water-tank above the staircase. They measure 36 centimetres vertically, and 14·5 centimetres horizontally at base. The length of the whole pendulum is 13·7 metres, the ball having a diameter of 18·5 centimetres, and weighing 27 kilograms. The photographic paper is attached to a curved platform, very rigidly fixed, the curved surface correspond-

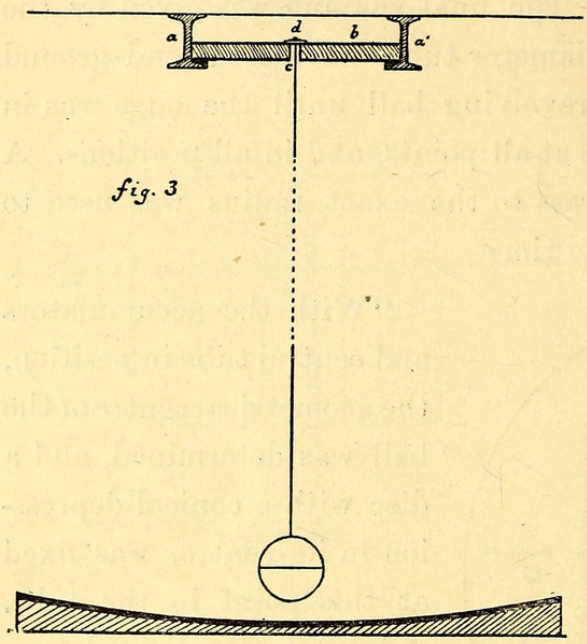


fig. 3

General arrangement of experiment: *a*, *a*, steel girders; *b*, wooden beam, rigidly wedged between girders; *c*, hole for suspending wire; *d*, Cardan suspension; *f*, platform for bromide-paper.

ing to the pendulum-length, so as to secure uniform definition in the photograph (Fig. 3).

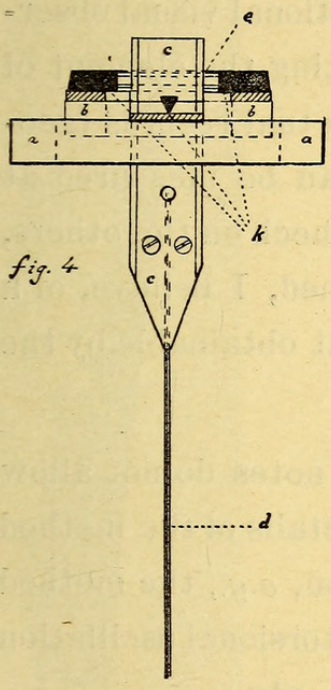


fig. 4

Cardan suspension: *a*, outer ring, screwed on *b*, (fig. 3); *b*, inner ring, on knife-edges; *c*, clamp for suspending wire (*d*), on knife-edges; *k*, knife-edges.

By the end of January last the apparatus was ready, and some trial photographs were obtained, one of which is reproduced in Plate XX, (A). Each of the experiments was made during the quietest portion of the night, some time between 1 a.m. and 4·30 a.m., and of course using red light. One of the two observers, while making the exposures (in pairs, North and South, or East and West) every five minutes, gave a signal of the instant of maximum excursion of the spot of light, the other observer noting the time with a half-second chronometer. In Plate XX, the alteration in azimuth during the five-minute intervals between the exposures is evident, and agrees fairly well with the theoretical value for the latitude of Sydney, 8° 21′ per siderial hour. But several slight perturbing influences were present, and are now to be eliminated. The elliptical path sooner or later always followed by the bob is also clearly visible, and capable of quantitative measurement. Obviously it is quite too rapidly generated, in this trial photograph; but in the next series of exposures, now about to be undertaken, I have reason to hope it will be greatly reduced, as well as some minor defects, with the introduction of a number of refinements in the apparatus and in the *modus operandi*.

Thus, as I have endeavoured to show, the main feature of this "photographic Foucault-pendulum," (which for convenience I have ventured to name "geogyrograph,"—not

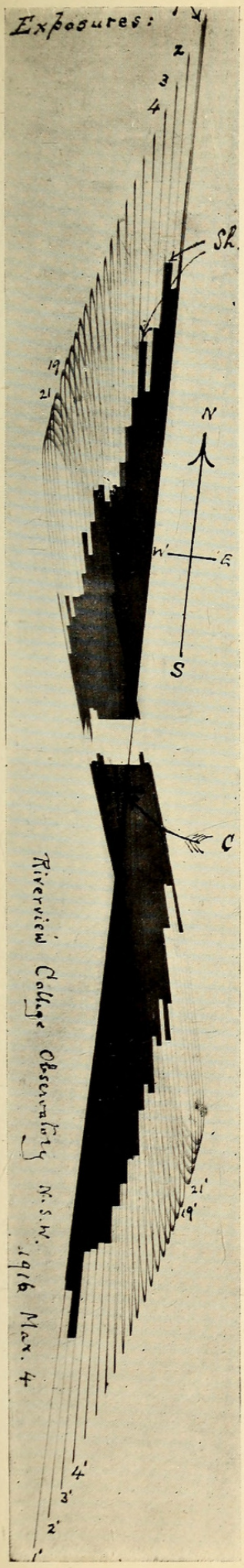
a very euphonious term, I admit, especially if the second "g" is pronounced soft, but sufficiently expressive—) is the substitution of photography for the traditional visual observations, thus to a large extent eliminating the element of "personal equation." By this means actual records (geogyrograms) of the Earth's rotation can be measured at leisure by a number of persons, each a check on the others, and quantitative determinations obtained, I believe, of a degree of accuracy at least equal to that obtainable by the visual methods hitherto employed.

These somewhat hurriedly-prepared notes do not allow at present of describing various other details of the method of procedure adopted to ensure precision, *e.g.*, the method of releasing the bob, removal of residual torsional oscillation in the bob, protection from air currents, etc.

I also postpone for the present giving any quantitative results of these experiments, (as well as of a second series also in progress, in the dome of the Queen Victoria Markets, Sydney, with a pendulum no less than 26 metres long) until the above mentioned improvements have been carried out, both series having been somewhat of a tentative character. In a subsequent paper, I hope to give the full results of all the experiments.

In conclusion, I wish to express my sincere thanks to Prof. Pollock, D.Sc., F.R.S., Prof. Vonwiller, B.Sc., Prof. Cotton, M.A., F.G.S., Messrs. Ranclaud, B.Sc., J. Lane Mullins, J.P., Murday and Breden, for valuable suggestions and kindly help; to the Surveyor-General and Mr. R. H. Cambage, F.L.S., for the loan of instruments for the new visual method I have adopted at the Queen Victoria Markets; and to the Lord Mayor, for having been so good as to grant me the use of this fine building for the research.

A


Exposures:
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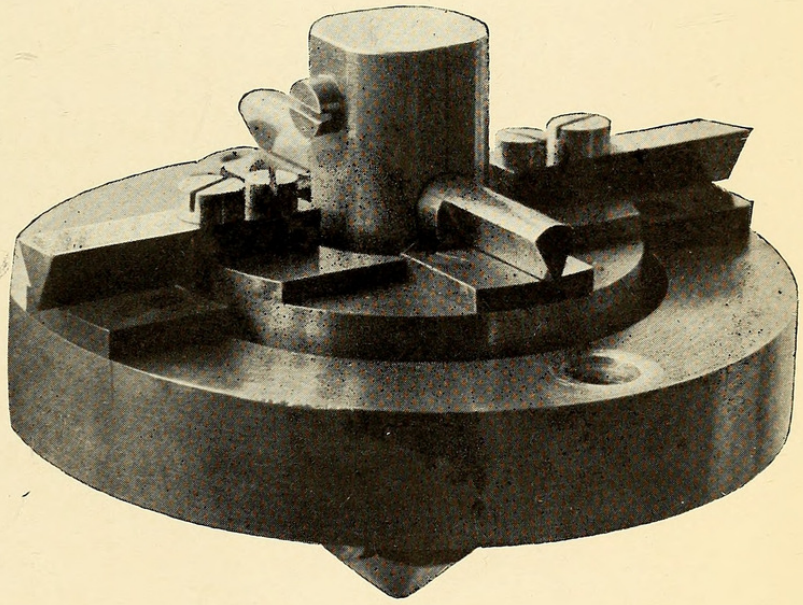

B

Explanation of Plate XX.

(A.)—Reproduction (reduced one-fifth) of Foucault-pendulum photograph (geogyrogram) taken 1916, March 4, from 2 h. 37 m. 54 s. a.m. to 4 h. 37 m. 55 s. a.m., (Sydney standard time). The exposures (in pairs) were made every five minutes, and the change of azimuth in the intervals is clearly seen. The twentieth pair of exposures was missed, owing to an accidental interruption.

Sh. indicates the edge of the occulting shutter or screen during the five-minute intervals.

C. is the zero-point of the oscillations.

(B.)—Cardan Suspension (see text-figure 4).

(N.B.—Text figures not strictly to scale.)

WIRELESS TIME SIGNALS—SOME SUGGESTED IMPROVEMENTS.

By W. E. and F. B. Cooke.

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Anticipating a re-determination of Australian longitudes by means of trans-Pacific radio signals, some experimental work has been recently undertaken at the Sydney Observatory, with a view of eliminating certain sources of error.

Prior to the war great and rapid progress was made with the new methods, culminating in the determination of the difference of longitude between Paris and Washington by means of radio signals across the Atlantic. In the course of this work every possible precaution to ensure great accuracy was taken. The results were undoubtedly good, but one gathers from the remarks of M. Baillaud (Director of the Paris Observatory) and others that there are still