practically to that of a school for civil engineers.

Of the great number of technical schools which have sprung up since 1850 there is no need to speak. But the interest in science has gradually passed far beyond the mere interest in its applications.

The striking features of the last twenty years have been the spread of science teaching by laboratory methods in the secondary schools, and the growth of university instruction in science, as distinguished from technical. The noble gift of Johns Hopkins, and its wise administration, began the latter movement, which resulted in the establishment of graduate schools all over the country. The State universities, with their large resources, were, in some parts of the land, great aids in this work, though in others they kept more closely in touch with the technical side, as is very natural with institutions supported by the public at large.

The growing fashion among students, of completing their years of study in Germany, has had a most important effect. The instructors in science in our colleges are drawn more and more from those who have added German training to that of their native country, and as a result the ideals in these institutions are approximating to the German ideals.

Ability in the direction of original research is in some places the first quality looked for in a student or required of an instructor, and the modern tendencies toward extreme specialization and hasty publication are natural results.

So far the movement has undoubtedly been productive of good to the whole educational system of this country. There has been an arousing, an awakening, in educational ideas and methods, not in science only, but in all other subjects, that is little less than marvellous to him who can look back five and twenty years. Whether, after our American fashion, the pendulum may swing too far, and the movement bring with it the difficulties which always attend exaggerations, it is too early yet to say, but, so far as we have gone at present, not only teachers of science, but all teachers, may join, in spirit at least, with the meeting at Boston, which really celebrates the beginnings, not merely of a scientific association, but of a great scientific and educational movement, of which the Association forms but a part.

Frank P. Whitman.

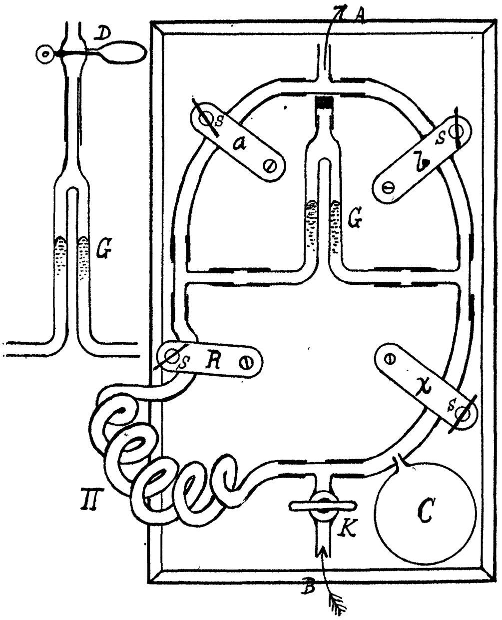
HYDRAULIC ILLUSTRATION OF THE WHEATESTONE BRIDGE.

Although it is undesirable to push the analogy between the electric current and the flow of water too far, or to get the idea of an actual current too firmly established in the student's mind, still a hydraulic illustration is often useful to point out how the results may follow.

To show the action of the Wheatestone bridge by flowing water is usually complicated by the effects of gravity, and illustrates the conditions of pressure rather than those of resistance to flow. Moreover, the question of the galvanometer is a troublesome one, inasmuch as most devices require such a flow of water as to interfere with the bridge effects which it is desired to bring out.

The arrangement described below has proved quite satisfactory in showing the simpler resistance effects in the bridge, but especially useful in making clear the effects of capacity and self-induction, and how the two may be balanced and compared.

The accompanying sketch is taken from a simple home-made bridge which was constructed as an experiment. Upon a board about $30 \times 50 \times 4$ cm. are fastened four glass T's of about 5 mm. inside diameter. Two of these T's have their side projections turned inward and are connected, by short pieces of rubber tubing, to the 'galvanometer' G. The other two T's have their side projections turned outward, and these connect by long pieces of tubing with two large aspirator bottles, not shown; a, b, R and x are brass strips held under a screw at the inside end and resting over rubber tubes which can be compressed and closed by the screws *ssss*. These screws are made by soldering a piece of brass about $15 \times 25 \times 1$ mm., with corners rounded, into the slot of a common wood screw. Under R is a piece of tubing several



feet long when self-induction is to be shown; otherwise a short piece is used, like those under a, b and x, just long, enough to connect the corresponding T's. C is a pint aspirator bottle, with its small side tubulure inserted into the side of the rubber tube. The 'galvanometer' is a T of peculiar form, as shown, closed at its top by a rubber tube and plug or pinch cock, as shown at D. It is really an electrometer, as it shows difference of pressure (potential) instead of current. In operation the board lies horizontal on a table and the tube G is stood up perpendicular so that it becomes a manometer. To start the appartus fill the large bottle connected with B and set it higher than the board, tilt the A end of the board up ten or fifteen degrees, place the A bottle lower than the B one and open the stop cock (key) K. The water will flow through the tubes, driving out the air, and a little manipulation of D will bring the water in the manometer to a convenient point. The board is then to be placed horizontal again. By compressing a and b about equally resistance to flow is introduced into these two arms of the bridge; then compressing x will require a corresponding compression of R in order to balance the pressure in G. It will be readily seen that the qualitative effects can be thus shown, but for quantitative relations it would be necessary to replace the crude compressors by graduated stop cocks. The capacity can be regulated by closing K, raising the A bottle and taking the cork out of C, allowing it to fill more or less and then replacing the cork; the 'capacity' is proportional to the air left in C. When C is full there is no capacity in x. Self-induction is proportional to the length and curvature of the long tube, II, under R. Self-induction and capacity are shown by a momentary difference in level in the manometer upon opening and closing K, the throw (balistic galvanometer) being in the opposite direction on closing K to that upon opening K. Changing the levels of the A and B bottles will show that the results are independent of the direction or value of the pressure (electro-motive force). The manometer (galvanometer) may be made more and more delicate by turning it down more and more nearly horizonal, and by projecting the image of G upon a screen its operation may be shown to a large class.

Individual ingenuity will devise many variations and improvements in details and experiments; the fancied merits of the apparatus lie in the galvanometer device and in the elimination of the effects of gravity pressure in the bridge itself, as well perhaps as in the self-induction and capacity elements.

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FAYERWEATHER HALL,
COLUMBIA UNIVERSITY,
July, 1898.

THE ECHELON SPECTROSCOPE.

THE invention of the Echelon spectroscope is the most important advance in optical research which has been made in many years. It has always been the ambition of the physicist to spread the spectrum with which he was working out to the greatest possible length to see if perchance the changes in color are continuous or not. Thus it happened that a single prism gave way to trains of prisms, each member of the train doing its share to wrest asunder the inconceivably minute vibrations which were the objects of study. With this same end in view prisms gave way to diffraction gratings, these latter giving purer and more diffused spectra. Great labor and skill have been expended in improving these gratings until now their perfection has been pushed to well-nigh the limit of human possibility by the masterful work of Professor H. A. Rowland.

It, therefore, becomes evident that if this resolution of the spectrum is to be carried notably further some entirely new means of attaining the end sought must be adopted.

The important discovery by Zeeman last year that the magnetic field alters the nature of the vibrations of light roused physicists generally to a new effort to render visible these changes which are very small, their details lying beyond the reach of the best of Professor Rowland's gratings.

The result of these efforts is the Echelon spectroscope, an instrument beautiful in its simplicity, yet powerful beyond anything ever seen before. To its inventor, Professor A. A. Michelson, belongs the credit of opening the door to a new and hitherto unattainable field of spectroscopic observation, a field which promises to yield much valuable information to mankind regarding the interaction between the infinitely small particles of matter and those unseen forces, electricity and magnetism.

What, then, is the principle of this new instrument? The theory of diffraction gratings tells us that their dispersive power depends on two things: First, on the distance between two consecutive openings; and, second, on the order of the spectrum. The dispersion is greater the smaller the distance between the openings and the higher the order of the spectrum. The efforts of physicists have hitherto been directed towards making the distance between the openings of a grating as small as possible as a means of spreading the spectrum out as far as possible. No attempt has, so far as I know, been made before this to produce spectra of higher order than the fourth.

This is the point of the new instrument. It is capable of giving spectra of almost any order, the limit depending on the accuracy with which the plates composing it can be prepared. In the actual trial instrument made in this laboratory the order of the spectrum given is in the neighborhood of 20,000.

For the mathematical theory of the instrument the reader is referred to Professor Michelson's two articles on the subject.*

One can gain a practical idea of its way of working as follows: A diffraction grating consists essentially, as is well known, of a series of equidistant openings. The spectrum of the first order is formed when the light in going from its source to the

* *American Journal of Science*, March, 1898; *Astrophysical Journal*, June, 1898.