Both are held over the circle at the extremity of a radial arm pivoted over its centre. The vernier moves in contact with the surface of the circle, while the microscope views it a short distance off; the former is usually applied to circles whose diameters do not exceed 12 inches, the latter to those of larger diameter. Both kinds of reader are applicable to linear scales as well as to graduated circles, the microscope being usually employed when most precision is desired.

The vernier is so called after its inventor, a Frenchman. Its principle is very simple. The space between any convenient number, *n,* of graduations on the circle is set off on the vernier and divided into (*n*+1) equal parts ; then some one division of the vernier will always coincide with a graduation of the circle. On counting the divisions from the index onwards it is found that the coinciding division, say the with, of the vernier is opposite the with gradua­tion of the circle, counting from the last one passed by the index. This indicates that the distance of the index from the last gradua­tion is parts of the space between the graduations ; *n* is in­variably taken as an odd number, such that the unit of *{n* +1 ) may be some convenient aliquot part of the circle, as a minute for a circle divided into degree spaces.

The micrometer microscope presents the combination of object and eye glasses met with in ordinary microscopes, with the addition of a wire-carrying diaphragm, movable by a screw, for micrometric measurements in the plane of the focus of the object-glass. The tube is conical at the object end and cylindrical at the eye end ; the box of the micrometer is mounted between these two parts at right angles with the visual axis. The tube is held at the extremity of the arm of an alidade, in a collar in which it may be moved closer to or away from the surface of the circle, or be turned round so as to place the micrometer tangentially to the circle. The distance between the micrometer and the object-glass is usually about four times that between the object-glass and the face of the circle, and thus a correspondingly magnified image of the spaces between the graduations is obtained in the plane of measurement. The object- glass is held in a small tube which can be screwed in or out of the principal tube, to enable the length of the image to be adjusted to an exact integral number of revolutions of the micrometer. The box of the micrometer and the wire diaphragm are rectangular, the latter sliding to the right or left within the former. Slow motion is communicated to the diaphragm by the micrometer screw, which passes into it through a collar in one side of the box, against which the shoulder of the screw is pressed by an internal spiral spring acting against the sides of the diaphragm and the box. The screw is furnished with a circular head divided into a number of equal parts—usually 60, each equivalent to 1" for circular arcs, and 100 for linear scales—and is rotated opposite an index arm fixed on the box ; complete revolutions are marked by the teeth of a stationary comb, which is fixed above the wire of the diaphragm and viewed with it through the eye-piece.

The spirit-level consists of a glass tube not quite filled with alcohol, a small quantity of air being left, which rises as a bubble to the highest part of the tube. In small and coarse levels the diameter of the tube is largest in the middle and decreases uni­formly towards the ends, which are closed by the blow-pipe ; in long and delicate levels the tube is cylindrical, but with a longi­tudinal portion of the interior surface ground to the curvature of a circle of greater or less radius according as the level is designed to be more or less sensitive, and it is sometimes closed by circular glass stoppers cemented into the ends. When the tube is held horizontally, with the curved surface of the interior uppermost, the middle part is occupied by the air bubble. Lines are etched on the outer surface at equal distances from the central point, to enable the tube to be set with the bubble exactly in the middle, or a scale graduated throughout its entire length is provided, to enable any deviation from centricality to be measured and the corresponding dislevelment to be calculated and allowed for subsequently in the reduction of the observations. The glass tube is commonly fixed in a metal tube, with plaster of Paris for protection ; but, as it is then liable, under changes of temperature, to torsion and strain, which may sensibly alter its curvature, it is preferable to place it in a metallic cradle and rest it on cork bearings, with due provision against sliding, the whole being covered with a glass cylinder if need be for further protection. The metallic cradle or tube is attached to any instrument on which the level is to be mounted by adjusting screws, for setting it correctly with reference to the axis of rotation with which it is associated. The value of a division of the scale, in seconds of arc, is usually called the “run,” and is determined by attaching the level with its scale to a (generally) vertical circle, and taking both the circle and the bubble end read­ings in different positions of the circle. As the length of the bubble is much affected by changes of temperature, and the curva­ture of the tube may not be identical at all points, values of the run are commonly obtained under widely differing temperatures.

The telescope consists of a tube, carrying an achromatic object- glass and an eye-piece which holds either a pair of lenses for viewing

the inverted image transmitted by the object-glass or a combina­tion of four lenses for inverting the image and causing all objects to be viewed naturally. The former is usually employed for ob­serving celestial objects, the latter for observing terrestrial. The field of view being more or less extensive, a central point is estab­lished in the tube, usually by the intersection of a pair of fine wires or spider lines—one vertical, the other horizontal—in the plane of the image, and the telescope is directed by bringing this point on any specific object in the field. As the interval between the object- glass and the image varies with the distance of the object, a tube is provided to slide within the telescope tube and carry the object- glass at one end, while the telescope tube carries the diaphragm and eye-piece at the other end, or *vice versa.* The image and the wires are brought into the same plane by a focusing screw, which acts on the inner through the outer tube. The wires are attached to the surface of an adjustable annular diaphragm, which is held in position by two pairs of antagonizing screws—one pair horizontal, the other vertical—with shoulders working against the exterior of the tube in which the diaphragm is contained, so as to move it to the right or left and up or down, in order to bring the point of intersection of the wires into the visual axis of the telescope. In practice the first adjustment is to set the eye-piece to distinct vision of the wires ; the object-glass is then set truly to focus, which is accomplished when no apparent parallax, or movement of the image relatively to the wires, is seen on shifting the position of the eye, for this would indicate that the image is either in front of or behind the plane of the wires. The line joining the point of intersection of the wires with the centre of the object-glass is called the “ line of collimation,” and the diaphragm should be so fixed that this line may always be perpendicular to the axis on which the telescope revolves.

The surveying compass gives the magnetic bearing of any object, and is the simplest of all instruments for measuring horizontal angles. It consists of a magnetized needle, with an agate centre, poised on the point of an upright pivot in the centre of the bottom of a circular box and carrying a concentric circular card or silver ring, the circumference of which is graduated into 360°, and is sometimes further subdivided. The aligner is constituted by a pair of sight vanes attached to the box at opposite extremities of a diameter, one vane having a narrow slit for the eye to look through, the other with a wider opening bisected by a vertical wire to be set on the observed object. There is no circle reader, the prolongation of the wire on to the graduations being estimated by the eye ; aud there is no level, for the circle poises itself horizontally on the supporting pivot.

The prismatic compass is similar to the surveying compass, with the addition of a prism in the eye vane through which the wire of the sight vane and the divisions of the circle are viewed apparently together ; the division with which the wire coincides when the needle is at rest indicates the magnetic azimuth of any object bisected by the wire. The sight vane carries a mirror turning on a hinge, to enable objects to be seen by reflexion which may be too high to be seen on the wire ; the eye vane is furnished with a pair of dark glasses to be employed when the sun is being observed.

Magnetic instruments are useful for rapid reconnaissance and rough survey, and for filling in the minor details of an exact survey, but they are not to be relied on to give bearings with errors less than ten to fifteen minutes. In plotting, however, bearings are preferable to angles, for, by drawing a number of meridional lines parallel to each other on the paper, each bearing may be plotted from an independent meridian without any accumulation of error, such as arises when a number of angles are plotted in succession with the protractor adjusted on short lines.

The plane table is in its usual form simply a rectangular board mounted horizontally on a stand, on which it may be turned round and set in any required position ; it is furnished with a flat sight rule, which usually carries a pair of sight vanes and has a bevelled edge, parallel to the line of sight, to serve as a ruler, also with a magnetic needle. Occasionally the construction is more elaborate, and the board is surrounded by a marginal frame with graduations radiating from the centre as the degrees of a circle, so that it may be used as an instrument for measuring horizontal angles, while the sight rule is furnished with a telescope, which takes the place of the vanes and is mounted on an axle to measure vertical angles. The size is made as great as is consistent with the limits of porta­bility in each instance, so that the sheet of paper to be drawn on may be as large as possible. The standard plane table of the Indian Survey measures 30 inches by 24, and is made of planks of well- seasoned wood 1 inch thick, with transverse edge bars below to prevent warping and buckling. It is set up on a stand, usually a braced tripod, to which it is clamped by a powerful hand screw passing through the head of the stand into a brass socket fixed centrally under the table ; the screw when relaxed serves as a pivot, round which the table may be turned in azimuth and set in any required position. The table is then firmly clamped so as to maintain a constant position during all the subsequent laying off of bearings. The sight rule is 30 inches long, *2* wide, and one-