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ART. XXV.—*Notes on Physiological Optics.* No. 5. *Vision by the Light of the Electric Spark;* by W. LeCONTE STEVENS.

IN previous papers the phenomena of optic divergence have been discussed, and also various peculiarities of vision under controllable physiological conditions. Among them was stereoscopy from a pair of perfectly similar figures, produced by so varying these in relative position that the retinal images of them were dissimilar. A geometric explanation of this was given, in which it was assumed that freedom of motion was allowed the eyes; but with the reservation that such motion is not necessary in obtaining the perception of binocular relief from stereographs constructed in the ordinary way, and that it was probably necessary only to the completeness of the perception in the present case when the dissimilarity of retinal images was very considerable.

In continuing this investigation the electric spark has been employed as a means of illuminating the pair of pictures. These were viewed with the aid of a reflecting stereoscope, already described as a device to indicate the value of the optic angle, positive or negative, that results from any possible relation between the visual lines of a pair of eyes. Vision may thus be made normal or abnormal at will. The use of the spark in the study of binocular vision is no novelty; but it seems not to have been employed hitherto in studying abnormal vision with the visual lines divergent, or the peculiar mode of stereoscopy recently devised.

The apparatus employed was a large induction coil, belong-

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sulphates, dissolving in cold water, adding hyposulphate of soda, and boiling; the precipitated thoria was collected on a filter, washed, ignited and weighed (Hermann's method.)\* The amount of cerium was arrived at by determining the excess of oxygen in  $CeO_2$  over  $Ce_2O_3$ ; this was obtained by dissolving the ignited oxides (free from thoria), in dilute sulphuric acid mixed with oxalic acid; the oxides dissolved and the higher oxide of cerium decomposed the oxalic acid, setting carbonic anhydride free, which was collected in potash bulbs and weighed. Silica was determined by decomposing the mineral with sulphuric acid, evaporating till fumes came off, soaking out with water and filtering.

A determination of sulphuric anhydride in a weighed quantity of the mixed sulphates of the cerium metals from the Portland variety gave for the joint molecular weight of the oxides 328.2, or a joint atomic weight of 140.1, which determination was used in the calculation of the three analyses. It may be stated that great care was taken to prove the identity of the thorium. Besides its giving all the reactions for that element, a weighed quantity of the oxide gave by conversion into sulphate an atomic weight of 238.5. This sulphate was not quite soluble in water, which readily accounts for the result being a trifle higher than that usually accepted for thoria. The atomic weight, 231.5, was used in calculating the analyses.

In closing I wish to express my thanks to Professors George J. Brush and E. S. Dana for kindly providing the material for carrying out this investigation.

Sheffield Scientific School, May 3, 1882.

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ART. XXVIII.—*On Irregularities in the Amplitude of Oscillation of Pendulums*; by C. S. PEIRCE.

[Communicated by the authority of the Superintendent of the U. S. Coast and Geodetic Survey.]

THE pendulum experiments conducted by me for the Coast Survey exhibit considerable differences in the rate of descent of the arc on different days. Mr. O. T. Sherman (this Journal, xxiv, 176) having suggested that this might be due to a periodic variation of the amplitude, I feel called upon to say,—what a study of my published observations will show,—that this supposition is inadmissible. For, in order to account, in this manner, for the observed discrepancies, it would be necessary to suppose a periodic variation too great to escape direct observation. In most of my observations, I have used an arc accurately divided into thousandths of the radius. The reading telescope has a sidereal magnifying power of from 60 to

\* Journ. f. pr. Chem., xxxiii, 90.

150 diameters, and is usually placed at a distance of about fifteen feet. The observations are made by placing the wire of this telescope successively in coincidence with the different lines of the graduated arc, and accurately noting the moment at which the point of the pendulum is just bisected by the wire at the extremity of its swing. It would thus be quite impossible to overlook a variation of the amplitude amounting to one ten-thousandth of the radius, while that of the pendulum was, say one-thirtieth of the radius.

The motion of a pendulum upon a flexible support has two harmonic constituents. One of these has nearly the natural period of the pendulum, the other nearly the natural period of the oscillation of the support. If the amplitude of the second motion is sensible, an irregularity of the arc of oscillation, often of a plainly periodic character, will necessarily result. The ratio of the amplitude of the second harmonic motion to that of the first depends upon the manner in which the pendulum is started; and upon a very flexible stand it is easy to start the pendulum in such a way as to produce a considerable variation in the amplitude. But theory shows that if the pendulum be started by pushing it to one side by a force applied at the center of oscillation and then letting it go, the second harmonic constituent vanishes. Now, this is the manner in which I always endeavor to start a pendulum. That, in point of fact, the second harmonic constituent is insensible is shown by the fact that it hardly shows itself even in the oscillation of the support, where it is relatively many times larger than in that of the pendulum. The equations showing this are given in my paper appended to the report of the Stuttgart meeting of the International Geodetic Association.

Mr. Sherman deduces the consequences which would result from the motion of the support having a different period from that of the pendulum. But for the considerable number of supports that I have examined in this respect, the mean period of the oscillation of support and pendulum have been the same. This is proved by the fact that, however long the experiment is continued, the oscillations of the one and of the other appear to be synchronous. There may, it is true, be a portion of the motion of the stand which is not synchronous with the main part of the motion of the pendulum; but this circumstance will have no appreciable effect on the period of the pendulum, if the latter is properly started.

Of the periodic phenomena observed by Mr. Sherman, I can propose no explanation, because I am unacquainted with the details of his experiments. But similar phenomena might result from a faulty mode of starting a pendulum upon a very flexible support.