Presque Isle I investigated, but they proved to be unfounded. Who can tell how this African snake found its way to the shore of Lake Erie and how long it had found subsistence there?

E. L. MOSELEY.

SANDUSKY, OHIO,
Oct. 27, 1901.

SHORTER ARTICLES.

THE UNEXPLAINED SOUTHERLY DEVIATION OF FALLING BODIES.

THE formula published by Mr. Roever, of Washington University (SCIENCE, July 12, 1901, p. 70), giving the southerly deviation of falling bodies due to the earth's rotation, is of special interest, because it marks a fresh attack upon a problem which in my 'History of Physics,' p. 75, I call an unsolved problem. The difficulty lies in a wide discrepancy between the theoretical and the observed results. The latter are over 1,000 times greater than the former.

1. *Experiments.*—When Robert Hooke undertook to verify experimentally Newton's prediction of an easterly deviation of falling bodies, due to the earth's rotation, he reported also a small southerly displacement.*

When in 1791 G. B. Guglielmini again undertook to verify Newton's prediction by a series of experiments from a tower at Bologna, a southerly deviation was again observed. He found H ('height' or distance fallen through) = 241 Paris feet (78.3 m.), E. D. ('easterly deviation') = 8.375 lines (18.894 mm.), S. D. ('southerly deviation') = 5.272 lines (11.894 mm.).†

In 1802 J. F. Benzenberg experimented from the St. Michael's tower in Hamburg. H = 235 feet (76.3 m.); E. D. = 3.99 lines (9.00 mm.); S. D. = 1.5 lines (3.4 mm.).‡

In 1804 Benzenberg experimented in a shaft of a coal mine at Schlebusch. H. = 260 ft. (84.4 m.). An E. D. was noticeable, but on selecting from the total number those experiments which, in his judgment, were made under the most favorable conditions, there seemed to be no indication of a S. D.*

In 1831 F. Reich experimented in a mine-shaft at Freiberg. H. = 158.5407 m., E. D. = 28.396 mm., S. D. = 4.374 mm. These results are deduced from six series of experiments. Altogether 106 balls were dropped. Reich's are the most carefully conducted experiments on the subject which have been made. Yet they differ much among themselves, though not as much as those of Benzenberg.†

In 1848 W. W. Rundell published experiments made in the shaft of a Cornish mine.‡ Balls were dropped through a distance of one-fourth of a mile and a S. D. of 10 to 20 inches (25 to 51 cm.) was noticed. From the account of the experiments it is difficult to convince oneself that sufficient precautions were taken against disturbances from air-currents.

All observers experimented with metallic balls. Are these observed southerly displacements due wholly to experimental error? Though we may incline to that opinion, we cannot deny the force of Benzenberg's remark: 'Sonderbar bleibt doch diese Tendenz der Fehler nach Süden.'

2. *Theory.*—Mr. Roever is not the first to derive a formula for S. D., due to the attraction of the rotating earth. This was done in 1803 by Gauss § and by Laplace.‖

Neglecting the resistance of the air, Gauss obtained

$$\text{E.D.} = y = \tfrac{1}{3} \cos \phi \, gnt^3,$$
$$\text{S.D.} = x = \tfrac{1}{6} \cos \phi \sin \phi \, gn^2t^4,$$

where u is the angular velocity of the earth, ϕ the latitude. Applying this to Benzenberg's

* See Ball, 'An Essay on Newton's Principia,' pp. 146, 149, 150.

† See Gilbert's Annalen, Vol. XI., p. 172; Vol. XII., 1803, p. 372; Vol. XIV., p. 222. Rosenberger, in his 'Geschichte der Physik,' Vol. III., p. 96, refers to Guglielmini's book, 'De diurno terrae motu, experimentis physico-mathematicis confirmato,' Bologna, 1792, but as early as 1803 the book is spoken of as being very rare.

‡ Gilbert's Ann., Vol. XIV., p. 222. Rosenberger refers to Benzenberg's book, 'Versuche über die Gesetze des Falles,' Hamburg, 1804.

* Gilbert's Ann., Vol. XVIII., p. 381.

† See Poggendorff's Ann., Vol. XXIX., 1833, p. 494. Rosenberger refers to Reich's book, 'Fallversuche über die Umdrehung der Erde,' Freiberg, 1832.

‡ Robertson's *Mechanic's Magazine*, London, Vol. XLVIII., p. 485.

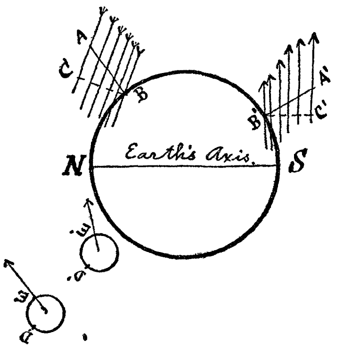
§ Gauss, 'Werke,' Vol. V., 1877, p. 495.

‖ *Bull. d. sciences par la Soc. Philomath.*, Plairial an 11 (1803).

data, Gauss took $\frac{1}{2}gt^2 = 235$, $\phi = 53°33'$, $t = 4$ seconds, $nt = \frac{366}{365}$ spatial minutes, and $1' = \frac{1}{3438}$ radians. Gauss found E. D. = 3.91 lines, the experimental value being 3.99. The formula gives S. D. = .00046 lines, the experimental value being 1.5 lines.

The resistance of the air was found by both Gauss and Laplace to make no appreciable difference in the S. D. Several writers deduced formulæ which seemed to give a much larger S. D. than those of Gauss and Laplace, but in every case some error in the reasoning has been detected.* The deductions of Gauss and Laplace have, thus far, stood the test of criticism.

Other than gravitational agents were considered by Oersted and Sir John Herschel.† They suggested that the 'electric currents * * * known to be circulating around the earth in the direction of the parallels of latitude' induce currents in a falling metallic body and cause deflection to the south. But they became doubtful of this explanation by the remarks of Grove, who said that "inasmuch as a falling body was



* See Gauss's criticism on Olbers, Gauss' 'Werke' Vol. V., p. 495; reference to Guglielmini's speculations in Gilbert's Ann., Vol. XII., p. 372; M. Petit's article in *Comptes Rendus*, Vol. XXXIII., p. 193, 1851, and M. Dupré's criticism of that article in Vol. XXXIV., p. 102, 1852, as well as Rosenberger's criticism of Dupré, in *Gesch. d. Physik*, Vol. III., p. 436; W. C. Redfield in *Am. Journal of Science*, Vol. III., p. 283, 1847, and the correction on p. 451 of same volume; the theoretical part, contributed by Professor Cowie, in W. W. Rundell's article, *Mechanic's Magazine*, Vol. XLVIII., p. 488.

† *Am. Journal of Science*, Vol. III., 1847, p. 139; *Report British Assoc.*, 1846, Misc. Communicat, p. 2.

moving between electrical currents, placed both north and south of its line of fall, in his opinion the effect of the one would counterbalance that of the other, so as together to produce no effect."

I myself have been considering the effect of a metallic ball falling through the varying magnetic field of the earth. Electric currents will be generated in the ball. Resolve the motion of the ball in the northern hemisphere into two components, one component, *AC*, parallel to the lines of force, the other, *CB*, perpendicular to them. The motion along *AC* produces no current in the ball. That along *CB* generates a current in a plane normal to the earth's magnetic lines of force. By Lenz's law, there is a resistance to and diminution of the motion producing the current. Hence, in all regions north of the magnetic equator there results a northerly deviation. Similar reasoning shows that south of the magnetic equator a falling metallic body experiences a southerly deviation.

Moreover, if the dip is greater in the lower levels of the atmosphere, then it will be seen from the two positions of the ball in our figure, that there is a relative motion of rotation between the ball and the earth's lines of magnetic force. The ball has in the northern hemisphere an *apparent* rotation about an axis pointing east and west, in a direction counter-clockwise when seen by an observer looking westward. Hence by Lenz's law the ball will experience a *real* rotation in a clockwise direction about the same axis. The interaction between the rotating ball and the air will cause the ball in the northern hemisphere to drift southward.

I have been unable to secure accurate data for the determination of the magnitude of the two effects, but, taking the largest rate of variation in the magnetic intensity and the dip, along a vertical line, given by Humboldt,* both effects are found much too small to cause a deviation measurable in an experiment.

It is evident that the problem of the southerly displacement of falling bodies needs reinvestigation, experimentally, and perhaps also theoretically. The Washington Monument, in

* *Cosmos*, Vol. V., pp. 97, 115, London, 1872.

our national capital, might be a good place for experimentation.

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ASTIGMATIC IMAGES OF THE BOTTOM OF A POOL OF WATER.

IF light radiate from a point below the surface of water, it can pass out through the surface only within a circle forming the base of a right cone whose semi-angle is the critical angle.

Consider such rays lying in a vertical plane passing through the radiant point. The rays which have passed out into the air, if produced below the surface, are tangent to a virtual caustic. This caustic is a portion of the evolute of an ellipse, one cusp of which is in a vertical through the radiant point, and at a depth $\frac{d}{n}$, where d is the depth of the radiant point, and n is the index of refraction. The branches of the caustic are tangent to the surface in the circle determining the critical angle. Successive sets of consecutive rays having an increasing angle of incidence do not intersect at a common point, but they intersect at consecutive points on the caustic. If the vertical plane be rotated slightly in azimuth, the rays from the same radiant point will intersect in the caustic in its new position. This caustic from the same radiant point will always lie on a surface of revolution, formed by revolving the caustic in any vertical plane about the vertical line through the radiant point.

If the radiant point be viewed by an eye placed at a fixed point, the pupil of the eye may be conceived divided into vertical zonal elements. Rays from the radiant point in these various elements will intersect in a definite area upon the surface of revolution. The point would, therefore, appear as a hazy patch upon the caustic surface. The text-books all represent the apparent position of a coin seen through a water surface, as being lifted up and towards the eye of the observer, upon the caustic surface.

It is, however, evident that if the rays diverging from the radiant point in all azimuths, and at a fixed angle of incidence, be produced backwards after passing out into the air, they will all intersect in a common point upon the vertical line through the radiant point. If, therefore, the pupil of the eye be divided into horizontal zonal elements, all the rays entering the eye will have a virtual intersection on this vertical line. The focus of the upper zonal elements of the eye will be slightly below those of the lower. Nevertheless, the intersection of all rays entering the eye from the radiant point will be upon a line, instead of being spread out over an area as in the other case. The fact is that a plumb line deeply piercing still water appears straight throughout. The image upon the vertical line is much more distinct than that formed upon the caustic surface. The latter image imparts a haziness to the appearance of the body viewed, but the apparent position is determined by lines which intersect in a common point, rather than by those which do not.

With this view of the matter the writer in May, 1881, presented to the Academy of Science of St. Louis a discussion of the apparent form of the flat bottom of a pool as seen through the surface.* The appearance was found to be represented by a conchoid, which was related in a simple way to the conchoid of Nicomedes. The equations of both curves were deduced, and several other cases were discussed.

In a recent number of *Annalen der Physik*,† Mattheissen has deduced the equations of these two conchoids and has pointed out that the surface produced an astigmatic effect. He likewise deduces the equation for the nebulous image due to intersection upon the caustic. The minimum of this surface and that of the conchoid are coincident and tangent to each other, and they have the water surface as a common asymptote.

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NOTES ON INORGANIC CHEMISTRY.

THE earliest determinations of the density o sulfur vapor were by Dumas and Mitscherlich, and gave figures which pointed to the molecule S_6, and this has passed current until quite recent times. In 1860 Deville and Troost found

* *Trans. Acad. of Sc. of St. Louis*, Vol. IV., No. 2, p. 325.

† No. 10, 1901, S. 347.