siderable portion of time is given to certain branches of mechanical engineering; so that, by his work in the laboratory of mechanical engineering, the student becomes familiar with the theory and practice of the steam-engine and other motors, and acquires skill in the use of the indicator and the different forms of dynamometer, and also takes part in numerous boiler and engine tests. He thus gains a knowledge, which, in case he enters upon any application of dynamo-electric machinery, will be very important to him.

Throughout the last year an extended course of lectures is given upon the technical applications of electricity, in which the theory and practice of telegraphy, both land and submarine, telephony, electric lighting, and the electrical transmission of power, are discussed. In order to add to the value of this course, the lectures and laboratory exercises given by the regular teachers of the school are supplemented by instruction from various gentlemen who are professionally engaged in the practical development of electrical science, who give courses of lectures, or single lectures, upon special subjects; so that the student has the opportunity of learning exactly what is considered as good practice among those actually employed in the profession which he has chosen.

In any course of this nature, very much depends upon the facilities which are furnished in the way of instruments for precise measurement. The importance of a proper supply of such apparatus has been recognized; and the Rogers laboratory of physics, in which the experimental electrical work is carried on, is well supplied with the necessary facilities. For line-testing, the student has access to actual telegraph-lines, and learns the methods of working most suitable for such purposes. Also an experimental study is made of dynamo-electric machinery, electrical motors, electric illuminating apparatus, and other similar appliances. The student is further required to undertake a certain amount of work of an original nature, and is thus stimulated to enter upon scientific research. A well-selected reference library, containing most of the physical and electrical journals, together with the leading works on these subjects, is accessible at all times.

The aim of the course, as a whole, is to give an education in which theory and practice shall go hand in hand. The pupil is taught, that, as science advances, the two become more and more closely allied; so that his professional success will be most probable, if, to as thorough a knowlege of theory as he can acquire in the four years of his undergraduate study, he adds a large amount of practice in the application of his theoretical knowledge to the solution of the problems with which the electrical engineers of the present time are especially concerned. And an attempt, at least, is made to give him such a preliminary training, that he will find himself well furnished with the necessary knowledge to continue his studies by himself, as opportunity may afterwards be furnished, or occasion require.

ELECTRICAL MEASURING INSTRUMENTS.

FOR the quantitative determination of an electrical current, any one of its effects may be employed, the law of which is known; and the choice of the effect to be utilized in the construction of a measuring instrument will be influenced by different considerations in different cases. The requirements of the practical uses of electricity necessitate, in general, instruments capable of measuring currents of great strength, varying through a wide range. The instruments must unite the characteristics of compactness and portability with simplicity of mechanism and manipulation, thus excluding many of the methods available in the permanent physical laboratory. The devices which have been employed are so various, and the forms of apparatus so manifold, that a mere catalogue of them would reach beyond the proper limits of an article. As they naturally fall into a comparatively small number of groups, however, the leading characters of certain typical forms may be indicated within a moderate compass, and the merits or defects of some of the more prominent pointed out.

The most common and obvious method of measuring an electrical current depends upon the deflection of a magnetic needle by the current itself. The simplest arrangement would be to use a straight vertical wire situated in the meridian of a very short magnetic needle, and at a moderate distance from it. Within certain limits of approximation, the tangent of the angle of deflection is proportional to the current strength. If the distance of the needle from the wire is made variable, an empirical scale can be experimentally formed, from which, in subsequent use, the current strength may at once be known from a single observation of deflection, the horizontal component of the earth's magnetism being supposed invariable, or its variation determined and allowed for in the reduction. In a permanent installation, such a plan would be feasible, and capable of giving useful results. But it involves some practical difficulties, the most prominent of which are the considerable length which must be given to the wire, and the fact that the wires bringing the current to the vertical portion of the circuit would themselves produce a disturbing effect upon the needle, unless particular dispositions were made to render them inoperative. The chief recommendation of this method is, that its mechanical execution is so extremely simple as to be within the reach of even an unskilled mechanician. Of course this contrivance entirely fails to meet the requisite of portability.

If the conducting circuit is bent into a circle, and the needle placed at its centre, we have the tangent galvanometer, which may be regarded as the fundamental type among electrical measuring instruments. As in this case, the tangent of the angle of deflection is proportional to the current strength; with a great increase in the magnitude of the latter, the angle becomes too large for accurate measurement, owing to the rapid variation of the tangent for large angles. This difficulty can be obviated by increasing the radius of the circle; but the instrument then becomes gigantic and unwieldy, and is no longer portable. Increasing the strength of the magnetic field is another remedy; and another still is found in increasing the distance of the needle from the circle upon a scale calculated from the theory of the instrument, and verified or corrected experimentally.

The last two devices are employed in Thomson's current galvanometer and potential galvanometer. In these, the coil is made of comparatively small dimensions, as is the whole instrument, rendering it very portable and convenient to use. A semicircular magnet placed over the coil gives a very intense magnetic field, diminishing the deflection of the needle to a suitable value when powerful currents are used; while the compass-box can be moved away from the coil along a graduated scale. These arrangements give the instruments great range in their indications; but as the intensity of the curved magnet is easily affected, they require constant verification. In a laboratory this is very easy, and the apparatus is admirably suited for a variety of applications; but its delicacy, and the need of constant oversight, render it unsuited for rougher work.

Various other methods may be resorted to for increasing the range of the tangent galvanometer. Shunting is a practical and useful device, if care is taken that the shunt is so placed, or so far removed, as not by itself to deflect the needle, or affect the intensity of its field. The current may be passed through another parallel circuit of smaller radius, so that only a differential effect is produced upon the needle by the two portions of the circuit, as has been done by Brackett. Or the coil may be made to turn about a horizontal axis, as in the cosine galvanometer of Trowbridge, re-invented later by Obach.

As in all these instruments, the effect upon the needle is dependent upon the intensity of the magnetic field; and this is usually that of the horizontal component of the terrestrial magnetism: the variation in this may occasion considerable errors unless its value is constantly and accurately known; and there is also the liability to the intrusion of foreign magnetic forces from the circuits and magnetic masses in the neighborhood, a cause of error which is by no means imaginary in practical cases.

A second class of instruments dispenses with the needle, and utilizes the action of a fixed circuit upon a movable one, which is traversed either by the main current, or a shunted portion of it, or an independent current which can be varied or controlled. One of the simplest forms consists of two circular parallel circuits, either single, or consisting of many turns, one of these circuits being freely movable. The strength of the current is then directly proportional to the force required to keep the circuits at a fixed distance apart. This has the important advantages of entirely avoiding the use of magnets, and of equal applicability to steady, variable, or alternating currents. While disturbing magnetic effects are not entirely excluded, they are not usually of serious import. No practical and compendious apparatus embodying this principle is in general use, though it has been employed with success in Hill's dynamometer. Further experiment in this direction seems desirable. The various forms of dynamometer in use generally have the movable circuit mounted, so as to turn about a vertical axis, like the needle of a galvanometer, the strength of the current being computed from the angle of deflection, or read from an empirical graduation. In Siemens's form, however, the movable coil is brought into a fixed relation to the stationary one, by torsion, the amount of which measures the force exerted by the current. But this necessitates constant manual control, and fails to meet one important requirement in such instruments, — that they shall give their indications both directly and continuously.

Another mode of avoiding the use of a magnetic needle, is illustrated by those instruments which employ the pulling action of a helical current upon a rod of soft iron in its axis; and of these there are very many forms. The volt-metre and ampère-metre of Kohlrausch have the core in the form of a thin tube of soft iron for lightness, suspended by a rather delicate spiral spring of many turns, similar to those used in Jolly's specific-gravity balance. The iron tube is closed at the top, and hangs over a cylinder of non-magnetic material, which is fixed in the axis of the coil, and is of such a size as to leave a narrow annular space between it and the iron. The air confined within the tube thus acts like the liquid in a dash-pot, but more freely, and damps the vibrations of the tube and spring very effectually. An index attached to the side of the iron tube moves in front of a vertical scale, one side of which is graduated experimentally to volts or ampères, the other in millimetres. The zero-point is readily adjusted by means of a sliding-rod and set-screw, from which the spiral spring is hung. The two instruments differ merely in the winding of the coils, the volt-metre having many turns of fine wire, with a very high resistance; while the coil of the ampère-metre has a few turns of very large wire, which has a resistance of but a small fraction of an ohm.

In the instruments of Ayrton and Perry, the same mechanical action of the current is used; but the indicator is novel, and very ingeniously uses the axial twist, developed by longitudinal traction in a helix formed from a ribbon of highly-elastic material. A pointer attached to the end of the helix, or to a rod in its axis, moves radially over a disk upon which is the graduation. The disk can be turned through a small arc for the adjustment of the zero. The instruments are very compact, simple, and strong, and very convenient in use; but the spring seems somewhat more likely to change than the simple spiral used by Kohlrausch.

Instead of the spring, Hopkins has proposed to use mercury confined in a capsule, the bottom of which is formed by an elastic diaphragm, upon which the iron core exerts a pull when the current passes. The capsule is filled with mercury, as is also a portion of a vertical glass tube inserted into it. The stress exerted upon the bottom of the capsule causes the mercury to fall in the tube, which may be provided with a scale, indicating current strength in the customary units. Various forms of apparatus recently described, involve the same or similar principles, using an iron rod floating in a cylinder partly filled with mercury, and an index-tube in which the mercury moves as displaced by the iron core, or having in the index-tube a lighter liquid for the purpose of increasing the range.

An entirely novel device has been employed by Lippmann. A horizontal tube, bent upward at the two ends, and partially filled with mercury, is placed between the poles of a strong magnet. By means of conducting-wires, the current is conveyed through the mercury in a vertical direction, at a point in the space between the poles of the magnet. The mercury, traversed by the current under the action of the magnet, is subject to a force which tends to move it laterally, thus changing the level in the two vertical arms, by an amount which is proportional to the intensity of the current. As the sensibility requires that the quicksilver column where traversed by the current should be very thin, this portion of the tube is given the form of a flat chamber only a fraction of a millimetre in thickness. If used for strong currents, the heating of the mercury would take place rapidly, and cause serious inconvenience. To avoid this would necessitate making the apparatus in much larger dimensions, with a loss of sensitiveness, or shortened range.

The rotation of the plane of polarization of a ray of light under the influence of an electrical current has been proposed as a means of measuring the current. Experiments, by a number of physicists, have shown that measurements may be made with considerable accuracy in this way; but as they all depend upon the determination of a plane of polarization, the device is found to be less convenient in its application than other methods.

We may notice in passing Cardew's volt-metre, in which the current is measured by the extension of a wire heated by it, an idea, which, though not new, has been applied to form a practical and useful instrument.

In all the instruments in which the current to be measured produces motion of a needle, or of a portion of the circuit, the action of external magnetic forces, whether of the earth, or of the machinery and circuits, as has already been noted, would be felt as soon as the sensitiveness of the instrument is pushed to the point required for great accuracy, and would make special provisions and precautions necessary. The spring instruments, as they utilize not the directive, but the attractive or repulsive action of the circuit, are almost entirely free from such disturbance, and are therefore better suited for those cases where time cannot be given to preliminary experiments for adjustment, and the determination of constants, or where it is desired to follow the changes of a rapidly varying current. It must be noted, moreever, as has been recently pointed out by Hospitalier, that where the changes in the current occur too rapidly, and especially in the case of intermittent or alternating currents, the self-induction in the coils of these instruments may give rise to considerable errors in their indications; and also that in all those cases where the effect to be measured depends upon the square of the current strength, instruments acting upon the principle of the dynamometer must be used to obtain trustworthy results.

ARTHUR W. WRIGHT.

INCANDESCENT LAMPS ON RAILWAYS.

FOR several months past, the Pennsylvania railroad company have been lighting nine of their cars with incandescent electric lamps. The electricity is produced by Brush storage batteries, which are charged once a week. The storage battery is carried underneath the cars in boxes built to receive them, — one-half being placed on each side. Each car requires six trays of four cells each. The trays are made so that the simple process of putting the trays in position completes the electric circuit. The battery when charged has an electro-motive force of forty-five volts; and, when the electro-motive force has fallen to thirty-nine volts, the battery is recharged. The batteries are charged at the depot in Jersey City by a sixteen-light Brush machine. In charging, the ordinary Brush manipulator, without the register, is employed.

Swan lamps consuming 1.1 ampères have been used almost exclusively, although Stanley-Thomson's lamps have been tried. The parlor-cars require ten sixteen-candle-power lamps, while the passenger-cars require but six. The lamps are all in parallel circuit, and so arranged that one-half may be used at a time. The wires are led through a clock mechanism, which registers the time they have been used. By an ingenious mechanical device, the clock is made to move half as fast when the switch throwing off half the lamps is turned.

Altogether, some seventeen batteries, of twenty-four cells each, are in use; and, as yet, only one cell has been disabled. As to loss of efficiency, due to deterioration, no tests have been made. Although the lamps are probably much less than sixteen-candle power, it is probable that their life is less than that of those used in buildings, because of the jarring to which they are subjected.