A SIMPLIFIED METHOD OF TEACHING EXPERIMENTAL PHYSICS.

BY JACQUES BOYER.

Until recently, experimental physics has been taught by rather superannuated methods in the *lycées* and colleges of France. The teachers lacked simple apparatus suitable for the initiation of their pupils into the mysteries of acoustics, optics, electricity and magnetism; although some of the schools possessed magnificent instruments, copies of those of half a century ago, which, in the language of M. Chassagny, the inventor of the apparatus described below, "were a joy to their makers" but of little use to their possessors. There were costly Hiero's fountains and Morin's machines which were used only once a year. The pumps and hydraulic presses were equally expensive and they gave the pupils a totally false conception of the pumps and hydraulic presses employed for practical purposes. Babinet's improved pneumatic apparatus is remarkable chiefly for its great display of polished copper. The Gay-Lussac eudiometers, Ramsden electric machines, condensers of Aepinus, Watts's machines and many others have now only historical interest. For several years French teachers of physics have been trying to modernize their cabinets of apparatus and to modify their instruments in order to simplify experimental observations. Prominent among these progressive teachers is M. Chassagny, inspector of the Academy of Paris, who has invented a number of efficient instruments of neat and substantial, though inexpensive, construction, with each of which various instructive experiments can be performed.

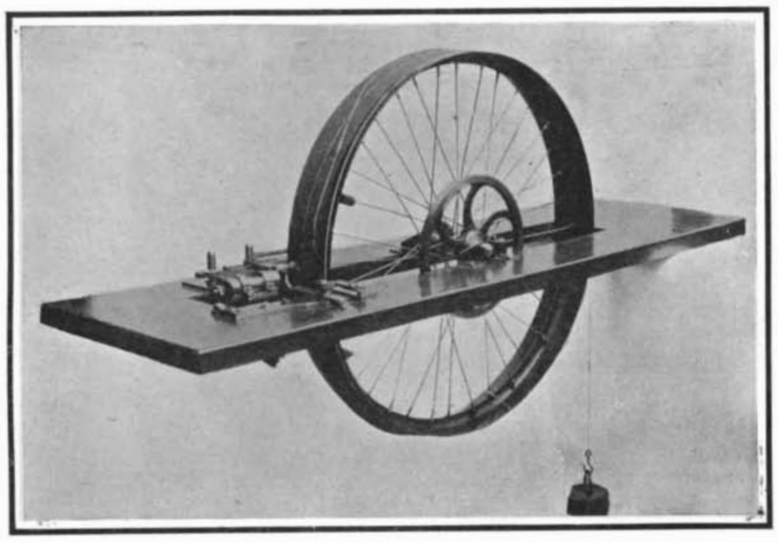

Fig. 1.—The mechanical recorder.

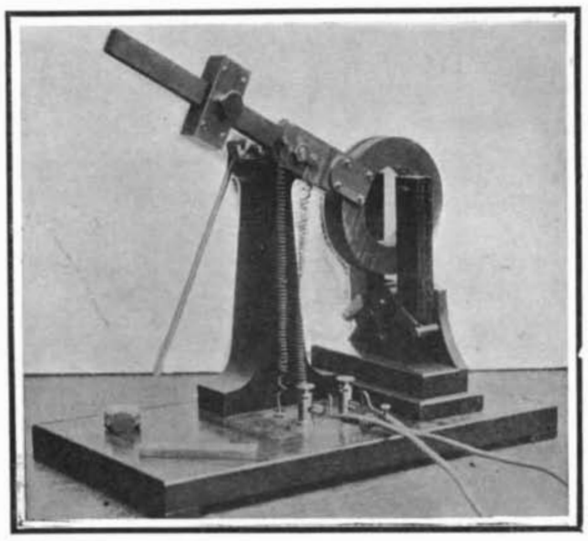

Fig. 6.—Chassagny's apparatus for electromagnetic induction.

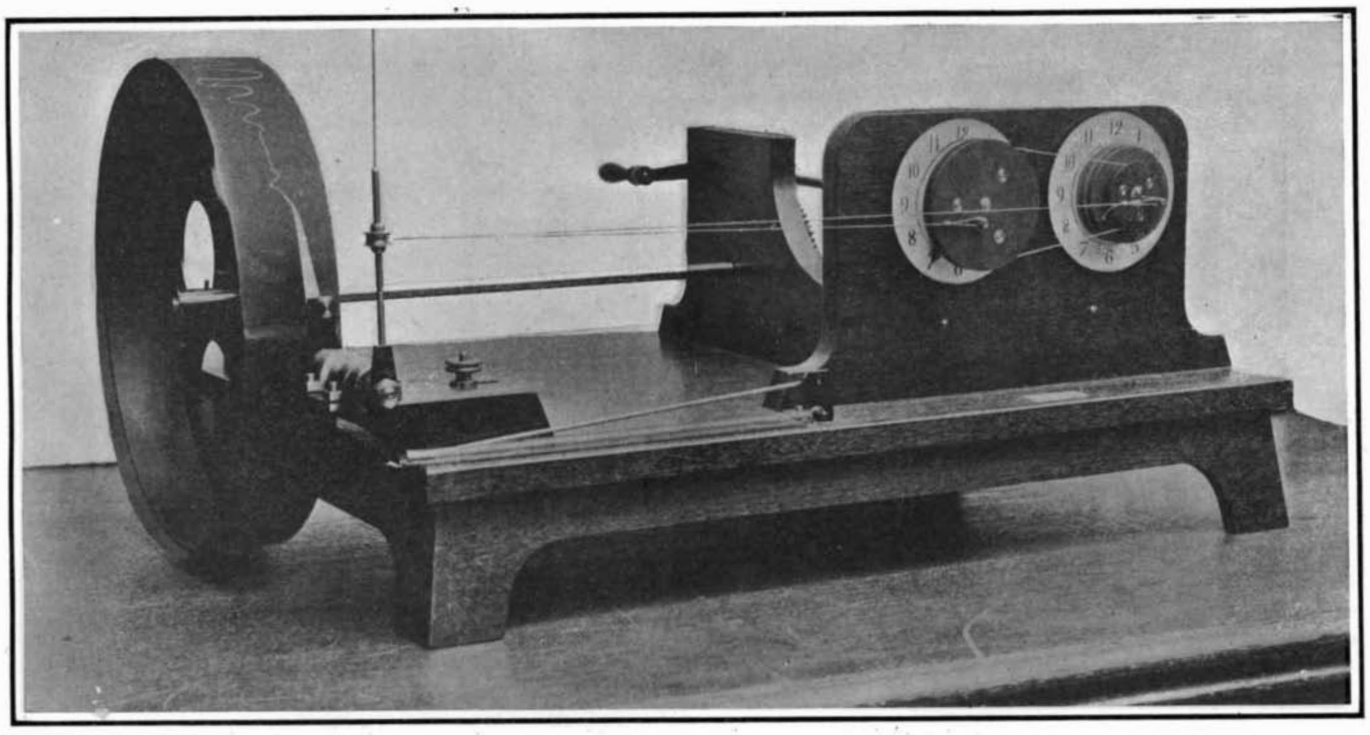

Fig. 2.—Apparatus for combining vibrations in the same plane.

The complicated machines of Atwood and Morin for the study of the laws of falling bodies are replaced by the mechanical recorder (Fig. 1), which is useful also in explaining the laws of the compound pendulum and the graphical method of recording movements in general. A bicycle wheel is mounted with its axle horizontal in a flat wooden frame. The rim of the wheel carries a wide band of sheet brass, forming a sort of drum, which can be covered with a band of smoked paper, and one end of the axle bears a small grooved driving pulley. The center of gravity can be brought accurately to the axis of rotation by means of sliding weights attached to two of the spokes. At one side of the drum a short pendulum, formed of a heavy cast-iron cylinder, is mounted on an axis perpendicular to that of the drum, on the blackened surface of which a record is traced by a flexible needle attached to the pendulum. The drum and the pendulum can be stopped, together or separately, by means of an adjustable lever, and the driver is also provided with an emergency brake.

With this apparatus some fifteen experiments can be performed, illustrating the static equilibrium of moments, inertia, the action of constant forces, the law of velocities, proportionality of force to acceleration, resistance of the air, friction, isochronism of small oscillations, the graphic method of registering movements, etc.

In demonstrating the principle of inertia the needle is brought into contact with the band of smoked paper carried by the drum, and the drum is turned. The pendulum being in the position of equilibrium, the needle traces a line which, when the paper is removed and laid flat, will be straight and will constitute a base line. This line having been traced, the pendulum is drawn to one side, a rotary impulse is given to the drum with the hand, the pendulum is released by moving the lever which holds it, and the needle traces an undulating line. The distances between consecutive intersections of this line with the base line represent equal intervals of time, corresponding to equal vibrations of the isochronous pendulum, and as these distances are also found to be sensibly equal in length, the experiment proves that the drum, set in motion by a momentary impulse, continues to rotate with practically uniform velocity (the effect of friction being negligible).

In studying the action of a constant force, the base line is traced as before. A cord is then wound round the drum and a weight of about one-quarter pound is attached to its free end, as shown in Fig. 1. The zero point is marked by allowing the pendulum with its needle to swing across the base line while the drum is held at rest. The pendulum is then drawn aside and, by a proper adjustment and manipulation of the lever, the pendulum and the drum are released simul-

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Fig. 4.—Chassagny's electroscope.

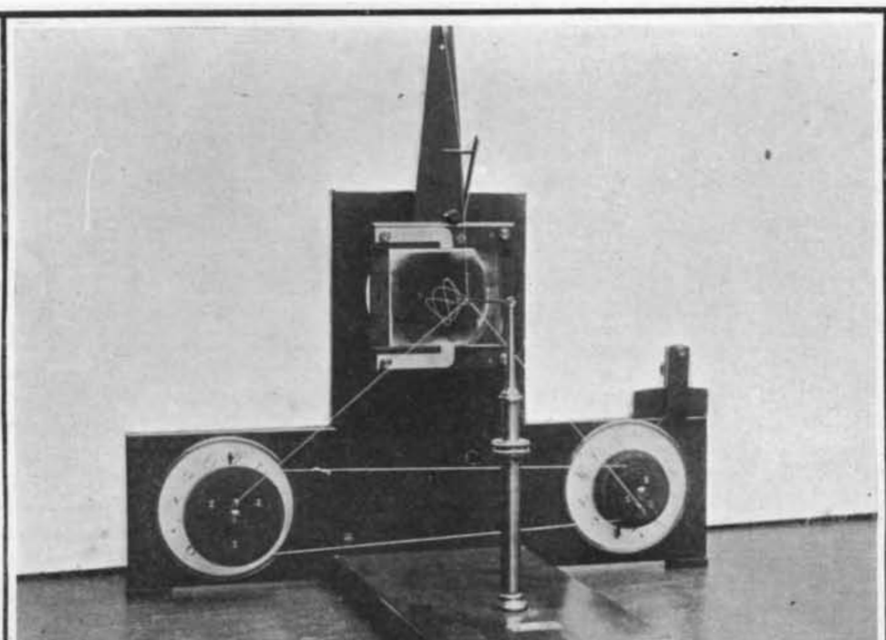

Fig. 3.—Apparatus for combining vibrations in mutually perpendicular planes.

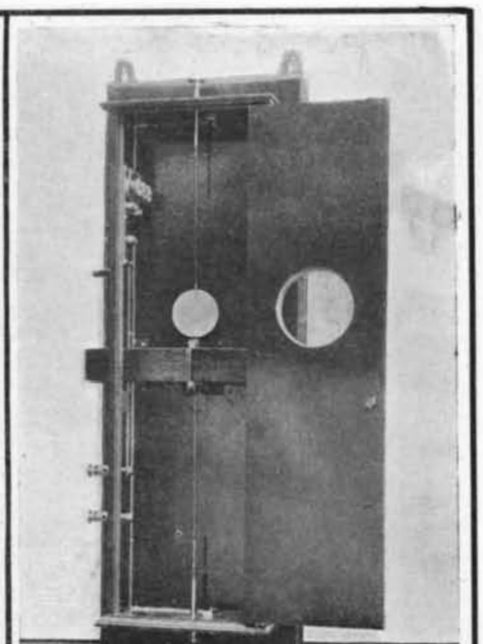

Fig. 5.—Chassagny's galvanometer.

A SIMPLIFIED METHOD OF TEACHING EXPERIMENTAL PHYSICS.

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Lamp attachment, vehicle, A. G. Thomson.. 936,831
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Mail box holder, J. H. Fisher............ 936,527
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Malt kiln, R. Roth 936,947
Manifolding pad, E. K. Bottle............. 936,697
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Melting furnace and using the same, Carr & Speer 936.758
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Metal, composite, J. G. Mellen............ 936,339
Metal, permanent magnetic, S. E. Gertler.. 936,530
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Metals, plating, W. Griffith 936,713
Metals, treating, H. D. Miller............ 936,650
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Mine firing device, T. C. Hallam.......... 936,885
Minerals, device for preventing waste of, Smith & Kongsli 936,377
Mining drill, J. R. Place................. 936,937
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Mop, J. F. McLaughlin.............936,655, 937.007
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Mower, J. T. Fritsche 936,881
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Nut lock, J. B. Lambeth 936,331
Nut lock, F. Moser 936,553
Nut lock, D. E. McDonell 936.929
Oar lock, T. C. Luce 937,004
Oil and air, apparatus for supplying, heating, and burning crude, H. E. Weaver. 936.688
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Oil burner, H. S. Milks 936.922
Oil waste cleaning apparatus, Orkin & Isaacs 936.657
Oiler, road, C. M. Haeske 936,716
1-para-dialkylaminoaryl-2-4-dialkyl-3-oxymethyl-5-pyrarolone, Stolz & Streitwolf... 936,380
Ore pulverizing and amalgamating apparatus, R. Luckenbach 936,645
Ores. amalgamating and separating metallic, R. Luckenbach 937.033
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Packing, piston, J. J. Hampson............ 936,717
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Paper box machines, paste applying mechanism for, A. W. Mitchell............. 936.796
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Pedal mechanism. A. G. Gulbransen........ 936.447
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Pencil making machine. R. H. Howard.... 936,722
Pencils and the like, thumb rest for, S. O. Donovan 936.868
Percussive machine and tool. W. Mauss.... 936.550
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Phonographic reproducer. R. B. Smith...... 936.826
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Piano, self playing, E. B. Bartlett........ 936.851
Piano sounding board, F. B. Long.......... 936.789
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Pipe, cigar holder. etc., J. R. Perry....... 936.734
Pipe coupling, train, W. M. Hiler......... 936.894
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Pipe tapping machine. W. B. Ford......... 936.618
Pipe wrench. A. A. Patton 936.804
Pitcher, P. Pollard 936.938
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Planers, feed roll controlling mechanism for wood, H. A. Perkins.............. 936.659
Planers, lathes, etc., cutting tool for, C. R. Middleton 936.793
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Planters, differential dropper mechanism for corn, F. P. Murphey 936.471
Plow, J. W. Newton 936.345
Plow, J. Brey 936.599
Plow and planter, combined lister, Shearer & Kirlin 936.483
Plow attachment, K. R. Van Winkle....... 936.962
Plow draft attachment, C. F. Strnad...... 936.829
Plow, gang, J. O. Fjarli 936,768

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taneously. The needle traces an undulating line which cuts the base line in a series of points whose distances from the zero point are proportional to 1, 4, 9, 25, etc., that is, to the squares of the times. In this way the laws of falling bodies can be verified to within 1 per cent. This is a much closer approximation than can be obtained with Atwood's or Morin's apparatus, with which the beginning and end of the fall cannot be determined very accurately.

In other experiments the drum is driven by a cord, passing over the pulley and a grooved wheel 6 inches in diameter, attached to a simple driving clock, such as is used to turn a spit. With this arrangement the gradual diminution of the amplitude of succesive oscillations of the pendulum, and the more rapid diminution brought about by attaching to the pendulum a paddle dipping into water, can be studied. The isochromism of small oscillations can be shown by giving the drum a uniform velocity of rotation, by means of the driving clock or of a weight which is stopped after it has fallen a certain distance. Then the base line and the undulations having been traced as before, the wave length, or distance between consecutive intersections of the two lines, is found to be constant, no matter what the amplitude or height of the wave may be, provided that it is small.

Chassagny's apparatus for compounding vibrations in the same plane (Fig. 2) comprises two wheels mounted on parallel shafts. The first wheel is turned by a crank and drives the other by means of a belt. The ends of a fine violin string are attached to pegs inserted in the faces of the wheels at unequal distances from their centers, and the middle part of the violin string, which is kept taut by a spring, passes round a pulley, which turns freely on a vertical rod, attached rigidly to the horizontal axle of the nave of a bicycle wheel mounted in bearings. When the crank is turned both wheels revolve, and the horizontal displacement of the pulley, at any instant, is equal to the algebraic sum of the horizontal displacements of the two pegs. The movement of the pulley is followed accurately by a writing point which is attached to the other end of the bicycle nave. This point presses against a strip of smoked paper wrapped round a drum, which is turned by the engagement of a toothed wheel on its shaft with an endless screw on the crankshaft. The amplitudes of the two vibrations whose combined effect is sought are varied by varying the distances of the pegs from the axes of the two wheels; the phases are varied by setting one wheel, at the start, more or less in advance of the other by means of pointers attached to the wheels and fixed graduated circles behind them; the periods are varied by employing wheels of diameters proportional to the periods desired. For example, two wheels of nearly equal diameters give a graphical record of the phenomena of "beats."

Vibrations in mutually perpendicular planes are combined by means of an apparatus based on the same principle (Fig. 3). The resultant curves are traced on smoked glass so arranged before a lantern that the curves can be immediately projected on a screen and explained and studied at leisure, with a thoroughness that is not possible with the evanescent projections of Lissajous's figures made in the usual way, by reflecting a pencil of light from mirrors attached to tuning forks.

Chassagny's apparatus for the study of refraction consists of a glass globe supported by fixing its horizontal neck in a copper sleeve. If the neck is regarded as one pole of the globe, the opposite pole is indicated by an interruption in a copper meridian, and the equator is graduated in intervals of five degrees. Water is poured into a funnel attached to the upper side of the neck until its surface

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attains the level of the break in the meridian. The laws of refraction and total reflection can then be studied by directing luminous pencils toward the center of the globe, in the equatorial plane, and viewing them with the eye placed in the same plane.

In his electroscope (Fig. 4) Chassagny has made use of the fact that platinized glass is sufficiently transparent to allow objects to be seen clearly through it and yet reflects bright images of objects nearer the eye. A vertical and rigid strip of copper and a flexible strip of aluminium foil are suspended from a copper rod and inclosed in a case of which two opposite sides are of glass and the rest of metal. The rod carries a charging disk at its upper end and is insulated by passing through a block of paraffin, which rests on the top of the case. One of the glass sides is platinized, and outside it is placed a graduated quadrant which is seen by reflection, while the deflected strip of aluminium is seen through the glass.

Chassagny's galvanometer (Fig. 5) is inclosed in a wooden case, which is attached to the wall. In a strong magnetic field, formed by placing the like poles of two horizontal horseshoe magnets almost in contact with each other, is suspended a coil of wire of electrolytic copper. The intensity of the field is further increased by a soft iron cylinder, supported independently inside the coil. A large mirror, attached to the coil, reflects the image of a lamp to a screen, where the movements of the spot of light can be followed by the whole class. The galvanometer is provided with three shunts.

In Chassagny's apparatus for the study of electromagnetic induction (Fig. 6), a coil of wire is attached, with its plane vertical, to one end of a lever which can turn round a horizontal axis, and is balanced by a counterpoise on the other end. A vertical horseshoe magnet, with its poles directed upward, is placed so that the coil can be brought between the poles, or raised above them, by turning the lever on its axis. The positive and negative currents produced by these movements are indicated by a galvanometer connected with the coil. An alternating current is produced by allowing the lever to oscillate freely. Other experiments in induction may be made by sending through the coil a current from a battery.

M. Chassagny has devised a number of other ingenious instruments, including a very practical rheostat, a eudiometer, a baroscope, etc.

THE LATEST SUBMARINES OF THE UNITED STATES NAVY.

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merged condition, certain valves in the interior of the boat are opened. This allows the water from the sea to run into great tanks built within the boat, and thus virtually sink her. These tanks are closely gaged, so that just the required amount of water is taken in. Under normal conditions, when the boat is at rest with the ballast tanks filled, she will have a few hundred pounds reserve buoyancy, which is represented by the top of her conning tower protruding above the water. If desired, this buoyancy may be entirely destroyed by admitting a small additional amount of water, equal in volume to the volume of that part of the conning tower above water. While in the submerged condition, all communication with the outside atmosphere is necessarily cut off. The crew, usually about fifteen men, then breathes the air contained in the body of the boat. The amount of air originally contained within the hull is sufficient to support life with comfort for at least twenty-four hours. But, in addition to the air thus contained, the boat carries a large supply of compressed air in steel flasks, which, if used for breathing purposes, would be sufficient for a number of days.

After having brought the boat to the submerged condition in the manner

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