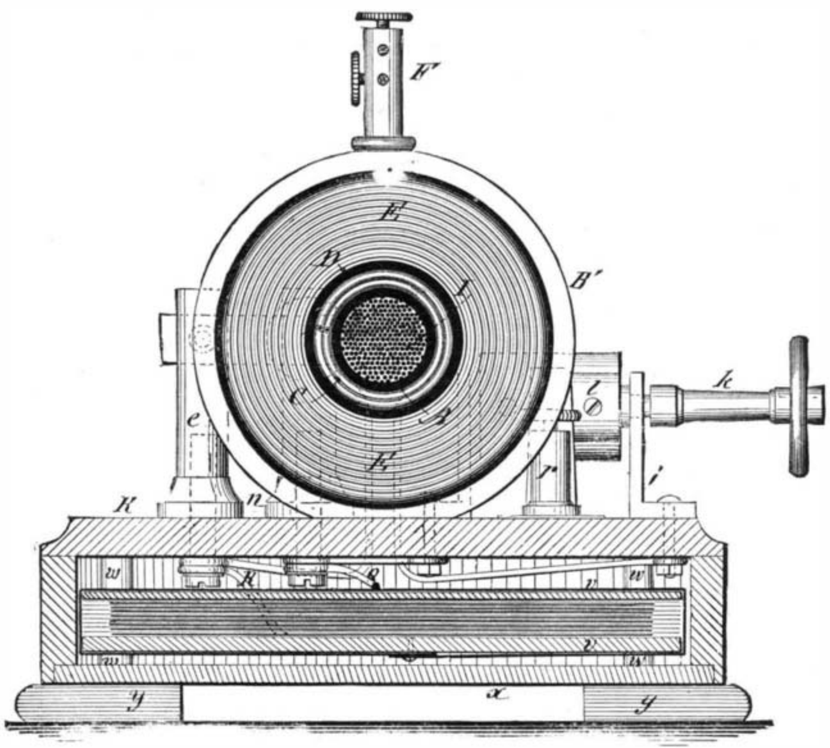
the binding posts, F, which are screwed into the upper edges of the heads, BB′. For the sake of strength the outer ends of the secondary wire may be four or six sizes larger than that of the coil. The outer layers of fine wire are each partly covered with a paper band, consisting of six layers of tea paper, which is wide enough to reach from the head over about two-thirds of the coil section; the whole is then enveloped in a wrapper of stout paper, having a hole directly in the middle at the top, through which is poured melted resin to which has been added a very small quantity of beeswax.

This forms the insulating medium, G, which prevents the spark from leaping from one section of the coil to the other. After the resin cools, the thick paper is removed and a covering of smooth heavy paper is neatly put around the coil, and upon it is wound as closely together as possible common smooth finished black thread. This latter is not essential, of course, but it gives the coil an excellent appearance and forms a really good covering.

FIG. 3.



TRANSVERSE SECTION OF INDUCTION COIL.—HALF SIZE.

In the tube, A, is placed a bundle, I, of No. 18 soft iron wires. They should be straight and of the same length, and their outer ends especially should be exactly even. The central hole in the head, B, is stopped by a wooden plug or button, J. The base, K, consists of a wooden box, neatly made, and the size of which may be readily obtained from the engravings. The coil is secured to the top of the box, a little nearer one end than the other, by two screws, *a b*, which pass upward into the heads. BB′. Near the head, B′, there is a brass standard, *e*, to which is secured one end of the spring, *f*, that supports the iron hammer, *f′*, exactly opposite the center of the wire bundle, I, and about ¼ inch distant from it. Opposite the middle of the spring, *f*, and ½ inch from it, there is a post, *n*, through which passes the platinum pointed screw, *o*, which touches a small platinum plate, riveted to the center of the spring, *f*. The post, *n*, is split longitudinally, and clamps the screw, *o*, with some little pressure to prevent it from jarring loose by the vibrations of the spring, *f*.

FIG. 4.

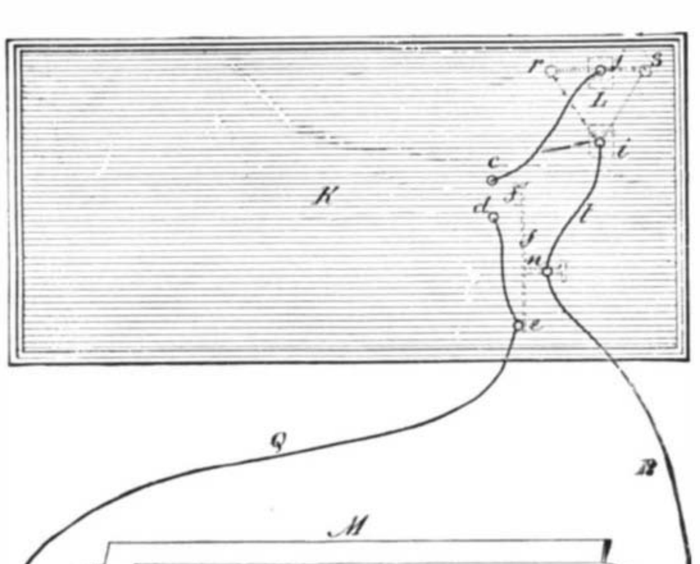


DIAGRAM OF CONNECTIONS, INDUCTION COIL.

The commutator, L, consists of a vulcanite cylinder on which are screwed two copper bars, *l m*, one of the screws of the bar, *l*, coming into contact with the pivot, *g*, and one of the screws of the bar, *m*, coming into contact with the pivot, *h*. The pivots, *g h*, turn in posts, *i j*, which spring against the shoulders of the pivots to insure a perfect contact. The pivot, *h*, is elongated and provided with a vulcanite handle, *k*. The binding posts, *r s*, are connected by copper springs, *p q*, with the copper bars on the vulcanite cylinder.

In the base of the instrument is placed the condenser, M, which is composed of sheets of thin tin foil alternating in position as shown in Fig. 4. The ends of the sheets, O, projecting beyond the sheets, P, to the right, the ends of the sheets, P, projecting beyond the sheets, O, to the left. The sheets, O, are insulated from the sheets, P, by sheets of paper, N, which have been coated with shellac varnish and well dried. While the sheets O, do not touch the sheets, P, the latter are all connected together at one end, and are in electrical connection with the wire, Q. Similarly the sheets, O, are connected with the wire, R.

A piece of pasteboard, *v*, is placed upon each side of the condenser thus formed, and the whole is fastened together with tape running around it in two directions, and the condenser is held in place by bits of cork, *w*, which are pressed by the bottom, X, when it is in its place. The condenser has 40 square feet of tin foil surface. The connections are made as follows: the battery wires are connected with the binding posts, *r s*, the current passes through the springs, *p q*, bars, *l m*, pivots, *g h*, to the posts, *i j*. The post, *j*, is connected directly with the terminal, *c*, of the primary coil, C. The post, *i*, is connected by the wire, *t*, with the post, *n*, and the terminal, *d*, of the primary coil, is connected with the post, *e*. The battery current passing through the primary coil renders the wire bundle, I, magnetic; the hammer, *f′*, is attracted toward it, breaking the electrical connection at the end of the screw, *o*, when the iron wire bundle loses its magnetism, and the hammer flies back until the spring, *f*, again touches the screw, *o*, when the hammer is again attracted, and so on. When the current is broken in this manner, if the condenser be detached, there is a large spark at the end of the screw, *o*, as the extra current is discharged from the primary coil; but when the condenser is connected by the wires, Q R, with the posts, *e n*, the spark is very much decreased in intensity, as the extra current is diffused in the condenser, and the strength of the secondary current is very much increased.

The binding posts, F, have each two holes and two binding screws. One set of holes receive the pointed rods, S, the other the conducting wires, T. This coil, if carefully made, will, when the current is interrupted, give a spark 1½ inches long between the points of the two rods, S, by using two large Grenet battery cells. The current may be reversed by turning the pole changer or commutator, L, through a half revolution, and it may be stopped altogether by turning the bars, *l m*, out of contact with the springs, *p q*.

It requires nearly a pound of wire for each section of the secondary coil; but, of course, the quantity will vary somewhat with the manner of winding. By observing the proportions, given coils of other sizes may be made from these drawings.

Another method of winding, to which I shall allude only briefly, consists in winding silk covered wire entirely across the spool, and insulating each layer by a coating of shellac, and two or three thicknesses of paper coated with shellac varnish or melted paraffin. Still another method consists in making the secondary coil of very thin sections, and insulating the sections one from the other by disks of hard rubber; but the plan here given is undoubtedly the easiest, and a coil made in this manner gives good results. With it most, if not all, of the experiments usually performed with induction coils may be accomplished.

For example, it will charge a Leyden battery, decompose water, explode blasting cartridges, light gas, exhibit the phenomena of electric light in vacuo, and may be used in many very interesting experiments.

SCIENTIFIC AMERICAN SUPPLEMENT, No. 166, will contain instructions for performing a number of interesting experiments with the induction coil.

ON THE MINUTE MEASUREMENTS OF MODERN SCIENCE.

By ALFRED M. MAYER.

ARTICLE XVI.

On the determination of the number of vibrations made in a second by a tuning-fork; with examples of the uses of the tuning-fork as a chronometer to mark and register minute intervals of time.

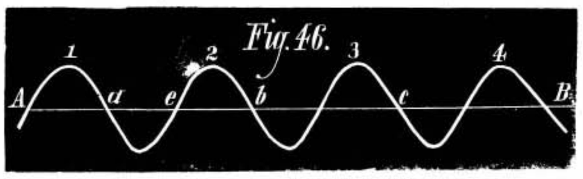
IN a subsequent article I purpose to show how, with revolving-mirrors, rotating-disks, and tuning forks, men of science have measured the minute intervals of time occupied by electric flashes, and have found out something as to the structure and compound nature of these flashes.

To make such investigations we must first of all provide ourselves with instruments whose parts will move so quickly that they can keep pace with these sudden and violent electrical motions, and also register the very minute times during which they exist.

A tuning-fork is an excellent chronometer, and when used skillfully will accurately measure intervals of time as minute as the 1-20,000th of a second. How a tuning-fork can serve as a time keeper the reader will readily understand after making the following experiment.

Take a tuning-fork the number of whose vibrations in one second we know. Suppose that it makes exactly 500 vibrations in one second. By a vibration we understand a to *and* fro motion of a prong of the fork. It is thus understood in this country, in England, and Germany, but in France a vibration is a to *or* fro motion of a prong of the fork. Blacken a piece of window glass by moving it about in the smoke of burning camphor, or in the smoky flame of a kerosene lamp. Tip one of the prongs of the fork with a delicate point made of a triangular piece of thin copper foil. Now vibrate the fork and quickly draw the tip of foil over the smoked surface. On holding the glass up to the light you will observe that the lampblack has been brushed by the tip from off the glass, in a sinuous or wavy line, as shown in a very enlarged scale in Fig. 46.

Each vibration to *and* fro of the fork made a part of the trace as long as from 1 to 2, or from 2 to 3, etc., or, what is the same, as long as from *a* to *b*, from *b* to *c*, or from *c* to *d*, measured on the axis, A B, of the curve. As the fork makes 500 of these double flexures in one second, it makes one of these double flexures (say from *a* to *b*) in the 1-500th of a second, and a single flexure (say from *a* to *e*, or from *e* to *b*) in 1-1,000th of a second. Thus it is evident that if we know the exact number of vibrations made by the fork in one second, we can use its wavy trace as a measure of the flow of time.



The velocity of rotation of a wheel measured by a tuning fork.—For an example, suppose we desire to know the velocity of rotation of the wheel of a gyroscope. Coat its disk or rim with lampblack, and touch the rotating wheel with the tip of foil on the prong of the vibrating fork. On counting the number of the flexures marked by the fork in the circumference of the wheel we have the number of thousandths of a second which the wheel took to make one revolution. Suppose we have found 25 flexures in the circumference of the wheel. This shows that the wheel made one revolution in 25-1,000ths, or 1-40th, of a second. In this very manner Dr. Thomas Young measured velocities of rotation in 1807. To this illustrious man of science is due the idea of using a tuning fork for a chronoscope, and the first published notice of this invention is found in his "Lectures on Natural Philosophy and the Mechanical Arts," London, 1807.

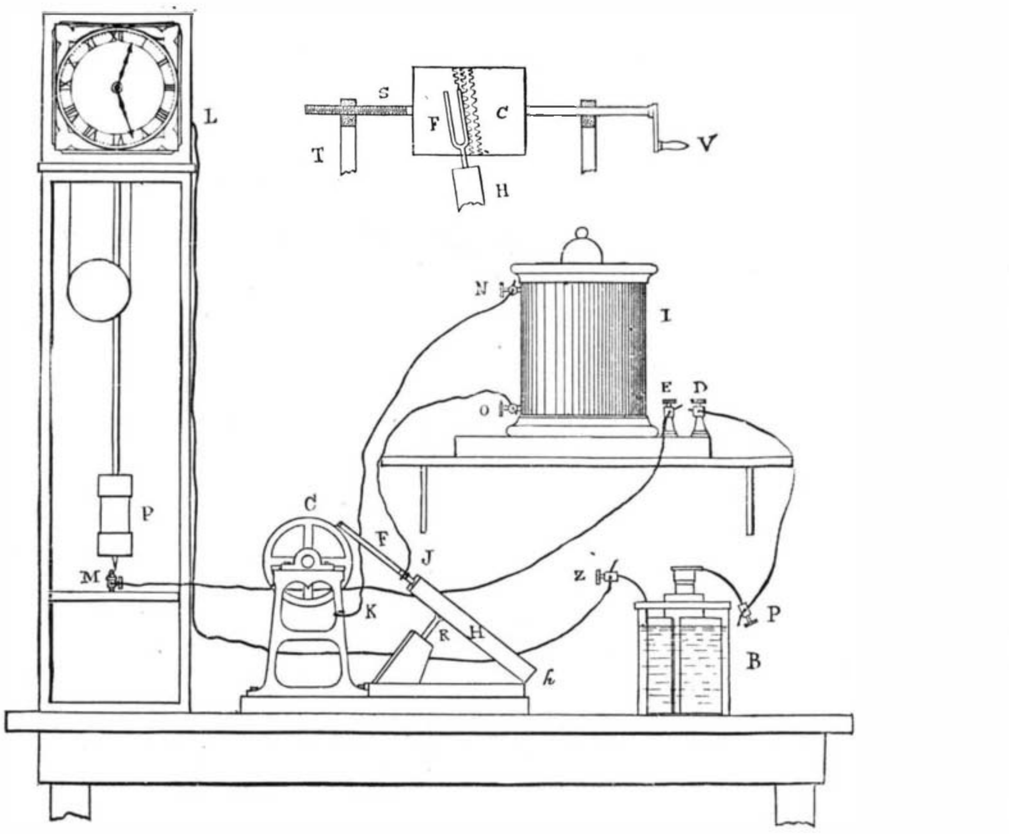
Evidently the knowledge of the exact number of vibrations made by the fork in one second lies at the foundation of this method of chronometry. To make this measure various methods more or less accurate have been devised, which we have not the space to enumerate. We will at once proceed to describe one which we consider as the most accurate that has been invented.

If it were possible to make a cylinder rotate with absolute uniformity of motion, and if we had the means of knowing the exact time taken by it in making one revolution, we might readily determine the number of vibrations made in one second by a fork. We would merely have to count the number of waves in the trace of the fork extending around the circumference of the smoked cylinder. This method has been tried; but all who have employed it have acknowledged the impossibility of getting a cylinder to revolve with sufficient uniformity for the purpose, and the difficulty of ascertaining the time occupied by the cylinder in one revolution.

A better plan is to let the cylinder revolve as it will, and to obtain the time not from the motion of the cylinder but from the fork itself. This is accomplished by sending at each second, through the intervention of a clock, a small spark of electricity from the tracing point of the fork on to a revolving metallic cylinder coated with smoked paper, and thus marking the exact intervals of seconds on the trace of the fork itself. By counting the number of flexures contained in the length separating two of these sparks we have the number of vibrations made by the fork in one second. A little consideration will show you that the velocity, whether slow or fast, uniform or irregular, has no influence on the determination of the number of vibrations of the fork, for an increase or diminution in the velocity of the cylinder does not change the *number* of the vibrations of the fork, but merely draws them out or crowds them together in the distance contained between two spark holes.

The manner of applying this method is as follows: At C, of Figs. 47 and 48, is a brass cylinder covered with paper, which is smoked by rotating the cylinder over a camphor flame. The foot of the fork, F, is screwed into a piece of hard wood, H, hinged at *h* to a base board. A triangular piece of platinum tipped foil is cemented to one of the prongs of the fork. This tip just touches the surface of the smoked paper, so that when the cylinder is revolved under the vibrating fork the latter makes its wavy trace on the smoked paper, as shown, very much magnified, on the cylinder of Fig. 48.

The cylinder turns on an axle which has a screw thread, cut on its length, S. This screw turns in a nut cut in the standard, T. On turning the crank handle, V, the cylinder revolves, and at the same time is moved horizontally by the action of the screw, S. By these motions the trace of the fork does not return on itself, but is written on the cylinder in a helical line, which is a reproduction of the screw, S.



FIGS. 47 and 48.

The spark is sent through the wavy trace of the fork by the following arrangement of apparatus: At L is a clock, beating seconds. The pendulum of the clock is formed of a rod of steel screwed into an iron cylinder, P, nearly filled with mercury. Attached to the bottom of this cylinder is a triangular slip of platiuum. The point of this slip, when the pendulum is vertical, goes into a globule of mercury, shown sticking at the top of the binding screw, at M. A cell of a voltaic battery is at B. From this cell, at P, a wire goes to D, one end of the primary coil in the inductorium, I. From E, the other terminal of the primary coil, the wire leads to M. When the pendulum is vertical it makes electrical connection with M and the works of the clock. A wire, L, joins the clockwork with the other pole, Z, of the battery. From this arrangement it is evident that whenever the pendulum, P, reaches the vertical, it enters and quickly leaves the globule of mercury, M, and by so doing it sends a momentary current of electricity into the primary coil of the inductorium. At the instant the platinum point attached to the pendulum *leaves* M, an electric current is sent from the secondary coil of the inductorium from O to the fork at J, thence it goes, *as a spark,* from the tracing tip on the fork *through the paper* to the cylinder. The latter is connected to the other terminal of the secondary coil of the inductorium by a wire leading from K to N. Thus, at each second a spark flashes from the tracing style of the fork and makes a small and sharply cut hole through the paper, directly in the wavy line which the fork traces. This electric flash must be formed of *one* spark, and this must be minute. This character of spark is obtained by using a small voltaic cell, and by interposing a sufficient electrical resistance between it and the inductorium.

To make a measure of the number of vibrations per second of the fork we proceed as follows: The cylinder is neatly coated with finely woven and thin printing paper, with its edges smoothly gummed together. Then the paper is smoked by traversing the cylinder over burning camphor placed in the interior of a little tin chimney. The battery connections are now made, the fork is vibrated by drawing a violin bow across its prong, and the cylinder is revolved. At each second a spark will be seen to flash out from the style attached to the fork. After the cylinder has been revolved through its whole length under the fork, the smoked paper is removed and (after writing on its smoked surface the number and character of the experiment) it is drawn through spirit varnish to fix the trace on the paper. If the paper is examined after one of these experiments, you will observe a minute white disk at each place where the spark flashed on to the paper, and on holding the paper between you and the light you will see that the center of each of these little white disks is perforated with a minute and clear round hole. This spark hole, when obtained as we have directed, is a very sharply defined point, so that it is not difficult to count the number of flexures between two holes to as near as 1-10th of the length of a flexure. It is indeed very interesting to see how the spark marks the exact beginning or end of a second, sometimes at one point, sometimes at another of the bend of the wavy trace.

After the paper has dried the count is made of the number and the fractions of waves contained in the length separating the spark holes. This count is made easier and less liable to error by marking off the waves contained between two spark holes into groups, each containing ten whole waves. The record on one sheet generally contains the traces made by the fork during twelve successive seconds.

As examples taken from actual determinations of the numbers of vibrations of forks we give the following tables of experiments:

A.	B.	C.
(1)	255·00	255·95
(2)	256·90	
(3)	255·05	255·97
(4)	256·90	
(5)	254·90	255·90
(6)	256·90	
(7)	254·70	255·92
(8)	257·15	
(9)	254·95	256·02
(10)	257·10	
(11)	254·90	256·02
(12)	257·10	
Mean..............................		255·96

The first column of numbers, inclosed in parentheses, denotes the successive seconds. The second column contains the number of vibrations made by the fork during these seconds. It will be observed that these numbers are alternately small and large; thus (1) = 255; (2) = 256·9; while (3) = 255·05; and (4) equals 256·9; and so on. This is so because the drop of mercury is not exactly in the center of the arc of vibration of the pendulum. This matters not, however, because the time by which the record of the first second is short of an exact second is added to the record of the next second; so, if we take the mean of the number of vibrations recorded in the first and second seconds, in the third and fourth, in the fifth and sixth, and so on—as we have really done in the third column of the above table—we will have the exact number of vibrations made by the fork in a second.

At the bottom of the third column is placed the mean of the means contained in this column, and this of course is taken for the final result of the determination as given by this series of experiments.

The difference between the largest number and the smallest in the column of means is 256·02 minus 255·90, which is only 12-100ths of a vibration. As the fork makes one vibration in 1-256th of a second, it follows that this extreme difference of 12-100ths of a vibration is, in time, only the 1-2,133d of a second. Calculating by the method of least squares the average error made in a single experiment, we find it equals plus or minus 3-100ths of a whole vibration of the fork; while the error of the mean of the whole twelve experiments amounts to only 1-77th of a vibration. One seventy-seventh of the 256th of a second is about the 1-20,000th of a second.

The above experiments are fair examples taken from scores of similar series which we have made on the forks of König of Paris. The fork used in the experiments given in the above table was stamped by König as giving 256 complete vibrations in a second. Our experiments show that when this fork was loaded with tip of foil and was scraping the lampblack off the paper it made 255·96 vibrations in a second at the temperature of 74° Fahrenheit. When the tip is very delicate and is so carefully adjusted that it just brushes the black off the paper, its effect on the time of vibration of the fork can barely be detected.

One cause of change in the number of vibrations per second of a fork is due to a change in its temperature. This, however, is fortunately very slight in its effects. We have found from many very carefully made experiments that an elevation of one degree Fahr. in the temperature of one of König's forks diminishes its vibratory period by about the 1-22,000th part.

The extent of the swing or amplitude of the fork's vibration has no appreciable effect on its time of vibration. Thus, in the experiments contained in the above table the extent of the swing of the fork during the first and second seconds averaged about two and a half millimeters, while in the eleventh and twelfth seconds it averaged only one half millimeter. Yet there is a difference of only 4-100ths of a vibration in a second. In the above series of experiments it appears that the fork moved a little faster as it ran down in amplitude, but this really shows nothing, for on examining any dozen series of similar experiments it will be found that the fork as often goes slower as faster as the amplitude of its vibrations gradually diminishes.

The above facts are sufficient to convince any one of the great value of a tuning fork as a chronometer which both marks and records minute intervals of time. It is a chronometer which requires to be regulated but once; that is, we have only once for all to determine the number of vibrations it makes per second at a known temperature. It does not get out of order, for if kept from rust it will, as far as we know, have the same rate ten years hence as it has today.

The laws of falling bodies written on a falling plate by a tuning fork.—We will give a few examples of its application to such purposes. We have already shown how the trace made by a vibrating fork on the rim of a wheel will give its velocity of rotation. In this case the velocity may be considered as uniform during one revolution. But variable motions are as readily studied. For example, if a plate of glass fall vertically, it will have a gradually increasing velocity so that the spaces it will describe in successive equal portions of time will be as 1 : 3 : 5 : 7 : 9, etc. This is readily shown by allowing a smoked plate to fall freely, while the style on a vibrating fork wipes off the lampblack from its surface. After the fall of the plate it will be seen that the successive waves made by the fork (beginning with its *first* wave) have lengths which are as 1 : 3 : 5 : 7 : 9, etc. But the time in which the fork made each of these waves is the same, hence the respective *lengths* of these waves show the respective distances through which the plate fell in successive small and equal portions of time. Instead of allowing the plate to fall near the stationary fork it may be more convenient to make a fork fall near a stationary vertical plate. The fork may be screwed into a board, whose lower edge is loaded with a bar of lead. The board must run accurately in vertical guides. With such a simple instrument may be shown all the laws of falling bodies.

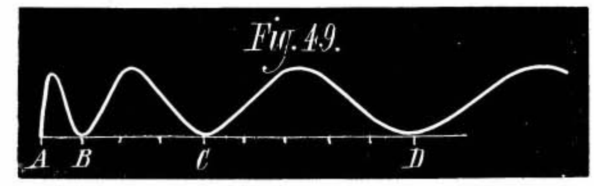


Fig. 49.

Fig. 49 gives the exact appearance of a trace made by a fork, or rather, by a vibrating steel rod, on a smoked glass plate which fell near it. It will be remembered that each of the half waves, A B, B C, C D, was made in the same period of time, but the spaces, A B, B C, and C D, are of different lengths, for they are really the distances through which the plate fell with a uniformly increasing velocity in equal portions of time. A scale of equal parts is drawn on A D, with the distance from A to B taken as its unit. The reader will observe that while A B contains one unit of length, B C contains 3, and C D contains 5. This curve shows in a very simple and neat manner that a body in falling vertically by the action of gravity goes over spaces in equal successive portions of time, which are of lengths as 1 is to 3, is to 5, is to 7, and so on. If after the experiment you flow spirit varnish over the smoked plate you will have a permanent record of the law of falling bodies written by Nature herself.

The velocities of cannon balls measured by the tuning fork.—It is evident that one of the conditions of efficiency of an army is that it shall be furnished with the best arms, ordnance, and gunpowder. To form accurate comparisons as to the relative merits of various forms of arms and cannon, and of powder of different compositions and structure, it is necessary to compare the various velocities given to the balls. For this purpose nothing answers so well as *the tuning fork chronoscope.* A fork, the number of whose vibrations is accurately known, is mounted with a delicate style touching a cylinder like that shown at C, in Figs. 47 and 48. Instead, however, of the primary circuit in the inductorium being broken by the pendulum, P, as in those experiments, it is broken by the ball passing through targets made of stretched wires placed at known distances apart. At each rupture of the wire of a target a spark flashes from the fork and makes a hole in its trace. At the next instant the electric circuit is closed by an electro-magnet before the ball has reached the next target, and so on in order at each target the circuit is broken and then instantly closed. After the flight of the ball through all of the targets, the number of waves contained in the spaces separating the successive spark holes is counted. These numbers multiplied by the time it takes the fork to make one vibration, give the times which the ball took in going through the distances separating the successive targets.

The speed with which the nervous motor and sensitive agent travels along the nerves measured with the tuning fork.—In physiological experiments the tuning fork is the chronometer which is universally used when minute intervals of time have to be accurately measured. The fork has timed the speed of the nervous motive agent and the velocity of the contractile waves in the muscles. To understand how such measures are made imagine a revolving cylinder whose smoked surface is touched by the longer arm of a delicate lever. The shorter arm of the lever rests on a muscle in which motion can be caused by the irritation of a certain nerve. This nerve we can excite at two points which differ by several centimeters in their distances from the muscle. The tipped prong of a tuning fork writes its trace on the revolving cylinder just below the line which is described on the cylinder by the long end of the lever when stationary. It is evident that when the muscle contracts the lever is tilted, and its end which touches the cylinder leaves the straight line which it was tracing to return to it when the muscle relaxes. On the cylinder is a projecting piece of metal which in its revolution with the cylinder comes in contact with another fixed piece of metal and then sends an electric discharge into the nerve. Now, suppose we thus excite the nerve at the point which is nearest the muscle; the latter contracts and moves the lever. This motion of the lever takes place a certain interval of time after the irritation of the nerve. If we now irritate the nerve at the point more distant from the muscle we will find that a longer interval of time exists between the irritation of the nerve and the motion of the lever. The difference in these two intervals of time is the time required by the nervous agent in traversing the space between the two points on the nerve.

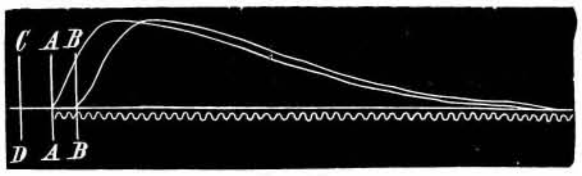


Fig. 50.

Fig. 50 gives a representation of the graphic results of an experiment on the speed of the nervous motive agent in man, and may serve to give a clear conception of these interesting experiments. At the same time it shows the velocity of the nervous motive agent, the time required for the muscle to move after the nervous agent has reached it, and also the character of the motion a muscle has during its contraction and elongation.

The horizontal line is the line made on the cylinder by the end of the lever when the latter is stationary. When the lever is moved by the contraction of the muscle it is deflected above the horizontal line, and then draws one of the curves shown in the figure. It will be understood that the smoked surface on the cylinder is moving from right to the left of the reader; hence the steep side of the curve is made on the contraction of the muscle, while the gradual descent toward the horizontal line is made during its elongation. This shows that the muscle contracts faster than it elongates.

The electric discharge into the nerve is made when the tracing point of the lever is on the vertical line, C D, but this point does not move till it reaches A in one experiment and B in the other. The motion of the lever at A was caused by the irritation of a point of the nerve quite close to the muscle, while its motion at B was caused by another experiment when a point of the nerve 30 centimeters farther removed from the muscle was irritated. Referring to the figure the reader will see that the fork wrote two and a half of its waves in this interval, A to B. As the fork made 250 vibrations in a second, it follows that the nervous motive agent in man goes over 30 centimeters in 1-100th of a second; or, has a velocity of 30 meters in one second. This speed is about that of the fastest railway trains in England.

In the above experiment the point of the nerve nearest the muscle was quite close to the shorter arm of the lever. If the lever had moved at the instant the nervous agent acted on it the deflection above the horizontal line would have taken place at the line, C D, instead of at A, as really occurred. This shows that it takes quite an interval of time for the muscle to move after the nervous agent has reached it. The distance from C D to A represents an interval of time a little over one hundredth of a second. This sluggishness of the muscle to obey the nervous agent has been called by Helmholtz *the lost time.*

The velocity with which the nervous sensitive agent is conducted along the nerves is about the same as that of the speed of the nervous motor agent. This fact opens curious reflections as to the interval of time which must always exist between the irritation of a nerve and the sensation caused by it. For example, if a man should have his toe cut off without his seeing the act, he would not be signaled of his loss till about 1-16th of a second after it had happened; then it is supposed that the brain requires about 1-30th of a second to receive and interpret the message and to order the foot to move. The sending of the order over the nerves will take another 1-16th of a second. After this order (or stimulus) has reached the foot, 1-100th of a second will elapse before the muscles of the foot can move. Adding together all of these intervals of time we find that 1-6th of a second will intervene between the injury to the foot and its motion. In reptiles the velocity of the nervous agent has probably about one half of the speed it has in man. Some of the serpents of the *Boidæ* family grow to 30 feet in length. If with a stealthy and sudden cut we should deprive one of these creatures of the tip of his tail, it is likely that a whole second would elapse before he could retract his body. In the above curious reflections we have assumed that no reflex action occurs in these phenomena to render inaccurate the computations which we have made.

COLLIN'S CITY TIME REGULATOR.

The problem of how to regulate uniformly the time of the different clocks of large cities, so that at least several times a day they correspond exactly to each other, has always been of difficult solution

The action of compressed air has been employed without satisfactory results. Later, the ordinary electro-magnetic chronometers were invented. Although tolerably precise in their action, when applied to a limited number of clocks, they failed as soon as they were required to unify the time of a more extended territory; besides, an omission of the correction having once occurred, it was not made good by the next regulation taking place, another omission would again increase the error, and thus the difference would sometimes accumulate within a few days to the same extent, as without electrical regulation.

There were exhibited at the Paris Exhibition several devices of a novel character, intended to do away with these difficulties, of which the most interesting are that of Foucault and Vérité, and that of Mr. Collin. The former is admirably adapted to all scientific and other purposes, where the greatest possible exactness is required. Its regulation takes place every second, thereby reducing the greatest possible inaccuracy to a minimal fraction of a second. The apparatus of Mr. Collin, which we illustrate above, corrects the time every hour only, but is of sufficient exactness for all ordinary purposes. Its simplicity makes it especially adapted to the unification of time of a large number of clocks, as in a large city.

The clock to be regulated, represented in Fig. 1, is arranged so that it has a very slight tendency to run ahead of the regulator, shown in Fig. 2. Every hour, as soon as the minute hand reaches 12, an electric mechanism stops the escapement wheel; thus the balance swings free, without effect, till the hand of the regulator has also arrived at 12. Then the circuit is broken again, and the two clocks move on perfectly synchronically. Nothing can be more simple than this contrivance. Should, for some reason or other, the action be omitted, the entire error will be corrected the next time it takes place again.

As the engraving shows, nothing has been altered in the mechanism of the clock proper. The electro-magnetic instrument is situated on a platform supported by the general frame. The interrupter is placed above the dial, resting on an eccentrical disk, moving simultaneously with the minute hand. Its most eccentrical point reaches the noon point exactly with the minute hand.

The armature of the electro-magnet is provided with a long lever, bent at its end in a right angle, so as to engage the teeth of the escapement wheel. The electro-magnet connects at one end with the arm below the interrupter, at the other end with the second wire of the circuit; the first wire of the latter connects with the interrupter arm resting on the eccentric.

The circuit is completed by the electric battery and the interrupter of the regulator (Fig. 2).

The interrupter of the latter is composed of two levers, the lower one of which also rests on an eccentrical disk. As long as it slides on the jutting part of the latter it remains in contact with the upper lever, but, when it drops down at the end of each hour the contact is severed, the circuit broken, and thereby the lever in the clock, Fig. 1, is caused to release the escapement wheel, upon which the clock moves on. The arm situated above the interrupter in Fig. 1 is not necessary, where only a single clock is to be regulated by the standard mechanism. In a complicated system, however, it acts as conjunctor of current.

It is obvious that this mechanism may be easily applied to all kinds of clocks, without increasing materially the cost.—*L'Electricité.*

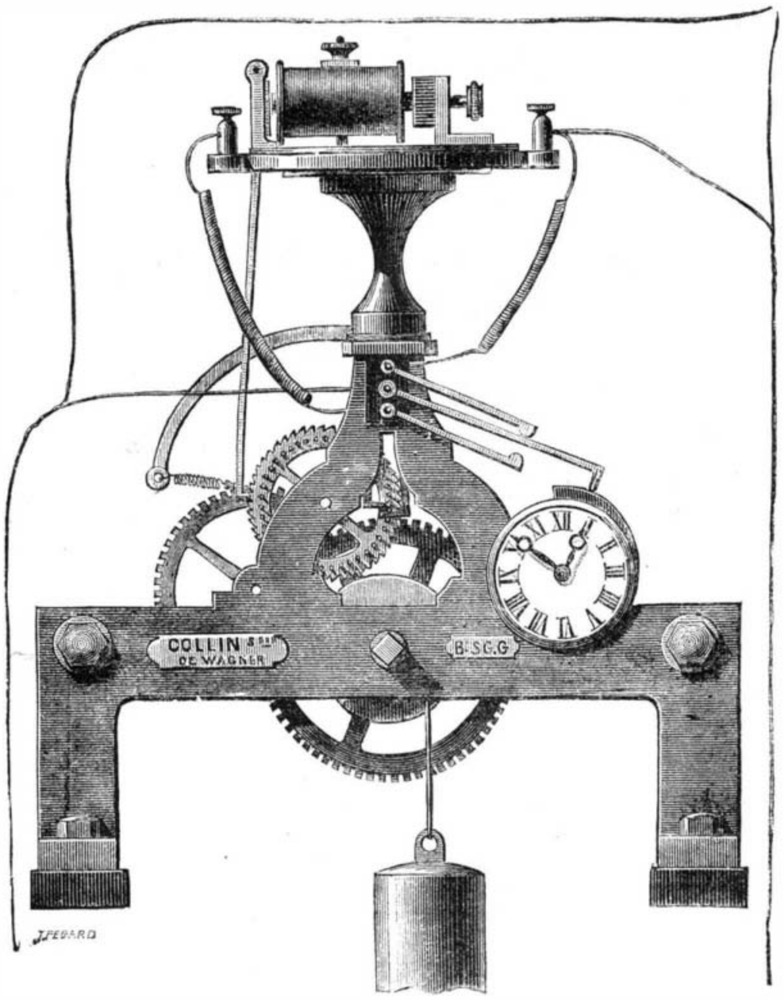


Fig. 1.

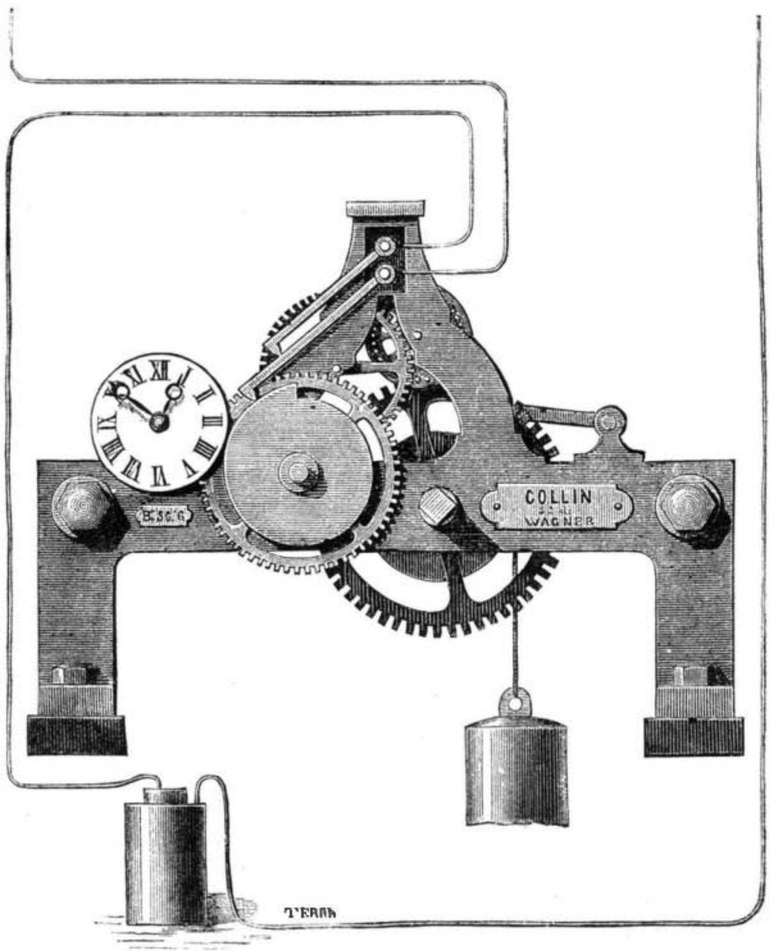


Fig. 2.

COLLIN'S CITY TIME REGULATOR.

STROUMBO'S APPARATUS FOR DETERMINING THE MAGNETIC INCLINATION AND DECLINATION.

This instrument, invented by Prof. Stroumbo, of Athens, Greece, and represented in the engraving on next page, serves to demonstrate the declination and inclination of the magnetic needle at different localities.

It consists of a horizontal graduated ring, H, and a vertical, graduated semicircle, V, which are firmly fastened together and supported by a tripod. The feet of the latter are provided with screws, X, by which the position may be regulated. In the ring plays an ordinary magnetic needle, while another one, provided with a lateral axis resting on supports formed by pieces of agate stone, as shown in the engraving, plays in a vertical plane. Both needles must be as much as possible of the same size and weight, and one at a time only must be used on the instrument. O is a brass plate, provided with a minute opening. Directly opposite is a vertical frame, P. Through the center of its open space is extended a horse hair, in front of which slides a marker, G. The frame, P, is divided into minute degrees on its entire length, beginning from zero, the zero point being in a horizontal line with the opening in O. The line, O P, is situated directly above the line, 0°—0°, of the scale, H, and is parallel to the vertical scale, V. The graduation on P gives the angles, formed by a line drawn from O to any point of the scale with the horizon.

To find the declination we proceed as follows:

The needle, I, being removed, the needle, D, is left to play, till it comes to rest. Then the instrument (or, in case the upper part is made movable, the scales, H and V), is turned, till the points of the needle are situated directly above the points, 0°—0°, of the scale, H. The direction indicated by the needle, D, is the *magnetic meridian* of the place of experimenting. A plane drawn through the same vertically passes through the center of the earth. The north is indicated by the blue end of the needle. As is well known, the magnetic meridian differs from the geographical meridian of the earth, a plane laid through the latter falling in that of the earth's axis. The angle formed by the two meridians is called the *magnetic declination.* To determine the latter, we must hence find the geographical meridian. This is done as follows: The apparatus being in horizontal position, a line of vision is drawn to a known star near the horizon, noting the point at which the line crossed the scale, P, as also the exact moment of observation and the angle formed by the needle, D, with the line, 0°—0°, on the scale, H. By means of the necessary astronomic tables the angle, formed by the plane laid through the opening, O, the horse hair at P and the star with the geographical meridian, may be found, from which the angle formed by the latter with the magnetic meridian may easily be calculated.

The declination is called western, when the blue point of the needle falls between N and W; eastern, when it falls between