CHAPTER 12

THE SAILINGS

INTRODUCTION

1200. Introduction

Dead reckoning involves the determination of a present or future position by projecting the vessel's course and distance run from a known position. A closely related problem is that of finding the course and distance from one known point to another. For short distances, these problems are easily solved directly on charts, but for trans-oceanic distances, a purely mathematical solution is often a better method. Collectively, these methods are called **The Sailings**.

Navigational computer programs and calculators commonly contain algorithms for computing all of the problems of the sailings. This chapter discusses basic calculation methods and tabular solutions. Navigators can also refer to National Geospatial-Intelligence Agency (NGA) *Pub. 151, Distances Between Ports*, for distances along normal ocean routes. Pilot charts also offer some track and distance information.

Because most commonly used formulas for the sailings are based on rules of spherical trigonometry and assume a perfectly spherical Earth, there may be inherent errors in the calculated answers. Also, differences in rounding practices will result in slightly varying solutions. Errors of a few miles over distances of a few thousand miles can be expected. These will generally be much less than errors due to currents, steering error, and leeway.

To increase the accuracy of these calculations, one would have to take into account the oblateness of the Earth. Formulas exist which account for oblateness, reducing these errors to less than the length of the typical vessel using them, but far larger errors can be expected on any voyage of more than a few day's duration.

There are two types of Sailings: Great Circle and Rhumb Lines. Both will be described in detail in this chapter.

1201. Terms and Definitions

In solutions of the sailings, the following quantities are used:

1. **Arc min**. Minutes of arc; for example, 234 arc min is usually indicated as 234' in formulae.

2. **Course (Cn)**. The vessel's true course, or a track-line's true course, as measured from 000°-360° T.

3. **Course Angle (C)**. The angular direction measured clockwise or counterclockwise from 000° through 090° or 180°. The reference direction (north or south) will be the prefix and the direction of measurement (east or west) will be the suffix. The parameters and procedure for labeling the prefix and suffix differs with the type of sailing. C is normally expressed as N/S xxx° E/W and converted to true course by reading "the true course is xxx° E/W of N/S."

4. **Departure (p or Dep.)**. The distance (in nautical miles) between two meridians at any given parallel of latitude; differentiated from DLo which is an angular measure of the same arc and does not change with latitude. Departure (p) between two meridians decreases with the cosine of the latitude as latitude increases. At the equator, departure is equal to DLo (in minutes). Departure becomes zero at the poles. Departure must be marked E or W depending on the direction it was measured. The relationship between departure and DLo is $p = (\cos L)\, DLo$.

5. **Difference of latitude (l or DLat or ΔL)**. The shorter arc of any meridian between the parallels of two places, expressed in angular measure. The difference in latitude between L1 and L2, usually expressed in minutes of arc.

6. **Difference of longitude (DLo or Δ Long or $\Delta\lambda$)**. The shorter arc of a parallel between the meridians of two places, expressed in angular measure. The difference in longitude between two points, usually expressed in minutes of arc; Differentiated from p (departure) which is the same arc measured in nautical miles. DLo will remain the same regardless of latitude. DLo_v is the difference in longitude between the point of departure and the great circle vertex. DLo_{vx} is the difference in longitude between the great circle vertex and a point on the great circle track.

7. **Distance (D or Dist.)**. Distance in nautical miles (nm) of 6,076.1 feet or 1,852 meters. D_v is the great circle distance to the vertex from the point of departure. D_{vx} is the distance from the vertex to a

point on the great circle track.

8. **Latitude (L)**. The latitude of the point of departure is designated L_1; that of the destination, L_2; middle (mid) or mean latitude, L_m; latitude of the vertex of a great circle, L_v; and latitude of any point on a great circle, L_x.

9. **Longitude (λ)**. The longitude of the point of departure is designated λ_1; that of the point of arrival or the destination, λ_2; of the vertex of a great circle, λ_v; and of any point on a great circle, λ_x.

10. **Mean latitude (L_m)**. Half the arithmetical sum of the latitudes of two places on the same side of the equator.

11. **Meridional parts (M)**. The meridional parts of the point of departure are designated M_1, and of the point of arrival or the destination, M_2. Meridional Parts can be found in Table 6 in Volume 2 with the latitude as an entering value.

12. **Meridional difference (m)**. The mathematical difference between the tabular values of M_2 and M_1.

13. **Middle or mid latitude (L_m)**. The latitude exactly mid-way between the point of departure and point of arrival latitudes. The latitude at which the arc length of the parallel separating the meridians passing through two specific points is exactly equal to the departure (p) in proceeding from one point to the other by mid-latitude sailing. The mean latitude is used when there is no practicable means of determining the middle latitude.

KINDS OF SAILINGS

1202. Great Circles

A **great circle** is the intersection of the surface of a sphere and a plane through the center of the sphere. It is the largest circle that can be drawn on the surface of the sphere and is the shortest distance, along the surface, between any two points on the sphere. Any two points are connected by only one great circle, unless the points are antipodal (180° apart), in which case an infinite number of great circles pass through them. Every great circle bisects every other great circle. Thus, except for the equator, every great circle lies half in the northern hemisphere and half in the southern hemisphere. Any two points 180° apart on a great circle have the same numerical latitude, but contrary names, and are 180° apart in longitude.

The point of greatest latitude on a great circle is called the **vertex**, and there is a vertex in each hemisphere, 180° apart. At the vertex, the great circle is tangent to a parallel of latitude and the direction along the great circle would be exactly due east or west. On each side of these vertices the direction changes progressively until the intersection with the equator is reached, 90° away, where the great circle crosses the equator at an angle equal to the latitude of the vertex. As the great circle crosses the equator, its change in direction reverses, again approaching east/west, which it reaches at the next vertex.

Great circle sailing involves the solution of courses, distances, and points along a great circle between two points. Great circle sailing takes advantage of the shorter distance along the great circle between two points, as compared to the longer rhumb line. The arc of the great circle between the points of departure and arrival is called the **great circle track**. The rhumb line appears the more direct route on a Mercator chart because of chart distortion. Along any intersecting meridian the great circle crosses at a higher latitude than the rhumb line. Because the great circle crosses meridians at higher latitudes, where the distance between them is less, the great circle route is shorter than the rhumb line.

The savings in distance offered by a great circle route, as compared to a rhumb line track, increases as

1. the latitude increases (the farther from the equator the route is)

2. as the difference of latitude between the two points decreases (the more easterly/westerly the track), and

3. as the difference of longitude increases (the longer the route is). Of course any track that runs exactly due north or south, or lies along the equator is itself a great circle and would be coincident with the rhumb line track.

On a Mercator projection, a great circle appears as a sine curve, concave to the equator, extending equal distances on each side of the equator. The rhumb line connecting any two points of the great circle on the same side of the equator is a chord of the curve. If the two points are on opposite sides of the equator, the direction of curvature of the great circle relative to the rhumb line changes at the equator. The rhumb line and great circle may intersect each other, and if the points are equal distances on each side of the equator, the intersection takes place at the equator. Along any intersecting meridian, the great circle crosses at a higher latitude than the rhumb line. If the two points are on opposite sides of the equator, the direction of curvature of the great circle relative to the rhumb line changes at the equator.

Despite the constant course changes required to follow a great circle, if the great circle could be followed exactly,

the destination would always be dead ahead (on the sphere). Since a great circle (other than a meridian or the equator) is a curved line whose true direction changes continually, the navigator does not attempt to follow it exactly. Instead, a number of waypoints are selected along the great circle, rhumb lines are drawn between the waypoints, and the vessel is steered along these rhumb lines. The number of points to use is a matter of personal preference. A large number of points provides a closer approximation to the great circle, but requires more frequent course changes. As a general rule, 5° of longitude is a convenient length. This method does not provide legs of equal length, but under normal conditions, this is acceptable. Care must be taken to apply the correct variation and deviation to magnetic compass headings as the vessel changes location and heading along the great circle route.

The decision to use a great circle sailing depends upon several factors. The savings in distance should be worth the additional effort, and of course the great circle route cannot cross land, nor should it carry the vessel into dangerous waters. If a vessel finds herself considerably off the desired great circle track, it may be preferable to generate a new great circle route for the remainder of the voyage, rather than return to the original route.

1203. Altering a Great Circle Track to Avoid Obstructions

Usually, great circle tracks are followed from an offshore point of departure, near a sea buoy for example, to a similar offshore point of arrival. However, obstructions such as land, ice, or prohibited areas may make following the great circle for the entire voyage impossible. One may also alter a direct route in order to take advantage of favorable winds or currents. If the great circle route needs to be modified the navigator may follow the great circle to the obstruction then follow a rhumb line course (or several) until clear of the obstruction, and then follow a great circle to the destination. One could also sail great circle to a point near the obstruction and then a different great circle from that point to the destination. Another solution is to use a composite sailing.

1204. Rhumb Lines

A rhumb line makes the same angle with all meridians it crosses and appears as a straight line on a Mercator chart. The principal advantage of a rhumb line is that it maintains a constant true direction and a ship following the rhumb line between two places does not change its true course. It is adequate for most purposes of navigation, bearing lines (except long bearing lines such as are obtained by radio bearings), and course lines both being plotted on a Mercator chart as rhumb lines, except in high latitudes.

Rhumb line sailings account for the spherical nature of the path using various mathematical formulae, and will yield different results for courses, distances and positions depending on the type of sailing used.

The types of rhumb line sailings are:

1. **Parallel sailing** is the interconversion of departure and difference of longitude when a vessel is proceeding due east or due west and thus sailing along a parallel of latitude.

2. **Plane sailing** solves problems involving a single course and distance, difference of latitude, and departure, in which the Earth is regarded as a plane surface. This method, therefore, provides solution for latitude of the point of arrival, but not for longitude of the arrival point. To calculate the longitude, the spherical sailings are necessary. Because of the assumption that the Earth is flat, plane sailing is not intended for distances of more than a few hundred miles.

3. **Mercator sailing** provides a mathematical solution of the plot as made on a Mercator chart. It is similar to plane sailing, but uses meridional difference and difference of longitude in place of difference of latitude and departure, respectively.

4. **Middle- (or mid-) latitude sailing** uses the mean latitude for converting departure to difference of longitude when the course is not due east or due west and it is assumed the course is steered at the mid latitude.

5. **Traverse sailing** combines the plane sailing solutions when there are two or more courses and determines the equivalent course and distance made good by a vessel steaming along a series of rhumb lines.

6. **Meridian sailing** describes a vessel is sailing due north or south along a meridian of longitude. No solutions are necessary because there is no departure or difference in longitude. Though course is constant, it actually is also a great circle sailing.

1205. Composite Sailing

A **composite sailing** (a combination of great circle and rhumb line tracks) is planned as a great circle route with rhumb line portions inserted as required to sail along a desired parallel of latitude, usually to avoid a navigational danger such as ice, land, or inclement weather. The composite track consists of a great circle from the point of departure tangent to a limiting parallel of latitude, a course line due east or west along the parallel of latitude, and a great circle tangent to the limiting latitude and to the destination.

Solution is made most easily by means of a great circle chart. Composite sailing only applies when the vertex lies between the departure and arrival points.

GREAT CIRCLE SAILING SOLUTIONS

1206. Great Circle Sailing by Chart

The graphic solution of great circle problems involves the use of gnomonic projection charts. NGA publishes several gnomonic projections covering the principal navigable waters of the world. On these great circle charts, any straight line is a great circle. Gnomonic charts however, are not conformal; therefore, the navigator cannot directly measure directions or distances as on a Mercator chart.

The usual method of using a gnomonic chart is to plot the route and pick points along the track every 5° of longitude using the latitude and longitude scales in the immediate vicinity of each point. These points are then transferred to a Mercator chart and connected by rhumb lines. The course and distance for each leg can then be measured on the Mercator chart, and the points entered as waypoints. See Figure 1206. A projection on which a straight line is approximately
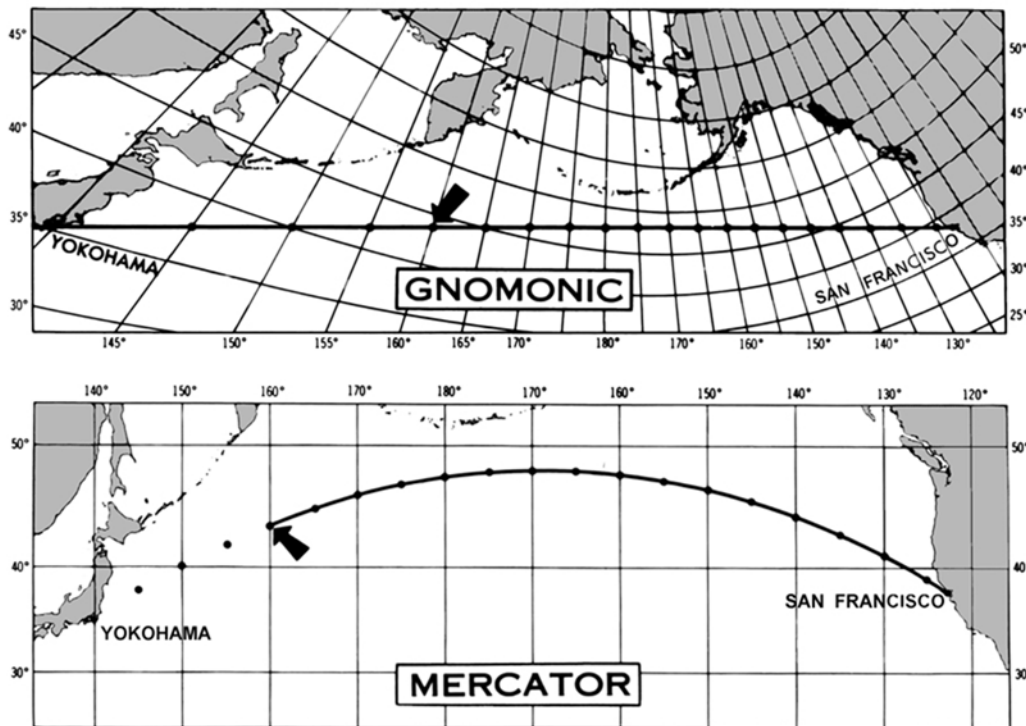

Figure 1206. Constructing a great circle track on a Mercator projection.

a great circle can be used in place of a gnomonic chart with negligible error. If the projection is conformal, such as a Lambert conformal chart, measurement of course and distance of each leg can be made directly on the chart.

1207. Great Circle Sailing by *Sight Reduction Tables*

Any method of solving a spherical triangle can be used for solving great circle sailing problems. The point of departure replaces the assumed position of the observer, the destination replaces the geographical position of the body, the difference of longitude replaces the meridian angle or local hour angle, the initial course angle replaces the azimuth angle, and the great circle distance replaces the zenith distance (90° - altitude). See Figure 1207b. Therefore, any table of azimuths (if the entering values are meridian angle, declination, and latitude) can be used

for determining initial great circle course. Tables which solve for altitude, such as *Pub. No. 229*, can be used for determining great circle distance. The required distance is 90° - altitude. Explanation can be found on pages xx-xxii in the introductions section of *Pub. No. 229*. Pub. No. 229 is available for download through the link found in Figure 1207a.

Figure 1207a. Pub No. 229.
https://msi.nga.mil/NGAPortal/MSI.portal?
*_nfpb=true&_st=&_pageLabel=msi_portal_page_*
62&pubCode=0013

For some inspection tables like those in *Pub. No. 229*, the given combination of L_1, L_2, and DLo may not be tabulated. In this case reverse the name of L_2 and use 180° - DLo for entering the table. The required course angle is then 180° minus the tabulated azimuth, and distance is 90° plus the altitude. If neither combination can be found, solution cannot be made by that method. By interchanging L_1 and L_2, one can find the supplement of the final course angle.

Solution by table often provides a rapid approximate check, but accurate results usually require triple interpolation.
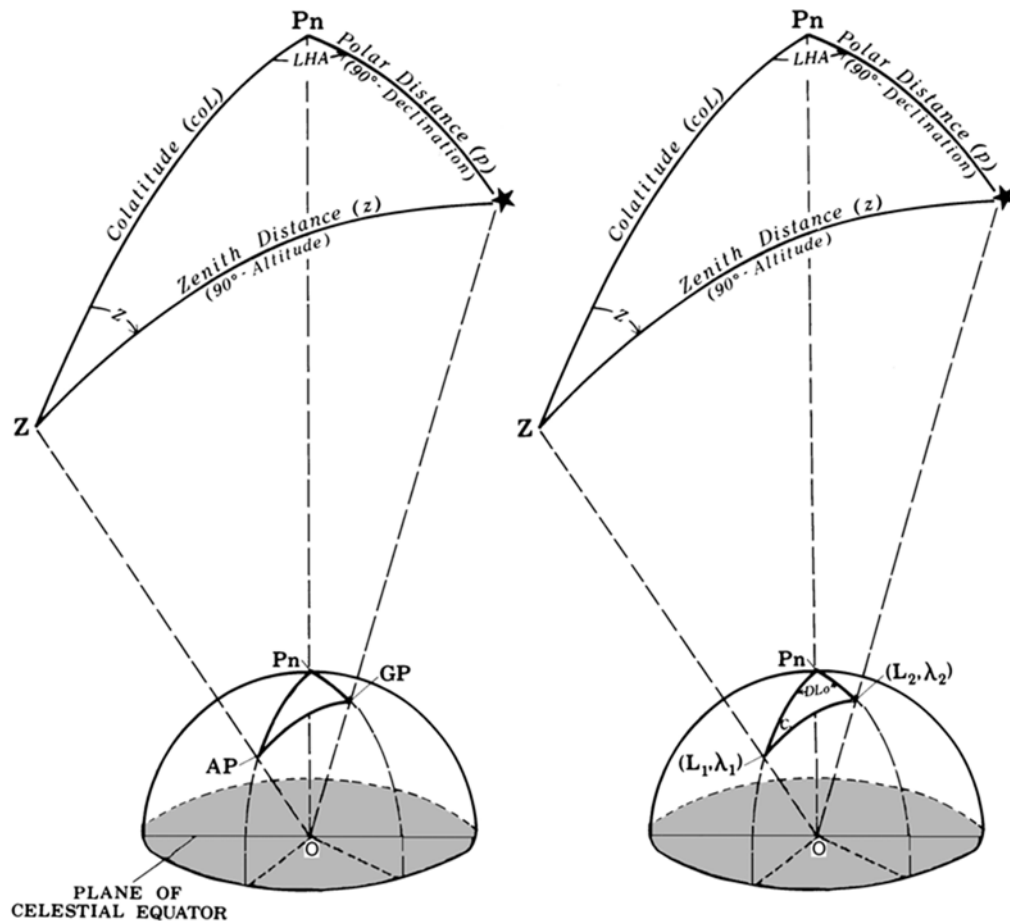

Figure 1207b. Adapting the astronomical triangle to the navigational triangle of great circle sailing.

Except for *Pub. No. 229*, inspection tables do not provide a solution for points along the great circle. *Pub. No. 229* provides solutions for these points only if interpolation is not required.

By entering *Pub. No. 229* with the latitude of the point of departure as latitude, latitude of destination as declination, and difference of longitude as LHA, the tabular altitude and azimuth angle may be extracted and converted to great circle distance and course. As in sight reduction, the tables are entered according to whether the name of the latitude of the point of departure is the same as or contrary to the name of the latitude of the destination (declination). If the values correspond to those of a celestial body above the celestial horizon, 90° minus the arc of the tabular altitude becomes the distance; the tabular azimuth angle becomes the initial great circle course angle. If the respondents correspond to those of a celestial body below the celestial horizon (meaning the Contrary/Same (C/S) line has been crossed), the arc of the tabular altitude plus 90° becomes the distance, and the supplement of the tabular azimuth angle becomes the initial great circle course angle.

When the C/S line is crossed in either direction, the altitude becomes negative and the body lies below the celestial horizon. For example: If the tables are entered with the LHA (DLo) at the bottom of a right-hand page and declination (L_2) such that the respondents lie above the C/S line, the C/S line has been crossed. Then the distance is 90° plus the tabular altitude and the initial course angle is the

supplement of the tabular azimuth angle. Similarly, if the tables are entered with the LHA (DLo) at the top of a right-hand page and the respondents are found below the C/S line, the distance is 90° plus the tabular altitude and the initial course angle is the supplement of the tabular azimuth angle. If the tables are entered with the LHA (DLo) at the bottom of a right-hand page and the name of L_2 is contrary to L_1, the respondents are found in the column for L_1 on the facing page. In this case, the C/S line has been crossed and the distance is 90° plus the tabular altitude, and the initial course angle is the supplement of the tabular azimuth angle.

The tabular azimuth angle, or its supplement, is prefixed N or S for the latitude of the point of departure (L_1) and suffixed E or W depending upon the destination being east or west of the point of departure (DLo).

If all entering arguments are integral degrees, the distance and course angle are obtained directly from the tables without interpolation. If the latitude of the destination is non-integral, interpolation for the additional minutes of latitude is done as in correcting altitude for declination increment. If the latitude of departure (L_1) or difference of longitude (DLo) is non-integral, the additional interpolation is done graphically.

Since the latitude of destination becomes the declination entry, and all declinations appear on every page, the great circle solution can always be extracted from the volume which covers the latitude of the point of departure.

Example 1: (L_1 and L_2 on same side of equator) *-Using Pub. No. 229, Vol 2, find the distance and initial great circle course from lat. 22°S, long. 116°E to lat. 20°S, long. 31°E.*

Solution: *Refer to Figure 1207b. The point of departure (L 22° S, λ 116° E) replaces the AP of the observer; The destination (L 20° S, λ 031° E) replaces the GP of the celestial body; The difference of longitude (DLo 085°) replaces local hour angle (LHA) of the body.*

Enter Pub. No. 229, Volume 2 with L 22° (Same Name), LHA 085°, and declination S 20° (page 172). The respondents fall above the C/S line, and thus correspond to a celestial body above the celestial horizon. Therefore, 90° minus the tabular altitude becomes the distance (90° - 11° 46.5' = 78° 13.5' = 4,693.5 nm); the tabular azimuth angle (Z), here S 073.0° W, becomes the initial great circle course angle, prefixed S for the latitude of the point of departure (L1) and suffixed W due to the destination being west of the point of departure (DLo).

Answer:
D = 4,693.5 nautical miles (nm)
C = S 073.0° W ∴ Cn = 253.0°T .

Example 2: (L_1 and L_2 on opposite sides of the equator) *- Using Pub. No. 229, Vol 2, find the distance and initial great circle course from lat. 28°N, long. 122°W to lat. 24°S, long. 151°E.*

Solution: *Refer to Figure 1207b. The point of departure (L 28° N, λ 122° W) replaces the AP of the observer; The destination (L 24° S, λ 151° E) replaces the GP of the celestial body; The difference of longitude (DLo 087°) replaces local hour angle (LHA) of the body.*

Enter Pub. No. 229 Volume 2 with L 28° (Contrary Name), LHA 087°, and declination S 24°. To find corresponding entries requires the C/S line be crossed. Thus, the respondents correspond to those of a celestial body below the celestial horizon. Therefore, the tabular altitude plus 90° becomes the distance (08° 33.2' + 90° = 098° 33.2' = 5,913.2 nm); the supplement of tabular azimuth angle (Z) becomes the initial great circle course angle, prefixed N for the latitude of the point of departure (L1) and suffixed W since the destination is west of the point of departure (DLo) (180° - 67.3° = 112.7°). Note that the data is extracted from across the CS Line from the entering argument (LHA 87°), indicating that the corresponding celestial body would be below the celestial horizon.

Answer:
D = 5,913.2 nm
C = N112.7° ∴ Cn = 247.3° T.

1208. Great Circle Sailing by Computation

In Figure 1208, 1 is the point of departure, 2 the destination, P the pole nearer 1, l-X-V-2 the great circle through 1 and 2, V the vertex, and X any point on the great circle. The arcs P1, PX, PV, and P2 are the colatitudes of points 1, X, V, and 2, respectively. If 1 and 2 are on opposite sides of the equator, P2 is 90°+ L_2. The length of arc 1-2 is the great circle distance between 1 and 2. Arcs 1-2, P1, and P2 form a spherical triangle. The angle at 1 is the initial great circle course from 1 to 2, that at 2 the supplement of the final great circle course (or the initial course from 2 to 1), and that at P the DLo between 1 and 2.

Great circle sailing by computation usually involves solving for the initial great circle course, the distance, latitude/longitude (and sometimes the distance) of the vertex, and the latitude and longitude of various points (X) on the great circle. The computation for initial course and the distance involves solution of an oblique spherical triangle, and any method of solving such a triangle can be used. If 2 is the geographical position (GP) of a celestial body (the point at which the body is at the zenith), this triangle is solved in celestial navigation, except that 90° - D (the altitude) is desired instead of D. The solution for the vertex and any point X usually involves the solution of right spherical triangles.

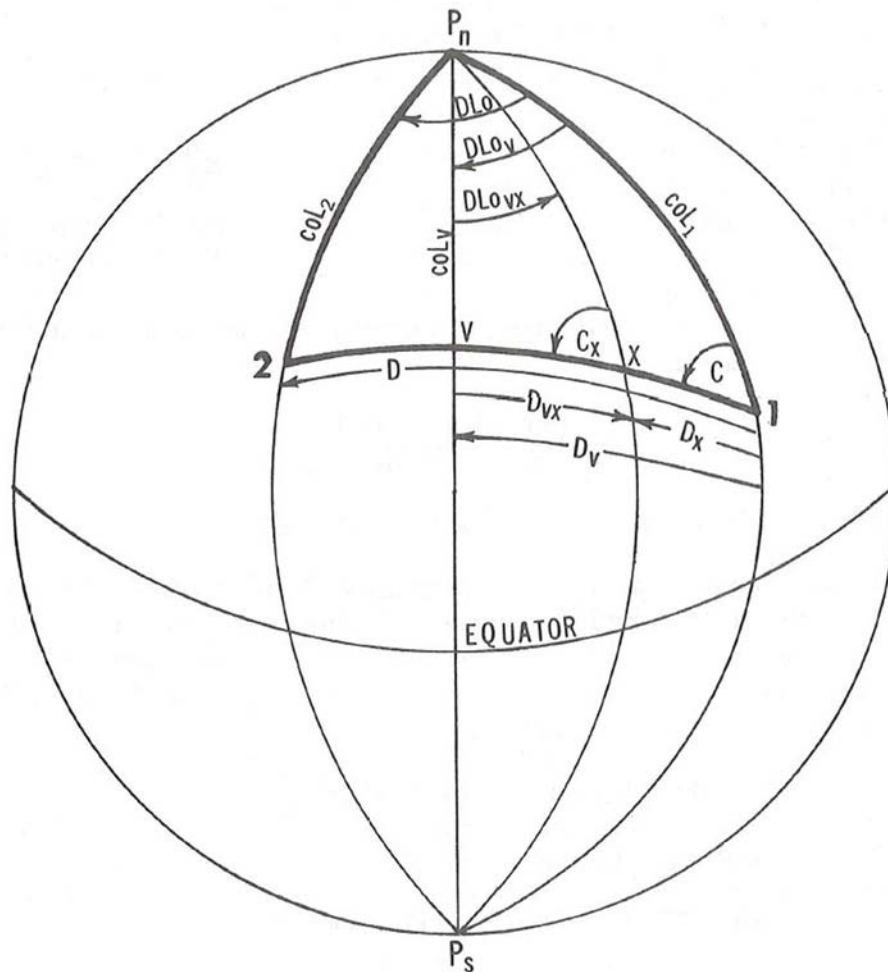There are many formulae appropriate for great circle

Figure 1208. The navigation triangle of great-circle sailing.

solutions. When solving by computation, angular measurements must be in decimal format to at least three decimal places. Rounding and varying levels of precision will generate differences in results. **Formulae intended for calculator-based solutions are provided below**:

$$\cos D = (\sin L_1)(\sin L_2) + (\cos L_1)(\cos L_2)(\cos DLo)$$

   - If crossing the equator, make L_2 negative

tan Initial Course Angle (C) =

$$\tan(C) = \sin DLo / (\cos L_1)(\tan L_2) - (\sin L_1)(\cos DLo)$$

   - Make L_2 negative if crossing the equator
   - If C is negative, add 180°
   - Prefix C by L_1 and suffix by DLo

cos Final Course Angle (C) =

$$\cos(C) = \sin L_1 - (\cos D)(\sin L_2) / (\sin D)(\cos L_2)$$

   - Make L_1 negative if crossing the equator

   - Label final course angle contrary to L2 and same DLo

Example 1 (L_1 and L_2 on same side of equator): *Using the calculations method, find the distance and initial great circle course from L 22 ° S, λ 116 ° E to 20 ° S, λ 031 ° E.*

Solution:
DLo = 085 ° W'ly
cos D = (sin 22°)(sin 20°) + (cos 22°)(cos 20°)(cos 85°)
cos D = 0.204
D = 78.23° = 4,693.8 nm
tan C = (sin 85°) / (cos 22°)(tan 20°) - (sin 22°)(cos 85°)
tan C = 3.2694
  ∴C = S 72.99° W ≈ S 73° W ∴Cn = 253° T

Answer:
D = 4,693.8 nm
Cn = 253° T

Example 2 (L1 and L2 on opposite sides of equator): *Us-*

ing the calculation method, find the distance and initial great circle course from L 28° N, λ 122° W to L 24° S, λ 151° E.

Solution:

DLo = 087° W'ly

cos D = (sin 28°)(sin -24°) + (cos 28°)(cos -24°)(cos 87°)

cos D = -.1487

D = 98.55° = 5,913.1 nm

tan C = (sin 87°) / (cos 28°)(tan -24°) - (sin 28°)(cos 87°)

tan C = -2.391

C = -67.3° (if C is negative, subtract from 180°) ∴C = N 112.7° W   ∴Cn = 247.3° T

Answer:

D = 5,913.1 nm

Cn = 247.3° T

Example 3 (Final Course Angle): *Using the calculation method, find the final course from L 22° S, λ 116° E to L 20° S, λ 031° E. Additional, D = 4,693.8 nm = 78.23°.*

Solution:

cos Final Course Angle (C) = sin L1 - (cos D) (sin L2) / (sin D) (cos L2)

cos C = sin 22° - (cos 78.23°) (sin 20°) / (sin 78.23°) (cos 20°) = .2988

∴C = N 72.6° W ∴Cn = 287.4° T

Answer:

Cn = 287.4° T

1209. Points Along the Great Circle

Since the great circle is continuously changing direction as one proceeds along it, no attempt is usually made to follow it exactly. Instead, a number of points along the route are selected (either at specific distances, arc, or DLo from the vertex) and rhumb lines are followed between these selected points. Since for short distances a great circle and a rhumb line almost coincide, this practice effectively yields the savings of the great circle route. This is normally done on a great circle chart. Points can also be determined by formulae or the sight reduction tables. In most cases, the position of the vertex must be known.

Keep in mind that DLo_v and D_v of the closest vertex are never more than 90°. When L_1 and L_2 are on opposite sides of the equator, the farther vertex, 180° away, may be the better vertex to use in the solution for points along the great circle track if it is nearer the mid-point of the route. Navigators may decide to select points along the great circle track by either selecting **equal distances** or **equal DLo** measures from the vertex.

1. Select **equal DLo** intervals each side of the vertex,

and solve for the corresponding latitudes. This method provides for shorter legs in higher latitudes and longer legs in lower latitudes. If DLo_v is less than 90°, L_x has the same name as Lv. If DLo_{vx} is greater than 90°, then L_x is of contrary name. Since the great circle is a symmetrical curve about the vertex, any DLo can be applied to λ_v in both directions (E and W) to find two points of equal latitude. However, if whole degrees of λ_x are desired, different E and W intervals are needed unless λ_v is a whole degree or exact half degree. The formula for the DLo technique is:

$$\tan L_x = (\cos DLo_{vx}) (\tan L_v).$$

2. Select **equal distances** from the vertex and solve for corresponding positions along the great circle route. In these formulae, distance must be expressed as degrees. If distance is greater than 90° (5,400 nm), L_x is of contrary name to L_v, and DLo_{vx} is greater than 90°. The formulae for the equal distance technique are:

$$\sin L_x = (\sin L_v) (\cos D_{vx})$$
$$\sin DLo_{vx} = (\sin D_{vx}) / (\cos L_x).$$

Example 1: *Determine points along the great circle track 12° on either side of the vertex, with Lv 41° 21.2' N, λ$_v$ 160° 34.4' W.*

Solution:

tan L$_x$ = (cos DLo$_{vxSolution}$) (tan L$_v$)

tan L$_x$ = (cos 12°) (tan 41.3533°) = (.9781) (.8802) = .8609

Answer:

Lx = 40.7252°

= 40° 43.5' N, λ$_x$ 172° 34.4'W and λ$_x$ 148° 34.4' W

Example 2: *Determine points along the great circle track 300 nm and 600 nm from the vertex, with L$_v$ 41° 21.2' N, λ$_v$ 160° 34.4' W.*

Solution (300 nm):

sin L$_x$ = (sin L$_v$) (cos D$_{vx}$)

sin L$_x$ = (sin 41.3533°) (cos 5°) = (.6607) (.9962) = .6582

∴L$_x$ = 41.1627° = 41° 09.8' N

sin DLo$_{vx}$ = (sin D$_{vx}$) / (cos L$_x$)

sin DLo$_{vx}$=(sin 5°)/(cos 41.1627°)=(.0872)/(.7528)= .1158

∴DLo$_{vx}$ = 6.6498° = 6° 38.9'

Answer:

L$_x$ 41° 09.8' N, λ$_x$ 167° 13.3' W (west of vertex)

and

λ_x 153° 55.5' W (east of vertex).

Solution (600 nm):

$\sin L_x = (\sin 41.3533°)\,(\cos 10°) = (.6607)\,(.9848) = .6507$

$\therefore L_x = 40.5944° = 40° 35.7'$ N

$\sin DLo_{vx} = (\sin D_{vx})\,/\,(\cos L_x)$

$\sin DLo_{vx} = (\sin 10°)\,/\,(\cos 40.5944°)$

$= (.1736)\,/\,(.7593) = .2286$

$\therefore DLo_{vx} = 13.2147° = 13° 12.9'$

Answer:

$L_x = 40.5944°$

$= 40° 35.7'$ N, λ_x 173° 47.3' W (west of vertex)

and

λ_x 147° 21.5' W (east of vertex).

Points along the great circle route may also be determined by using **sight reduction tables**, if the latitude of the point of departure and the initial great circle course angle are integral degrees, points along the great circle are found by entering the sight reduction tables with the latitude of departure as the latitude argument (always Same Name), the initial great circle course angle as the LHA argument, and 90° minus distance to a point on the great circle as the declination argument. The latitude of the point on the great circle and the difference of longitude between that point and the point of departure are the tabular altitude and azimuth angle, respectively. If, however, the respondents are extracted from across the C/S line, the tabular altitude corresponds to a latitude on the side of the equator opposite from that of the point of departure; the tabular azimuth angle is the supplement of the difference of longitude.

Example 1: *Find a number of points along the great circle from L 28° N, λ 125° W when the initial great circle course angle is N 111° W using sight reduction tables.*

Solution: *Entering the tables in Pub. 229 with L 28° (Same Name), LHA 111° (found at the bottom of page 323), and with successive declinations of 85°, 80°, 75°, 40°, etc., the latitudes and differences in longitude from 125°W are found as tabular altitudes and azimuth angles respectively:*

Answer:

D (nm)	300	600	900	3000
D (arc)	5°	10°	15°	50°
Dec.	85°	80°	75°	40°
Hc = Lat.	26° 06.6' N	24° 02.5' N	21° 48.8' N	03° 24.2' N

Table 1209a

Dep.	125° W	125° W	125° W	125° W
(Z) = DLo	5.2°	10.2°	15.1°	45.8°
Long.	130.2° W	135.2° W	140.1° W	170.8° W

Table 1209a

Example 2: *Find a number of points along the great circle track from L 28° N, λ 125° W when the initial great circle course angle (C) is N 069° W using sight reduction tables.*

Solution: *Enter the tables with L 28° (Same Name), LHA 069° (found on page 322), and with successive declinations as shown. Find the latitudes and differences of longitude from 125° W as tabular altitudes and azimuth angles, respectively:*

Answer:

D (nm)	300	600	900	6600
D (arc)	5°	10°	15°	110°
Dec.	85°	80°	75°	20°
Hc = Lat.	29° 41.2' N	31° 09.0' N	32° 22.1' N	27° 15.1' N
Dep.	125° W	125° W	125° W	125° W
(Z) = DLo	5.4°	10.9°	16.6°	80.7°
Long.	130.4° W	135.9° W	141.6° W	154.3° W

Table 1209b

Example 3: *Find a number of points along the great circle from L 28° N, λ 125° W when the initial great circle course angle is N 111° W (Cn = 249° T, which is SW'ly) by calculation. Determine points 5°, 10° and 15° from the point of departure.*

Solution:

First, find the vertex: $\cos L_v = (\cos L_1)\,(\sin C)$

$\cos L_v = (\cos 28°)\,(\sin 111°)$

$= (.8829)\,(.9336) = .8243$

$\therefore L_v = 34.4824° = 34° 29.9'$ N

$\sin DLo_v = (\cos C)\,/\,(\sin L_v)$

$= (\cos 111°)\,/\,(\sin 34.4824) = (-.3584)\,/\,(.5662)$

$\sin DLo_v = -.6329$ $\therefore DLo_v = -39.2644°$ *(E'ly)*

$= 39°15.9'$ *E'ly*

position of vertex: L 34° 29.9'N, λ 085° 44.1' W

Now find points along the track:

DLo_{vx} *for 5° = 130°W - 085.7356° = 44.2644°*

DLo_{vx} *for 10° = 135°W - 085.7356° = 49.2644°*

DLo_{vx} *for 15° = 140°W - 085.7356° = 54.2644°*

$\tan L_x = (\cos DLo_{vx})\,(\tan L_v)$

Answer:

$\tan L_{5°} = (\cos 44.2644°)(\tan 34.4824°)$

$= (.7161)(.6868) = .4918$

$\therefore L_{5°} = 26.1879° = 26° \; 11.3' \; N$

$\tan L_{10°} = (\cos 49.2644°)(\tan 34.4824°)$

$= (.6526)(.6868) = .4482$

$\therefore L_{10°} = 24.1419° = 24° \; 08.5' \; N$

$\tan L_{15°} = (\cos 54.2644°)(\tan 34.4824°)$

$= (.5840)(.6868) = .4011$

$\therefore L_{15°} = 21.8557° = 21° \; 51.3' \; N.$

1210. Direction at Various Points Along the Great Circle Track

To determine direction at any point along the great circle route, the following formulae may be used, but unless L_2 is of the same name and equal to or greater than L_1, it leaves doubt as to whether C is less or greater than 90°. The formulae are:

$$\sin C = (\sin DLo)(\cos L_2) / (\sin D), \text{ and}$$
$$\cos C = (\sin L_v)(\sin DLo_v)$$

if the location of the vertex is known.

1211. Finding the Vertex

The vertex will always be equal or greater than L_1 or L_2. If C is less than 90°, the nearer vertex is toward L_2. If C is greater than 90° the vertex is in the opposite direction. Since every great circle circumscribes the entire globe, there is a vertex in each hemisphere. A vertex may be either embedded within the vessel's great circle route, or may be beyond the vessel's intended route and fall either ahead of or behind the intended track. The vertex nearer L_1 has the same name as L_1.

Using *Pub. No. 229* to find the approximate position of the vertex of a great circle track provides a rapid check on the solution by computation. This approximate solution is also useful for voyage planning purposes.

Using the procedures for finding points along the great circle, inspect the column of data for the latitude of the point of departure and find the maximum value of tabular altitude. This maximum tabular altitude and the tabular azimuth angle correspond to the latitude of the vertex and the difference of longitude of the vertex and the point of departure. The vertex can also be calculated (here, C is initial course angle):

Latitude of the vertex

$$\cos L_v = (\cos L1)(\sin C)$$

(name L_v same as L_1)

Difference in λ from departure point to the vertex

$$\sin DLo_{1v} = (\cos C) / (\sin L_v)$$

(If initial course is < 090° vertex is ahead of the vessel and DLo and DLo_v have the same name. If initial course is > 090°, DLo and DLo_v have opposite names and the vertex is behind the vessel).

Distance to the vertex

$$\sin D_v = (\cos L_1)(\sin DLo_v)$$

Longitude when crossing the equator is determined by applying 90° to the longitude of the vertex in the direction of DLo. The longitude of crossing must lie between the points of departure and arrival in the direction of DLo from the vertex.

Example 1: *Find the vertex of the great circle track from lat. 28°N, long. 125°W when the initial great circle course angle (C) is N 069°W.*

Solution: *Enter Pub. No. 229 with L 28° (Same Name), LHA 069° (found on page 322), and inspect the column for L 28° to find the maximum tabular altitude. Maximum altitude (Hc) of 34° 28.9' occurs when declination is 56°. The distance of the vertex from the point of departure can be calculated as 90° - Dec. Thus, 90° - 56° = 34° = 2,040 nm. The corresponding tabular azimuth angle (Z) is 039.3°. Therefore, the difference of longitude between vertex and point of departure is 39.3°.*

Answer:
Distance of the vertex from the point of departure = 2,040 nm
Latitude of vertex = 34° 28.9' N
Longitude of vertex = 125° W + 39.3° W = 164.3° W.

Solution by calculation:
$\cos L_v = (\cos L_1)(\sin C) = (\cos 28°)(\sin 69°)$
$= (.8829)(.9336) = .8243$
$\therefore L_v = 34.4824° = 34° \; 28.9'N$
$\sin DLo_v = (\cos C) / (\sin L_v)$
$= (\cos 69°) / (\sin 34.4824°)$
$= (.3584) / (.5662) = .6329$
$\therefore DLo_v = 39.2644° = 39° \; 15.9'$

Answer:
Latitude of vertex = 34° 28.9' N
Longitude of vertex = 125° + 39.2644° = 164° 15.9' W.

1212. Altering a Great Circle Track to Avoid Obstructions

Land, ice, or severe weather, or other operational constraints may prevent the use of great circle sailing for some or all of one's route. One of the principal advantages of the solution by great circle chart is that any hazards become immediately apparent. The pilot charts are particularly useful in this regard. Often a relatively short run by rhumb line is sufficient to reach a point from which the great circle track can be followed. Where a choice is possible, the rhumb line selected should conform as nearly as practicable to the direct great circle.

If the great circle route passes too near a navigational hazard, it may be necessary to follow a great circle to the vicinity of the hazard, one or more rhumb lines along the edge of the hazard, and another great circle to the destination. Another possible solution is the use of composite sailing; still another is the use of two great circles, one from the point of departure to a point near the maximum latitude of unobstructed water and the second from that point to the destination.

1213. Composite Sailing

When the great circle would carry a vessel to a higher latitude than desired, a modification of great circle sailing called **composite sailing** may be used to good advantage. The composite track consists of a great circle from the point of departure and tangent to the limiting parallel, a course line along the parallel, and then a great circle tangent to the limiting parallel and through to the destination.

Solution of composite sailing problems is most easily made with a great circle chart. For this solution, draw lines from the point of departure and the destination, tangent to the limiting parallel. Then measure the coordinates of various selected points along the composite track and transfer them to a Mercator chart, as in great circle sailing.

Composite sailing problems can also be solved by computation, using the equation:

$$\cos \mathrm{DLo_{VX}} = \tan \mathrm{L_X} \cot \mathrm{L_V}$$

The point of departure and the destination are used successively as point X. Solve the two great circles at each end of the limiting parallel, and use parallel sailing along the limiting parallel. Since both great circles have vertices at the same parallel, which is the limiting latitude, computation for C, D, and $\mathrm{DLo_{VX}}$ can be made by considering them parts of the same great circle with L_1, L_2, and L_v as given and $\mathrm{DLo} = \mathrm{DLo_{v1}} + \mathrm{DLo_{v2}}$. The total distance is the sum of the great circle and parallel distances.

Example 1: *Determine the longitude at which a limiting latitude of 47° N will be reached when using a composite sailing from L 36° 57.7 N, λ 075° 42.2' W to L 45°-39.1' N, λ 001° 29.8'W. Also determine the longitude when the limiting latitude should be left and the great circle track resumed.*

Solution (for limiting latitude):
L_1 36° 57.7' N = 36.9617°

L_2 45° 39.1' N = 45.6517°

L_v = 47° N

$\cos \mathrm{DLo_{vx}} = (\tan L_x) / (\tan L_v)$

$\cos \mathrm{DLo_{v1}} = (\tan 36.9617) / (\tan 47)$

$= (.7525) / (1.0724) = .7017$

$.:\mathrm{DLo_{v1}} = 45.4364° = 45° 26.2'$ E'ly

Answer:
λ_1 = 075° 42.2' W + 45° 26.2' E'ly

= 030° 16.0' W *(start rhumb line along L 47° N).*

Solution (for λ_2) :
$\cos \mathrm{DLo_{v2}} = (\tan 45.6517) / (\tan 47)$

$= (1.0230) / (1.0724) = .9539$

$.:\mathrm{DLo_{v2}} = 17.4651° = 17° 27.9'$ W'ly

Answer:
λ_2 = 001° 29.8' W + 17° 27.9' W'ly

= 018° 57.5' W *(end rhumb line along L 47° N).*

TRAVERSE TABLES

1214. Using Traverse Tables

Traverse tables can be used in the solution of any of the sailings except great circle and composite. They consist of the tabulation of the solutions of plane right triangles. Because the solutions are for integral values of the course angle and the distance, interpolation for intermediate values may be required. Through appropriate interchanges of the headings of the columns, solutions for other than plane

sailing can be made. For the solution of the plane right triangle, any value N in the distance (Dist.) column is the hypotenuse; the value opposite in the difference of latitude (D. Lat.) column is the product of N multiplied by the cosine of the acute angle; and the other number opposite in the departure (Dep.) column is the product of N and the sine of the acute angle. Or, the number in the D. Lat. column is the value of the adjacent side, and the number in the Dep. column is the value of the side opposite the acute angle.

Hence, if the acute angle is the course angle, the adjacent side in the D. Lat. column is meridional difference (m); the opposite side in the Dep. column is DLo. If the acute angle is the mid-latitude of the formula p = DLo cos Lm, then DLo is any value N in the Dist. column, and the departure is the value N (cos L_m) in the D. Lat. column.

The examples below clarify the use of the traverse tables for plane, traverse, parallel, mid-latitude, and Mercator sailings.

1215. Plane Sailing

In plane sailing the figure formed by the meridian through the point of departure, the parallel through the point of arrival, and the course line is considered a plane right triangle. This is illustrated in Figure 1215a. P_1 and P_2 are the points of departure and arrival, respectively. The course angle and the three sides are as labeled. From this triangle:

$$\cos C = \frac{l}{D} \qquad \sin C = \frac{p}{D} \qquad \tan C = \frac{p}{l}.$$
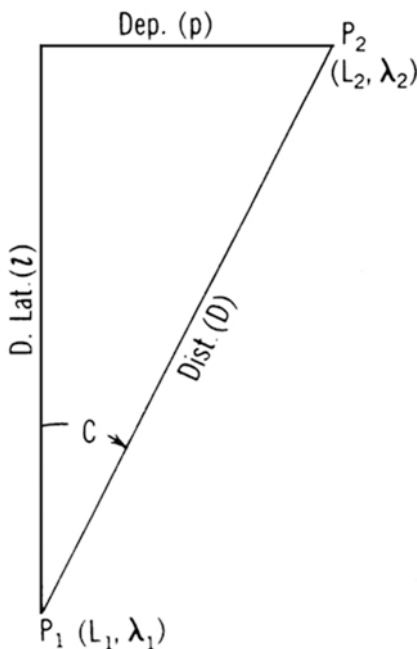
Figure 1215a. The plane sailing triangle.

From the first two of these formulas the following relationships can be derived:

$$l = D \cos C \qquad D = l \sec C \qquad p = D \sin C.$$

Label *l* as N or S, and p as E or W, to aid in identification of the quadrant of the course. Solutions by calculations and traverse tables are illustrated in the following examples:

Example 1: A vessel steams 188.0 nm on course 005°T.

Required: (1) Difference of latitude (l) and departure (p) by computation and (2) Difference of latitude (l) and departure (p) by traverse table.

(1) - Solution by computation:
Difference of latitude (l) by computation:
$l = D (\cos C)$
$l = 188.0 \text{ nm} (\cos 5°) = 188.0 (.9962) = 187.2856$
$l = 187.3' N$
$l = 3° 07.3' N$

Departure (p) by computation:
$p = D (\sin C)$
$p = 188.0 (\sin 5°) = 188.0 (.0872) = 16.3936$
$p = 16.4 \text{ nm}$

Answer:
$l = 3° 07.3' N$
$p = 16.4 \text{ nm E}$

(2) - Solution by traverse tables: See Figure 1215b. *Enter the traverse table and find course 005° at the top of the page. Using the column headings at the top of the table, opposite 188 in the Dist. column extract D. Lat. (l) 187.3 and Dep. (p) 16.4 nm.*

Answer:
$l = 187.3' N = 3° 07.3' N$
$p = 16.4 \text{ nm E}$

Example 2: A ship has steamed 136.0 nm north and 203.0 nm west.

Required: (1) Course and distance by computation and (2) Course and distance by traverse table.

(1) - Solution by computation:
Course by computation
$\tan C = p / l \therefore C = \arctan p / l$
$C = \arctan (203.0/136.0) = \arctan 1.4926$
$C = N 56.18° W \quad N 56° W$
$C_n \approx 304°T$

Draw the course vectors to determine the correct course. In this case the vessel has gone north 136 nm and west 203 nm. The course, therefore, is northwesterly and must have been between 270° and 360°.

Distance by computation:
$D = l / (\cos C)$
$D = (136) / (\cos 56.18°)$
$D = (136) / (.5566) = 244.34$
$D = 244.3 \text{ nm}$

	355°	005°		TABLE 4								355°	**005°**	
	185°	175°		Traverse	**5°**	Table						185°	175°	
Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.
1	1.0	0.1	61	60.8	5.3	121	120.5	10.5	181	180.3	15.8	241	240.1	21.0
2	2.0	0.2	62	61.8	5.4	22	121.5	10.6	82	181.3	15.9	42	241.1	21.1
3	3.0	0.3	63	62.8	5.5	23	122.5	10.7	83	182.3	15.9	43	242.1	21.2
4	4.0	0.3	64	63.8	5.6	24	123.5	10.8	84	183.3	16.0	44	243.1	21.3
5	5.0	0.4	65	64.8	5.7	25	124.5	10.9	85	184.3	16.1	45	244.1	21.4
6	6.0	0.5	66	65.7	5.8	26	125.5	11.0	86	185.3	16.2	46	245.1	21.4
7	7.0	0.6	67	66.7	5.8	27	126.5	11.1	87	186.3	16.3	47	246.1	21.5
8	8.0	0.7	68	67.7	5.9	28	127.5	11.2	88	187.3	16.4	48	247.1	21.6
9	9.0	0.8	69	68.7	6.0	29	128.5	11.2	89	188.3	16.5	49	248.1	21.7
10	10.0	0.9	70	69.7	6.1	30	129.5	11.3	90	189.3	16.6	50	249.0	21.8

| 60 | 59.8 | 5.2 | 20 | 119.5 | 10.5 | 80 | 179.3 | 15.7 | 40 | 239.1 | 20.9 | 300 | 298.9 | 26.1 |
| Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. |

	275°	085°		**85°**		Dist.	D. Lat.	Dep.
	265°	095°				N.	N x Cos.	N x Sin.
						Hypotenuse	Side Adj.	Side Opp.

Figure 1215b. Extract from Table 4.

Answer:

C = 304° T

D = 244.3 nm

(2) - Solution by traverse table: *See* Figure 1215c. *Enter* the table and find 136 and 203 beside each other in the columns labeled D. Lat. and Dep., respectively. This occurs most nearly on the page for course angle 56°. Therefore, the course is 304° T. Interpolating for intermediate values, the corresponding number in the Dist. column is 244.3 nm

	326°	034°		TABLE 4								326°	034°	
	214°	146°		Traverse	**34°**	Table						214°	146°	
Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.
1	0.8	0.6	61	50.6	34.1	121	100.3	67.7	181	150.1	101.2	241	199.8	134.8
2	1.7	1.1	62	51.4	34.7	22	101.1	68.2	82	150.9	101.8	42	200.6	135.3
3	2.5	1.7	63	52.2	35.2	23	102.0	68.8	83	151.7	102.3	43	201.5	135.9
4	3.3	2.2	64	53.1	35.8	24	102.8	69.3	84	152.5	102.9	44	202.3	136.4
5	4.1	2.8	65	53.9	36.3	25	103.6	69.9	85	153.4	103.5	45	203.1	137.0

| 60 | 49.7 | 33.6 | 20 | 99.5 | 67.1 | 80 | 149.2 | 100.7 | 40 | 199.0 | 134.2 | 300 | 248.7 | 167.8 |
| Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. |

	304°	056°		**56°**		Dist.	D. Lat.	Dep.
	236°	124°				N.	N x Cos.	N x Sin.
						Hypotenuse	Side Adj.	Side Opp.

Figure 1215c. Extract from Table 4.

Answer:

C = 304° T

D = 244.3 nm

1216. Traverse Sailing

A **traverse** is a series of courses or a track consisting of a number of course lines, such as might result from a sailing vessel tacking on various courses, or a vessel with operational needs requiring legs of various courses and distances. **Traverse sailing** is the finding of a single equivalent course and distance.

Though the problem can be solved graphically on a chart, traverse tables provide a mathematical solution. The distance to the north or south and to the east or west on each course is tabulated, the algebraic sum of difference of latitude and departure is found, and is then converted to course and distance.

If the effect of an estimated current is to be considered, the set is treated as an additional course, and the drift times the number of hours involved should be used as the distance. If direction and distance from some point, such as a lighthouse, other than the point of departure is desired, the bearing from the selected position to the point of departure is used as the first course and the distance between these points as the first distance.

Example: A ship steams as follows: course 158°, distance 15.5 nm; course 135°, distance 33.7 nm; course 259°, distance 16.1 nm; course 293°, distance 39.0 nm; course 169°, distance 40.4 nm.

Required: Equivalent single (1) course and (2) distance.

Solution: Solve each leg as a plane sailing and tabulate each solution as follows: For course 158°, extract the values for D. Lat. and Dep. opposite 155 in the Dist. column. Then, divide the values by 10 and round them off to the nearest tenth. Repeat the procedure for each leg.

Course	Dist. (nm)	N (nm)	S (nm)	S (nm)	W (nm)
158°	15.5		14.4	5.8	
135°	33.7		23.8	23.8	
259°	16.1		3.1		15.8
293°	39.0	15.2			35.9
169°	40.4		39.7	7.7	
Subtotals.		15.2	81.0	37.3	51.7
			-15.2		-37.3
Total			65.8S		14.4W

Table 1216a

*Thus, the latitude difference is S 65.8 nm and the departure is W 14.4 nm. **Convert this to a course and distance** using the formulas discussed for plane sailings, above.*

$l = 65.8$ S and $p = 14.4$ W

$\tan C = p / l = 14.4 / 65.8 = .2188$

$\therefore C = S\ 12.3°\ W$

$\therefore C_n = 192.3°\ T$

$D = l / \cos C$

$= 65.8 / \cos 12.3°$

$= 65.8 / .9770 = 67.3$ nm

Answer:

Cn = 192.3° T

D = 67.3 nm

1217. Parallel Sailing

Parallel sailing consists of the interconversion of departure and difference of longitude. It is the simplest form of spherical sailing and is used when a vessel is sailing due east or west. The formulas for these transformations are:

$$DLo = p\ \sec L \qquad p = DLo \cos L$$

Example 1: The DR latitude of a ship on course 090° is 49°30' N. The ship steams on this course until the longitude changes 3°30'.

Required: The departure by (1) computation and (2) traverse table.

Solution:

(1) Solution by computation:

$DLo = p / (\cos L)\ \therefore p = (DLo)(\cos L)$

$DLo = 3°\ 30' = 210'$

$p = (210')(\cos 49.5°) = 136.4$ nm

*(2) **Solution by traverse table:** See* Figure 1217a. *Enter the traverse tables with latitude as course angle and substitute DLo as the heading of the Dist. column and Dep. as the heading of the D. Lat. column. Since the table is computed for integral degrees of course angle (or latitude), the tabulations in the pages for 49° and 50° must be interpolated for the intermediate value (49° 30'). The departure for latitude 49° and DLo 210' is 137.8 nm. The departure for latitude 50° and DLo 210' is 135.0 nm. Interpolating for the intermediate latitude, the departure is 136.4 nm*

Answer:

p = 136.4 nm.

Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.
21	15.8	13.8	81	61.1	53.1	141	106.4	92.5	201	151.7	131.9	261	197.0	171.2
22	16.6	14.4	82	61.9	53.8	42	107.2	93.2	02	152.5	132.5	62	197.7	171.9
23	17.4	15.1	83	62.6	54.5	43	107.9	93.8	03	153.2	133.2	63	198.5	172.5
24	18.1	15.7	84	63.4	55.1	44	108.7	94.5	04	154.0	133.8	64	199.2	173.2
25	18.9	16.4	85	64.2	55.8	45	109.4	95.1	05	154.7	134.5	65	200.0	173.9
26	19.6	17.1	86	64.9	56.4	46	110.2	95.8	06	155.5	135.1	66	200.8	174.5
27	20.4	17.7	87	65.7	57.1	47	110.9	96.4	07	156.2	135.8	67	201.5	175.2
28	21.1	18.4	88	66.4	57.7	48	111.7	97.1	08	157.0	136.5	68	202.3	175.8
29	21.9	19.0	89	67.2	58.4	49	112.5	97.8	09	157.7	137.1	69	203.0	176.5
30	22.6	19.7	90	67.9	59.0	50	113.2	98.4	10	158.5	137.8	70	203.8	177.1

Figure 1217a. Extract from Table 4.

Example 2: *The DR latitude of a ship on course 270° is L 38° 15' S. The ship steams on this course for a distance of 215.5 nm.*

Required: *The change in longitude by (1) computation and (2) traverse table.*

Solution:

(1) Solution by computation:
p = 215.5'
DLo = (215.5') / (cos 38.25°)
DLo = (215.5') / (0.7853) = 274.4'
DLo = 274.4' W = 4° 34.4' W

Answer:

DLo = 4° 34.4' W

(2) Solution by traverse table: *See* Figure 1217b. *Enter the traverse tables with latitude as course angle and substitute DLo as the heading of the Dist. column and Dep. as the heading of the D. Lat. column. As the table is computed for integral degrees of course angle (or latitude), the tabulations in the pages for 38° and 39° must be interpolated for the minutes of latitude. Corresponding to Dep. 215.5 nm in the former is DLo 273.5', and in the latter DLo 277.3'. Interpolating for minutes of latitude, the DLo is 274.4' W.*

Figure 1217b. Extracts from Table 4.

321° 219°	039° 141°			TABLE 4 Traverse **39°** Table								321° 219°	039° 141°	
Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.
35	27.2	22.0	95	73.8	59.8	55	120.5	97.5	15	167.1	135.3	75	213.7	173.1
36	28.0	22.7	96	74.6	60.4	56	121.2	98.2	16	167.9	135.9	76	214.5	173.7
37	28.8	23.3	97	75.4	61.0	57	122.0	98.8	17	168.6	136.6	77	215.3	174.3
38	29.5	23.9	98	76.2	61.7	58	122.8	99.4	18	169.4	137.2	78	216.0	175.0
39	30.3	24.5	99	76.9	62.3	59	123.6	100.1	19	170.2	137.8	79	216.8	175.6

Dist.	D. Lat.	Dep.
D Lo	Dep.	
	m	D Lo

Figure 1217b. Extracts from Table 4.

Answer:
DLo = 4° 34.4' W

1218. Middle-Latitude Sailing

Middle-latitude sailing combines plane sailing and parallel sailing. Plane sailing is used to find difference of latitude and departure when course and distance are known, or vice versa. Parallel sailing is used to interconvert departure and difference of longitude. The mean latitude (L_m) is normally used for want of a practical means of determining the middle latitude, or the latitude at which the arc length of the parallel separating the meridians passing through two specific points is exactly equal to the departure in proceeding from one point to the other.

The mean latitude (L_m) is half the arithmetic sum of the latitudes of two places on the same side of the equator. It is labeled N or S to indicate its position north or south of the equator. If a course line crosses the equator, solve each course line segment separately.

This sailing, like most elements of navigation, contains certain simplifying approximations which produce answers somewhat less accurate than those yielded by more rigorous solutions. For ordinary purposes, the solutions are more accurate than the navigation of the vessel using them. A correction could be applied to eliminate the error introduced by assuming that the departure and arrival meridians converge uniformly (as the two sides of a plane triangle), rather than as the approximate sine of the latitude. The correction is usually some correction to the middle latitude to obtain a "corrected middle latitude" for use in the solution. Tables for such correction have been published for both spherical and spheroidal earths. However, the actual correction is not a simple function of the middle latitude and DLo, as assumed, because the basic formulae of the sailing are themselves based upon a sphere, rather than a spheroid. Hence, the use of such a correction is misleading, and may introduce more error than it eliminates. The use of any correction is therefore not justified; if highly accurate results are required, a different solution should be used.

The formulae for these transformations are:

$$l = D\,(\cos C) \quad \therefore \cos C = l\,/\,D$$
$$p = D\,(\sin C) \quad \therefore \sin C = p\,/\,D$$
$$\tan C = p\,/\,l$$
$$DLo = p\,/\,(\cos Lm) \quad p = (DLo)\,(\cos Lm)$$

The labels (N, S, E, W) of l, p, and C are determined by noting the direction of motion or the relative positions of the two places.

Example 1: *A vessel steams 1,253 nm on course 070° from lat. 15°17.0' N, λ 151°37.0' E.*

Required: *Latitude and longitude of the point of arrival by (1) computation and (2) traverse table.*

Solution:

(1) Solution by computation:
$D = 1253.0$ nm
$Cn = 070°\,T \therefore C = N\,070°\,E$
$l = (1,253.0)\,(\cos 070°) = 428.6'\,N = 7°\,08.6'\,N$
$p = (1,253.0)\,(\sin 070°) = 1,177.4$ nm E
$L_1 = \quad 15°\,17.0'\,N$
$\underline{+l = \quad 7°\,08.6'\,N}$
$L_2 = \quad 22°\,25.6'\,N$
$L_m = 18°\,51.3'\,N = 18.855°$
$DLo = p\,/\,(\cos Lm) = 1,177.4\,/\,\cos 18.855° = 1,244.2'$
$DLo = 1,244.2'\,E = 20°\,44.2'\,E$
$λ_1 = 151°\,37.0'\,E$
$\underline{+DLo \quad 20°\,44.2'\,E}$
$λ_2 = \quad 172°\,21.2'\,E$

Answer:

$L_2 = 22°\,25.6'\,N$
$λ_2 = 172°\,21.2'\,E$

(2) Solution by traverse tables: Refer to Figure 1218a. Enter the traverse table with course 070° and distance 1,253 nm. Because a number as high as 1,253 is not tabulated in the Dist. column, obtain the values for D. Lat. and Dep. for a distance of 125.3 nm and multiply them by 10. Interpolating between the tabular distance arguments yields D. Lat. = 429' and Dep. = 1,178 nm. Converting the D. Lat. value to degrees of latitude yields 7° 09.0'. The point of arrival's latitude, therefore, is 22° 26' N. This results in a mean latitude of 18° 51.5' N.

Reenter the table with the mean latitude as course angle and substitute DLo as the heading of the Dist. column and Dep. as the heading of the D. Lat. column. Since the table is computed for integral degrees of course angle (or latitude), the tabulations in the pages for 18° and 19° must be interpolated for the minutes of L_m. In the 18° table, interpolate for DLo between the departure values of 117.0 nm and 117.9 nm. This results in a DLo value of 123.9. In the 19° table, interpolate for DLo between the departure values of 117.2 and 118.2. This yields a DLo value of 124.6.

Having obtained the DLo values corresponding to mean latitudes of 18° and 19°, interpolate for the actual value of the mean latitude: 18° 51.5' N. This yields the value of DLo =124.5'. Multiply this final value by ten to obtain DLo = 1,245' = 20° 45' E.

Add the changes in latitude and longitude to the original position's latitude and longitude to obtain the final position.

Answer:
L_2 = 22° 26' N
λ_2 = 172° 22.0' E

Example 2: A vessel at lat. 8°48.9'S, λ. 89°53.3'W is to proceed to lat. 17°06.9'S, λ 104°51.6'W.

Required: Course and distance by (1) computation and (2) traverse table.

Solution:

(1) Solution by computation:
p = DLo (cos L_m)
tan C = p / l
D = l / (cos C)

The labels (N, S, E, W) of l, p, and C are determined by noting the direction of motion or the relative positions of the two places.

DLo = 14° 58.3' W = 898.3'
L_m = 12° 57.9' S = 12.965° S
p = (898.3') (cos 12.965°) = 875.4' = 875.4 nm

L_1 = 8.815° and L_2 = 17.115°
l = 17.115° - 8.815° = 8.3° = 498'
C = arctan (875.4'/498') = arctan (1.7578) = S 60.4° W
Cn = 240.4° T
D = 498' / (cos 60.4°) = 498' / (.4939) = 1,008.3 nm

Answer:
Cn = 240.4°
D = 1008.2 nm

(2) Solution by traverse tables: Refer to Figure 1218b. Enter the traverse table with the mean latitude as course angle and substitute DLo as the heading of the Dist. column and Dep. as the heading of the D. Lat. column. Since the table is computed for integral values of course angle (or latitude), it is usually necessary to extract the value of departure for values just less and just greater than the L_m and then interpolate for the minutes of Lm. In this case where L_m is almost 13°, enter the table with L_m 13° and DLo 898.3' to find Dep. 875 nm. The departure is found for DLo 89.9', and then multiplied by 10.

Reenter the table to find the numbers 875 and 498 beside each other in the columns labeled Dep. and D. Lat., respectively. Because these high numbers are not tabulated, divide them by 10, and find 87.5 and 49.8. This occurs most nearly on the page for course angle 60°. Interpolating for intermediate values, the corresponding number in the Dist. column is about 100.5. Multiplying this by 10, the distance is about 1005 nm.

Answer:
C = 240°
D = 1005 nm.

The labels (N, S, E, W) of l, p, DLo, and C are determined by noting the direction of motion or the relative positions of the two places.

1219. Mercator Sailing

Mercator sailing problems can be solved graphically on a Mercator chart. For mathematical solution, the formulas of Mercator sailing are:

$$tan C = DLo/m \;\; .:DLo = m (tan C)$$

After solving for course angle by Mercator sailing, solve for distance using the plane sailing formula:
$$D = l/(cos C)$$

The labels (N, S, E, W) of l, p, DLo and C are determined by noting the direction of motion or the relative positions of the two places.

If the true course is near 090° or 270°, a small error in C introduces a large error in DLo. Thus, solving C to the

340°	020°				TABLE 4						340°	020°
200°	160°			Traverse	**20°**	Table					200°	160°

Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.
1	0.9	0.3	61	57.3	20.9	121	113.7	41.4	181	170.1	61.9	241	226.5	82.4
2	1.9	0.7	62	58.3	21.2	22	114.6	41.7	82	171.0	62.2	42	227.4	82.8
3	2.8	1.0	63	59.2	21.5	23	115.6	42.1	83	172.0	62.6	43	228.3	83.1
4	3.8	1.4	64	60.1	21.9	24	116.5	42.4	84	172.9	62.9	44	229.3	83.5
5	4.7	1.7	65	61.1	22.2	25	117.5	42.8	85	173.8	63.3	45	230.2	83.8
6	5.6	2.1	66	62.0	22.6	26	118.4	43.1	86	174.8	63.6	46	231.2	84.1
7	6.6	2.4	67	63.0	22.9	27	119.3	43.4	87	175.7	64.0	47	232.1	84.5

Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.

290°	070°				**70°**				Dist.	D. Lat.	Dep.
250°	110°								N.	N x Cos.	N x Sin.
									Hypotenuse	Side Adj.	Side Opp.

342°	018°				TABLE 4						342°	018°
198°	162°			Traverse	**18°**	Table					198°	162°

Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.
1	1.0	0.3	61	58.0	18.9	121	115.1	37.4	181	172.1	55.9	241	229.2	74.5
2	1.9	0.6	62	59.0	19.2	22	116.0	37.7	82	173.1	56.2	42	230.2	74.8
3	2.9	0.9	63	59.9	19.5	23	117.0	38.0	83	174.0	56.6	43	231.1	75.1
4	3.8	1.2	64	60.9	19.8	24	117.9	38.3	84	175.0	56.9	44	232.1	75.4
5	4.8	1.5	65	61.8	20.1	25	118.9	38.6	85	175.9	57.2	45	233.0	75.7

Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.

288°	072°				**72°**				Dist.	D. Lat.	Dep.
252°	108°								D Lo	Dep.	
										m	D Lo

341°	019°				TABLE 4						341°	019°
199°	161°			Traverse	**19°**	Table					199°	161°

Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.
1	0.9	0.3	61	57.7	19.9	121	114.4	39.4	181	171.1	58.9	241	227.9	78.5
2	1.9	0.7	62	58.6	20.2	22	115.4	39.7	82	172.1	59.3	42	228.8	78.8
3	2.8	1.0	63	59.6	20.5	23	116.3	40.0	83	173.0	59.6	43	229.8	79.1
4	3.8	1.3	64	60.5	20.8	24	117.2	40.4	84	174.0	59.9	44	230.7	79.4
5	4.7	1.6	65	61.5	21.2	25	118.2	40.7	85	174.9	60.2	45	231.7	79.8

Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.

289°	071°				**71°**				Dist.	D. Lat.	Dep.
251°	109°								D Lo	Dep.	
										m	D Lo

Figure 1218a. Extracts from the Table 4.

347°	013°		TABLE 4									347°	013°	
193°	167°		Traverse **13°** Table									193°	167°	
Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.
27	26.3	6.1	87	84.8	19.6	47	143.2	33.1	07	201.7	46.6	67	260.2	60.1
28	27.3	6.3	88	85.7	19.8	48	144.2	33.3	08	202.7	46.8	68	261.1	60.3
29	28.3	6.5	89	86.7	20.0	49	145.2	33.5	09	203.6	47.0	69	262.1	60.5
30	29.2	6.7	90	87.7	20.2	50	146.2	33.7	10	204.6	47.2	70	263.1	60.7
Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.

283°	077°		**77°**		Dist.	D. Lat.	Dep.
257°	103°				D Lo	Dep.	
						m	D Lo

Figure 1218b. Extract from Table 4.

$$D = l / (\cos C)$$
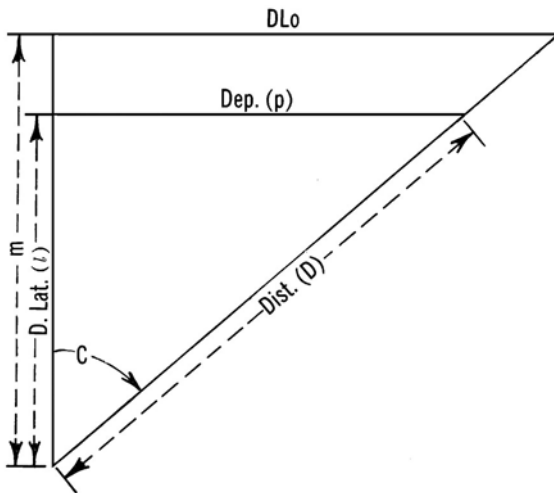
Figure 1219a. Mercator and plane sailing relationship.

First calculate the meridional difference by entering Table 6 Meridional Parts and interpolating for the meridional parts for the original and final latitudes. The meridional difference is the difference between these two values. Having calculated the meridional difference, solve for course and distance using the equations above. Figure 1219a depicts the relationship between Mercator and plane sailings.

$M_2 (36° 58.7' N) = 2377.1$
$M_1 (32° 14.7' N) = 2033.4$
$m = 343.7$
$\lambda_2 = 075° 42.2' W$
$\lambda_1 = 066° 28.9' W$
$DLo = 9° 13.3' W = 553.3' W$
$\tan C = DLo / m \therefore C = \arctan (DLo / m)$
$= \arctan (553.3'/343.7') = N 58.2° W$
$\therefore C_n = 301.8° T$
$L_2 = 36° 58.7' N$
$L_1 = 32° 14.7' N$
$l = 4° 44.0' = 284.0'$
$D = l / (\cos C) = 284.0' / (\cos 58.2°) = 538.9 \text{ nm}$

Answer:
$C = 301.8° T$
$D = 538.9 \text{ nm}$

nearest 0.1°, as is done by the traverse tables, may introduce a large error in DLo if the true course is near due east or west.

Example 1: *A ship at lat. 32°14.7'N, λ 66°28.9'W is to head for a point near Chesapeake Light, lat. 36°58.7'N, λ 75°42.2'W.*

Required: *Course and distance by (1) computation and (2) traverse table.*

Solution:

(1) Solution by computation:

$$\tan C = (DLo) / m \therefore DLo = m (\tan C)$$

(2) Solution by traverse table: *Refer to Figure 1219b. Substitute m as the heading of the D. Lat. column and DLo as the heading of the Dep. column. Inspect the table for the numbers 343.7 and 553.3 in the columns relabeled m and DLo, respectively. Because a number as high as 343.7 is not tabulated in the m column, it is necessary to divide m and DLo by 10. Then inspect to find 34.4 and 55.3 abreast in the*

	328°	032°										328°	032°
	212°	148°		Traverse	**32°**	Table						212°	148°
Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.
1	0.8	0.5	61	51.7	32.3	121	102.6	64.1	181	153.5	95.9	241	204.4	127.7
2	1.7	1.1	62	52.6	32.9	22	103.5	64.7	82	154.3	96.4	42	205.2	128.2
3	2.5	1.6	63	53.4	33.4	23	104.3	65.2	83	155.2	97.0	43	206.1	128.8
4	3.4	2.1	64	54.8	33.9	24	105.2	65.7	84	156.0	97.5	44	206.9	129.3
5	4.2	2.6	65	55.1	34.4	25	106.0	66.2	85	156.9	98.0	45	207.8	129.8
6	5.1	3.2	66	56.0	35.0	26	106.9	66.8	86	157.7	98.6	46	208.6	130.4

Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.
351	297.7	186.0	411	348.5	217.8	471	399.4	249.6	531	450.3	281.4	591	501.2	313.2
52	298.5	186.5	12	349.4	218.3	72	400.3	250.1	32	451.2	281.9	92	502.0	313.7
53	299.4	187.1	13	350.2	218.9	73	401.1	250.7	33	452.0	282.4	93	502.9	314.2
54	300.2	187.6	14	351.1	219.4	74	402.0	251.2	34	452.9	283.0	94	503.7	314.8
55	301.1	188.1	15	351.9	219.9	75	402.8	251.7	35	453.7	283.5	95	504.6	315.3
56	301.9	188.7	16	352.8	220.4	76	403.7	252.2	36	454.6	284.0	96	505.4	315.8
57	302.8	189.2	17	353.6	221.0	77	404.5	252.8	37	455.4	284.6	97	506.3	316.4
58	303.6	189.7	18	354.5	221.5	78	405.4	253.3	38	456.2	285.1	98	507.1	316.9
59	304.4	190.2	19	355.3	222.0	79	406.2	253.8	39	457.1	285.6	99	508.0	317.4
60	305.3	190.8	20	356.2	222.6	80	407.1	254.4	40	457.9	286.2	600	508.8	318.0

| Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. | Dist. | Dep. | D. Lat. |

	302°	058°			**58°**			Dist.	D. Lat.	Dep.		
	238°	122°						D Lo	Dep.			
									m	D Lo		

Figure 1219b. Extract from Table 4 composed of parts of left and right hand pages for course angle 58°.

m and DLo columns, respectively. This occurs most nearly on the page for course angle 58° or course 302°. Reenter the table with course 302° to find Dist. for D. Lat. 284.0'. This distance is 536 miles.

Answer:
Cn = 302° T
D = 536 nm

Example 2: A ship at lat. 75°31.7' N, λ 79°08.7'W, in Baffin Bay, steams 263.5 nm on course 155°.

Required: Latitude and longitude of point of arrival by (1) computation and (2) traverse table.

Solution:

(1) Solution by computation:
l = D (cos C); and DLo = m (tan C)
D = 263.5 nm
Cn = 155° T   ∴C = S 25° E
l = 263.5 (cos 25°) = 238.8' S = 3° 58.8' S
L_1 75° 31.7' N
+l   3° 58.8' S
L_2 71° 32.9' N

M_1 = 7072.4
M_2 = 6226.1
m = 846.3
DLo = 846.3 (tan 25°) = 394.6' E = 6° 34.6'
DLo = 6° 34.6' E
$λ_1$ = 079° 08.7' W
+DLo   6° 34.6' E
$λ_2$ = 072° 34.1' W

Answer:
L_2 = 71° 32.9' N
$λ_2$ = 072° 34.1' W

The labels (N, S, E, W) of l, DLo, and C are determined by noting the direction of motion or the relative positions of the two places. Here the vessel is steaming SE'ly.

(2) Solution by traverse table: Refer to Figure 1219c. Enter the traverse table with course 155° and Dist. 263.5 nm to find D. Lat. 238.8'. The latitude of the point of arrival is found by subtracting the D. Lat. from the latitude of the point of departure. Determine the meridional difference by Table 4 (m = 846.3).

335°	025°			TABLE 4						335°	025°	
205°	155°		Traverse	**25°**	Table					205°	155°	

Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.	Dist.	D. Lat.	Dep.
21	19.0	8.9	81	73.4	34.2	141	127.8	59.6	201	182.2	84.9	261	236.5	110.3
22	19.9	9.3	82	74.3	34.7	42	128.7	60.0	02	183.1	85.4	62	237.5	110.7
23	20.8	9.7	83	75.2	35.1	43	129.6	60.4	03	184.0	85.8	63	238.4	111.1
24	21.8	10.1	84	76.1	35.5	44	130.5	60.9	04	184.9	86.2	64	239.3	111.6
25	22.7	10.6	85	77.0	35.9	45	131.4	61.3	05	185.8	86.6	65	240.2	112.0
33	29.9	13.9	93	84.3	39.3	53	138.7	64.7	13	193.0	90.0	73	247.4	115.4
34	30.8	14.4	94	85.2	39.7	54	139.6	65.1	14	193.9	90.4	74	248.3	115.8

Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.	Dist.	Dep.	D. Lat.

295°	065°				
245°	115°	**65°**			

Dist.	D. Lat.	Dep.
D Lo	Dep.	
	m	D Lo

Figure 1219c. Extract from Table 4.

Reenter the table with course 155° to find the DLo corresponding to m = 846.3. Substitute meridional difference m as the heading of the D. Lat. column and DLo as the heading of the Dep. column. Because a number as high as 846.3 is not tabulated in the m column, divide m by 10 and then inspect the m column for a value of 84.6. Interpolating as necessary, the latter value is opposite DLo 39.4'. The DLo is 394' (39.4'   10). The longitude of the point of arrival is found by applying the DLo to the longitude of the point of departure.

Answer:
$L_2 = 71°32.9'$ N.
$\lambda_2 = 072°34.7'$ W.

1220. Additional Problems

Example: A vessel steams 117.3 nm on course 214° T.
Required: (1) Difference of latitude, (2) departure, by plane sailing.

Answers: (1) l 97.2'S, (2) p 65.6 nm W.

Example: A steamer is bound for a port 173.3 nm south and 98.6 nm east of the vessel's position
Required: (1) Course, (2) distance, by plane sailing.

Answers: (1) C 150.4°; (2) D 199.4 nm by computation, 199.3 nm by traverse table.

Example: A ship steams as follows: course 359° T, distance 28.8 nm; course 006°, distance 16.4 miles; course 266° T, distance 4.9 nm; course 144°, distance 3.1 nm; course 333° T, distance 35.8 nm; course 280°, distance 19.3 nm.
Required: (1) Course, (2) distance, by traverse sailing.

Answers: (1) Cn 334.4° T, (2) D 86.1 nm.

Example: The 1530 DR position of a ship is lat. 44°36.3'N, λ 031°18.3'W. The ship is on course 270° T, speed 17 knots.
Required: The 2000 DR position, by parallel sailing.

Answer: 2000 DR: L 44°36.3'N, λ 033°05.7'W.

Example: A ship at lat. 33°53.3'S, λ 018°23.1'E, leaving Cape Town, heads for a destination near Ambrose Light, lat. 40°27.1'N, λ 073°49.4'W.
Required: (1) Course and (2) distance, by Mercator sailing.

Answers: (1) Cn = 310.9° T; (2) D 6,811.5 nm by computation, 6,812.8 mi. by traverse table.

Example: A ship at lat. 15°03.7'N, λ. 151°26.8'E steams

57.4 nm on course 035° T.

__Required:__ (1) Latitude and (2) longitude of the point of arrival, by Mercator sailing.

__Answers:__ (1) L 15°50.7'N; (2) λ 152°00.7'E.