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MODERN LESSONS

—IN—

DYNAMICAL GEOGRAPHY

AND TOPOGRAPHY,

WITH THE USE OF

THE TERRESTRIAL GLOBE.

SOLD BY WILLIAMSON & CO.,
STATIONERS,
5 KING STREET WEST, TORONTO, ONTARIO,
1887.

A MANUAL

—OF—

THE IMPROVED NEWTONIAN ASTRONOMICAL GLOBE.

No. 1.

Terrestrial Sun View and place of the Pole at Vernal Equinox, March 20th.

No. 2.

Terrestrial Sun View and place of the Pole at Northern Solstice, June 21st.

t Northern

A MANUAL

OF THE IMPROVED

NEWTONION

ASTRONOMICAL GLOBE,

AS CONSTRUCTED STRICTLY IN ACCORDANCE WITH THE PRINCIPLES OF MODERN ASTRONOMICAL SCIENCE,

BY M. TURNBULL,

SCHOLAR OF THE BIRCKBECK INSTITUTE, LONDON, ENG.

SECOND EDITION.

ILLUSTRATED.

"It is difficult to say when Astronomy *ends* and Geography *begins*, the two sciences are so joined together."—PROF. SIMON NEWCOMB, Washington, D.C.

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SECTION IV.

PREFATORY NOTE.

In the recent history of geography it is very noticeable that enlarged views of the objects of the science have been highly popular, and principally in England, among the magnates of the Royal Geographical Society, who have pressed its claims on the attention of all the Universities and High Schools throughout the Empire. The subject being one of the most progressive of all the different divisions of science, *class books* and every kind of auxiliary used *ceases* after a time to fully satisfy the onward, increasing state of this branch of knowledge.

The past practice of loading the memory with mere names of places and crude terms, is rapidly being abandoned for more direct intellectual information of the natural state of the globe as a member of the solar system, and of all those physical laws which govern the constantly changing surrounding phenomena.

As the present new system, in the manufacture of Globes for educational and other purposes, of arranging the mechanism round the globe has been pronounced by some of the most eminent in practical astronomy to be a great improvement on the methods formerly adopted it has inspired, the Inventor to claim for the design the important property of having rescued the use of the terrestrial globe from all those astronomical and geometrical errors which have so long marred its usefulness as an educational appliance.

TORONTO, Sept. 1, 1887.

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SECTION I.

EXPLANATORY ACCOUNT OF THE VARIOUS MECHANICAL ARRANGEMENTS ADAPTED TO "THE NEWTONIAN ASTRONOMICAL GLOBE."

In the following description of the new apparatus for the study of topographical and physical geography a very slight examination of the various illustrations given will make it clear that nearly all the circles used in the design differ greatly from those used with all the globes formerly constructed. It will be observed in the present design that they are treated not as graduated circles, or as they used often to be considered, mere ornaments to please the fancy or the eye, and to look grand in a drawing-room. In the astronomical plan of arrangement they are all *representative* in their character of some important terrestrial phenomena, which always surround and accompany the globe in its motion round the sun. It will be observed, that this representative system enables the geographer at once to get possession of astronomical *ideas* through *visible objects*, instead of, as formerly, through mere *verbal definitions* of various parts of the subject. Another manifest and useful feature is the correct position given to the above circular objects to be explained, such as *The Ecliptic and its Axis*, *The Twilight Belt*, *The Movable Meridian*, *The Quadrant of Sun's Altitude*, &c. They are all situate round the globe, where astronomy imperatively places them—a matter never before attended to in the construction of the old-fashioned educational globe. A further important improvement consists in so arranging the different circles of the sphere that they FOLLOW the apparent motion of the sun in the heavens, instead of, as formerly, being viewed as FIXTURES on the earth's surface. By the application of this principle the student is furnished with a large list of entirely new problems, hitherto not given, or even thought of, in this branch of the science. In fact, the entire mechanism forms, through the use of the new system of celestial perspective, an exact representation of the globe for any day or hour in the year.

At the outset of the following explanations it may be necessary—*First*, to remind the reader or the geographer that, as in all planetary bodies, of which our globe is one, the dynamical study of the earth may be prosecuted from two separate standpoints;

the *Geocentric* and the *Heliocentric*. In the geocentric position everything around the observer is viewed from the surface of the earth where he stands, and everything as seen from that place is said to occupy its APPARENT PLACE. From the heliocentric position, that is, from the point of view of the sun's surface, all things either upon or around the globe appear in their REAL PLACE, a fact which in dynamical geography cannot be too strictly emphasized. Here it will be observed, also, that the eye is always inspecting the globe and the objects in the sphere from the direct point of solar illumination, which reveals correctly all the daily changing physical surroundings. Again, as every object about the astronomical globe is seen in its REAL PLACE, it will be noted by the student that he is relieved completely from the former annoying expedient of having to rectify the axis in solving problems. The new globe requires no rectifying of the axis, as it claims to be a complete representation of the existing *planetary original*, and appears exactly in that state in which the Divine Author and sustainer of all things arranged that it should appear.

Of the different parts of the apparatus now to be specially explained we ask, *first*, the attention of the student to the properties of the large circle resting upon the tripod in the two illustrations given of the design. In both the sciences it is named the *ecliptic plane*, being the real annual pathway of the globe and the apparent tract of the sun in the heavens.

The importance of this circle in astronomical geography will appear from the numerous references always made to it in the two sciences. In the matter of the inclination of the globe's axis to this plane, or in the direction taken by a parallel of latitude from axial rotation, or in showing the causes of the varying intensity of the sun's heat in any portion of the two hemispheres—the great key to all is in the position they hold and the relationship they sustain to this great plane. Hence this circle forms one of the fundamental features in the whole design.

In the interest of progressive geography we have in this place to call attention to the novel alterations effected on the ecliptic plane, caused by the motions of the circles of the sphere round the great axis of the ecliptic circle. That plane in the astronomical globe is now composed of two concentric circles, read in one plane, the outer one being fixed to the tripod, as it carries the twelve immovable ZODIACAL CONSTELLATIONS, and also the calendar of the days in the year, each day being placed opposite to the degree where the sun's apparent centre will be found. The other inner circle moves round the calendar and the fixed constellations, and carries several of the representative circles formerly mentioned, along with a small circular VERNIER, which points out the day of the month and the degree in the heavens where the sun is situate at any time of the year. As the astronomical ecliptic details give a totally new aspect to the terrestrial globe, as now manufactured, we shall first describe the celestial portion and its uses in astronomical geography.

On the outer portion of the ecliptic circle, containing the twelve constellations of the zodiac, a number of the most conspicuous stars are inserted and marked in BAYER's notation (the Greek alphabet), while a number of them are marked in their ancient *Arabic names*. It will be seen by this arrangement that the geographer can learn optically the places wherein in longitude or right ascension the most prominent stars are situate in the sun's track during the year.

In connection with this branch of celestial geography we have an opportunity to point out one of the highest improvements effected by the use of the stars on the new ecliptic circle, and the case requires to be specially attended to by the geographical scientist, as it is well known that every globe, map, and published geography indicates that the sun, among the zodiacal stars, at the EQUINOXES is in Aries and Libra and in the solstices in Cancer and Capricorn.

In practical astronomy it is one of the cardinal events of the year, when the sun's centre is exactly situate in the celestial plane of the globe's equator, an *epoch* of time which is universally named the VERNAL EQUINOX, a term which implies equal nights in every place between the two poles of the globe. The importance and use of this annual phenomenon may be said in a great degree to constitute the Alpha and Omega of the two sciences, because it is the chief source whence is derived not only the true place in the ecliptic, where the poles of the globe is POISED, and gives the duration of the three great annual periods of time known in astronomical geography, as the *Anomalastic*, *The Siderial*, and the *Solar Year*. With the above explanation it will now be easily understood (especially when it is borne in mind that it is an unchanging geometrical law in the doctrine of the sphere, that the solsticial plane where the globe's axis is constantly placed in the ecliptic constellations, is always a *right-angle*, or 90° east of the above GREAT EQUINOXIAL UNIT of time) that the motion and true place of the globe's axis must constantly VIBRATE westward, in close unison with the annual precession of the equator of the globe round the Zodical pole. It may be observed that when the sun was on the equator and at the same time in *Aries* it was in the times of the illustrious Hipparchus, who first clasified the stars, now over two thousand years ago. In Loomis's American Catalogue of the Stars, as well as in the British Association Catalogue, Alpha *Aries* in the head of the *ram* has a right ascension of 1h. 58m. 43s. or is nearly thirty degrees east of the sun at the vernal equinox in the present age; hence when the phenomenon now takes place (March 20th,) the sun is passing the stars in the constellation *Piscium* or *Pisces* and the northern solstice in *Gemini* (June 21st) as arranged on the new ecliptic plane; however to point out practically here to a student who may possess an astronomical globe we will give a direct illustration with the apparatus. Bring the sun's place on the ecliptic plane to the vernal equinox, March 20th. It will then be observed that the great luminary has just passed in right ascension a star of the fifth magnitude in the constellation *Pisces*, and marked 33 from Flamstead's numbers, or according to the Greenwich Twelve Years Catalogue, it has a right ascension 23h, 57m, 39s, which is only two and a half minutes of arc behind the sun when it is crossing the equator, hence this object is among the nearest, optically to the sun at present, when the above great annual phenomenon takes place. From the foregoing facts in modern astronomical geography it will now be almost unnecessary to point out to the scientific geographer that it is a scientific *fraud committed*, the placing of terrestrial globes in libraries and schools which have their axis placed in Cancer and Capricon, the constellations where all the old globes have it placed and the error extends also to the title or name of the tropics of declination as they are always situate in the solstices of the passing hour. The scientific pupil has to bear in mind the fact that, the terrestrial poles revolve around the axis of ecliptic in somewhat over 26,900 years, —the orbits of the two poles being constantly under the Celestial *Arctic* and *Antartic* circles.

It will be remembered that the last important civil time, corrections which were introduced by *Pope Gregory*, known universally as the "New Gregorian style," is entirely founded upon the unchanging zodiacal arc of 90°, which always exists between the vernal equinoxal plane and the northern solstice. The calendar of days and the northern solstice by this means can never alter, thus securing the regular flow of Spring, Summer, Autumn and Winter; among the whole list of new problems which the astronomical design of mounting *has created* and can solve, few are more instructive and elevating than the annual history it gives of the sunshine at the two poles around the ecliptic axis It will be remembered that it was stated that the ecliptic plane consists of two concentric circles, the inner portion being made to revolve around the globe; this circle carries three most useful appendages for solving some very important new problems: the first consists of an arrangement to represent the sun's centre which moves over the days of the calendar and at the same time the degrees on the fixed ecliptic. In general this part is the first to be used in solving many of topographical questions; the second is a brass semi-circle graduated into 90° each which revolves around the sun's centre and moves with it to indicate how far the observer is from a zenith sun: this part also enables one to determine the solar energy on the different portions of the globe through the law that heat diminishes as the square of the angular distance increases from a zenith sun. In addition to the functions of the above circle the inner circle has the property to keep the daily solar terrestrial meridian upon the sun's apparent centre, thus affording the means of determining the APPARENT NOON for any place on the earth. In connection with this part of the apparatus it will be observed by those who possess this globe, how truly the sun's place is made to pass over the tropical parallels of latitude and degrees of the movable brass meridian, showing optically not only the declinations of the sun, but also the source dynamically whence they arise, as the sun moves east in its daily right ascensions.

The next representative circle to be described is that great BELT OF LIGHT known as twilight which precedes sunrise in the morning and begins again in the evening immediately following the setting of the sun. The introduction of a permanent representation of this phenomenon forms one of the leading factors in the study and use of the astronomical globe. The twilight zone, it will be observed, moves constantly with the sun's place round the *axis of the ecliptic* and forms the great SOLAR HORIZON or LIGHT TERMINATOR round the globe.

In practical work, especially in solving problems, this part is constantly in use, as it enables the student to search out the globe's physical state relative to *sun*, *light*, and *heat* in all the higher regions of both the temperate and frigid zones. In describing the functions and properties of the twilight zone round the globe, it involves the study of the annual terrestrial illumination of our planet, seeing that it plays such an important part in *distributing* mechanically on the surface of the globe the whole solar energy of that great luminary. As an expositor of problems in geography, its functions are altogether new; as witness its successful illustrations and the solutions of the four grand new problems of the poles motion through the summer sunlight and winter's gloomy shades. In reference to the correctness of the new system of illustration of *globe illumination*, we may state that the principle is chiefly founded on the demonstration of Euc, III and XVIII. which proves that "if a straight line touch a *Circle*, *Globe* or *Sphere*, a straight line from its centre to the point of contact shall be a right-angle." Now we may notice what the student will not fail to observe, that the two lines of the Theorem are well represented in the apparatus by the *Radius Vector* or line joining the centres of the earth and sun, and that the great twilight circle where they cut each other and come into contact, are always at right-angles to each other.

Another important mechanical connection with the twilight circle, is the uses of the two small graduated *quadrants* placed upon the front of the twilight zone. Their object is to trace by geometrical principles the place of the two poles of the globe during their annual progress through sunlight and darkness. Annually the north and south pole as seen from the sun move twice over the chord of the segment of forty-seven degrees, or twice the angle of its axis with the ecliptic axis. Hence the *cosines* of those two quadrants will point out the true place of the pole and indicate the direct angle of the axis with the ecliptic axis on any day in the year. The great advantages obtained by the introduction of this addition to the astronomical globe, are, *first*, that it brings directly before the eye the real perspective motion of the poles of the earth in the solar system, which the design shows to be a straight line during both their seasons of sunlight and darkness.* *Second*, that the twilight circle also furnishes an *expert* geographer with everything necessary to chart on a planosphere of the earth any parallel of latitude at any period of the year.

The next and final part to be described are the mechanical arrangements for finding either the siderial or the true civil time.

It may be mentioned, that as both the world of *commerce* and of *science* have accepted the meridian of Greenwich for the unification of terrestrial longitude, the study of geographical astronomy is just what is needed to convey thoroughly, both optically and mentally, the new time system adopted. The solution of time problems by the use of the modern arrangements is a process in miniature somewhat similar to that which may be observed at fixed times daily in any national observatory. In the new globe the position of the great solar luminary is represented in its true place, in right ascension among the ecliptic stars, and the constant changing angles of the NOON brass meridian with the ecliptic axis are all well illustrated. It will be observed, from the two cuts of the design, that there is connected with the globe's axis a large *hour circle* upon an improved plan; it revolves round the southern axis of the globe, and is attached to the daily eastern progress of the prime meridian of any place. The circle is graduated into degrees of arc, and likewise into hours of civil time: thus, with the use of a moveable *vernier* placed around the globe's southern axis the geographer can solve the solar right ascensions for any hour, even to one-fourth of the sixtieth of an hour, of civil time. Before closing this descriptive account we wish to call attention again to one of the most prominent of the new problems which the astronomical system of mounting is especially adapted to illustrate and solve.

It is generally well understood to be one of the highest and most useful lessons in geography, to be able to construct a correct PLANOSPHERE of the globe for any day in the year,—one showing the real path any city will take, or the direction any parallel of latitude will have from sunrise to sunset. In acquiring this useful accomplishment it is claimed that the new globe has no competitor in furnishing all the elements on which the solution of the problem rests. It may first be observed that the two poles of the globe, as formerly shown, viewed from the

*As the angle of the globe's axis 23° 28', is always a constant quantity with the ecliptic plane, making the ULTERIOR ANGLES equal on every day of the year. Hence the pole must appear to describe annually the above straight line, Euc. 1st and 27th.

sun, revolve with the seasons through a STRAIGHT LINE. This line is just equal to the diameter of the semi-circular scale of *sines* and *cosines* placed upon the revolving twilight circle. Hence, the annual perspective motion of the poles round the ecliptic axis becomes the chief *factor* to depend upon in completing the map: the following may be used to make the foregoing a little plainer. Bring the sun's place on ecliptic plane say to the vernal equinox, the 20th of March. At this period, which is the great *astronomical zero siderial time period*, the north pole will be seen to be just leaving its last six months' obscuration and entering upon the direct illuminated disc of the earth's sunlight perspective. (See cut No. 1.) Its place is now right below the twilight circle, and upon the very *edge* of the sunlight perspective of the globe. Again, move the sun's place in right ascension, say 2h. or 30°. Now it will be observed that the sun in the calendar of days is over the 19th of April. At this time the place of the north pole is indicated by the scale where it has moved towards the ecliptic axis to 30° on the line of *cosines*, so this is the distance of the pole from ecliptic axis for the given period. Hence a straight line from the point through the globe's centre will give on a chart the true angle which the globe's *perspective axis* has on the 19th of April. Again, move the sun's place 6h. or 90° in right ascension, which occurs on the 21st of June. At this period it will be apparent that the globe's axis lies exactly *towards the centre of the sun's disc*, and that both are situate in the solisticial plane. (See cut No. 2.) Hence, since March 20, when the *pole* was first seen in the sunlight horizon, till June 21st, it has moved over the entire length of the cosine of 90° as indicated by the twilight scale. Moreover, it will be further observed that during the next three months of the poles perspective motion, it will finish its six months track in sunlight, which astronomically takes place on the day of the autumnal equinox, (Sept. 22nd.) The cosines and sines on the perspective twilight scale are placed for every ten degrees of the solar right ascensions, thus ensuring a numerous TRAIN of PLACES to point to where the pole is situate during its annual motion. It will now be apparent, from the foregoing PANORAMIC MOTION of the POLE during the four seasons, how useful the astronomical globe is in solving problems, or in charting the perspective surface of the earth. In the study of this division of the science, and to give a fuller exposition of the principles contained in several of the above paragraphs, we herewith insert in the next section, two finished CHARTS of the two paths which Toronto describes IN SUNLIGHT on March the 20th and June the 21st, with a full explanation of the geometrical method which was greatly practised by the three distinguished astronomers of Greenwich, viz: Messrs. Flamsteed, Halley, and Bradley.

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SECTION II.

Before proceeding to project geometrically a chart of the globe or any hemispherical parallel of latitude through sunlight, it may be servicable to some readers to premise a few things for describing the terms used in the delineation.

A.—It is now CERTAINLY known in modern GEODAESEA, that the earth is nearly of a globular shape. However, when it is viewed from a great distance, such as the sun's centre, it will appear as a flat surface, something like the *moon* at night; now this appearance is called the *earth's disc.*

B.—By the constant rotation of the globe around its axis, every place on the surface describes a circle equally distant from the equator, and the plane described by the place is named the PATH OF THE VERTEX OF THAT PLACE.

C.—The phases of the paths of places in sunshine on the globe's disc, are not always of the same form; they all differ with the sun's high ascension; when the sun is in either of he equinoxial points, the paths of all places are represented by straight lines such as they are in cut No. 1, and when the sun is in any other degree of the zodiac, they are represented by ELLIPSES more or less eccentric as the sun is nearer to or further from the equinoxial plane.

D.—In describing these paths on the earth's disc special attention must be had to the position of the axis of the globe in the direct beam of sunlight, as every parallel of latitude changes its position with the ecliptic axis at the time.

E.—When the sun is in the ascending signs, which is a period from December 21st to June 21st, the globe's axis lies to the right hand of the ecliptic axis (see cut No. 1), but when it is in the descending sig[illegible]he axis lies to the left hand. When the sun is in either of the solsticial points or plan, the axis coincides (see cut No. 2), and when it is in the equinoxial they make the greatest angle, viz., 23° 28′. When the sun is in any of the six northern signs, viz., Pisces, Aries, Taurus, Gemini, Cancer, and Leo, the north pole of the earth is in the enlightened part of the earth's disc, and when he is in the southern signs, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius, the north pole of the earth is in the obscure or sunless part of the disc.

F.—The transverse or largest diameter of any eliptical parallel of latitude is always at right angles with the globe's axis, and the conjugate or minor axis of any elipse is constantly regulated in its length by the solar longitude or right ascensions of the sun, and which continually affects its declinations, thereby altering daily the dimensions of the minor axis which any place has from equinox to solstice.

A GEOMETRICAL PROJECTION ON THE GLOBE'S NORTHERN HEMISPHERE OF THE PATH OF TORONTO ON MARCH 20 AND JUNE 21.

(SEE DIAGRAM ON OPPOSITE PAGE.)

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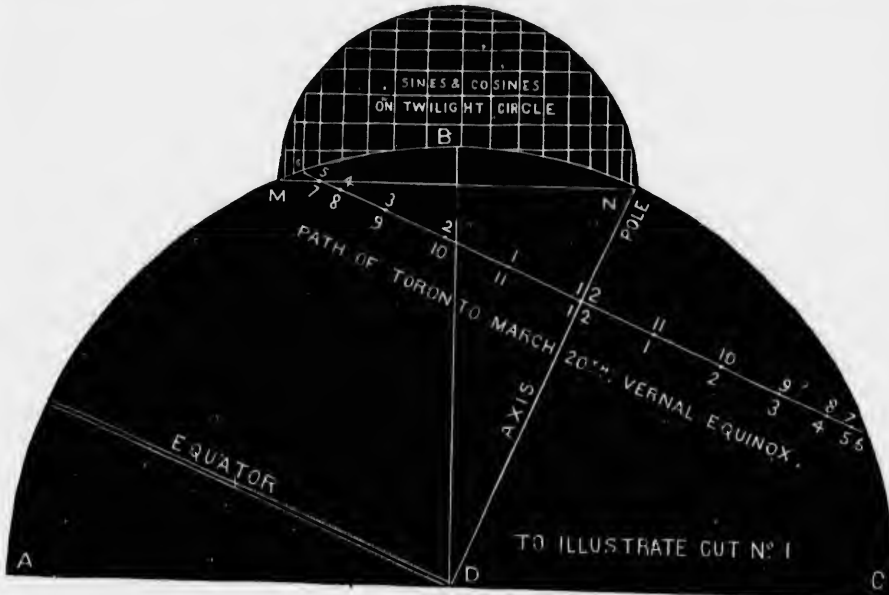

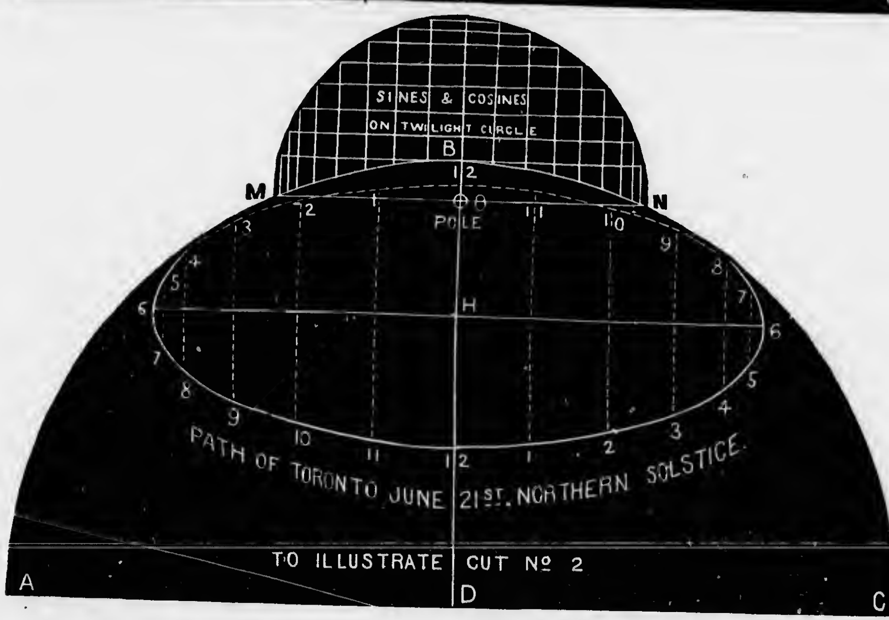

With any convenient radius, as A D, describe the semi-circle A B C, upon the centre D, draw the straight line D B, perpendicular to the diameter A D C, so A D C shall represent a part of the ecliptic plane and D B its axis. Take the chord of the obliquity of the globe's axis to ecliptic plane corresponding to radius A D, and set it off on the circle A B C upon each side of B to N and M, draw the line N M cutting ecliptic axis in O. Now, as formerly shown, the pole of the globe, as viewed from the sun, revolves twice in the course of the seasons through the line N O M, and since N is its place at the vernal equinox (see chart No. 1), its distance on any day from N will be equal to the cosine of the scale on the face of twilight circle. On the 21st June, the present case, the sun's right ascension, is exactly six hours or 90°. Hence as the cosine of 90° is always equal to radius N, O will be the extent which the terrestrial pole has shifted in the solar perspective since the 20th of March. Therefore, O on the ecliptic axis is the true or the real place of the globe's pole on June 21st, or, in other words, the angle of the earth's axis with the ecliptic axis completely VANISHES at the two solstices.

Next, to draw the path of Toronto on the northern half of the globe's planosphere, it may be mentioned, that had the latitude of the city been the same as the sun's declination, Toronto would be seen at D, the centre of the perspective disc. However, as the city's latitude, in round numbers, is 44°, which exceeds the sun's declination by 20° 30′, take the sine of 20° 30′ to the radius D C, and set it off from D to 12, which point on the axis will be the true place of Toronto at noon on June 21st. Again, it can be easily understood that could Toronto be seen from the sun at midnight on June 21st, its place would be somewhere upon the line D B, and north of the point 12.

Now the point ANTIPODAL where the sun is vertical at midnight, as seen at D, is as many degrees SOUTH of the equator as the sun's declination is north, plus 20° 30′. The distance of Toronto, then, at the above day in the year will be equal to its latitude added to the sun's declination, which amounts to 67° 30′. Therefore, with the sine of 67° 30′ set off from D upon the line D B to 12, which is a little beyond O, the point representing the true PERSPECTIVE place of Toronto at MIDNIGHT. It will now be observed that the line 12 H 12 will be the conjugate or minor axis of the ELLIPSE into which the parallel of latitude appears projected from being seen obliquely; and the point H midway between 12 and 12 is its centre. Hence, the line 6 and 6 drawn through H perpendicular to the globe's axis D B, (cut No. 2,) or D N, (cut No. 1,) is the transverse or longest diameter. To find the length of the longest axis of the above elliptical path use the cosine of the complement of the latitude of Toronto, viz., 44°, and setting it off both ways from H to 6 and 6, those points on the DISC will be the place where the city will be seen at six in the morning, and at six in the evening of June

21st. Lastly, to trace the place of Toronto at any hour of the twenty-four, the following geometrical details have to be closely attended to. With a radius equal to H 6 on the transverse axis of ellipse take the sine of 15° and set it off on each side of the point H on the line 6 and 6; do the same with the sines of 30°, 45°, 60°, and 75°, as shown on the chart No. 2. Then through these points draw lines parallel to D B, the globe's axis. Next on the quadrantal radius equal to H 12 take the sine of 75° and set it off on each side of the transverse of ellipse at the hours 1, 11, on the right hand of H. In the same way set off the sines of 30°, 45°, 60°, 75° on each side of H in the transverse lines of ellipse and the points obtained in this way represent the place of Toronto at the different hours of the twenty-four. Thus an ellipse drawn as shown through all the various places will represent the apparent path of the city for the above selected day. It will be seen from chart No. 2 that the parallel of Toronto touches the perspective periphery of the disc at a few minutes before 4 a.m., and at a few minutes after 8 p.m., and these places divide the path into two parts, one representing the path by day and the other by night.

To construct a chart of a parallel of latitude at the equinoxes, very little work is required to make the delineation (see cut No. 1.) At this annual period, as the sun's centre is in the equatorial plane the direct rays as formerly explained fall upon the edge of every plane of latitude from the equator to the poles, and being all at right angles to the globe's axis the path of every place appears as a straight line on the globe from sunrise to sunset. The line, therefore, from 6 and 6, in chart No. 1, is the place and appearance in sunlight of the path of Toronto at the vernal equinox, March 20, and the figures show the place of the city during the day. The hours above the line, or path 6 and 6, being the midnight time and those below represent the different hours in sunlight.

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SECTION III.

PRELIMINARY OBSERVATIONS ON THE "DOCTRINE OF THE SPHERE" AND THE USE OF ASTRONOMICAL CIRCLES TO PHYSICAL GEOGRAPHY.

Before dealing with the solution of problems the Newtonian Globe is adapted to solve it may be useful to some to call their attention to a few of the points in the "*Doctrine of the Sphere*" which relates to those CIRCLES placed round the Globe with its new arrangements, and supposed to be extended to the heavens. In the first place it is important to bear in mind that wherever a spectator is situate in the *mundane sphere* his eye will be the centre of the sphere as applied to the open sky. The fixed stars will always have the same magnitude and the constellations the same form, whether he view them from the earth or in the mind's eye from the sun. Hence generally it is instructive to view that immense *scene* from the *mathematical standpoint*, which has only position without any magnitude. Moreover, in order to form just ideas of the earth's surface with all its *different parts*; of their situations, magnitude and distances from each other, and from our place upon the globe. Many circles are supposed to be described and being produced to the heavens divide the concave into similar parts, whereby we can speak more intelligently of their vast extent and describe the phenomena better than could be done without such contrivances. Now, in physical geography all these circles are called "*Circles of the Sphere*," and they are either great or small. Every *great circle* hath the same centre with the sphere and a small circle divides the sphere into two unequal parts. The axis of a circle is a straight line passing through its centre, and consequently is perpendicular to its plane. The poles of a great circle are two points in the surface of the sphere diametrically opposite and equally distant from every point of the great circle. A small circle, like the various latitudes on the earth, which are all parallel to the equatorial plane, have the same poles. Great circles which pass through the poles of another great circle cut it at right angles and are called secondiaries. Some circles of the sphere retain always the same position, and are therefore named *fixed circles*. On such circles the properties of the astronomical globe chiefly depend; others depend on the position of the spectator and move along with him, and are called movable circles. A great circle, when it is described on the earth, is called the equator, and when extended to the heavens is termed the equinoctial. With its secondaries and all the parallels of latitude on the globe are fixed circles; these are delineated on artificial globes and on all maps of the surface of the earth. The axis of the equator, called the axis of the world, is in the same straight line with that of the earth, and its extremities are the north and the south poles, whether of the earth or of the heavens. Great circles passing through the poles and at right angles to the equator are its secondaries, and with respect to places on the earth they are named meridians. In the heavens they are called circle of right ascension and sometimes hour circles. Latitude is the distance of a place north or south from the equator, and is always reckoned upon the meridian. Hence places which lie north and south of each other have the same meridian and have noonday at the same instant of time. Longitude is the distance of a place from the prime or first meridian, reckoned upon the equator, and according to the new method of calculating longitude it continually runs eastward round the globe until the reckoning ends where it began. Topographical longitude of any place is therefore an arc of the equator between the first meridian and the meridian of that place, and may be expressed in time by counting 15° of the equator one hour, every degree four minutes, and every minute four seconds. The length of a degree of longitude on the equator is sixty geographical miles, but a degree on the parallel of 60 degrees is only 30 miles. The way to measure the different arcs by the new globe is given in the section containing the list of problems. Parallels of latitude on the earth, being extended to the heavens, are called parallels of declination, and four of them are especially remarkable, as they form important factors in the use of the Astronomical Globe. They are distinguished by particular names, viz.: The two Tropics and the two Polar Circles. The two Tropics are produced by the inclination of the globe's axis, to the ecliptic axis, having each an angle of 23° 28'. We have scientifically demonstrated from Loomis's American Catalogue of the Stars that the sun's place on June 21 is in Gemini. Hence, in the present age, the name of that constellation is now the real name of the tropic in the northern hemisphere of the globe. In the southern hemisphere, at the solstice, as the sun reaches Sagittarius on Dec. 21st, the name of that constellation for the same reason becomes the correct name of the southern tropic. These two parallels are the limits of the sun's declination annually, which regulate greatly the temperature of the two hemispheres. The two polar circles are described round the poles at the distance of the axial inclination. That in the north is called the Arctic Circle, which names its centre the Arctic Pole. The other, at the same distance from the South Pole, is called the Antarctic Circle, as being opposite to the former, and for the some reason this pole is named the Antarctic Pole. On the surface of the globe, between the two Polar Circles, the sun rises and sets daily, dividing the twenty-four hours into day and night. But within the Polar Circles there are six months in which the sun neither rises nor sets. Hence at the poles the year consists o[illegible] of one continuous sunlight day and one continuous night.

We now come to notice another useful application of the circles of the sphere in this branch of geography, viz., To the uses of the Tropics and the Polar Circles in dividing the earth's surface into five parts, termed zones, namely, one TORRID, two TEMPERATE, and two FRIGID Zones. The space between the two tropics, having the equator in the middle, is called the Torrid Zone, on account of the excessive heat, of the sun in this region. This zone is by far the largest of the five, being 47 degrees broad and comprehends a great portion of both Asia and Africa and North and South America, with the adjacent seas and islands. In this region or zone the inhabitants have the sun sometimes to the north and sometimes to the south of their zenith at noon. Their noonday shadows fall towards the north or the south according to the position of the sun. For this reason they are named AMPHISCIANS, and when the sun is in the zenith at noon the inhabitants have no shadow, therefore they are called ASCIANS, or shadowless. It will be noticed that in the above zone the year is not divided into summer and winter as it is in the other zones of both hemispheres. The Temperate zones of both hemispheres are next to the Torrid, one on the north and the other on the south side of it. The space on the globe between the Tropic of Gemini and the Arctic Circle is called the North Temperate Zone. It is 43 degrees wide and embraces almost all of Europe, the greater part of Asia, a small part of the north of Africa, and a considerable part of North America. In this zone, the sun being always south of the zenith, the shadows of the inhabitants fall northward at noon. The days and nights are unequal, except at the two equinoxes. The space embraced between the tropic of Sagittarius and the Antarctic Circle, is called the South Temperate Zone, which is also 43 degrees broad, and includes a small part of Africa and a great part of South America, including New Holland and a number of the adjacent islands. Here the days and nights are always unequal, except at the equinoxes. The sun being always north of the zenith the noonday shadows of the inhabitants fall continually southwards. Hence the inhabitants of the two Temperate Zones are styled Heteroscians, because their noonday shadows always fall the same way. The space within the Arctic Circle, having the North Pole in the middle of it, is called the North Frigid Zone, on account of the intense cold which prevails there. The diameter of the Arctic Circle is 47 degrees, or 3,820 geographical miles, and embraces a part of Europe and Asia, East and West Greenland, with Nova Zembla and some of the northern parts of North America. There is very little habitable land here, and few inhabitants. The South Frigid Zone is a space in extent and in all other respects the same as the Northern Frigid Zone, only less land has been discovered in high southern latitudes. The inhabitants of the two frigid zones are named PERISCIANS, because when the sun is visible their shadows fall towards every point of the compass in every axial rotation of the glove. In the use of the Astronomical Globe it is of great importance to remember that the newly arranged ecliptic plane divides both the earth and the heavens into northern and southern hemispheres; and the signs upon it are divided in the same way. The first six are called the northern signs, because they are all on the north side of the equinoxial; and the other six are called southern signs, as they are southward of the equinoxial plane. The Ascending signs begin at the south point of the Ecliptic Circle, viz., when the sun reaches the southern tropic; they are Sagittarius, Capricornus, Aquarius, Pices, Aries, and Tarius. The other six are the descending signs, viz., Gemini, Cancer, Leo, Virgo, Libra, and Scorpio. The meridian, which passes through the equinoctial points is called the equinoctial colure, and that which passes through the solsticial points is called the solsticial colure. These two great meridians cut each other at right angles in the poles of the equinoctial plane, and divide the ecliptic and equinoctial, as also the whole visible heavens into four equal parts. It may be noticed in passing that the equinoctial colure is called the First Celestial Meridian. The right ascensions or hour circles of the equator and the longitude upon the ecliptic plane are all eckoned from the above great celestial meridian. It will now be observed by the student that the poles of the ecliptic are points situate in the solsticial colure 23° 28′ distant from the poles of the earth. Hence in the use of the Astronomical Globe this part in the study of the subject should be clearly understood, as it optically illustrates that while the earth turns upon its axis, and at the same time advances east in its orbit round the sun, conjointly with the axial parallelism of the globe, it makes the pole of the ecliptic plane appear to describe annually the two polar circles. Hence in the use of the new globe, the above facts are worthy of the closest attention, as it is from the aforesaid conditions that the motion of the terrestrial pole in the sunlight has its source and shows how the Newtonian globe so well illustrates this dynamical phenomenon.

Great circles passing through the ecliptic poles are called circles of longitude; longitude is, therefore, an arc of the zodiac between the vernal equinox and the required longitude, in the order of the signs. Small circles parallel to the zodiac are named parallels of latitude in the heavens. The ecliptic constellations occupy a celestial belt embraced between two parallels of latitude on each side of the ecliptic plane, where all the orbits of the planets, except one or two, are to be found. In former ages these constellations were situated as they are at present in the heavens, but now in a different situation as regards the terrestrial globe, with its various annual perturbed motions, and principally influenced by the slow motion, 50″ of an arc annually of the equinoctial points westwards, called the precision of the equinoxes. In consequence of this the stars in the zodiac appear further east than formerly, so that Pices is now in the place where the sine Aries was 2,000 years ago, as before noticed, and the constellation Aries is in the sine TARUS, &c., &c. For the sake of tracing the ecliptic constellation with greater ease astronomers suppose them to be marked by the outlines of some animal or figure. By this means the motions of the different members of the solar system are more readily compared and described; although with many of them it is almost impossible to trace the slightest resemblance. Objects in the sphere which have the same right ascension with the sun are in the meridian at noonday; but those which have the right ascension otherwise come to the meridian either before or after the sun, and here the hours are reckoned from one to twenty-four, because the day now begins and ends at noon. The right ascension of the sun increases about one degree or four minutes of time every day, but the right ascension of a star is the same for a long period; the variation seldom exceeds five or six seconds of time in a year.

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SECTION IV.

PROBLEMS IN PHYSICAL GEOGRAPHY, WROUGHT OUT BY THE NEWTONIAN ASTRONOMICAL GLOBE.

Problem I.

Solve with the Globe.

Illustrate optically the four seasons of the year, by the perspective motion and place of the north pole in its apparent annual orbital course and axial parallelism, round the ecliptic plane.

Rule.—Bring the Sun's place to the Vernal Equinox, the 20th March. At this period, which has been shown to be the great Astronomical zero time period of the year, the north pole is just leaving its last six month's obscuration and entering the direct illuminated disc of the globe, (see cut No. 1). Its place, as seen from the Sun, is now upon the very edge of the sunlight disc. Trace now a portion of the pole's motion through continuous sunlight, viz., move the sun's place in ecliptic longitude, say 2h, or 30°, which will be seen occurs about the 19th April. On the above day the place of the pole in the sun's rays is indicated by the twilight scale of sines. It will be found to have moved towards the ecliptic axis to 30° on the quadrant of cosines, hence this distance is the real perspective place of the pole for the given days, therefore a straight line drawn from the point through the centre of a circle the size of the globe, will exhibit the true angle which the axis has in the sun on the 19th April. Again move the sun's place 6h, or 90°, in longitude, which occurs on the 21st June, at this time it will be apparent the globe's axis lies exactly towards the centre of the Sun's place; they are both situate in the solstical plane, (see cut No. 2), it will be thus observed that since March 20, when the pole was first seen in the sunlight horizon till June 21st, it has moved in the solar perspective over the entire length of the Cosine of 90° as indicated by the twilight scale. It will again be apparent that during the next three months of the polar motion it will close its six months tract in sunlight, which astronomically takes place on the day of the autumnal equinox, Sept. 22nd, hence from the foregoing panoramic motion of the pole during the two first seasons of summer quarters, it will be observed how useful the new construction becomes, and especially to any who may try to chart on a planosphere of the globe, the place of any City and its path through sunlight or darkness during any day in the year.

With the above and all the following problems, the geographer must always see, that the sun's place vernier indicating the sun's centre on ecliptic plane, is in a straight line between his eye and the globe's moveable meridian.

This condition must be strictly attended to in solving problems with this instrument.

Problem II.

When the North pole enters the twilight zone and the sun gets invisible to it at the Autumnal equinox, Sept. 22nd; how long is it in moving through the twilight belt before it reaches the circle or boundary of midnight darkness?

Solve with Globe.

Rule.—Bring the Sun's place to the Autumnal equinox, Sept. 22nd, then move it east on ecliptic plane, till the pole is just below the circle next midnight, which in the calendar of days, note, and the days passed over by the Sun's place will be the time required.

Answer.—76 days, viz., from Sept. 22nd to Nov. the 6th.

Problem III.

When the North pole enters the midnight darkness, how long does it remain there, and when will it be again in twilight zone?

Solve with Globe.

Rule.—Place the Sun's centre on ecliptic circle over the day on which the pole entered midnight darkness, (Nov. 6), note the time, and again when it passes the same circle into twilight, the arc in longitude passed over by the Sun's place will indicate the number of days the pole has been in real midnight.

Answer.—85 days, viz., from Nov. 6 to January 30.

Problem IV.

When the North pole enters again the twilight belt, which appears from the last problem to be about Jan. 30, how long will it be before it reaches the direct rays of the sun?

Solve with Globe.

Rule.—Bring the Sun's place to the day when the pole entered again the zone of twilight (Jan. 30.) Then move the sun's place east till the pole is below the front twilight circle, this place, note in the calendar of days, as it gives the day when the pole was first visible from the sun.

Answer.—The time of passage was forty-nine days, viz., from Jan. 30 to March 20th, which day is the vernal equinox, or the great SIDERIAL ZERO of time.

PROBLEM V.

Sir John Franklin, in 1845, spent that winter on Beach Island, about latitude 76°.

When did the sun set at the place for the winter and when did it appear again, also what was the length of their night?

Solve with Globe.

RULE.—Bring Beachy Island, right below the front circle of twilight and note the day, and the place of the sun on ecliptic plane,next move the sun, place east until the Island again is below the twilight circle, and note the day. The length of the night is the number of days between sunset and sunrise shown by the calendar.

Answer.—Sunset took place, astronomically, on Oct. 29, and it rose again next year on Feb. 9. The duration of the night was 102 days.

PROBLEM VI.

What is the altitude of the sun at New York, U.S., and its distance from the zenith sun on May 12th, at 19h, (or 9 a.m.)?

RULE.—Place New York below the movable meridian and screw to the axis of the globe the hour pointer when the city is in the meridian for that day, then bring New York west to the front circle of twilight and note the degree on the hour circle, afterwards move the pointer till it reaches the given hour, 9 a.m., and the arc passed over will be the altitude sought.

Answer.—The Sun's attitude at 9 a.m. was about 60° and its distance from the zenith Sun 30°, 40°, on May 12th.

PROBLEM VII.

Solve the properties of the geometrical scale of sines and cosines placed on the face of the twilight circle, and, on which is determined the length of the cosine that subtend the axial sunlight angle of the earth's axis, with the ecliptic axis on any day in the year. It has been shown that the pole of the globe moves twice over the two radii of the two quadrants which compose the twilight scale. Hence the Sun's right ascension being given for every day on the ecliptic plane, that element known for any time will show the sine on the scale which cuts the cosine at a point that determines the size of the angle the polar axis has with the solstical plane where the angle vanishes. For example, when the sun's right ascension is 4h, or 60°, which of the SINES on the scale points down to the globe where the pole is situate in sunlight at the given day, and what direction in sunlight is the axis placed at the time?

Answer.—The sine of 60° and 300° of the right hand quadrant, points to the place of the pole, and the axis lies in sunlight to the right hand of ecliptic axis.

Again, if the sun's right ascension be 8h, or 120°, which of the SINES on the scale points down to the globe where the pole is situate in the sunlight, at the time, and what is the direction in which the globe's axis lies in the sun's rays ?

Answer.—The sine of 120° and 240° of the left hand quadrant points to the place of the pole and the axis in this case lies in sunlight to the left hand of the ecliptic axis.

PROBLEM VIII.

At any assumed place within the tropics find all the places which have the same distance from it within the circle of solar illumination.

RULE.—Bring the sun's place in the ecliptic directly over the given place and the places required will all be shown *in degrees* by the brass graduated semi-circle which revolve round the sun's centre.

Q. What places have the same distance from La Plata, in South America ?

Answer.—Congo (Guinea,) Fernando Po., Timbuctoo, Morocco, Cadiz, and Orgeon City.

PROBLEM IX.

Dr. Kane, in 1854, spent that year at Rensselaer Bay in the arctic circle, in latitude 78°, 30′, how long was his arctic day, how long was the sun absent, and how often did it rise and set to the place ?*

Solve with Globe.

RULE.—Bring the place to the apparent solar meridian and exactly below the front edge of the great terminator or twilight circle, then screw firm to the globe's axis the hour vernier, and move the sun's place till Rensselaer Bay is again on the meridian and in front below the twilight circle, then the problem can be solved.

Answer.—The sun shown constantly from Feb. 15th to Oct. 25, length of the day 252 rotations, and the sun was absent 113 days ; also the sun rose and set from Feb. 15 to April 16, viz., 62 days.

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*The following abstract has been taken from Dr. Kane's notes, to enable the reader to compare the above globular solution with what he actually experienced at the place during the year—the reader being expected, with the globe before him, to place the sun in the ecliptic to the days mentioned in the Doctor's notes :—

RENSSELAER BAY, *October 11th.*—The long staring day, which has clung to us for months past, to the exclusion of the stars, has begun to intermit its brightness ; even Aldebaran, the red eye of the "bull," flared out into familiar recollection as early as ten o'clock, and the heavens, still somewhat reddened by the gaudy tints of midnight, gave us Capella and Arcturus, and even that lesser light of home memories, the Pole Star.

November 7th.—The darkness is coming on with insidious steadiness, and its advances can only be perceived by comparing one day with its fellow of some time back. We still read the thermometer at noonday without a light, and the black masses of the hills are plain for about five hours, with their glaring patches of snow, but all the rest is darkness

PROBLEM X.

To find the longitude of any given place on the globe ?

RULE.—Bring the prime meridian (London, Eng.) to the solar meridian's place, fix the axial vernier to the prime meridian, rotate the globe by the handle till the place comes below the edge of meridian, then if London or Greenwich has moved east, on the hour circle, the arc passed over by vernier will show the degrees of west longitude, and if it has moved west, the arc will show the degrees of east longitude.

Q. What is the longitude of Washington ? Five hours 8 minutes west.

Q. What is the longitude of Dublin ? Twenty-five minutes, west.

PROBLEM XI.

To find the sun's place in the ecliptic on any given day ?

Solve with Globe.

RULE.—Find the day in the calendar and directly opposite to it on the outer graduated ecliptic circle will be found the sign and degree of the sun's place.

Q.—Where is the sun situate in the zodiac on Dec. 21st. A.—1° Sagittarius. Where on May 12th ? A.—22° Arius.

PROBLEM XII.

The latitude and longitude of a place being given to find the place on the globe ?

Solve with Globe.

RULE.—Place the hour vernier at the prime meridian chosen. Then move it east or west on the hour circle to the given arc of longitude. The place on the globe right below the latitude given by meridian will be the place required.

Q.—What is the name of the city in longitude 82° east and the latitude 37° north ? A.—Cincinnati.

What is the name of the place in longitude 55° east and latitude 37° north ? Astrabad, on the east coast of the Caspian Sea.

The stars of the sixth magnitude shine out at noonday. Our darkness has ninety days to run before we shall get back again even to the contested twilight of to-day ; altogether, our winter will be sunless for about one hundred and ten days.

November 19th.—Wishing to get on the south-west cape of our bay before the darkness set in thoroughly, I started in time to reach it with my Newfoundlanders at noonday, the thermometer indicating 23° below zero.

December 15th.—We have lost the last vestige of our midday twilight ; we cannot see print, and hardly paper ; the fingers cannot be counted a foot from the eye ; noonday and midnight are alike ; and except a faint glimmer in the sky that seems to define the hill outlines to the south on the meridian, we have nothing to tell us that this arctic world of ours has a sun.

January 21st.—First traces of returning light, the southern horizon having for a short time a distinct orange tinge.

February 21st.—We have had for some days the sun silvering the ice between the headlands of the bay ; and to-day towards noon, I started out to be the first of my party to welcome him back. I saw him once more, and upon a projecting crag, nestled in the sunshine ; it was like bathing in perfumed waters.

Problem XIII.

Where is the place on the globe which has neither latitude nor longitude?

Solve with the Globe.

Rule.—Bring the movable meridian over Greenwich and the place on the globe below the meridian and over the equator or zero of latitude will be the place required.

A.—The place will be on the South Atlantic Ocean, about 600 miles south of *Gold Cape* in *Ashantie*, in Africa.

Problem XIV.

To find the places which have the same longitude as any given place?

Solve with Globe.

Rule.—Bring the given place to the edge of the movable solar meridian and all places from pole to pole, under the meridian have the same longitude.

Q.—What places are nearly under the meridian of St. Petersburg?

A.—Odessa, Cairo, and Constantinople.

Problem XV.

When does the sun rise and set at Edinburgh on June 21st, and how long is the day?

Rule.—Bring the Sun's place to the apparent meridian, and screw the axial vernier to that plane, then move by the handle of globe the city west till it comes to the twilight circle and note the time, do the same for the evening hours and the problem will be solved.

A.—The sun rises at 10 minutes to 3 a.m. and sets at 16 minutes to 9h, p.m.

Problem XVI.

To find all the places over which the sun will pass vertically on any given day?

Rule.—Bring the sun in the ecliptic to the given day, then rotate the globe by the handle, and all the places over which the sun's centre will pass will have the sun vertical on the given day.

Q.—What places will the sun pass over on the following days? Jan. 5th. A.—Trinidad, Hebrides, Mauritttus Isle, and Madagascar. On April 5th. Colombo, (in Candy) Caroline Islands, and Borneo.

Problem XVII.

To find how many geographical miles make a degree of longitude at any given parallel of latitude?

Rule.—With any suitable appliance, take the distance between two places on the given parallel of latitude, and note the number of degrees is enclosed on the equator, multiply the number by 60, divide this by 15, and the result will give the geographical miles.

Problem XVIII.

To find at any place the sun's altitude or distance in degrees from the solar terminator, or where it rose in the morning on any day and at any hour ?

Rule.—Bring the sun's centre to the meridian for the day and fix the hour's pointer to the above place, rotate the globe by handle till the place is just below the face of twilight circle and note the hour; then bring the pointer to the required time, and the number of degrees it passes over the hour circle will be the altitude sought.

Q. What is the suns altitude at Chicago, on June 16th at 8 a. m.

A. The sun's altitude is 55°

Problem XIX.

On the Island of Disco, stands the capital of Greenland, within the Arctic circle. When does the sun cease to rise every year, and on what day does it again appear at the place ?

Rule.—Bring the south of Disco to the front edge of twilight circle, and the place of the sun will point out the day in the calender when it ceases to rise, move next the sun in longitude east till the Island is again below the twilight circle, and the day when the sun will appear will be found.

A.—The sun sets at Disco on Oct. 29th, and rises again the next year about Feb. 8th.

Problem XX.

Two regions of the globe are each one day in the year astronomically without either midnight or twilight. Where are they situate on the earth and on what days do the phenomena take place ?

Rule.—Bring the sun on ecliptic plane to either of the two solstices and note the place of the twilight circle on the earth. The distance between its place and the poles give half of the diameter of each of the regions referred to.

A.—The two regions are the Frigid zones, and the two days are June 21 and Dec. 21 n each year.

Problem XXI.

To find when twilight begins and ends at any particular place on an given day ?

Rule.—Bring the sun's place in the calendar over the given day and the particular place to the solar meridian. Fix the hour pointer on the axis at noon, then bring the place given to the two edges of twilight zone end the pointer will indicate when twilight began and ended in the morning, do the same for the evening portion of the zone, and the hour index will show when the evening twilight began and ended.

Q.—When did twilight begin and end at Toronto June 28 ?

A.—At 16m. after 2h. a.m., and ended at 24 after 4h. a.m.

PROBLEM XXII.

As the sun passes vertical twice over NAVIGATORS' ISLES, In what degree of the ecliptic and days of the calendar do the circumstances occur ?

Solve with the Globe.

RULE.—Bring the sun's centre on the ecliptic circle to the degree where he first passes over the Isles. Note the degree and the day to the same when next the sun is in the same position over the Isles, and the degrees and the days will be found. A.—When the sun is first vertical he is in the 4″ Libra on October 25. At the next transit the sun is in 27″ Capricorn on the 14th February.

PROBLEM XXIII.

When does the sun rise and set at the Bermudas, on January 27, and how long is the place in passing through the evening and morning twilight ?

RULE.—Bring the place to the movable meridian for the day given and screw fast the hour pointer to the globe's axis, while it remains at rest. Then turn the globe west till the Bermudas are below the circle marked "twilight begins," and also when they reach the point of sunrise. The difference of the two times gives the period of the morning passage through twilight and the latter number the time of sunrise. Do the same at the evening setting sun and the problem will be solved.

A.—The place is in the morning twilight 1h. 25m., and the time of sunrise 4m. after 7h. a.m. Time in the evening twilight, 1h. 38m., and the sun sets at 5h. 2m. p.m.

PROBLEM XXIV.

To find the longitude between two different places on the globe ?

Solve with Globe.

RULE.—Bring one of the places to the solar meridian and place the axial pointer to that plane, rotate the Globe by the handle till the other place is below the meridian, and the degrees of arc passed over will give the difference of longitude.

Q.—What is the difference of longitude between London (Eng.), and Toronto ? A.—5h. 17m. west. Between New York and Toronto 20m. in west longitude.

PROBLEM XXV.

To find when continuous twilight takes place after sunset. How long it continues at the following different places in England, Scotland and Ireland.

Solve with the Globe.

RULE.—Work as directed in Problem XXI.

London—Twilight begins May 21st; ends July 22nd.

Bristol—Twilight begins May 21st; ends July 19.

The Lands End—Twilight begins June 4th; ends July 10.

Edinburgh—Twilight begins May 16th; ends August 4.

Dublin—Twilight begins May 16th; ends July 26.

Liverpool—Twilight begins May 14th; ends July 27.

Problem XXVI.

What places in British America have continuous twilight during the various summer months.

Solve with Globe.

Rule.—This problem, like the last, is solved by the rule in XXII. Every place within the parallels of latitude of 50° and 66° 30′ have continuous twilight after sunset, from the end of May to nearly the 10th July, which includes a region in the Dominion from the Lake of the Woods in the south to the southern shores of the Great Bear Lake, besides the Copper Indian territory in the north. So that the twilights are continuous over every fishing lake north of the parallel of the mouth of the St. Lawrence during the above period.

Problem XXVII.

To find by the Globe the three cases, viz., the Antœci, Periœci, and Antipodes of any given place on the earth?

Rule.—Bring the place to the solar meridian and note its latitude. Then count the same number of degrees from the equator in the opposite hemisphere and the Antœci, of the place will be found. Next, Perioci, being situate on the same latitude, but on opposite meridians, set the hour pointer to the given meridian and rotate the globe by handle 180°, in east longitude. Then the place on the globe below the same degree first assumed will be the Periœci required.

As the Antipodes lie opposite upon the globe, with feet to feet on opposite meridians and parallels of latitudes, the Antipodes will be found under the same degree of the opposite solar meridian, where at first the Antipodes stood.

Solution.—First—What place on the globe is the Antœci of Quebec, 48° north?

A.—Cape Blanco, in Patagonia.

Second—What place on the globe is the Periocei of Toronto, 44° north?

A.—The Blue Lake in the West of China.

Third—What place is antipode to Cape Horn, in South America?

A.—Cereina, in the north of Asia.

Problem XXVIII.

The time of a Lunar Eclipse being given, to find all the places on the globe where it will be visible?

Rule.—Find where the sun will be vertical at the time of the moon's opposition; bring the sun's place to the solar meridian; then, as the sun will be visible to all parts of the globe from the place of the sun to the twilight circle, and the moon being at the time of an eclipse exactly opposite, the eclipse will be visible to all of the opposite or dark hemisphere, at any point of which the different phases will be seen.

Problem XXIX.

When it is 12 or noon at Montreal, Canada, what is the civil time at Sydney, Australia.

Rule.—Bring Montreal to movable meridian for the day, fix the hour vernier to meridian plane; then keep meridian fixed, and turn the globe by the handle till Sidney is below the meridian. The arc passed over by the pointer either east or west will show the Sidney time.

SECTION IV.

SOME ADDITIONAL EXPLANATIONS ON THE IMPORTANT FUNCTIONS OF THE TWILIGHT CIRCLE IN THE STUDY OF THE DYNAMICAL BRANCH OF PHYSICAL GEOGRAPHY.

It is well understood, twilight is due to that optical property of the atmosphere, whereby, when the sun is below the local horizon, its rays by reflection and refraction are enabled to illuminate a portion of the sky beyond the twilight circle or the real geometrical boundary of the globe's illumination. This partial illumination occurs as long as the sun is less than 18° below the edge of the zone. As soon as it descends further then that distance twilight ceases, hence the globe viewed in the perspective from the outside, and from a point at right angles to the line joining the globe and sun, it will present the following appearances: It will have a brilliant, half illuminated hemisphere towards the sun, then a baund or zone of faint light, named twilight, 18° or about 1250 miles wide on the globe's surface, and lastly a large portion of a half hemisphere, in total darkness. Now in the daily rotation of the earth every portion except the two Frigid zones passes through the twilight phase twice in every rotation of the globe. Hence very great differences occur in the duration of twilight according as the place passes below the solar horizon perpendicularly or obliquly. On looking at the apparatus it is obvious that when any place passes perpendicularly it will reach the distance of 18° much sooner than where it passes very obliquely. In the study of this branch of topography it will always be very profitable to the pupil to illustrate the different conditions in which the globe and the twilight is placed in, and especially at the beginning of the various seasons of the year. For example, examine the position of the twilight at the two solstices. At this period it will be manifest that the zone will be concentric over every meridian on the earth at the noon passage, at right angles to them, and every place, when it comes to the twilight circle passes from below at the same instant of time, an occurence which takes place at no other time in the year. Hence from pole to pole on the earth every place on June 21st and Dec. 21st have their shortest twilights, because every parallel of latitude moves through the zone at RIGHT ANGLES, which is the shortest path.

Again it will next be observed, as a consequence of terrestrial curviture, the twilight lengthens as we proceed from the Equator to the poles. At the Equator every degree of longitude being equal to four minutes of time, and the zone 18° in width. It follows that the length of twilight will be 10 x 4 or 72 minutes of time.

In acquiring a knowledge of the actual history of the difference of time any placeis in twilight, the following may be attended to. That at the parallel 72° north every place NORTH is below the zone after sunset at the equinoxes, and consequently midnight darkness there entirely ceases, there being 12 hours of sunlight and 12 hours of twilight. Thus in both hemispheres the twilight varies from 72 minutes at the equator to 12 hours, at all latitudes north or south of 72 degrees; that is within 18° of the poles. It is worthy to note here by bringing the sun's place to the northern tropic Gemini, the sun then has a declination of 23° 28′. Yet notwithstanding that obliquity, the duration of the twilight at the equator is practically the same as at the equinoxes, about 72 minutes. At the parallel of Toronto, for example, about 44° N., it will be found that the twilight has extended so obliquely on the globe when the sun is in Gemini—the time of the city's passage through it, is fully two hours and twenty minutes—so that real night, then, only lasts about three hours and twenty minutes. Moreover, north of the latitude 66° 30′ at the above time in the year, the sun does not set during the twenty-four hours, so that there, there is neither night nor twilight at the above day in the year.

At the autumnal equinox, all the conditions as regards twilight, are identically the same as at the vernal equinox, excepting that the globe's axis, when viewed by the astronomical system of study, it inclines now to the left hand, instead of, as before, to the right of the ecliptic axis.

In the annual progress of the twilight round the ecliptic axis it will be observed when the sun reaches the southern solstice (Sagittarius), the twilight is now in the equinoxial plane, and that all the illuminating phases observed in the summer of the northern hemisphere takes place now in the southern, From the parallel 66° 30′ south to the pole it is constant day, and at all latitudes between 66° 30′ south of the equator there are alterations of DAY, TWILIGHT and NIGHT.

The reader who may now have attended practically to the foregoing explanations, may quite readily discover with what ease and accuracy all the new problems can be solved by the Astronomical Globe, and we presume it is almost unnecessary to allude to its importance in the study of the globe's surface, since you cannot reason or point out intelligently any particular phase in the work without its use. In a great measure the terrestrial globe, without all the astronomical mechanical details, is very similar to a chronometer without either dial or index. In fine, in revising and tracing the causes of the distribution of light and heat upon the globe, which is principally the great object of this apparatus, with all the variations in the lengths of the days and nights in a year, with the observed variable periods of light and darkness within the Polar Circles. The following conclusions may be safely come to as to whence they arise :—

First—To the orbital revolution of the globe around the sun in the ecliptic plane, and to the fact of the centres of the two bodies remaining always in the above plane.

Second—To the inclination of the terrestrial axis to the globe's path in the solar system.

Third—To the parallelism of the axis to itself, combined with the globe's axial rotation every 24 hour.

In the study of this branch of geography with the Astronomical Globe it may be added all the geographical definitions should be fully riveted in the memory; and chiefly the mechanical portions which represent terrestrial phenomena, and such should be studied and taken from the apparatus itself. Also, it should be remembered, the full structure of terms used by geographers are of a mixed character, a portion being purely astronomical, viz., those relating to the circles of the sphere, and those which relate or describe the conditions of the surface of the earth. Hence the use and necessity of uniting together the study of the two branches, Topography and Geographical Astronomy.

The following are the most prominent DEFINITIONS used in solving problems with the new globe, and they should all be closely traced on the APPARATUS and committed to memory.

First—The great imaginary AXIS of the GLOBE is a straight line or diameter, around which the whole mass turns once every twenty-four hours.

Second—The POLES of the GLOBE are the two places in its surface at the extremity of its axis north and south.

Third—The NORTH POLE determines the direction in which the axis points to in the Heavens, and the South Pole determines the opposite extremity. In the present age no telescopic star happens to be exactly over the two celestial points.

Fourth—Meridians on the globes surface are HOUR CIRCLES, and when read on the globes equator, they are called RIGHT ASCENSIONS, but when referred to the ecliptic plane they indicate the ecliptic longitude.

Fifth—The angles of RIGHT ASCENSION are at the poles of the globe's axis and the LONGITUDE is at the poles of the ECLIPTIC PLANE.

Sixth—The EQUATOR is a great circle equidistant from the two poles, it divide the globes into two hemispheres named after the poles, Northern and Southern Hemispheres.

Seventh—Parallels of latitude are circles parallel to the equator and they diminish in diameter on the globe from the equator to the two poles.

Eighth—Parallels of DECLINATION are circles parallel to the EQUINOXIAL PLANE and they diminish in diameter on the celestial sphere from the ecliptic plane to its two poles.

Ninth—The LATITUDE of a place on the GLOBE in degrees of arc is the distance of the place from the EQUATOR NORTH or SOUTH, hence all places north have north latitude, and all places south have south latitude.

Tenth—The longitude of any place on the globe is its distance EAST or WEST from a given assumed meridian Greenwich, (England) being now the prevailing PRIME MERIDIAN in popular astronomical geography, however for the Western Hemisphere, the Americans often for their maps and globes take the meridian of Washington.

Eleventh—The declination of the sun is its distance in degrees of arc from the Equator, (often called the equinoctial or the line), when it is north of this line or circle it is named NORTH DECLINATION, and when it it is south it is SOUTH DECLINATION.

Twelfth—The ECLIPTIC PLANE or the orbit of the globe in the solar system, is the Sun's apparent place among the stars in the mechanical arrangements of the new globe, the above orbit is represented by the great lithographic circle fixed to the tripod stand of the apparatus.

In the construction of these globes the greatest care is taken to insure excellence of workmanship and accuracy in the different scientific adjustments required. The Manufacturer therefore, is confident, that all educators who are desirous to procure improved school or library terrestrial globes will find that for giving accurate scientific exhibitions of terrestrial phenomena the new Newtonian Globe excels all others which are sold either in Europe, England, or the United States.

It may be mentioned in closing here, when the foregoing apparatus was fully completed it was expressly examined by the Hon. G. W. Ross, Minister of Education, who AT ONCE ORDERED ONE for the DEPARTMENT, where it formed part of the school appliances which were sent from the Department to the Colonial and Indian Exhibition, London, and at the Exhibition the new Globe obtained a special notice of its merits, and also it was awarded a diploma and medal.

SELECT TESTIMONIALS.

The following Critical Notices have been selected from a number the Inventor has received from different eminent educators and astronomers, who have had an opportunity to examine the instrument:—

DEARBORN OBSERVATORY,
CHICAGO, Ill., April 25, 1885.

I have examined with great interest the Terrestrial Globe as arranged by Mr. M· Turnbull. It presents a number of novel appliances which make it of the greatest value as an educational instrument.

The apparent annual motion of the sun, the change of the seasons—twilight, zone, and other terrestrial phenomena—are more clearly explained by its use than by any other apparatus yet devised.

G. W. HOUGH, Director.

Appended to the above was the following from Mr. Burnham, the great Chicago discoverer and measurer of the Binary systems at the Chicago Observatory:

I have examined M. Turnbull's new Globe, and can fully concur in Professor Hough's high endorsement of it. It is truly a good thing, and should be extensively introduced.

S. W. BURNHAM.

The following notice appeared in the London "Monthly Observatory," edited by the present Astronomer Royal of England:—

Mr. Turnbull, of Toronto, has arranged a form of terrestrial globe which is highly useful for showing the changes of the four seasons—for finding the duration and position of twilight round the globe, and for solving a number of important new geographical problems.—*Greenwich Monthly Observatory.*

Testimonial from Dr. Swift, Warner Observatory:—

MR. M. TURNBULL,

Dear Sir,—I have made a somewhat critical study of the principles involved in the construction of your astronomical globe, and am free to give it my hearty and unqualified approval. By its use many abstruse truths may be very plainly demonstrated. The varied phenomena produced by the inclination of the earth's axis to the plane of its orbit, of which we are daily witnesses, though but few are able to understand, may, by means of this globe and its attachments, be made comprehensible by all. The geometrical scale of sines and cosines attached to the twilight circle over the inclined terrestrial axis, gives a useful and true illustration of the sunlight orbit of the globe's poles round the ecliptic axis a devise highly useful to a draftsman in tracing the different phases that any parallel of latitude can take through sunlight and darkness during the year.

LOUIS SWIFT, Director.

Warner Observatory, Oct. 22nd, 1886.

Testimonial from Prof. O. C. Wendale, of Cambridge Astronomical Observatory :—

MR. TURNBULL,

I have examined the terrestrial globe as devised by you and find it is a highly useful article. It comprehends several novel devices quite unlike those of ordinary terrestrial globes, and by it several new problems may be solved, while for use in the school it must prove to be an excellent accessory.

Harvard, Cambridge, Oct. 30th, 1886. O. C. WENDALE.

UNIVERSITY COLLEGE, Toronto Jan. 21st, 1886.

Dear Sir,—Your improved globe was recently examined by Dr. McLellan, and a number of prominent public school inspectors, and the opinion formed of it by all who took part in the examination was in the highest degree favourable, I know that the doctor himself is of the opinion that one of your globes ought to be at least, in every County Model School in the Province, and that it would be of material service to have it introduced into as many as possible of the public and high schools. It would enable pupils readily to understand various important matters in physical geography, which, for the most part, they now *really learn by rote.* Yours very truly,

GEORGE PAXTON YOUNG.

Testimonial which was received from the late S. J. Watson, an eminent scientist and poet of Toronto :—

I have carefully investigated the principles on which Mr. M. Turnbull has constructed his Astronomical Globe. These principles are at once natural, scientific, and easy of comprehension. By this Globe the study of geography, which was before a task for the young, will now become a pleasure. The apparatus presents a complete and visible explanation of the physical phenomena which characterise the earth as a member of the solar system.

From the time when globes first came into use for illustrating the science of geography to the present day no such invention as Mr. Turnbull's has been given to the world. It will mark the beginning of a new era in the art of geographical and astronomical instruction. It is the work of a man who has been gifted with the rare faculty of translating great scientific knowledge into the shape of an apparatus which is a masterpiece of practical and beautiful mechanism.

S. J. WATSON,
Late Parliamentary Librarian, Ontario.