THE GLOW-LIGHT OSCILLOGRAPH.[1]

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All teachers of physics—I presume—very much desire to have a Duddell oscillograph in their possession, but no doubt, most of us, like myself, have not yet mustered up sufficient courage to ask our boards of education to appropriate the considerable sum needed for the purchase of one. However, the glow-light, or Gehrcke-Ruhmer, oscillograph is a fairly satisfactory substitute for the true oscillograph, and its cost is so small, between ten and fifteen dollars, that its purchase is possible for every one of us.

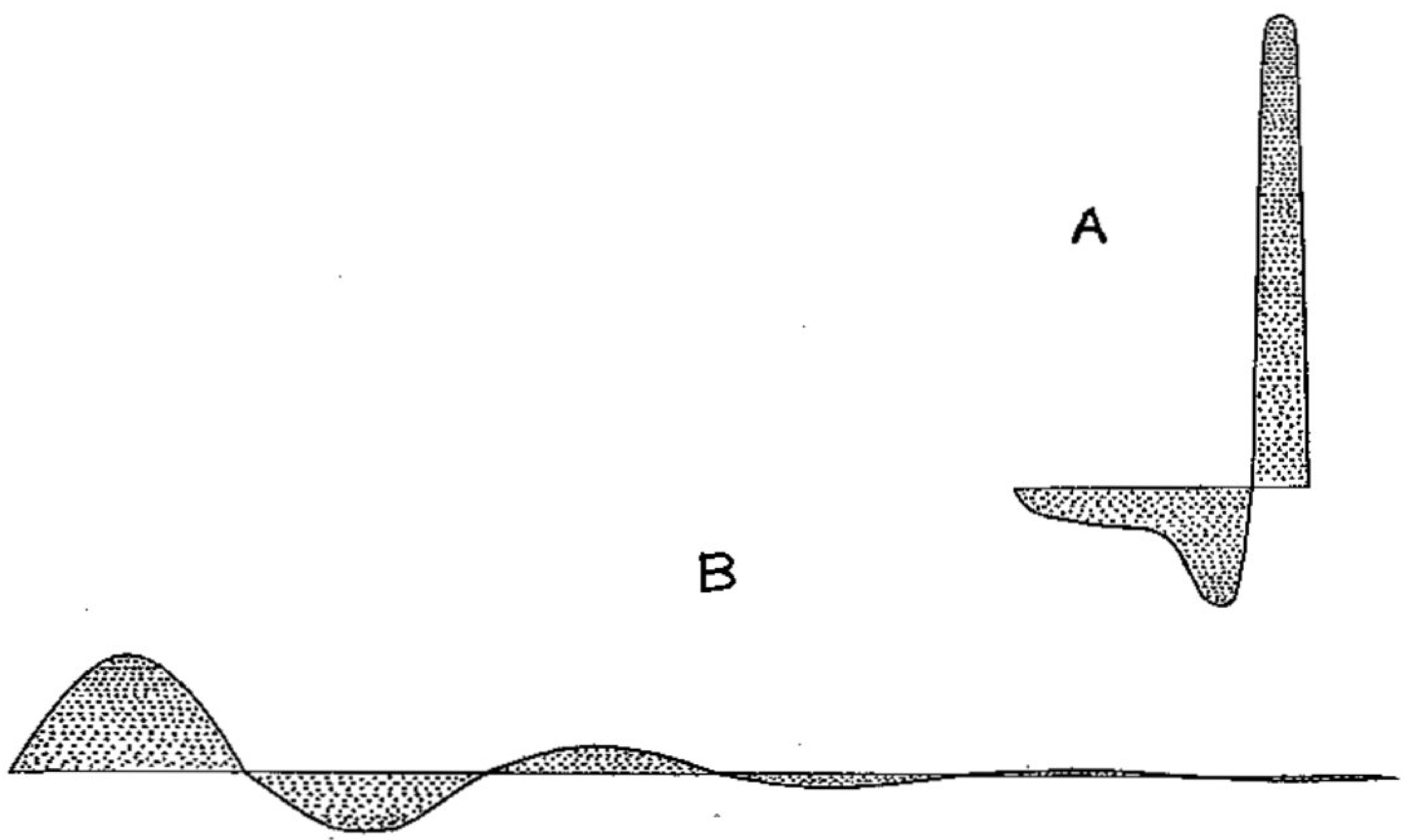

Fig. 1.

The instrument, shown in Figure 1, A, consists of a cylindrical glass vacuum-tube provided with two electrodes of aluminium wire. The diameter of the wire is about one millimeter. The electrodes extend along the axis of the tube towards the center. They come quite close together at the center of the tube, being separated by a space of about a millimeter and a half. Our tube, which was purchased from Max Kohl, Chemnitz, Saxony, is about thirty-five centimeters long and four centimeters in diameter. Though a potential difference of about 1000 volts will cause the electrodes of the tube to glow, it is well to use a transformer giving several thousand volts; for a high resistance must be placed in series with the oscillograph. This

[1]A brief discussion of the theory of the glow-light oscillograph is given in F. Parkman Coffin's article on the Physical Phenomena of the Mercury Arc Rectifier published in the October, 1913, number of the General Electric Review of Schenectady, New York.

is done in order to prevent a strong current from flowing through the tube, thus injuring or destroying it. I found it convenient to use an oil-immersed induction coil as a step-up transformer. As is shown in Figure 2, B, the primary of the step-up transformer was supplied with alternating current through an auto-transformer having a range of 10 to 110 volts in steps of 10 volts. As a rule, the auto-transformer was so adjusted as to make the potential difference of the terminals of the secondary of the step-up transformer about 5000 volts. The water rheostat was made of two glass tubes, each about sixty centimeters long and three centimeters in internal diameter. These tubes were filled with distilled water and provided with terminals so arranged that the tubes could readily be connected in series, or in parallel, or used separately.

Let us suppose that the apparatus is connected and that the potential difference applied to the oscillograph is of such a value that the cathode glow appears to extend along each electrode for a distance of one centimeter. In reality there is a glow upon a given electrode only while it is the cathode. The distance that the glow extends along the electrode is a function of the instantaneous value of the potential of the electrode; therefore it is only at the maximum of the potential wave that the glow extends so far as one centimeter. Assuming that the alternating wave is of pure sine form and that the distance along the electrode that the glow extends is directly proportional to the potential; at 22½ electrical degrees, the glow extends .38 centimeter, at 45 degrees, .71 centimeter, at 67½ degrees, .92 centimeter, at 90 degrees, 1.00 centimeter. Between 90 and 180 degrees the distance decreases at the same rate as it increased between 0 and 90 degrees. Beyond 180 degrees the glow leaves the first electrode, which we may assume to be the upper one, appears upon the lower one and there changes in length according to the same law. Absolutely instantaneous photographs of the electrodes, taken at proper intervals, would present the appearance shown in Figure 2, C. Unless the tube be supplied from a very low-frequency alternating current generator, of lower frequency than any machine in commercial use, persistence of vision causes the glow on each of the electrodes to appear to be continuous. It is, therefore, necessary to view the electrodes in a rotating mirror. In order to obtain the best results, the mirror should be driven by a synchronous motor fed from the source that supplies the tube. I have, however, obtained very satisfactory results by using a direct current motor provided with a speed-regulating device that changes the speed by very small steps. The angular speed of the mirror should bear an integral relation to the frequency of the alternating potential applied to the tube. For example; if there be 7200 alternations per minute, the mirror may make 180 or 360 .... turns per minute, but not 170 or 380 ..... In the first case the wave forms as a whole will appear to be stationary; in the second case in which the speed is too low, the whole series will appear to move rapidly toward the right or left, as the case may be; in the third case in which the speed is too high, the apparent motion will be in the opposite direction. A small departure from the integral relation, as 361 instead of 360 turns, causes a slow motion of the series, too slow materially to weaken the effect of the demonstration.

Figure 2, D is a sketch of the wave form seen in the rotating

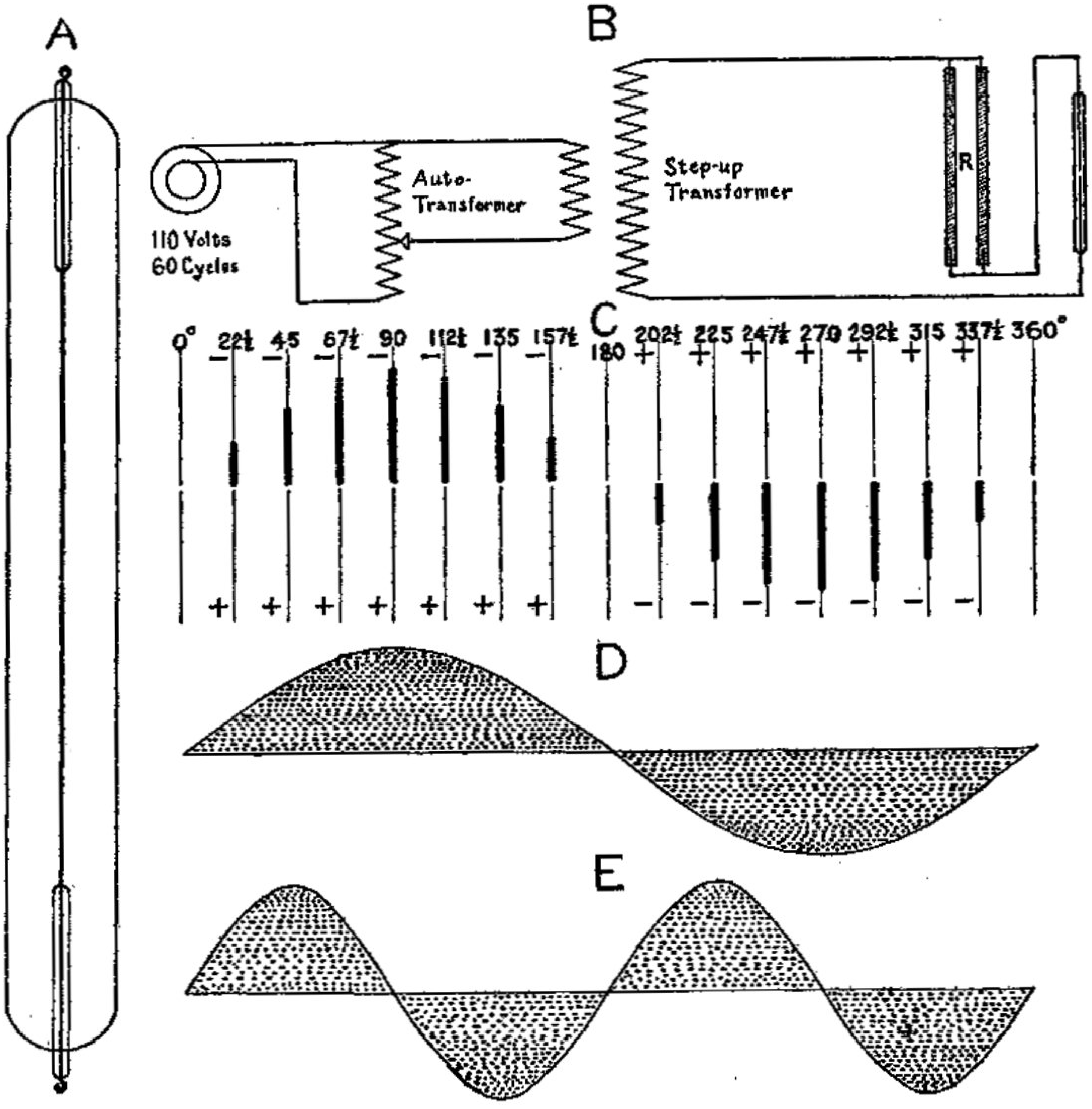

FIG. 2.

mirror while the oscillograph tube was operated by 60 cycle current from the city mains. E shows the form while the source was one phase of a small three-phase generator. Since the speed of the mirror was the same in the two cases—it was driven by a direct current motor—a comparison of the two sets of wave forms shows that the small generator is a 120-cycle machine.

Figure 1, A shows the wave form produced by the discharge of an induction coil through the tube. The speed of the mirror was about twice that used in the preceding experiments. Since I used an induction coil as a step-up transformer in obtaining the alternating wave forms, the only changes in connections necessary were to throw a double-pole, double-throw switch, thus connecting the primary of the induction coil with a 110 volt, direct current circuit, including a suitable resistance and a Wehnelt interrupter; and to connect the two halves of the water rheostat in series. The latter change was necessary because the maximum potential difference of the secondary terminals is so much greater when the coil is used as an induction coil than when it is used as a transformer.

Figure 1, B shows the wave form produced by the discharge of two Leyden jars through the secondary of the induction coil. The water rheostat was not used. In fact, with apparatus mentioned the discharge was not oscillatory while the water rheostat was in the discharge circuit; for its resistance added to the other resistances in the circuit exceeded twice the square root of the ratio of the inductance of the circuit to its capacity.

$$R \angle 2\sqrt{L/C}$$

By making suitable changes in the amount of inductance and capacity in the discharge circuit, it is, of course, possible to show the dependence of the period of oscillation of the discharge circuit upon the magnitude of the product of its inductance and capacity.

In conclusion, I wish to call the attention of the reader to the fact that all of the apparatus needed to perform the experiments described, except the oscillograph tube itself, is standard apparatus, and is, therefore, already in the possession of every well-equipped school. A suitable water rheostat may, perhaps, not be at hand, but one can very quickly be made up from standard material.