supposed to be the fluid employed) be put in action; then the air in its passage will strike the side of each opening in the movable plate in an oblique direction (as shown in fig. 16), and will therefore urge the latter to rotation round its centre. After 1/nth of a revolution, the two sets of perforations will again coincide, the lateral impulse of the air repeated, and hence the rapidity of rotation increased. This will go on continually as long as air is supplied to the cylinder, and the velocity of rotation of the upper plate will be accelerated up to a certain maximum, at which it may be maintained by keeping the force of the current constant.

Now, it is evident that each coincidence of the perforations in the two plates is followed by a non-coincidence, during which the air-current is shut off, and that consequently, during each revolution of the upper plate, there occur *n* alternate passages and interceptions of the current. Hence arises the same number of successive im­pulses of the external air immediately in contact with the movable plate, which is thus thrown into a state of vibration at the rate of *n* for every revolution of the plate. The result is a note whose pitch rises as the velocity of rotation increases, and becomes steady when that velocity reaches its constant value. If, then, we can determine the number *m* of revolutions performed by the plate in every second, we shall at once have the number of vibrations per second corresponding to the audible note by multiplying *m* by n.

For this purpose the axis is furnished at its upper part with a screw working into a t∞thed wheel, and driving it round, during each revolution of the plate, through a space equal to the interval between two teeth. An index resembling the hand of a watch partakes of this motion, and points successively to the divisions of a graduated dial. On the completion of each revolution of this toothed wheel (which, if the number of its teeth be 100, will com­prise 100 revolutions of the movable plate), a projecting pin fixed to it catches a tooth of another toothed wheel and turns it round, and with it a corresponding index which thus records the number of turns of the first toothed wheel. As an example of the applica­tion of this siren, suppose that the number of revolutions of the plate, as shown by the indices, amounts to 5400 in a minute, that is, to 90 per second, then the number of vibrations per second of the note heard amounts to 90n, or (if number of holes in each plate = 8) to 720.

H. N. Dove (1803-1879) produced a modification of the siren by which the relations of different musical notes may be more readily ascertained. In it the fixed and movable plates are each furnished with four concentric series of per­forations, dividing the circumferences into different aliquot parts, as, for example, 8, 10, 12, 16. Beneath the lower or fixed plate are four metallic rings furnished with holes corre­sponding to those in the plates, and which may be pushed round by projecting pins, so as to admit the air-current through any one or more of the series of perforations in the fixed plate. Thus may be obtained, either separately or in various combinations, the four notes whose vibrations are in the ratios of the above numbers, and which therefore form the fundamental chord (CEGC1). The inventor has given to this instrument the name of the *many-voiced siren.*

Helmholtz *(Sensations of Tone,* ch. viii.) further adapted the siren for more extensive use, by the addition to Dove’s instrument of another chest con­taining its own fixed and movable perforated plates and perforated rings, both the movable plates being driven by the same current and revolving. about a common axis. Annexed is a figure of this instru­ment (fig. 17).

*Graphic Methods,—*The relation between the pitch of a note and the frequency of the corresponding vibrations has also been studied by *graphic* methods. Thus, if an elastic metal slip or a pig’s bristle be at­tached to one prong of a tuning­fork, and if the fork, while in vibration, is moved rapidly over a glass plate coated with lamp-black, the attached style touching the plate lightly, a wavy line will be traced on the plate answering to the vibrations to and fro of the fork. The same result will be ob­tained with a stationary fork and a movable glass plate; and, if the time occupied by the plate in moving through a given distance can be ascertained and the number of complete undulations exhibited on the. plate for that distance, which is evidently the number of vibrations of the fork in that time, is reckoned, we shall have determined the numerical vibration­value of the note yielded by the fork. Or, if the same plate be moved in contact with two tuning-forks, we shall, by compar­ing the number of sinuosities in the one trace with that in the other, be enabled to assign the ratio of the corresponding numbers of vibrations per second. Thus, if the one note be an octave higher than the other, it will give double the number of waves in the same distance. The motion of the plate may be simply produced by dropping it between two vertical grooves, the tuning-forks being properly fixed to a frame above.

Greater accuracy may be attained with a revolving-drum chrono­graph first devised by Thomas Young *(Lect. on Nat. Phil.,* 1807, i. 190), consisting of a cylinder which may be coated with lamp-black, or, better still, a metallic cylinder round which a blackened sheet of paper is wrapped.

The cylinder is mounted on an axis and turned round, while the style attached to the vibrating body is in light contact with it, and traces therefore a wavy circle, which, on taking off the paper and flattening it, becomes a wavy straight line. The superiority of this arrangement arises from the comparative facility with which the number of revolutions of the cylinder in a given time may be ascertained. In R. Koenig’s arrangement *(Quelques expériences d'acoustique,* p. 1) the axis of the cylinder is fashioned as a screw, which works in fixed nuts at the ends, causing a sliding as well as a rotatory motion of the cylinder. The lines traced out by the vibrating pointer arc thus prevented from overlapping when more than one turn is given to the cylinder. In the phonauto­graph of E. L. Scott *(Comptes rendus,* 1861, 53, p. 108) any sound whatever may be made to record its trace on the paper by means of a large parabolic cavity resembling a speaking-trumpet, which is freely open at the wider extremity, but is closed at the other end by a thin stretched membrane. To the centre of this membrane is attached a small feather-fibre, which, when the reflector is suit­ably placed, touches lightly the surface of the revolving cylinder. Any sound (such as that of the human voice) transmitting its rays into the reflector, and communicating vibratory motion to the membrane, will cause the feather to trace a sinuous line on the paper. If, at the same time, a tuning-fork of known number of vibrations per second be made to trace its own line close to the other, a comparison of the two lines gives the number corresponding to the sound under consideration. The phonograph (*q.v.*) may be regarded as an instrument of this class, in that it records vibrations on a revolving drum or disk.

*Lissajous Figures.—*A mode of exhibiting the ratio of the fre­quencies of two forks was devised by Jules Antoine Lissajous (1822- 1880). On one prong of each fork is fixed a small plane mirror. The two forks are fixed so that one vibrates in a vertical, and the other in a horizontal, plane, and they are so placed that a converging beam of light received on one mirror is reflected to the other and then brought to a point on a screen. If the first fork alone vibrates, the point on the screen appears, lengthened out into a vertical line through the changes in inclination of the first mirror, while if the second fork alone vibrates, the point appears lengthened out into a horizontal line. If both vibrate, the point describes a curve which appears continuous through the persistence of the retinal impression. Lissajous also obtained the figures by aid of the vibra­tion microscope, an instrument which he invented. Instead of a mirror, the objective of a microscope is attached to one prong of the first fork and the eyepiece of the microscope is fixed behind the fork. Instead of a mirror the second fork carries a bright point on one prong, and the microscope is focused on this. If both forks vibrate, an observer looking through the microscope sees the bright point describing Lissajous figures. If the two forks have the same frequency, it is easily seen that the figure will be an ellipse (including as limiting cases, depending on relative amplitude and phase, a circle and a straight line). If the forks arc not of exactly the same frequency the ellipse will slowly revolve, and from its rate of revolution the ratio of the frequencies may be determined (Rayleigh, *Sound,* i. § 33). If one is the octave of the other a figure of 8 may be described, and so on. Fig. 18 shows curves given by intervals of the octave, the twelfth and the fifth.

The kaleidophone devised by Charles Wheatstone in 1827 gives these figures in a simple way. It consists of a straight rod clamped in a vice and carrying a bead at its upper free end. The bead is illuminated and shows a bright point of light. If the rod is circular in section and perfectly uniform the end will describe a circle, ellipse or straight line; but, as the elasticity is usually not exactly the same in all directions, the figure usually changes and revolves. Various modifications of the kaleidophone have been made (Rayleigh, *Sound,* § 38).

Koenig devised a clock in which a fork of frequency 64 takes the place of the pendulum *(Wied. Ann.,* 1880., ix. 394). The motion of the fork is maintained by the clock acting through an escapement, and the dial registers both the number of vibrations of the fork and the seconds, minutes and hpurs. By comparison with a clock of known rate the total number of vibrations of the fork in any time may be accurately determined. One prong of the fork carries a. micro­scope objective, part of a vibration microscope, of which the eyepiece is fixed at the back of the clock and the Lissajous figure