Compliments of the Author.

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The "Astronomer's" Globe.

A. E. DOUGLASS.

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PLATE IV.

THE ASTRONOMER'S GLOBE.

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A. E. DOUGLASS.

FOR POPULAR ASTRONOMY.

The accompanying plate presents a view of a globe so mounted that spherical triangles of any dimensions can be solved graphically upon it to within half a degree, or less, of the correct result. The sphere itself is the ordinary commercial globe carried to the stage that precedes the fastening on of map, and has the ends of the axis removed. The finish is hard and smooth and lead pencil marks may be erased from it with a hard rubber and ink may be taken out by powdered pumice and leather. The globe represented in the photograph is twelve inches in diameter.

The base of the mounting is a circular piece of wood 16 inches in diameter and is supported on three small feet. Over the feet are three uprights supporting a wooden "horizon plane" passing round the horizontal circumference of the globe. Each upright has an adjustable point projecting inward from it; upon these three points the globe rests and therefore becomes adjustable in any direction. Upon the horizon plane two concentric graduated circles of brass move freely; the plane of the upper surface of these circles intersects the globe through its center. Each circle is hinged at points 180 apart, so that the two semicircles thus made in each, can fold together. The accuracy of work upon the globe depends largely upon the excellence of figure and graduation of these circles and with more care in that particular the results of work upon a twelve inch globe might easily be relied upon to with one-tenth of a degree.*

By proper adjustment of the semi-circles it becomes possible to place any kind of a spherical triangle of sufficient magnitude upon the globe and thus to solve graphically, to a limited degree of accuracy, any problem in spherical trigonometry. It has the advantage of all graphic solutions that the main conditions of the problem are presented to the eye and thus mistakes are less likely to occur than in using "soulless" formulas. In many operations it is far more direct and rapid than a mathematical solu-

* The cost of the entire globe and mounting as described above and a box for holding it, was under twenty-five dollars.

tion, is sufficiently accurate for the class of observations and offers a better means of estimating the value of the final results. In illustration of this statement the following paragraphs are added in order to indicate some of the uses to which it may be put and the general methods of operating it. In each case the globe is supposed to be ruled with meridians and parallels ten degrees apart, the equator and occasional meridians further marked to degrees and the semicircles, of course, graduated accurately to degrees, the end of each being marked 0 and its center 90.

Sunspot Work.– For the work necessary in followiug the movement of sunspots the horizon plane of the globe indicates the apparent limb of the Sun, the graduation on the globe represents heliocentric longitude and latitude and the apex or "centre" of the globe is set at the longitude and latitude of the Earth. This is done by raising two semicircles into the exact vertical position so that they intersect at right angles; their point of intersection will be the apparent centre of the Sun or the apex of the globe. As measurements upon the Sun are made from north and south, or east and west lines it is necessary to know these directions on the globe. That is easily done, it being only necessary to mark once for all the positions in longitude and latitude occupied by the poles of the Earth. Passing, therefore, one vertical semicircle through the apex and one of these poles, and the other semicircle at right angles to the first, they are ready to plot the position of the spot. The distance of the spot from the rectangular coördinates is then measured in terms of a radius and reduced directly to degrees; the corresponding degree mark is then selected on each semicircle and the two points brought into coincidence; the point on the globe beneath this intersection will be the position of the spot expressed in longitude and latitude.

If it is assumed that the pole of the Sun is known then let the meridians and parallels of the globe represent soligraphical positions; plot and graduate the ecliptic with reference to this solar longitude and latitude and mark as before the position of the poles of the Earth. By these means the centre of the globe may be set and the circles oriented and adjusted as before and the position of the spot on the Sun read off at once.

This method not only enables the observer to reduce his work with great rapidity and judge at once of the general agreement of his observations but also anything of peculiar character which ought to be more carefully observed, will immediately attract his attention. This process applies equally well to visual or photographic measurements. If in any measurement one coördinate is in error, it will be at once apparent and the other coördinate remains good and may be plotted upon the globe and be of value, so that the observation is by no means wholly lost.

Terrestrial Work.—Right ascension and declination may be turned into longitude and latitude, or the reverse, roughly, but with all the accuracy required, for instance, by Gegenshein or Zodiacal Light observations. For this operation either a horizontal or vertical pole may be used and the globe and circles may represent respectively right ascension and declination and longitude and latitude, or the reverse, as found most convenient. For an example, we might set the centre of the globe at the right ascension and declination of the north pole of the ecliptic, the graduation of the globe itself representing right ascension and declination; the horizontal semicircles will then give longitude and the vertical semicircles, latitude. By this setting, also, the relative effect of precession in different parts of the sky may be obtained directly.

Transposition may also be affected between altitude and azimuth and right ascension and declination, and also, by considering the coördinate on the globe to be longitude and latitude and adding the celestial pole and equator, the transposition may be carried directly from altitude and azimuth to longitude and latitude. As always, the solution is rough and is useful as a check, or in preliminary reductions. In these instances the globe will, of course, give the celestial coördinates and its apex be set at the latitude of the place and the sidereal time; the circles will measure altitude and azimuth.

This use of the globe will perhaps be especially valuable in such work as determining directions of motion of a star with reference to altitude and azimuth, or the displacement in celestial position produced by refraction. Such a problem as this can be solved with ease:—What is the effect of refraction upon measurements of polar and equatorial diameters of a planet. In this the most natural method is to set the centre at the sidereal time and latitude of the place. A vertical semicircle will give the altitude and the parallactic angle may be marked and measured at once by a special sector arranged for the purpose, or afterward by changing the position of the globe. In the absence of such a sector the distinctly better plan is to proceed as follows for each observation: Let the globe coördinates represent stationary celestial positions with both the pole and planet in the horizon plane. Set the joint of one of the circles over the position of the planet and place the other circle at right angles to this one, with half of it raised to the upright position for measuring the parallactic angle. Then let the zenith be the movable point and locate it for each observation by means of its right ascension and declination. Pass the first upright semicircle through this zenith point and read off from it the zenith distance, and from the other semicircle the parallactic angle. For reducing many observations it is best to draw a line which represents the motion of the zenith, and graduate it. It will then serve for all reductions of this character at a given Observatory. Of course the parallactic angle needs to be further corrected by the position angle in which the measurements were made; the effect of refraction upon the vertical diameter of the planet at the altitude determined may then quickly be reduced to its lesser effects in the direction used.

If it is desired to work out even this latter reduction on the globe it may be done with great precision as follows: The effect of refraction, except near the horizon, is to change a circle into an approximate ellipse. Incline the pole of the globe far enough from the apex so that the difference between the projection of the equator and the equator itself, represents the effect of refraction upon the form of a circular planet. This inclination takes place in a direction representing the vertical, and unity minus the cosine of its amount represents the effect of refraction on the vertical radius. Now turn one of the circles so that its pole, that is, a line joining its hinges, represents the direction of measurement and swing one half of it into an upright position and by testing measure the distance from the hinge to the nearest point on the equator of the globe. The horizontal projection of this nearest point is the projection of the one actually used in measurement and unity minus the cosine of the distance is the effect of refraction on the radius measured. By this process the effect of the elliptical form is fully taken into account. In case the planet itself is not circular we may consider the diameter of the globe to represent, for instance, its polar diameter; the effect of refraction upon the equatorial diameter will then have to be made proportionate to its size.

These processes thus far have been described in considerable detail to render more clear the use of the globe and to draw attention to the fact that there are often several methods of solution, one of which may be much more practicable than the others.

Planetary Work Exemplified by Work on Mars.—It was for the solution of many problems occurring in work on Mars that the globe was originally invented and constructed and it has been used in all those processes mentioned below. It is therefore specially adapted to that grade of accuracy and available for many different operations, and whatever use it has here may similarly be found applicable to work on other planets though in varying degrees.

The first application is in correctly reproducing or comparing drawings and especially the portion of drawings more than half a radius distant from the centre. Owing to the distortion of markings seen in such regions large errors in position or identification are likely to occur unless the drawings are reproduced on the actual curved surface of a sphere. Personal experience with and without the globe has produced this opinion.

In such work on Mars the apex of the globe is set at the longitude and latitude of the centre as taken from the ephemeris and, if necessary, one of the semicircles is supported in an inclined position to represent the terminator. This of course is easily located from the angle between the true and phase poles and the angle of defect of illumination, that is, the phase angle.

Next, it may be used in determining the Areographical position of objects measured on the apparent disk by applying the methods already described under the subject of sunspots. The same advantages mentioned there apply here; no observation is lost through lack of the other coördinate and a good idea is at once obtained of the accuracy of the resulting position of a given point and of the individual observations.

Furthermore by marking roughly on each plotted latitude observation the Martian meridian distance at which it occurred, every point which received several observations at different places on the disk will give valuable data for determining the correctness of the position of the assumed pole.

It is evident that by the setting first described in connection with Mars the Areographical position of the cusps, terminator centres, and so forth, may be read off at once. Irregularities or other objects on the terminator whose locations were measured by the position angle of the adjacent portion of the terminator, may be readily solved by placing the pole of one circle at right angles to the recorded position angle and then finding the point on the terminator nearest the hinge of the circle. The coördinates of the point on the globe beneath this will be the required Areographical position.

The phase correction for a diameter measured in any given direction may be found by the method already described under the effect of refraction upon a planet's diameters. In fact observatlons upon the ellipse which involve tangents to the curve or the use of polar coördinates can be solved upon the globe.

In one other process of Martian work it is difficult to suggest any other method of solution. This is the plotting of canals or long marks whose position angles had been observed. With the globe it is necessary to set the apex at the Martian longitude and latitude at the time of observation and place the pole of one of the circles at right angles to the observed position angle and then choosing a point through which the canal runs, to hold a pencil against the upright semicircle and by swinging the semicircle backwards and forwards to produce a line of the given position angle. Of course sketches or other measurements must serve to indicate length and general location of this line. Position angles thus taken and plotted are a great help in map making by connecting together the many independent measurements of position.

Instruction.—It will not be amiss to suggest that this globe might be useful in class-room work by presenting graphically to pupils the actual operation involved in working out a set of formulas.

There are two appliances which will help its working, but which have hardly been mentioned because as yet they lack actual trial. One is a sector for measuring any angle occurring between the two upright semicircles and the other is a movable pin which serves to steady the lower invisible pole of the globe so that the globe may be turned on its axis and set more quickly for a succession of observations. For this purpose the ends of the steel bar passing through the globe should be bored to a depth of half an inch and a small pin for entering it arranged on the end of an arm attached to a sliding carriage. The carriage slides upon, and clamps to, a semicircle of slightly greater radius than the globe and passing beneath it and the purpose of the extended thin brass arm is to allow the pin to pass up between the globe and the horizon plane and circles and avoid interfering with the motions of the latter.

LOWELL OBSERVATORY, Mexico,
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