SPHERICAL TABLES AND DIAGRAM, WITH THEIR APPLICATION TO GREAT CIRCLE SAILING, AND VARIOUS PROBLEMS IN NAUTICAL ASTRONOMY

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AND VARIOUS PROBLEMS

IN

NAUTICAL ASTRONOMY.

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[ENTERED AT STATIONERS' HALL.]

PREFACE.

The Author of the following Work being engaged in examining the Exmeridian Tables of Mr. Towson, the idea occurred to him that as there are many problems in Navigation and Nautical Astronomy, where minute accuracy is not required for practical purposes, and that as the Traverse Tables contain the computed values of right-angled plane triangles, and thus we are able to solve them to a certain degree of approximation, so Tables might perhaps be formed containing the computed values of right-angled spherical triangles, and thus we would also be able to solve them to a certain degree of approximation. Partly pursuant to this idea, and partly as a means of employing his leisure time, he commenced a series of spherical investigations and calculations, and in doing so observed the principle on which the Tables are founded; by means of that principle it is unnecessary to compute all the parts of the triangles.

The Tables are arranged particularly for the solution of the Great Circle problem, and the Author trusts that the methods by inspection, of finding the first course, latitude of vertex, longitude from vertex, and distance to any integral point on the great circle, where it may be desired to change the course, will be worthy of notice. By means of the diagram which the Author has devised, the latitude of vertex, and longitude from vertex—and thence the courses can be found with the same facility as by the excellent Tables of Mr. Towson; but in the Author's opinion the method of finding the first great Circle Course by inspection, is even more simple than the middle latitude, or Mercator's method of finding the Chart Course by inspection. With regard to the degree of dependence to be placed upon it, by means of a very extensive induction, the Author has arrived at the conclusion, that for any difference of longitude large enough (say 15°, and in many instances less,) to make great circle-sailing worth attending to, the method may be depended upon generally to less than one-eighth of a point; in some instances when the difference of longitude is small and the latitude high, the course may be erroneous nearly one-quarter of a point; but this will not happen with more than 15° difference of longitude and less than 60° of latitude, which may therefore be taken as the limit: as a general rule, the "lat." or "latitude" at the bottom of the Tables should never be less than 7°.

In the absence of the Author, the work will be published under the superintendence of Mr. Edward Temple, of Blyth, Teacher of Navigation and Nautical Astronomy.

Blyth, March 19th, 1857. W. C. Bergen.

Analytical Investigation of the Principle in (33).

A C B, A H G are two right-angled spherical triangles having the right angle at B and G respectively.

$$AG = CE = \text{complement } AC.$$

Angle A is the same in both triangles.

Proof that angle H = complement B C.

$$\begin{aligned}\cos H &= \cos AG \, . \, \sin A \\ &= \cos CE \, . \, \sin A \\ &= \sin AC \, . \, \sin A \\ &= \sin BC\end{aligned}$$

Therefore H = complement B C.

Proof that G H = complement angle C.

$$\begin{aligned}\tan GH &= \sin AG \, . \, \tan A \\ &= \sin CE \, . \, \tan A \\ &= \cos AC \, . \, \tan A \\ &= \cot C\end{aligned}$$

Therefore G H = complement C.

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The principle in (33) may be easily deduced from the complementary triangles A C B, E C F.

For the angles at C are equal, and A B, F E, are respectively the complements, of B D, E D.

DEFINITIONS.

1. A SPHERE is a solid, conceived to be generated by the revolution of a semicircle about its diameter.

2. A boy's ball or marbles, cannon-balls, common musquet-shot, drops of rain, are so many examples of spheres; many roots and fruits are of a nearly spherical form, for instance, oranges and apples; and if we cut such an object into two parts perfectly flat, the section will be a circle, and if this section pass through the centre of the sphere, it is called a great circle, it being the largest that can be described; if the section does not pass through the centre, it is called a small circle.

3. The earth we inhabit is shown, by the researches of astronomers, to be of a spherical form; and it seems to be placed in the centre of an immense hollow sphere, having the centre of the earth for its centre, and apparently revolving round the earth once in twenty-four hours, and carrying the sun, moon, and stars with it in its revolution.

4. To point out the position of objects on the surfaces of the earth, and apparent concavity of the heavens, with respect to each other, astronomers suppose certain points, lines, and circles to be described.

5. Thus that point in the heavens near the polar star, and around which the celestial sphere seems to revolve, is called a pole; if a straight line be conceived to be drawn from it, through the centre of the earth, and limited by the opposite side of the celestial sphere, it is called the axis, and its extremities, the poles of that sphere. The portion of the axis of the celestial sphere, intercepted by the surface of the earth, is called the axis, and the points where it is intercepted, the poles of the earth.

6. Great circles, which pass through the celestial poles, are called celestial meridians, or circles of right ascension, and the corresponding great circles passing through the poles of the earth, are called terrestrial meridians.

7. The great circle equidistant from the celestial poles, is called the equinoctial, and the corresponding great circle equidistant from the terrestrial poles, is called the equator.

8. Small circles parallel to the equator are called parallels of latitude.

9. The point in the celestial sphere, directly over the spectator's head, is called the zenith, and the opposite point under his feet the nadir.

10. Great circles passing through these two points are called vertical or azimuth circles.

11. The horizon is that great circle equidistant from the zenith and nadir; and it is parallel to that circle which bounds the view of the spectator at sea, and which is called the sensible horizon.

12. A meridian passing through any place is called the meridian of that place.

13. A meridian passing through some remarkable place is chosen as the one from which the others are reckoned, and it is called the first meridian.

14. The longitude of any place may be defined to be the arc of the equator, intercepted by the first meridian, and the meridian passing through the place.

15. The difference of longitude between two places may be defined to be the arc of the equator, intercepted by the meridians passing through the two places.

16. The latitude of a place is the portion of the meridian passing through it, intercepted between the equator and the place.

17. It is a principle that every great circle divides every other great circle into two equal parts, hence the equator bisects every other great circle.

18. That point in any great circle midway between its points of intersection with the equator, is called its vertex.

19. The meridian passing through the vertex is called the meridian of vertex.

20. The portion of the meridian of vertex, intercepted by the vertex and the equator, is called the latitude of vertex.

21. The arc of the equator intercepted by the meridian of vertex, and the meridian passing through any place, is called the longitude from vertex of that place.

22. The arc of the horizon, intercepted by the meridian passing through the zenith, and the vertical circle passing through any object, is called the azimuth of that object.

23. The vertical circle which is at right angles to the meridian passing through the zenith, is called the prime vertical.

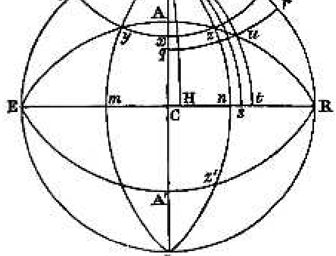
24. The amplitude of an object, is the arc of the horizon intercepted between the prime vertical and the object at rising or setting.

25. The altitude of an object is the arc of the vertical circle, intercepted by the object and the horizon.

26. The meridian distance of an object is the arc of the equinoctial, intercepted by the meridians passing through the zenith and the object.

PRINCIPLE AND CONSTRUCTION OF THE DIAGRAM.

27. In the annexed figure let C, the centre of the primitive P E L R, be the projection of a point on the earth's equator, P L that of the meridian passing through the point, and E R that of the equator, and let P be the nearest pole, P *m* L, P *n* L meridian circles equally inclined to the primitive; then it is evident that P L bisects the angle *m* P *n*, and therefore *m* P *n* is double of C P *n*.



Again, let a great circle E A R be drawn through E R, cutting P *m*, P L, P *n* in the points *y*, A, *z*, and through *y z* let the parallel of latitude *p y x z o* be drawn.

Now if the quadrant P C E be conceived to turn round the radius P C (which remains fixed), and placed on the quadrant P C R, the projections of the one will fall on the equal projections of the other, and will coincide with them; P *m* will therefore coincide with P *n*, A E with A R, *p x* with *o x*, and the point *y* with *z*.

Now A is the vertex of the great circle E A R (18), P L is the meridian of vertex (19), A C is the latitude of vertex (20), and C P *n* measured by C *n*, is the longitude from vertex of the point *z* (21).

28. Hence when two places are given on the same parallel of latitude, to find the latitude of vertex, and longitude from vertex, let C *n* be equal to half the difference of longitude, and *o z* part of the parallel of latitude passing through the places, with a pointed instrument trace up the meridian P *n*, and with another trace along the

parallel *o x*, until the curves meet in the point *z*, then trace the great circle R *z* A passing through *z*, until it meets the meridian of vertex in A; then C A is the latitude of vertex, and C *n* is the longitude from vertex.

29. Again, if the places are on the same side of the equator, and in different latitudes *o x*, *r q*; let P *n*, P *s*, P *t*, be meridians equidistant from each other, and C *s* equal to half the difference of longitude; with the right hand trace up the meridian P *s*, until it cuts the lowest latitude *r q*, then with the left hand trace it up again, until it meets the highest latitude *o x*, then trace the lowest latitude to the right hand, and the highest to the left, being careful to move an equal number of degrees on each side of the meridian P *s*, until the curve of a great circle pass through both points, let these be *z u*, and let R *u z* A be the great circle; then A C is the latitude of vertex, C *n* is the longitude from vertex of *z*, and C *t* that of *u*.

30. It is evident that if *y* be the place of the ship, and *u* that of her destination, or conversely, the meridian of vertex falls between them, and that *m n* added to *n t* is the difference of longitude; but C *n* is the half of *m n*, and therefore twice C *n* added to *n t*, is equal to the difference of longitude. Now *n s* is the half of *n t*, and when twice C *s* is considered as the difference of longitude, when the hand is moved to the left from *s* to *n*, twice *n s* is taken from the difference of longitude, but the other hand being moved from *s* to *t*, they are distant from each other *n t*, which is equal to twice *n s*, and *n t* being added to twice C *n* the difference of longitude is the same as at first.

31. Again, if *z* be the place of the ship, and *u* that of her destination, or conversely, then the meridian of vertex falls without them, and *n t* is their difference of longitude, and *n s* half their difference of longitude. Let C H be equal to *n s*, and let P H be traced up as before, then in this case, the left hand will meet the meridian of vertex without meeting the great circle, and the right hand must be moved until it is at a distance from the meridian of vertex, equal to the difference of longitude, and both hands being then moved equally, until they arrive at the points *z* and *u*, where the great circle passes through them; then as before, A C is the latitude of vertex, and C *n* or C *t* the longitude from vertex.

32. To meet the case of the places being on different sides of the equator, conceive the opposite pole of the primitive to be taken as the projecting point, and equal circles to be projected on the lower right hand quadrant L C R, and it being turned on the radius C R, it will fall on the quadrant P C R, and the projections of the one will coincide with the equal projections of the other; and if the places are in equal latitudes $z z^1$, then *n* R will be half the difference of longitude, C *n* half its supplement; hence by taking the supplement of the difference of longitude, and proceeding exactly as in the other cases, the latitude of vertex A C or A^1 C, and the longitude from vertex C *n* or C *t* will be found.

Note.—The diagram is drawn to a radius of 16 inches, and to every degree of inclination to the primitive, and also of latitude; every fifth degree is numbered, and drawn stronger than the others, and in order still farther to distinguish them, the alternate degrees between them are dotted. Underneath the equator line the degrees from the meridian of vertex are numbered, thus showing the longitude from vertex, and the half difference of longitude; and under this again these numbers are doubled, indicating the difference of longitude; and to obviate the necessity of taking the supplement of the difference of longitude, in the case of the places being on different sides of the equator, a third line of numbers is given, containing the difference of longitude reckoned from the point R, where the ship crosses the equator.