will be 4·8ths of 3°. So with the other intermediate points. In this way, then, Digges enabled a much greater accuracy to be attained in this circle reading.

The next great improvement after that of Digges was one made by M. Vernier, a Frenchman, who, in about the year 1631, invented the instrument which bears his name. The following is the arrangement. Let the scale on which the measurements are made be divided into a number of parts. Take a second scale called the vernier, shorter than the first by the length of one of its divisions, and make the number of divisions in this vernier equal to the number of divisions in the scale. Then each of the divisions of the vernier, will be less than each of the parts of the scale, by a fraction having one for its numerator, and the number of divisions in the scale or vernier respectively for its denominator. Thus, if the number of divisions be ten (see Fig. 6, page 348,) and the vernier equal in length to nine of such parts has also ten divisions, each of these divisions will be shorter by 1-10th than each of the parts of the scale. If the number of divisions be seventeen (see Fig. 8) the different parts of the vernier will be less by 1-17th than each of the divisions of the scale. So when the number of divisions is thirty (see Fig. 9), the parts of the vernier will be less by 1-30th than the divisions of the scale. The arrangement, however, is not limited to straight scales. It may also be used for the determination of small fractions of degress on a circle. Fig. 10 represents a vernier giving tenths of degrees on a circle. It need hardly be said that the vernier may be constructed to give readings upon the inner as well as the outer edge of the graduation.

In using the vernier the observer looks along it until he meets a coincidence, that is for a point where one of the divisions on the scale coincides with a division on the vernier. If this occurs at the eighth division, then the observation is some whole number, and 8-10ths, 8-17th, or 8-30ths, according as the scale used is divided into ten, seventeen, or thirty parts. In Fig. 7 the coincidence occurs at the third division; the reading in that case would be some whole number and 3-10ths.

To the instrument of Tycho Brahe, then, the vernier, which can be adapted to it, has now been added. Of course by taking division enough the measurements may be made as fine as possible. A vernier of 100 divisions may replace the vernier of 10, or 17, or of 30 divisions. Seventeen have been chosen to show that the principle is not limited to tenths. Any number of divisions may be taken. A very fine degree of accuracy can be attained then in angular measurement, owing to the introduction of the vernier, and that is why there is what is practically a vernier upon almost every measuring instrument in every workshop and laboratory. The question next arises whether with the introduction of the vernier the limit of accuracy has been reached, or whether it be possible to go beyond this. A negative reply may be made to this question. The limit of accuracy has not here been reached. In order to get more accuracy in this angular measurement, it is only necessary to add some branch of physical science to those geometrical considerations by means of which circles have been so finely divided. The astronomer calls certain portions out of the science of optics, and uses them for his purpose. It is perfectly clear that the reason a limit is reached, with an arrangement of the nature of the vernies is, that at least the divisions get so small that the eye cannot distinguish them, so that optical principles have to be appealed to to increase the power of the eye.

Before discussing this question of whether it be possible to select some principal of optics, by the application of which the power of the eye may be increased, it will be well to consider in what it is that that power consists. Fig. 11 will give a rough notion of those parts which specially relate to this matter. First comes the curved surface *Cn*, the cornea, and next *Aq*, the small anterior chamber which contains the aqueous humour. Behind this comes, *Ir*, the iris, which limits the amount of light entering the eye, this being immediately succeeded by *Cry*, the crystalline lens. Then comes the large posterior chamber of the eye which contains the vitreous humour. Behind this the optic nerve enters the eyeball, expanding itself into the delicate layer of nervous elements, *Rt*, which lines the inner surface of the vitreous cavity.

When any object is seen by the eye, the rays of light emanating from that body, impinging first upon the curved corneal surface, have to pass successively through *Aq*, *Cry*, and *Vt*, before they can effect the nervous retinal elements and cause the sensation of light. In passing through these portions of the eye, the rays of light are dealt with in a peculiar manner, especially perhaps by the crystalline lens, and are brought together to form what is called an image on the retina. This image influences the nervous elements of which the retina is composed in such a way, that a sort of telegram is sent to the brain through the optic nerve, and the brain becomes conscious of having seen something, the particular object seen being included in the message.

ELECTRICITY AND MAGNETISM.

BY PROF. W. GARNETT.

Newton's third law of motion is as follows:—

Law. III. *Action and reaction are equal and opposite.*

In the first interpretation Newton gives of this law he points out that whenever one body presses or pulls, attracts or repels, another, it is pressed or pulled, attracted or repelled by the second body with a force exactly equal to that which itself exerts, so that forces always come into existence in pairs, each pair consisting of two equal and opposite forces, or an action and an equal and contrary reaction. Action and reaction together constitute a *stress*, and the forces themselves may be regarded simply as aspects of the stress. It is, however, often convenient to abstract one of the forces, together with the part of the system on which it acts, and to omit the consideration of the other force or opposite aspect of the stress. Thus, we may consider the effect of the sun's attraction on the earth's motion without taking into account the equal and opposite attraction exerted by the earth upon the sun, and the consequent disturbance of that body.

In Newton's second interpretation of the third law of motion he states the principle of the conservation of energy, so far as it could be stated before the fate of the work done against friction and other similar forces was known.

Def. The energy of a system is its capacity for doing work, and is measured by the number of units of work it is capable of performing in passing from its existing state into some standard condition.

A mechanical system may possess energy in virtue of (1) its configuration, or the relative positions of its parts, or (2) of the relative motions of its parts.

The energy possessed by a system in virtue of the relative positions of its parts is called its *potential energy*. The energy which it possesses in virtue of the relative motions of its parts is called its *kinetic energy*.

The work done by a falling weight or a bent spring is due to the potential energy of the earth and weight or of the elastic spring, while the work done by a cannon shot on its target is due to the kinetic energy of the system consisting of the earth and target and the cannon shot moving relatively to them.

The principle of the conservation of energy was stated by Maxwell as follows:—

The total energy of a system is a quantity which can neither be increased nor diminished by any actions between the parts of the system, though it may transformed into any of the forms of which energy is susceptible.

When work is done against forces which, like gravity, are independent of the motion of the moving body on equivalent amount of *potential energy* is produced.

When work is done against forces which, like friction, are reversed in direction as soon as the direction of motion of the moving body is reversed, an amount