becomes flattened at the poles and increases in diameter at the equator, perfectly illustrating the manner in which the earth received its present form.

The glass water globe represented in motion in Fig. 8 exhibits a cylindrical air space extending through it parallel with the axis of rotation, the water having been carried as far as possible from the center of rotation by centrifugal action.

When the speed of the globe is reduced, gravity asserts itself and the air space assumes a parabolic form, as shown in Fig. 9 (Plate II.)

In the globe represented in Fig. 10 the filling consists of water and mercury. The rotation of the globe causes the mercury to arrange itself in the form of a narrow band at the equator of the globe.

Fig. 11 shows a globe filled with air, oil, and water, which, when the globe is revolved, arrange themselves in the order named, beginning at the center of the globe.*

A Hero's fountain, operated by centrifugal force instead of gravity, is shown in Fig. 12 (Plate II.) The metallic vessel contains three concentric compartments. The jet tube extends downward into the central compartment and is bent laterally, so that it nearly touches the wall of the compartment. The intermediate compartment communicates with the outer compartment, and the outer and central compartments are connected by an air duct. The central and intermediate compartments are filled with water, and as the vessel is revolved the water in the intermediate compartment is carried by centrifugal action into the outer compartment, and, compressing the air contained in that compartment, drives it through the air duct, with a force due to the centrifugal action, into the central compartment, where it exerts a pressure on the water sufficient to cause it to be discharged through the jet.

* See also chapter on projection.

CHAPTER III.

THE GYROSCOPE.

This instrument has always been a puzzle to physicists. Its phenomena seems to be incapable of explanation in a popular way. In view of the complicated nature of the calculations involved, no attempt will here be made to explain the action of the gyroscope mathematically,* the object of the present article being merely to describe a few modifications of the instrument and to mention peculiarities noticed in the performance of some of these modified forms.

Fig. 12.

Toy Gyroscope.

The difficulty of securing a high speed in a large gyroscope led to the application of a friction driving device, as shown in Figs. 13 and 13*a*, by means of which an initial velocity of from 4,500 to 5,000 revolutions per minute may readily be attained.

The instrument, after being set in motion, behaves like other gyroscopes not provided with means for maintaining the rotary motion of the wheel, but its size and the facility with which it may be operated render it very satisfactory.

The gyroscope wheel is 6 inches in diameter, $\frac{5}{8}$ inch thick, and, together with its shaft, weighs $3\frac{1}{2}$ pounds. The annular frame weighs $1\frac{3}{4}$ pounds. So that $5\frac{1}{4}$ pounds must be sustained by gyroscopic action when the counterbalance is not applied.

The driving wheel is $7\frac{3}{4}$ inches in diameter. Its face is

* For a mathematical explanation see "Rotary Motion as applied to the Gyroscope," by Gen. J. G. Barnard.

$\frac{3}{4}$ inch wide. Its shaft is journaled in an arm pivoted to the base, with its free end adapted to enter a recess in the edge of the annular frame, for supporting the gyroscopic wheel while motion is being imparted to it. Upon the shaft of the

Fig. 13.

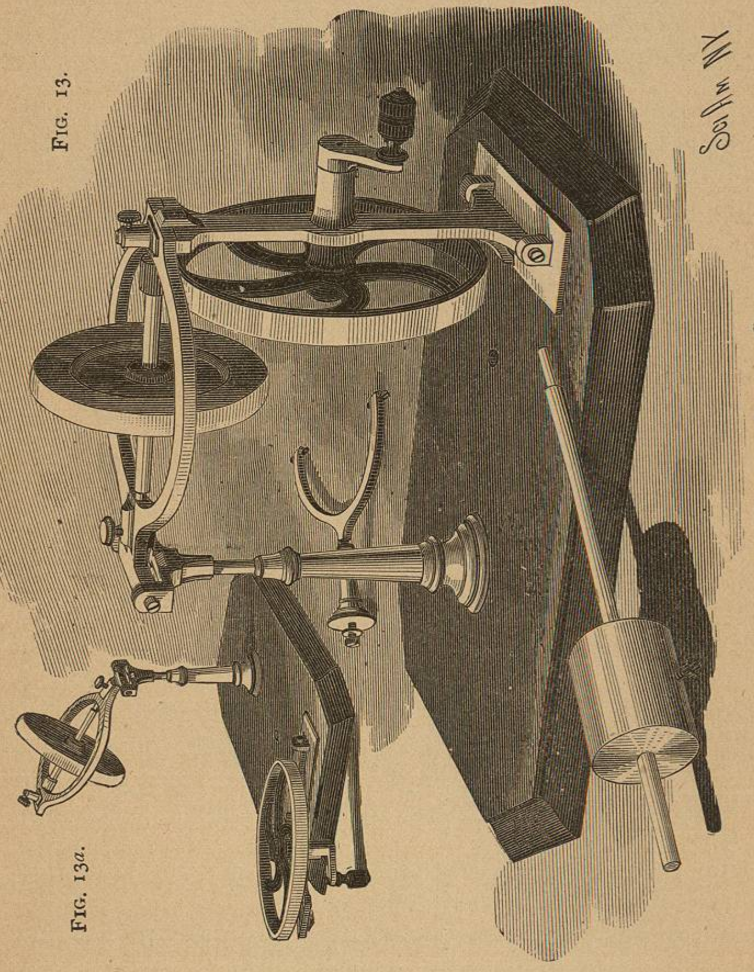


Fig. 13a.

Gyroscope with Friction Driving Gear.

gyroscope wheel is secured a soft rubber tube having an external diameter of nine-sixteenths inch. This shaft makes 13·84 revolutions to one turn of the drive wheel, so that when the drive wheel is turned six times per second, the

gyroscope wheel will make very nearly 5,000 turns per minute (4,982).

This gyroscope may be arranged as a Bohnenberger apparatus by removing the tall standard and attaching the shorter one to the center of the base by means of a bolt. The annular frame of the instrument is suspended on pivotal screws in the extremities of the semicircular support, which is capable of turning on the upper end of the short standard. In the engraving the short standard, together with the semicircular support, is shown lying on the table. The usual counterbalance is also shown lying on the table. Fig. 13 shows the drive wheel in position for imparting motion to the gyroscopic wheel, and Fig. 13*a* shows the driving wheel withdrawn and the gyroscope in action.

As this instrument does not differ from the ordinary one, except in the application of the driving mechanism, it will be unnecessary to go into particulars regarding its performance.

In Figs. 14, 15, and 16 are shown pneumatic gyroscopes, and Fig. 17 represents a steam gyroscope.

The pneumatic gyroscope shown in Fig. 14 consists of a heavy wheel provided with flat arms arranged diagonally, like the vanes of a windmill. The wheel is pivoted on delicate points in an annular frame having an arm pivoted in a fork at the top of the vertical support. The arm of the annular frame carries a tube, which terminates near the vanes of the wheel in an air nozzle which is directed toward the vanes at the proper angle for securing the highest velocity. The opposite end of the tube is prolonged beyond the pivot of the frame.

The support of the annular frame, shown in vertical section in Fig. 15, consists of an inner and outer tube, the inner tube having a closed upper end terminating in a pivotal point. The lower end of this tube communicates with the horizontal tube, through which air is supplied to the machine.

A sleeve, closed at its upper end and carrying the fork in which the arm of the annular frame is pivoted, is inserted in the space between the inner and outer tubes, and turns

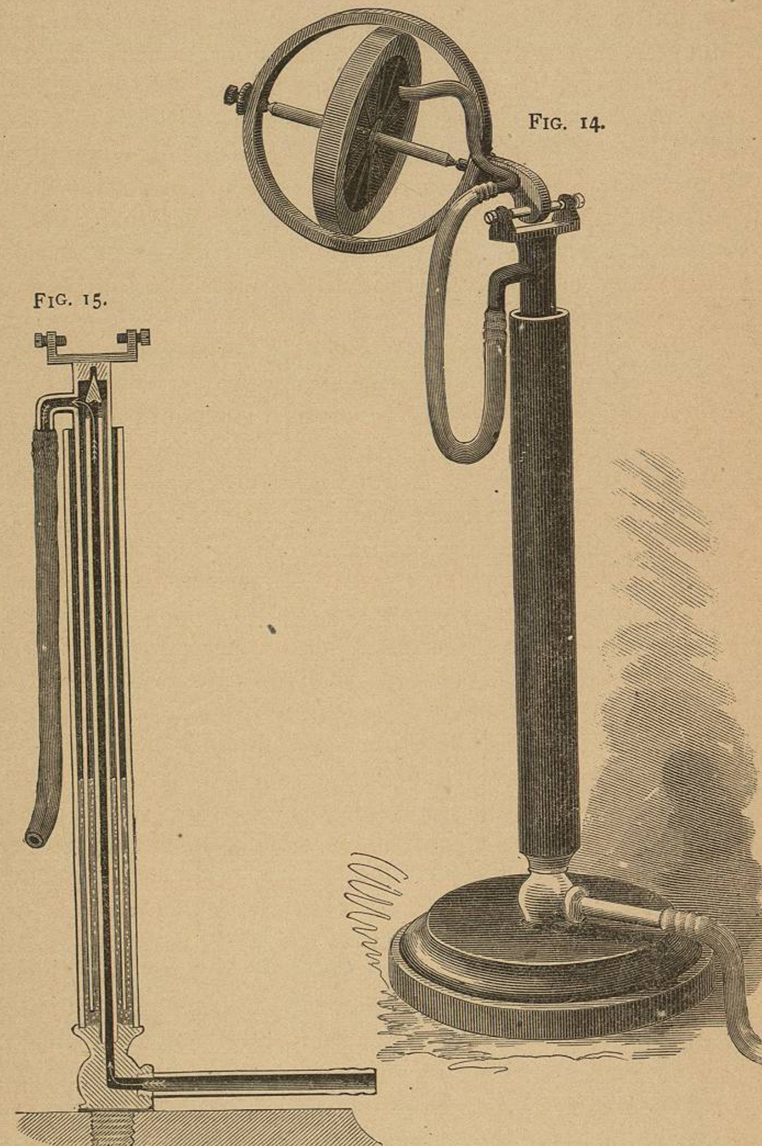


Fig. 14.

Fig. 15.

Pneumatic Gyroscope.

on the pointed end of the inner tube. The inner tube is perforated near its pointed end, to permit of the escape of air to the interior of the sleeve, and the lower end of the sleeve is sealed by a quantity of mercury contained by the space between the inner and outer tubes. The air pipe carried by the annular frame communicates with the upper end of the sleeve by a flexible tube. When air under pressure passes through the inner pointed tube, through the sleeve, and through the air nozzle, and is projected against the vanes of the wheel, the wheel rotates with great rapidity, and the gyroscope behaves in all respects like the electrical gyroscope referred to.

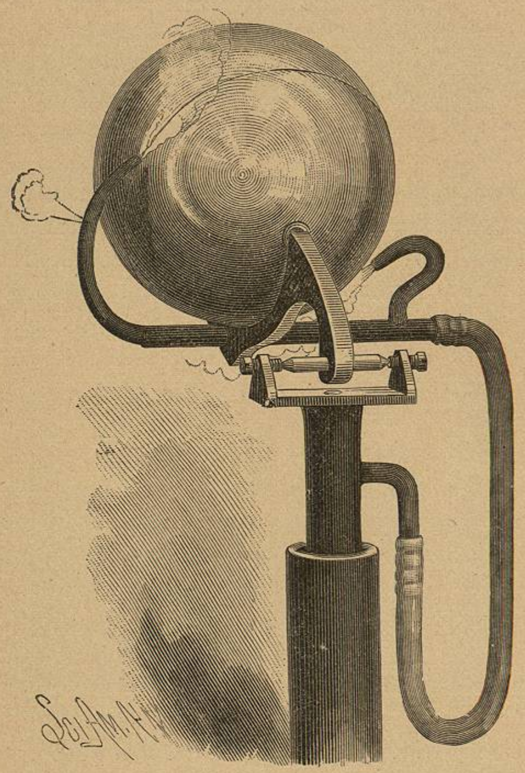
The gyroscope shown in Fig. 16 is adapted to the standard just described, but the heavy wheel is replaced by a very light paper ball, whose rotation is maintained by two tangential air jets, which play upon it on diametrically opposite sides, and nearly oppose each other, so far as their action on the surrounding air is concerned. The rotary motion is produced solely by the friction of the air on the surface of the ball. The upwardly turned nozzle is arranged to deliver an air blast which is a little stronger than that of the lower nozzle, so that a slight reactionary force is secured, which assists the gyroscope in its movement around the vertical pivot sufficiently to cause the ball to maintain its horizontal plane of rotation continuously. In fact, this gyroscope will start from the position of rest, raise itself in a spiral course into a horizontal plane, and afterward continue to rotate in the same plane so long as air under pressure is supplied.

It may be questioned whether this machine is a true gyroscope. However this may be, it is certain that the reactionary power of the stronger air jet is of itself insufficient to produce the motion about the vertical pivot; neither is there a sufficient vacuum at the top of the ball to produce any appreciable lifting effect.

The steam gyroscope shown in Fig. 17 hardly needs explanation. It differs from all the others in generating its own power within its moving parts. The boiler is supported by trunnions resting in a fork arranged to turn on a fine vertical pivot. The engine is attached to the boiler, so that both engine and boiler swing on the trunnions in a vertical plane. The wheel of the engine is made disproportionately large and heavy, to secure the best gyroscopic action.

The performance of the steam gyroscope is like that of

Fig. 16.



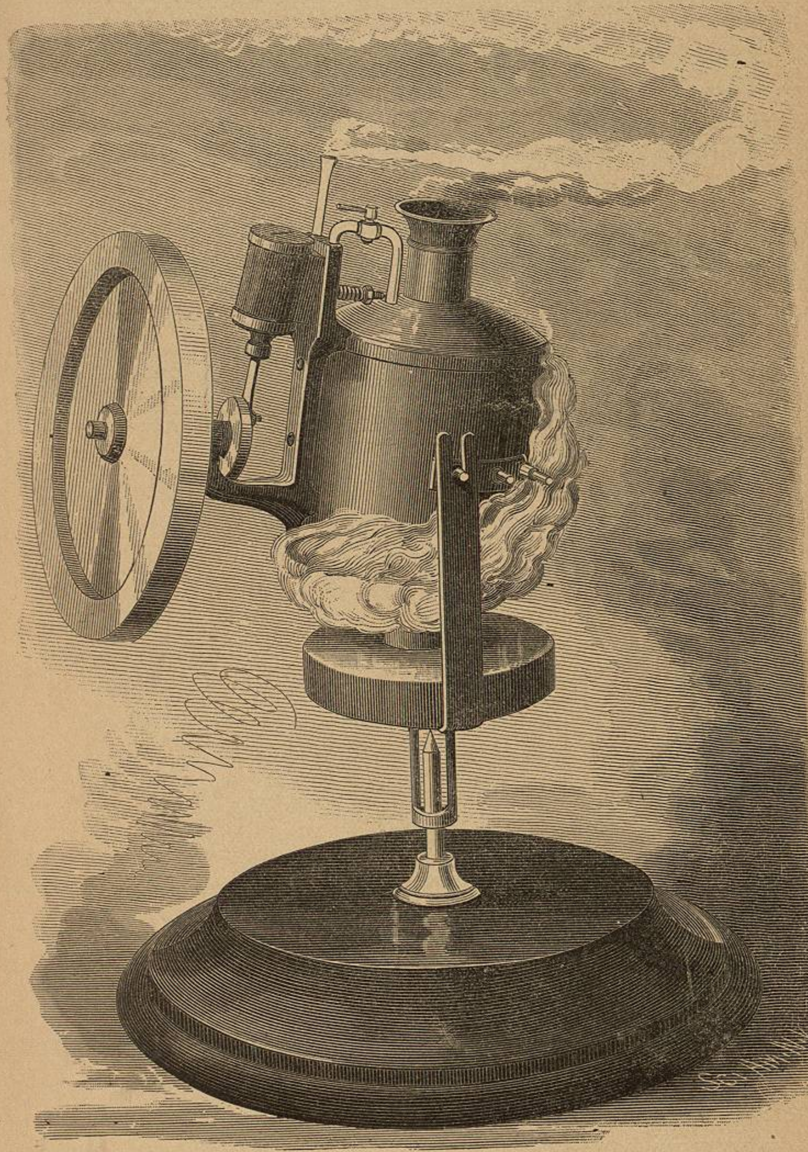
Pneumatic Gyroscope having Continuous Action.

the other power-propelled gyroscopes, and needs only a reactionary jet of steam or some other slight force to keep up the rotation around the vertical pivot, and thus render the action of the instrument continuous.

AN ELECTRICAL GYROSCOPE.

To render the operation of the gyroscope as nearly con-

Fig. 17.



Steam Gyroscope.

tinuous as possible, so that its movements may be more thoroughly studied, electricity has been applied as a motive agent.

The gyroscope illustrated in Plate I. (frontispiece) and in Fig. 18 has a weighted base piece, from which projects a pointed standard that supports the moving parts of the instrument. The frame, of which the electro-magnets form a part, has an arm in which is fastened an insulated cup, that rests upon the point of the standard. One terminal of the magnet coil is connected with this cup, and the other terminal is connected with the yoke connecting the cores of the two magnets.

To the top of the yoke is secured a hard rubber insulator, which supports a current-breaking spring arranged to touch a small cylinder on the wheel spindle twice during each revolution of the wheel.

The wheel, whose plane of rotation is at right angles with the magnet cores, carries a soft iron armature, which turns very near the face of the magnet, but does not touch it. The armature is arranged in such relation to the contact surface of the current-breaking cylinder that twice during each revolution, as the armature nears the magnet cores, it is attracted, but immediately the armature comes directly opposite the face of the magnet cores, the current is broken, and the acquired momentum is sufficient to carry the wheel forward until the armature is again within the influence of the magnet.

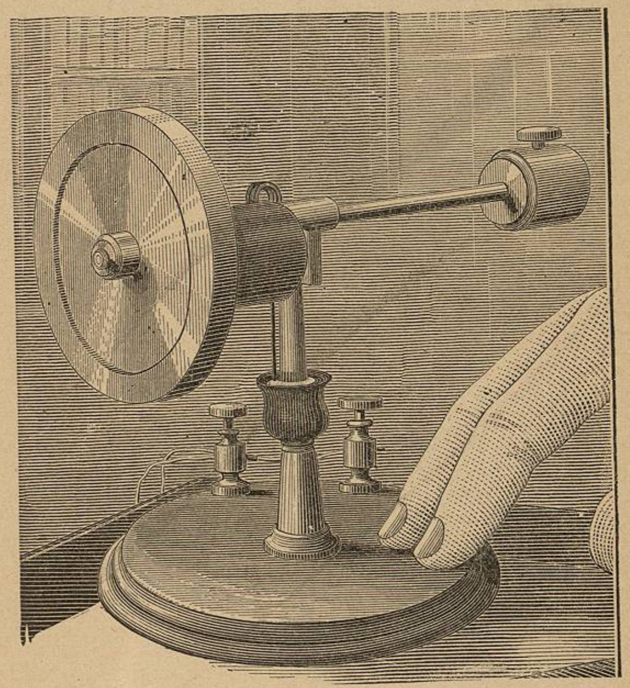
The current-breaking spring is connected with a fine copper wire, that extends backward as far as the pointed standard, and is coiled several times to render it very flexible, and is finally bent downward so as to dip in mercury contained in an annular vulcanite cup placed on the pointed standard near the base piece.

The base piece is provided with two binding posts for receiving the battery wires. One of the binding posts is connected with the pointed standard, and the other communicates by a small wire with the mercury in the vulcanite cup.

The wheel, magnet, and parts connected therewith are

free to move in any direction on the point of the standard. When two large or four small Bunsen cells are connected with the gyroscope, the wheel revolves with enormous velocity, and upon letting the magnet go (an operation requiring some dexterity), the wheel sustains not only itself, but also the magnet and other parts between it and the point of the standard, in opposition to gravity.

FIG. 18.



Electrical Gyroscope.

The wheel, besides rotating rapidly on its axis, sets up a slow rotation about the pointed standard in the direction in which the under side of the wheel is moving.

By attaching the arm and counterbalance shown in the engraving, so as to exactly balance the wheel and magnets on the pointed standard, the whole remains stationary. By overbalancing the wheel and magnets, the rotation of the ap-