TEXT BOOK

ON

RAILROAD SURVEYING

BY

GEORGE WELLINGTON PICKELS, C.E.

INSTRUCTOR IN CIVIL ENGINEERING
UNIVERSITY OF ILLINOIS

AND

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ASSOCIATE IN CIVIL ENGINEERING
UNIVERSITY OF ILLINOIS

FIRST EDITION
FIRST THOUSAND

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PREFACE

This book was written primarily for the use of students in Railroad Surveying, and is practically a summary of the notes used by the authors in their classes for a number of years.

The aim throughout has been to present the *essentials* of the subject in simple, concise form and to give modern practical methods only. To this end detailed mathematical solutions are omitted, obsolete methods abandoned, and only the more common problems outlined; consequently the subject-matter occupies considerably less space than the ordinary hand-book, but at the same time covers all phases of the subject thoroughly.

From the standpoint of the instructor, some of the essential characteristics of the book are:

(1) A co-ordination of the entire subject, indicating the general order and the solution of the various steps in the work.

(2) The explanation of reasons for or conditions under which the various problems arise.

(3) The assumption of a knowledge of elementary surveying and plane trigonometry on the part of the reader.

(4) The consequent omission of detailed mathematics. Outlined solutions only are given, and hence the student must follow the solution of a problem through step by step instead of substituting blindly in some formula which has the appearance of being suitable. The student is therefore more thoroughly trained in the plan of attack, and consequently can more readily handle the multitude of problems which he can not find "all worked out" in this or any other book.

Although designed as a book for student use, it is believed that it will appeal to the practicing engineer as well, and the latter's attention is respectfully called to the following features:

(1) The simplified curve nomenclature as recommended by the American Railway Engineering Association has been adopted.

(2) The "Spiral" has been co-ordinated with the circular curve, where it properly belongs under modern railroad practice. It will be noted that the spiral here given is of a general form and is

equally applicable with chords of any desired length as a so-called "Six-chord" or "Ten-chord" spiral.

(3) "Turnouts" are presented in practical form as actually used on steam roads in America, *i.e.*, with *straight* frogs and switches.

Acknowledgment is hereby made of the courtesy of Prof. J. C. Nagle in permitting the use of Tables 5, 6, 8, and 9, which are taken from his "Field Manual for Railroad Engineers"; to Professor Carhart, for Table 7, which is taken from his "Field Book for Civil Engineers"; and to Prof. Walter Loring Webb, for Tables 9 and 10 from his work on "Railroad Construction," which appear as Tables 10 and 11 in this volume.

George Wellington Pickels,
Carroll Carson Wiley.

University of Illinois, Urbana, Ill., August, 1913.

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TEXT BOOK ON RAILROAD SURVEYING

CHAPTER I

RAILROAD SURVEYS

THE practice in railroad location surveys in one part of the United States is entirely different from that in another part, so that rules which will apply in one locality will not apply at all in others. All country can be broadly classed in three divisions: (1) level prairie country offering no obstacles in the way of hills, valleys, etc., and allowing the locating engineer much latitude in the placing of his line, and consequently reducing distance and curvature to a minimum; (2) rolling, hilly country through which several lines are possible, none of them departing to any great extent from the direct line between controlling points; and (3) mountainous country, which taxes the skill and ingenuity of the locating engineer to the utmost.

Reconnoissance Surveys

1. The terminals and intermediate points connected by a railroad are determined by its promoters with a view to the amount of traffic that can be expected from them. The nature and the amount of the traffic and the direction of heaviest haul determine the maximum gradients and curvature advisable. The first thing to be determined by the locating engineer is the directions of the lines joining controlling points. This information can usually be obtained with sufficient accuracy from a map of the territory which it is generally possible to obtain. The topographic maps published by the government are the best.

2. A reconnoissance is then made of the strip of country through which the road is to pass, as the result of which some of the routes are eliminated as impractical and one or more chosen for a more detailed survey.

3. **If the country is of the first class,** no reconnoissance is necessary and the survey is in the nature of a preliminary.

4. **For country of the second class,** the reconnoissance should be made across-country on horseback, following the direction of the line determined from the map. If in following the direct line between controlling points obstacles are met with which can not be surmounted, such as high hills, the engineer should explore on both sides of the obstacle and decide if possible which route offers the least resistance. Before deflecting from a straight line, the engineer must be sure that his reasons for so doing are justified from an economic standpoint. In country of the second class it is seldom that grades cause much trouble, and the main lookout of the engineer is to keep the amount of curvature as low as possible. The result of the reconnoissance through country of the second class is that one or more routes are selected for a more detailed survey.

5. **It is in mountainous country**—third class—that all the skill of the engineer is brought into play. The drainage of the country should be carefully studied, as it plays a very important part in the location of a railroad. If the controlling points are in the same valley, the main problem is solved; and the conforming of the alinement to the topography is merely a matter of detail. But when the controlling points are in different valleys, the ridges between them have to be crossed, and the principal object of the reconnoissance is to discover the most favorable crossing places in the valleys and on the ridges. The saddles in the ridges and the most favorable river crossings become secondary controlling points. The location of all such points is platted on the map, and their elevations and distances apart are recorded. The most important and useful "instruments" used on reconnoissance are the judgment and experience of the locating engineer, as upon these depend the amount and cost of more detailed surveys and the cost of construction and of operation.

Preliminary Surveys

6. In country of the first class, a preliminary line is run for direction. The magnetic bearing of the direct line between controlling points is scaled off the map, and a line having this direction is initiated from the first controlling point and produced to the second controlling point. Since the direction of the line as obtained from the map and this direction as laid off in the field are subject to considerable error, the first line run will probably pass to one side of the second controlling point. The distance by which the transit line misses its mark is noted and the correction that must be applied to the first line is computed. The next line run will be the location.

In running the preliminary line stakes should be placed only at transit points. A straight line is the most difficult one to run, and particular care must be taken to avoid errors. It must be remembered that the preliminary is a reference line, and if it is not straight the purpose for which it is run is defeated. The distances between hubs can be determined with sufficient accuracy by means of the stadia.

7. In country of the second class, preliminary lines are run over each of the routes chosen by the locating engineer on the reconnoissance survey. The data taken are such that the several routes can be compared with respect to distance, grades, and curvature. Usually lines run with the transit and stadia will give sufficient data as regards distance and curvature; and the elevations of enough commanding points can be taken with the stadia to indicate the grades that will be required by the several routes. From these data one of the routes will usually appear superior to the others, and what is generally known as a preliminary survey is then made over the selected route. A preliminary survey as generally understood is a topographic survey of a narrow strip of country within which the road must pass. The purpose of this survey is to secure data from which a topographic map can be platted upon which the *paper location* is projected. The transit and stadia line already run over the chosen route is used as the base line from which the topography is taken. Although this line is usually measured with the tape, time used for this purpose is wasted, as it is impossible to plat the traverse distances to a consistent degree of accuracy. Spirit levels are then run over the line to determine the elevations of the transit points, and bench marks are established at half-mile intervals.

8. In country of the third class, several preliminary lines are required, each following one of the routes chosen by the locating engineer. The approximate grades of the lines between secondary controlling points are obtained from the data taken on the reconnoissance survey, and the preliminary line should be chosen so that the grade line so determined will conform as nearly as possible to the surface of the ground. If this is done, topography will not have to be taken as far on each side of the line as would otherwise be necessary. In mountainous country topography can be taken more accurately with the hand level than with the stadia, and line stakes are placed every 100 feet and their elevations determined by spirit leveling so that this can be done. In other respects the methods of surveying in mountainous country are the same as those used in country of the second class.

Location Survey

9. On location the line is run very carefully, stakes are driven every 100 feet, the plusses and angles of all property lines are taken, and curves are run in where indicated on the map. The distances from intersections with property lines to the nearest government section monument, or other legal monument, are carefully chained, so that accurate descriptions of the right of way can be drawn up. All buildings near the line which will be damaged by it must be located and an estimate of the damage be made. A level party follows the transit party taking profile levels and establishing bench marks unless previously established. From these data alinement maps, right of way maps, and profiles are made; and after the grade line is established on the profile, construction can begin.

Construction Surveys

10. Reference stakes. After the location has been made and accepted, and just before construction begins, the beginning and end of all curves and intermediate points on long tangents are "tied-in" by reference stakes so that after the construction work is completed these points can be re-located in their correct positions. There are several methods of referencing a point; the one shown in Fig. 1 is very satisfactory. *A* is the point to be referenced. First choose permanent points at *C* and *E* at least 300 feet from *A*, making the angle *CAE* as nearly a right angle as possible. A distant windmill or house-chimney makes an ideal point. If these are not to be had, a nail

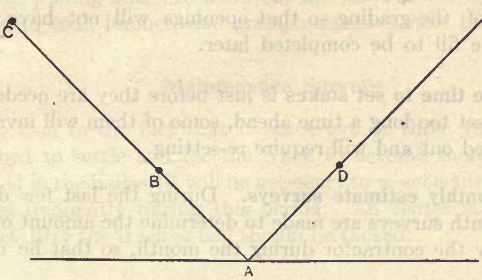

FIG. 1.

driven into the trunk of a tree about five feet from the ground is good. If hubs are used they should be made as permanent as possible, and located so that they will not be disturbed. After *C* and *E* have been determined, set a hub at point *B* on the line *AC*, and another one at *D* on the line *AE*. *B* and *D* should be placed far enough from the center line of the road so that they will not be disturbed during construction. Point *A* is re-located after construction by the intersection of the lines *CB* and *ED*, the transit being set-up at *B* and *D*. Care and judgment should be used in locating reference points, as they *should be* used after the roadbed has settled for locating permanent monuments.

11. Slope stakes are then set at each station on each side of the center line at the points where the side slopes of the cut or fill will intersect the ground surface. These stakes are for the guidance of the contractor, and have marked on them the vertical distance from the ground at the stake to the level of the roadbed. (For method of setting slope stakes, see paragraph 100.)

12. Distribution stakes are set to show the contractor the desired movement of the earth from the cuts into the fills. (See paragraph 108.)

13. Borrow-pit stakes are set to indicate to the contractor the limits within which he may borrow earth for making the fills.

14. The location of culverts and trestles must also be staked out. If possible, these should be constructed in advance of the grading so that openings will not have to be left in the fill to be completed later.

15. The time to set stakes is just before they are needed. If they are set too long a time ahead, some of them will invariably be knocked out and will require re-setting.

16. Monthly estimate surveys. During the last few days of every month surveys are made to determine the amount of earth moved by the contractor during the month, so that he can be paid.

17. Finishing stakes. From the slope stakes the contractor can construct the roadbed to within a few inches of the correct grade. At this stage of the work it is customary to give finishing stakes, which are stakes driven to grade at the edges of the roadbed at each station. From these the contractor is able to finish the roadbed to the correct grade and width.

18. Center stakes. After the earthwork is completed, the important points on the center line are re-located from the reference stakes, and center stakes (usually untacked) are driven from which the track is laid.

19. Grade stakes. After the track is laid, grade stakes are driven at every station and at those points where the grade changes with their tops to the grade of the final top or base or rail. Grade stakes are placed *on the inside of curves.*

20. Right of way stakes. The right of way fences are usually built as soon as the materials for construction can be hauled over the line. For the guidance of the fence foreman, stakes are placed on each right of way line (1) opposite the beginning and end of all curves, (2) opposite each station on curves, (3) from 300 to 500 feet apart on tangents, and (4) at all jogs in the right of way. These stakes should be long enough to be seen above the weeds, wheat, oats, etc. Laths are excellent for this purpose.

21. Special surveys. After the track is laid, special structures, such as station buildings, water tanks, cattle pens, etc., will require staking out. In addition, the parts of the right of way leased to coal, lumber, and grain companies must be staked.

Maintenance Surveys

22. Due to the fact that it takes two or three years for the roadbed to settle and for the track to become thoroughly embedded in the ballast, it will be necessary to re-set center and grade stakes frequently during this period. All center stakes which are set after the track is laid should be tacked.

23. Monumenting. After the track and roadbed have settled thoroughly, permanent monuments should be placed at the beginning and end of all spirals and circular curves, between the branches of compound curves, and at intermediate points on long tangents.

24. Additional tracks, such as side tracks, business tracks, branch-line tracks, yard tracks of various kinds, cross-overs, etc., are required to be staked out from time to time. There is no end to surveys of this kind, and all the large railroads employ maintenance parties who do nothing else.

Organization of Parties

The field corps is usually divided into (1) a transit party, (2) a level party, (3) a topography party, and sometimes (4) a land-line party.

25. TRANSIT PARTY.—The members of the transit party and their duties are as follows:

The Locating Engineer is the chief of the entire surveying corps, and receives his instructions from and reports to the Chief

Engineer of the railroad company. His duties are: to direct all the surveys from the reconnoissance to the location, to provide accommodations for his party, to pay all general expenses, and in case a camp is necessary to purchase all supplies and to manage the camp.

The Transitman is next in rank to the locating engineer, and in his absence is in charge of the party. His duties are: to do the transit work, which consists of lining in the chainmen, measuring the angles between successive tangents, noting the bearings of the tangents, measuring the angles which the line makes with all railways, highways, streams, and property lines, and recording the plusses at which they cross the line; and to keep the notes of the transit party. On construction the transitman usually becomes **Resident Engineer** and has charge of from 8 to 15 miles of construction.

The Head Chainman ranks next to the transitman *in the transit party*, and is directly in charge of the rear chainman, stakeman, and axmen. His duties are: to see that the distances are chained correctly; to see that the stakes are driven on line, that they are driven straight, and that they are marked correctly; to direct the axmen where to cut in opening up the line; to set new transit points; and to direct the taking of plusses. The head chainman has a very important position, as he regulates the speed of the entire party. In open country frequently the locating engineer takes this position. The head chainman carries the *zero end* of the tape.

The Rear Chainman's duties are: to hold his end of the tape on the last stake driven while the head chainman gets the distance; and to take and record all plusses which he turns over to the transitman at frequent intervals.

The Rear Flagman's duties are: to give the transitman a sight on the back sight station whenever he signals for it; and to carry excess baggage. The rear flagman *should be* a wide-awake man with good eyesight.

The Stakeman's duties are: to carry the stakes; to mark the station numbers on the stakes; and to drive the stakes as directed by the head chainman.

The Axmen do all the necessary clearing in order that the transit and level parties may have a clear path. They are sometimes required to make the stakes.

26. THE LEVEL PARTY.—The members of the level party and their duties are as follows:

The Levelman is chief of the level party and ranks next to the transitman in the surveying corps. His duties are: to run profile levels over the line and to establish bench marks; and to keep the level notes.

The Rodman's duties are: to hold the rod vertical upon the ground at each station, and at those intermediate points where the longitudinal slope of the ground changes; and to keep "peg notes" as a check on the levelman's computations.

27. THE TOPOGRAPHY PARTY.—The members of the topography party and their duties are as follows:

The Topographer usually holds equal rank with the levelman in the surveying corps. This position is a very important one and *should be* filled by an experienced man. The duties of the topographer are: to take all data necessary for making an accurate contour map of a strip of country sufficiently wide to enable the engineer to make an intelligent projected location; and to record these data in such a way that they will be readily understood by the draftsman. The topographer is assisted in his work by a rodman and a tapeman.

28. THE LAND-LINE PARTY.—The duties of this party are: to measure the angles which the line makes with all railways, highways, streams, and property lines; to tie-in the line to the nearest government monuments so that legal descriptions may be prepared of the required right of way; and to secure the names of the property owners.

29. Drafting. In addition to the above field parties there is the field draftsman, who does his work in camp. His duties are to plat the notes taken by all the parties the previous day, which necessitates the use of two sets of field note-books or else loose-leaf note-books. In some cases the draftsman, with the help of the locating engineer and the transitman, plats the notes each night; and the levelman plats the profile of the line over which he ran levels that day. Thus the map is kept up to date, and the locating engineer can project his location as the line advances.

Methods of Making Preliminary Surveys

The preliminary survey is the most expensive survey, and is of primary importance since the location depends directly upon it. Hence the method of making it should be given considerable thought in order that it may be done with accuracy and economy. There are at present three general methods used: (1) the transit and tape method, (2) the transit and stadia method, and (3) the plane table method.

30. The transit and tape method is by far the most common. The transit party runs the line with transit and tape, the level party follows taking profile levels, and the topography party follows the level party; the land-line party may come in anywhere after the transit party. This kind of a survey will require from six to fifteen men, depending on whether the several parties have a separate personnel and on the number of axmen required to open the line.

31. The transit and stadia method consists in running the line with the transit and stadia. Stakes are placed only at transit stations, and the elevations of these points are determined by transit and trigonometric leveling. The location and elevations of important intermediate points along the line are determined in a similar manner. While the transit is at each station, the topography around that point is taken with the stadia. Thus all the needed data are taken as the line advances. These data may be recorded in the note-book and worked up later by the party draftsman; but it is much better if the draftsman plats the notes as the transitman takes them and draws in the contours while the landscape is before him. The draftsman holds a very important position in this party and should be an expert in that line of work. A survey by this method is very accurate as regards the contours, which are the most important item on a preliminary map; and, if good men are employed, it is more efficient than the first method. This method requires a transitman, a draftsman, two rodmen, and as many axmen as the nature of the country may require.

32. The plane table method is very similar to the one just described and differs from it mainly in the use of instruments.

The plane table takes the place of the transit, and the plane tableman does the drafting. Owing to the difficulty in handling and setting up the plane table, it is doubtful whether this method is as efficient as the transit and stadia method; and although the services of the draftsman are dispensed with, yet the progress is possibly not as rapid.

33. Remarks. For long lines that justify the employment of a large number of men the transit and tape method is probably the most efficient. In other cases, however, the transit and stadia method will prove the more economical. The latter method has not been used to any considerable extent, due to the fact that few engineers fully appreciate the advantages of the stadia method; but in the few cases in which it has been tried it has fully demonstrated its superiority, particularly for open country.

34. Bench marks. When spirit-levels are run over the line, bench marks should be established at half-mile intervals, approximately, and should be placed far enough from the center line so that they will not be disturbed during construction. After construction, permanent bench marks should be established on all permanent structures, such as concrete bridges, and at every station building along the line. The common practice of using spikes driven in telephone poles and mile posts is a very *dangerous one*, as these are frequently moved and re-set. If the road has few concrete or steel structures, then bench marks may be established on trestles. When these are renewed, the elevations of the several parts will rarely be changed more than an inch; while a bench mark on a telephone pole may be changed several feet.

Note.—For further information on the subject of Railway Surveys and the Economics of Railway Location, see A. M. Wellington's "Economic Theory of the Location of Railways;" F. Lavis' "Railway Location Surveys and Estimates," or W. L. Webb's "Economics of Railroad Construction."

CHAPTER II

MAPS

Reconnoissance Maps

35. The reconnoissance map consists of a general sketch of the country which the locating engineer has investigated, and shows the several routes that are possible. Only controlling points, such as towns to be passed through, available stream crossings, saddles in the ridges, etc., are shown. If an existing map of the country is available, it is best to draw in the routes directly upon it. The notes taken on the reconnoissance survey regarding the geological formations, the cultural features of the country, the width, depth, and current of streams, etc., are considered part of the reconnoissance map, and frequently have great weight in the choice of routes.

36. The reconnoissance profile is made from the elevations of the controlling points and the distances between them. Profiles are made for each of the several routes and are frequently placed on the same sheet, so that a more intimate comparison can be made. The purpose of the reconnoissance maps is to eliminate the impractical routes and to determine which ones will bear a more detailed investigation.

Preliminary Maps

37. The first preliminary maps show the transit and stadia lines run, and all railroads, highways, and streams that cross the lines.

38. The preliminary profiles corresponding to the first preliminary maps are made from the elevations of the traverse stations. From a study of these maps one route—occasionally two—will appear superior to the others, and the preliminary survey proper is then made over this route.

39. The preliminary map is generally made to a scale of from 200 to 400 feet to the inch, and is a complete topographic map of a strip of country from 100 to 1,000 feet wide. All highways, railways, streams, and buildings are shown. Frequently it is desirable to show the property lines, the names of land owners, and government monuments. Also all geological formations and other features that might affect the location of the line are indicated. Occasionally, special features may require an *auxiliary* map to a scale of 50 or 100 feet to the inch over short stretches of the line.

40. The projected location is then made on the preliminary map. First project *that line which will give the best alinement and grades.* This will be the best line from the standpoint of operation, and the one to be used unless the cost of construction is prohibitive. In this case determine the line whose construction will come within the allowable cost and at the same time keeps within the allowable limits of curvature and grade. This can be done only by trial and requires a large amount of skill and judgment. In order to determine the grades and the amount of earthwork for the several projected lines, it will be necessary to construct a profile for each of them from the contour map. In locating grade lines on these profiles it must be remembered (1) that intersecting railways must be crossed either at grade or at a clearance distance above or below grade, (2) that highways can be raised or lowered within certain limits, and (3) that streams must be crossed a safe distance above high-water mark.

After satisfactory tangents have been projected, they are connected by curves which most nearly conform to the contour of the ground, and at the same time keep within the maximum curvature. If the curves are to be spiraled, allowance must be made at this time.

41. Location notes are then made from the accepted projected location. The bearings of tangents, the plusses of the beginnings and ends of all curves, the central angles of all curves, and the degrees of curve are scaled off the map and recorded. These condensed notes are used in making the final location.

Location Map

42. The location map is usually made to the same scale as the preliminary map, and shows all railways, highways, streams, and property lines that cross the line, together with their plusses;

the names of the property owners and the amount of right of way required from each; the government subdivision lines and the numbers of sections, etc.; the distances from the line to government monuments; the boundaries of each field through which the line passes; the location and size of all openings; and any other data that will be of use to the construction engineer or to the right of way agent.

The location map can often be made by adding the necessary data to the preliminary map, and then making a new tracing, omitting the contours and such other features that are not desired on the final map.

43. The location profile is made from the profile levels which were run over the located line, and shows: the ground line; the grade line, including the per cent. of grade of the different portions and the elevations of all points where the grade changes and all points on vertical curves; the location and dimensions of all openings in the embankment; the plusses of railways, highways, streams, and openings in the embankment; the elevations of the top of rail of all intersecting railroads, and the high-water mark of streams; the descriptions and elevations of all bench marks; a rectified alinement map at the bottom of the profile sheet, containing practically all the data that are shown on the location map; the distribution diagram, which is drawn between the profile proper and the alinement; on the profile proper the economical movement of the earth from the cuts into the fills; and the amount of excavation, overhaul, and borrow at all points along the line. In fact, the location profile contains practically all the information needed by the resident and construction engineers. It is used by them in staking out all the construction work, with the exception of large bridges and trestles, for which separate plans are made.

44. Additional profiles are made for any change in the elevations of highways and railways. These profiles are short and are sometimes (and preferably) placed on the location profile opposite the points where the changes are made.

Right of Way Maps

Right of way maps are of two kinds: (1) legal maps and (2) maintenance of way maps.

45. Legal right of way maps are made on sheets which are the same size as the sheets on which the conveyance deeds are drawn up (usually $8\frac{1}{2}$ x 13). A separate map is made for each description, and a blue-print is attached to the deed and becomes a part of it and is recorded along with the deed. The railroad company preserves its copies of the deeds along with the right of way maps in the form of a book, which is known as the right of way book.

46. Maintenance of way right of way maps are made from the location map and a separate sheet (about $8\frac{1}{2}$ x 10) is used for each section (*i.e.*, government section) or for each mile of track. These sheets are bound into a book and are used by the maintenance of way department.

Construction Maps

47. Station maps are usually made to a scale of 50 or 100 feet to the inch, and show the proposed buildings and tracks at each station. Any changes in the plans which are made during construction are recorded on the map. Some railroads have standard plans for station layouts, and these are followed as closely as conditions will permit.

48. Progress profiles. Each month after the monthly estimate surveys have been made, the amount of grading done during the month is shown graphically on the location profile in colored pencil. Each month a different color is used, so that the chief engineer and other railroad officials can see at a glance the progress of the construction work and can compare the amount done each month with that of former months.

49. Progress photographs. For the same reason photographs should be taken each month or oftener of the various structures under construction, such as concrete arches, bridges, trestles, station buildings, etc. Photographs are excellent auxiliaries to a written report.

CHAPTER III

DISTANCE, CURVATURE, AND GRADES

In the location of a railroad there are three factors that make for success or failure from a financial standpoint, namely, distance, curvature, and grades. The best location is that in which each of these is a minimum. This would be when the line between terminals was perfectly straight, and on a uniform grade. This ideal line involves a maximum expenditure for construction and a minimum outlay for operation. Such a line, of course, is a financial if not a physical impossibility. It must be remembered that the first cost is a fixed amount, while the cost of operation continues as long as the road exists; and in time the additional cost of operating a cheaply located road will more than offset the amount saved in the construction. This statement is borne out by the fact that all the large railroads are spending huge amounts yearly for the reduction of curvature and grades, in order that operating expenses may be reduced. The locating engineer must take all of these things into consideration in making his location. Of the three named items, grades is by far the most important, while distance is the least important.

Distance

50. Additional distance in the length of a line affects the initial cost of construction, the cost of maintenance, and the cost of operation. The cost of construction and maintenance is proportional to the distance and may be readily determined. The cost of operation does not vary directly as the distance. The cost of operating a small additional distance will be only about one-third as much per train-mile as the average cost over the whole line. When the additional distance becomes several miles, the cost is increased to about one-half of the average cost per train-mile.

Curvature

51. Curvature affects the cost of construction, the cost of maintenance, and the cost of operation.

The cost of construction is increased since curvature means an increase in the length of the line; and also if structures such as trestles and bridges come on curves their cost is largely increased thereby.

The cost of maintenance is increased since curved track requires more care in alinement and surface than straight track, and also there is greater wear on both the track and the rolling stock due to the curvature.

The cost of operation is increased because more power is required on curves than on straight track, and frequently a sharp curve will limit the weight of train that can be operated over the line. Also, sharp curves limit the speed of passenger trains, which may be an important item where there is a competing line. It has been determined by experiment that the additional tractive force required to draw a train around a one-degree curve is the same as that required by a grade of from 0.03 to 0.05 per cent. This resistance does not vary directly as the degree of curve, but decreases as the degree of curve increases. For curves up to about 8 degrees, however, the curvature resistance is usually taken as 0.04 per cent. per degree of curve; for curves from 8 to 15 degrees, 0.03 per cent. per degree; and for curves above 15 degrees, 0.02 per cent. per degree. The resistance to a train in starting is about double that given above, and must be considered if a stopping place comes on a curve. In general, curve resistance is not serious until it becomes so great that when added to grade resistance the total resistance limits the weight of train that can be hauled over the line. Therefore all the steeper grades should be *compensated for curvature*.

52. Choice of curvature. The *total* resistance offered by a curve depends directly upon the central angle, and is practically independent of the radius. Hence the important point is to keep the *amount* of curvature a minimum, and after the tangents have been decided upon the problem is to make the *rate* of curvature as uniform as the topography will permit. Little is gained by having a few flat curves and a number of sharp ones. The proof of this statement is in the fact that in the vast amount of re-alinement work that the railroads have been doing in the past few years there are very few, if any, cases where *an increase in radius* is the only benefit derived from the improvement. The object of all this work has been to reduce the total amount of central angles in curves and at the same time to reduce the *maximum* rate of curvature.

Grades

Grades may be classified as (1) minor grades, (2) ruling grades, and (3) pusher grades.

53. Minor grades are those which do not limit the weight of train which can be hauled over the line by one engine. Such grades are of three kinds according to their effect on the performance of the engine.

First, there are those grades whose drop (vertical height) is sufficiently small that a locomotive can operate without shutting off steam, or, in other words, will not reach a dangerous speed due to the down-grade while exerting a constant pull on the train. The effect of these grades on train operation is negligible, both as regards the effort required of the engine and the time required for the train to traverse a given distance, since the kinetic energy acquired in descending one grade is utilized in ascending the opposite grade.

The second kind of minor grades consists of those whose drop is so great that steam must be shut off to prevent the train from acquiring a dangerous velocity, and hence the effort of the engine must be increased on the opposite up-grade. Therefore there is a loss of power, since the engine is working intermittently and not at its greatest efficiency.

The third kind of minor grades consists of those which require the use of brakes in descending them. This causes an enormous loss of energy because part of the kinetic energy gained by the descent is absorbed by the brakes, and hence is not available on the next up-grade. Further, the engine is working at a disadvantage, and there is considerable wear on equipment due to the action of the brakes.

54. Ruling grades are those which limit the weight of the train which can be hauled by one engine. Cars can not be picked up or dropped off along the line to make up a train in accordance with the grades met with, and hence a train must run through from one terminal of a division to the other. Therefore, excluding pusher grades, and such short steep grades which can always be operated by momentum, the maximum grade is the ruling grade on that division.

55. A pusher grade is one which is so steep that one or more extra engines are required to haul the train which one engine can handle on the remainder of the division. It will nearly always happen that some grades on each division will be considerably greater than the majority of the grades, and unless these can be reduced to the general average at a reasonable cost or a pusher engine is used, they limit the weight of train over the division and become the ruling grades.

A pusher grade adds enormously to the cost of operation since the auxiliary engines must be maintained; and, further, they pass twice over the line for each train handled, and hence do not operate at maximum efficiency. Obviously, therefore, a pusher grade must be considerably in excess of the ruling grade on the remainder of the division before its extra cost of operation would be justifiable.

56. Choice of grades. The total energy available to carry a moving train up a grade is the sum of the kinetic energy of the train due to its velocity (momentum) and that developed by the engine. The maximum amount of energy which the engine can develop is a fixed quantity, but the amount of kinetic energy which can be utilized depends on the initial speed of the train.

A given engine can just pull a train of given weight up such a grade that the sum of the frictional resistances and the grade resistances (including curvature resistances) equals the total force exerted by the engine. Or, conversely, the weight of train which a given engine can pull up a given grade is such that the sum of frictional and grade resistances again equals the effort of the engine. The frictional resistances are practically constant at about 8 pounds per ton for freight trains, while the grade resistance is 20 pounds per ton for each per cent. of grade. The length of such a grade is limited only by the endurance of the engine.

If the train approaches this grade at considerable speed, its kinetic energy may be utilized to overcome *additional* grade resistance, hence the engine can pull the train up a much steeper grade to the point where the additional vertical rise has absorbed all the kinetic energy. If the end of the grade is reached first, the train will pass over easily, suffering only a reduction in speed; if the grade extends further than this point, the train will be stalled.

Thus it is seen that for minor grades it is more the vertical height than the rate of slope which affects the operation. And also the ruling grade—the one which limits the train weight—may not be the one of steepest slope, provided that the heaviest trains can always approach it at sufficient speed to reach its top with the aid of momentum.

Therefore if a grade line can be established with alternate descents and ascents of such small amount that the train can always make use of its momentum, the rate of slope is of small importance. But, if the slopes are so long that momentum can not be utilized all the way, or the grade must be entered at very low speed, the rate of slope limits the train weight.

The first step in projecting a grade line on a profile is to determine approximately the ruling grade. The lowest value of the ruling grade is that of a uniform slope between terminals. The maximum value depends on the type and weight of locomotives, the weight of trains, etc., and can never be exactly determined, and therefore it is more usual to simply choose a maximum or ruling grade which will probably fit the territory through which the line runs. In assuming this maximum value, due consideration should be given to the direction of heaviest traffic, and easier grades secured if possible for trains in this direction.

A grade line is then laid out on the profile, keeping below this maximum if possible in such a way that the fills will balance the cuts and the total amount of earthwork will be kept as low as possible in order to reduce the cost of construction. The laying out of this line will require several trials, and each trial should be carefully studied as to its effect on operation as well as on first cost. After such a line has been laid out it may be found that the assumed maximum grade has been exceeded at some point, and study must be given as to whether it is possible to reduce this grade or whether it is justiifiable to perhaps increase it sufficiently to be operated as a pusher grade. Or it may be found that only one grade approaches the chosen maximum, and again the line must be studied to determine if it is possible to reduce this grade to the general average. For example, the maximum grade on a division is found to be 1 per cent., while there are no others over 0.8 per cent., and possibly only two of these, the next lower being 0.5 per cent. The problem then is to decide the advisability of reducing the 1 per cent. grade to 0.8 per cent., and then possibly the three 0.8 per cent. grades to the average of 0.5 per cent. And this process of reducing the ruling grade could be continued until the additional cost of construction equals the sum which can profitably be spent for the purpose of reducing the ruling grade.

57. VERTICAL CURVES.—The intersections of the several portions of the grade line must be rounded off to avoid undue stress in the drawbars. The curve used for this purpose is a parabola because of its convenient characteristics. Such curves are termed *vertical curves* to distinguish them from the curves in the alinement.

The length of vertical curves depends on the total change in the grade which is the algebraic difference of the intersecting grades, G_1 and G_2, and on the rate of change of the vertical curve. Ascending grades are plus, and descending grades are minus.

The rate of change per station, r, of the vertical curve as recommended by the American Railway Engineering Association is 0.1 foot for summits and 0.05 foot for sags for first-class railways; and double these amounts for second-class and electric railways. It is to be noted, however, that a large number of first-class roads use the second-class rating. Since the change at the ends of the curve is from tangent to chord instead of from chord to chord, the rate of change of the first and last stations on the curve is just *one-half the rate* used on the remainder of the curve.

In solving a vertical curve problem, the first step is to find the length of the curve. This is done by dividing the algebraic difference of the grades by the assumed rate of change per station. This will usually give an odd length which is inconvenient to handle, and therefore the next higher *even* number of stations is chosen as the length of the curve.

The second step is to divide the algebraic difference of the grades by the length of curve as found in step one. The quotient will be the rate of change per station which is to be actually used.

The third step is to find the station numbers and elevations of the *T.C.* and *C.T.* (beginning and end of curve).

The fourth step is to find the elevations of the intermediate stations on the curve. This is done by starting at the *T.C.* and adding (or subtracting as the case may be) the changing grades successively until the *C.T.* is reached. The grade from the *T.C.* to the first station will be $G_1 - \frac{1}{2}r$, from the second to the third station it will be $G_1 - \frac{3}{2}r$, from the third to the fourth it will be $G_1 - \frac{5}{2}r$, and so on till the *C.T.* is reached. The elevation thus found for the *C.T.* should check with that determined from step three.

Example. A +0.8 per cent. grade meets a −0.6 per cent. grade at station 30 + 00, whose elevation is 750.50. It is desired to connect these grades by a vertical curve whose rate of change per station is approximately 0.2 foot.

$$\text{Length of curve} = \frac{G_1 - G_2 \text{ (algebraically)}}{r} \quad . \quad . \quad . \quad (1)$$

$$L = \frac{1.4}{0.2} = 7 \text{ Sta.}$$

Making $L = 8$,

$$r = \frac{1.4}{8} = 0.175$$

Taking everything into consideration it is better to make L = 800 feet (400 feet each side of apex), and to use a value of $r = 0.175$ than it is to make L = 700 ft. and use a value of $r = 0.2$.

Sta. of *T.C.* = 30 − 4 = 26 + 00.

Sta. of *C.T.* = 30 + 4 = 34 + 00.

Elev. of *T.C.* = Elev. *P.I.* − $\frac{1}{2}LG_1$ = 750.50 − 3.20 = 747.30

Elev. of *C.T.* = Elev. *P.I.* − $\frac{1}{2}LG_2$ = 750.50 − 2.40 = 748.10

Elevation Station 26 = 747.30 = 747.30

" " 27 = 747.30 + (0.8 − 0.0875)

= 747.30 + 0.7125 = 748.01

Elevation Station 28 = 748.01 + (0.7125 − 0.175) =
748.01 + 0.5375 = 748.55
" " 29 = 748.55 + (0.5375 − 0.175) =
748.55 + 0.3625 = 748.91
" " 30 = 748.91 + (0.3625 − 0.175) =
748.91 + 0.1875 = 749.10
" " 31 = 749.10 + (0.1875 − 0.175) =
749.10 + 0.0125 = 749.11
" " 32 = 749.11 + (0.0125 − 0.175) =
749.11 − 0.1625 = 748.95
" " 33 = 748.95 + (−0.1625 − 0.175) =
748.95 − 0.3375 = 748.61
" " 34 = 748.61 + (−0.3375 − 0.175) =
748.61 − 0.5125 = 748.10

It should be noted that the highest point on the vertical curve comes at Sta. 31 instead of Sta. 30.

The elevation of each station on the vertical curve is shown on the location profile, and is used in setting slope stakes. If the distance from the sub-grade to the top of rail (from 1.5 to 2.0 ft.) is added to the above elevations the results are the elevations of the final top of rail. These elevations are used after the grading has been completed for setting grade stakes for surfacing the track.

Note.—For a further discussion on the Economics of Railway Location, the student is referred to Wellington's "Economic Theory of the Location of Railways," or Webb's "Economics of Railroad Construction."

CHAPTER IV

CURVES

Part I. Circular Curves

RAILWAY alinement consists of

1. Tangent, or straight track.
2. Curves, which unite the tangents.

Curves are of two kinds; (1) arcs of circles, and (2) arcs of spirals. The circle is employed for the body of all curves since it is more easily located with the transit and tape than any other form of curve. Spirals are used for easements at the ends of the circular arcs.

Circular curves are classified as Simple, Compound, and Reversed.

Simple Curves

58. FUNCTIONS.

A simple curve is an arc of a circle which unites two tangents

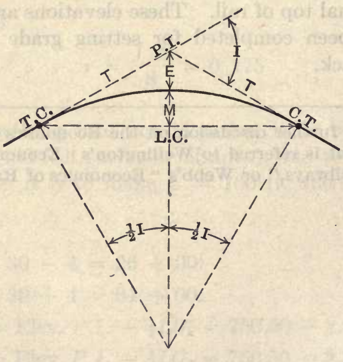

FIG 2.

differing in direction. The functions of a simple curve are shown in Fig. 2.

Point of Intersection—$P.I.$—is the point where the two tangents intersect.

Tangent to Curve—$T.C.$—is the end of the tangent and the beginning of the curve.

Curve to Tangent—$C.T.$—is the end of the curve and the beginning of the tangent.

Intersection Angle—I—is the *deflection angle* between the two tangents, and is equal to the angle at the center.

The Radius of the curve is denoted by R.

Tangent Distance—T—is the distance from the $T.C.$ or the $C.T.$ to the $P.I.$

$$T = R \tan \tfrac{1}{2}I. \quad \dots \dots \quad (2)$$

Long Chord—$L.C.$—is the chord from the $T.C.$ to the $C.T.$

$$L.C. = 2R \sin \tfrac{1}{2}I. \quad \dots \dots \quad (3)$$

Middle Ordinate—M—is the ordinate to the curve from the middle of the Long Chord.

$$M = R - R \cos \tfrac{1}{2}I = \mathrm{R} \operatorname{vers} \tfrac{1}{2}I \quad \dots \quad (4)$$

External Distance—E—is the distance from the middle of the curve to the $P.I.$

$$E = \frac{R}{\cos \frac{1}{2}I} - R = R \operatorname{exsec} \tfrac{1}{2}I \quad \dots \dots \quad (5)$$

Degree of Curve—D—is the angle at the center subtended by one 100-ft. chord, two 50-ft. chords, or four 25-ft. chords, depending upon the length of the radius. The intention is to make the difference between the length of the chord and the arc so small that it may be neglected.

Length of Curve—L—is the distance along the curve between the $T.C.$ and the $C.T.$

$$L \text{ (in stations)} = \frac{I}{D} \quad \dots \dots \quad (6)$$

Deflection Angle—$\frac{1}{2}D$—From geometry the angle between two chords, or a chord and a tangent, intersecting on the circumference of a circle is measured by one-half the intercepted arc. For a chord 100 feet in length this angle is called the *deflection angle,* and therefore is $\frac{1}{2}D$.

Subdeflection Angle—d—is a similar angle for a chord of less than 100 feet.

If C is the length of the chord in feet,

$$d \text{ (in degrees) } = \tfrac{1}{2}D\frac{C}{100} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$d \text{ (in minutes) } = 0.3CD \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Total Deflection Angle is the angle at the $T.C.$ between the tangent and a chord to any point on the curve.

Total deflection angles are taken to the nearest 0.5 *minute.*

59. The relation between R and D. If the degree of curve be defined as the angle at the center subtended by a 100-ft. *arc*, an exact relation between R and D may be found, as follows. The circumference of a complete circle in terms of the radius is $2\pi R$; and in terms of the degree of curve is $100\frac{360}{D}$, hence

$$R = \frac{100 \times 360}{2\pi D} = \frac{5729.58}{D} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

From (9) it is evident that R varies *inversely* as D. Therefore knowing the radius of a 1 degree curve, the radius of any other degree of curve can be found by simple proportion.

Since the chord is used instead of the arc, the value of R from

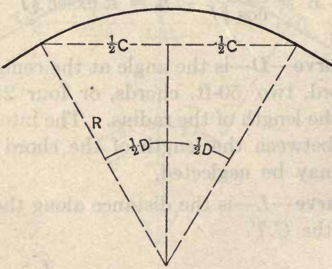

FIG. 3.

(9) can not be used, and a new value of R must be found which will agree with the chord-definition of the degree of curve.

In Fig. 3, $R \sin \frac{1}{2}D = \frac{1}{2}C$

Whence $$R = \frac{\frac{1}{2}C}{\sin \frac{1}{2}D} = \frac{1}{2}C \operatorname{cosec} \frac{1}{2}D \quad . \quad . \quad . \quad . \quad (10)$$

When C is 100 ft., $$R = 50 \operatorname{cosec} \frac{1}{2}D \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

The difference in the values of R as computed from (9) and (11) becomes about 0.5 ft. when D is 7 degrees. Since a difference greater than this is objectionable, curves above 7 degrees are staked out with 50-ft. chords. When C is 50 ft.,

$$R = 25 \operatorname{cosec} \frac{1}{4}D \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

When D becomes 14 degrees, the difference in R as computed from (9) and (12) again become objectionable, and 25-ft. chords are used. When C is 25 ft.,

$$R = 12.5 \operatorname{cosec} \frac{1}{8}D \quad . \quad . \quad . \quad . \quad . \quad (13)$$

When D becomes 28 degrees, 10-ft. chords should be used. Table 5 of radii was computed from (11), (12), and (13).

It is customary to consider the radius of a 1 degree curve as 5730 ft., and to assume that R varies inversely as D. Hence

$$R = \frac{5730}{D} \text{ (approx.)} \quad . \quad . \quad . \quad . \quad . \quad (14)$$

The difference between R as given in Table 5, and as computed from (14) is so small that it may be neglected.

By substituting R in terms of D in (2) to (6) it is seen that the various functions of a curve for any given value of I are approximately inversely proportional to D. Therefore, if these functions are known for any degree of curve, they can be found for any other degree of curve by simple proportion. Table 6 gives the functions of a 1 degree curve for intersection angles from 0 degree to 100 degrees.

60. FIELD WORK.

In laying out a curve successive points are located by a measurement from the preceding point and by line. The line is not the same for all points and is determined by the total deflection angle calculated for each point. Thus in Fig. 4, point 1 is located by the chord *T.C.*—1 and the total deflection angle *A*; point 2 by the chord 1-2 and the total deflection angle *B*; and point 3 by the chord 2-3 and the angle *C*.

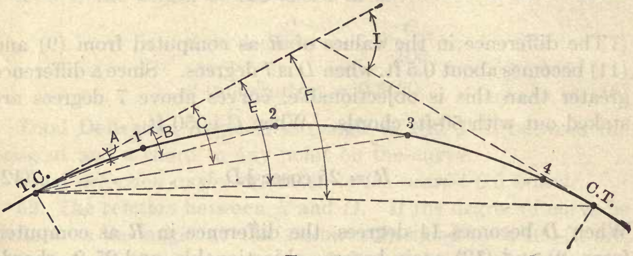

FIG. 4.

Stakes are usually placed 100 feet apart except on sharp curves where the interval is reduced to 50 or 25 feet. However, *the stationing is continued unbroken around the curve.* The *T.C.* and the *C.T.* will therefore usually fall at a plus station, hence there will usually be a subdeflection angle at each end of the curve.

The first step in the field work is to determine the station numbers of the *T.C.* and the *C.T.* and to compute the total deflection angles for the entire curve. In Fig. 4, *T.C.*—1 and 4–*C.T.* are odd distances, and 1–2, 2–3, and 3–4 are full stations. Then *A* is the subdeflection angle (d_1) for the chord *T.C.*–1, and is computed by Eq. (8).

$$A = d_1$$

Then $B = A + \frac{1}{2}D = d_1 + \frac{1}{2}D$

And $C = B + \frac{1}{2}D = d_1 + \frac{1}{2}D + \frac{1}{2}D$

$$E = C + \tfrac{1}{2}D = d_1 + \tfrac{1}{2}D + \tfrac{1}{2}D + \tfrac{1}{2}D$$

$$F = E + d_2 = d_1 + \tfrac{1}{2}D + \tfrac{1}{2}D + \tfrac{1}{2}D + d_2 = \tfrac{1}{2}I$$

The total deflection angles are thus computed by successive additions, and the entire series of computations is checked if the last value is $\frac{1}{2}I$. If stakes are placed 50 feet apart the increments are $\frac{1}{4}D$, and if 25 feet apart they are $\frac{1}{8}D$, instead of $\frac{1}{2}D$ as above. The form of notes is shown in Fig. 5.

On the ground the *T.C.* and the *C.T.* are located by measuring the tangent distance *T* from the *P.I.* The curve can then be run in by means of angles and distances as explained above.

Since in turning off an angle with a transit, an error as large as 0.5 minute may easily be made—which amounts to 0.15 of a foot at 1000 feet from the transit—the length of sight on a curve should never exceed 1000 feet.

It has been found by experience that if the angle between the tape and the line of sight is more than about 30 degrees, the location of the point is inaccurate. Therefore the angle between the line of sight and the tangent at the transit station should never be more than 30 degrees, *i.e.*, the product of the length of sight in stations and $\frac{1}{2}D$ should be less than 30 degrees.

It is good practice *in any case* to run a portion of the curve from the *C.T.*, since the errors of surveying can be adjusted more satisfactorily on the curve than at the *C.T.* There should be no more error, however, in either line or distance than is permissible in good chaining under the particular conditions.

If the entire curve can not be run in from the *T.C.* and the *C.T.*, one or more intermediate set-ups on the curve will be necessary. There are, therefore, three possible positions of the transit in running in curves, *viz.*, the *T.C.*, any intermediate point, and the *C.T.* The curve notes as computed above are used in all three cases, as follows:

At the *T.C.* Orient the transit by a sight along the tangent with the plates set at zero. Turn off the total deflection angle of each station, successively, and chain the corresponding distances between them.

At any intermediate point. Orient the transit by a backsight on the *last transit station with the telescope inverted* and the plates set at the total deflection angle of that station *as recorded in the notes.* To continue the curve, plunge the telescope * and set the plates at the total deflection angles of the succeeding stations and measure the corresponding distances between them.

At the *C.T.* Orient the transit by a sight along the tangent with the telescope normal and the plates set at the total deflection angle of the *C.T.*, *i.e.*, $\frac{1}{2}I$. To run in the curve, set the

* The line of collimation must be in adjustment.

TRANSIT NOTES FOR LINE L

STATION	ALINEMENT	TOTAL DEFL. ANGLE	CALC. BEAR.	MAG. BEAR.	REMARKS
+ 55.8	⊙ C.T.	35°-41′	N00°-39′ W	N00°-40′ W	½ I = 35°41′
		Check			
62		34 -34			
61		32 -34			
10 560		30 -34			D = 4°00′
59		28 -34			I = 71°22′
58		26 -34			
57		24 -34			
56		22 -34			P.I. 10 555 + 00.3
55		20 -34			T = 1028.7
54	⊙	18 -34			
53		16 -34			
52	4°Curve Right	14 -34			
51		12 -34			
10 550		10 -34			
49		8 -34			
48		6 -34			
47		4 -34			
46		2 -34			
45		0 -34			
+ 71.6	⊙ T.C.	0°-00′	N72°-01′ W	N72°-10′ W	
44					
43					

FIG. 5.

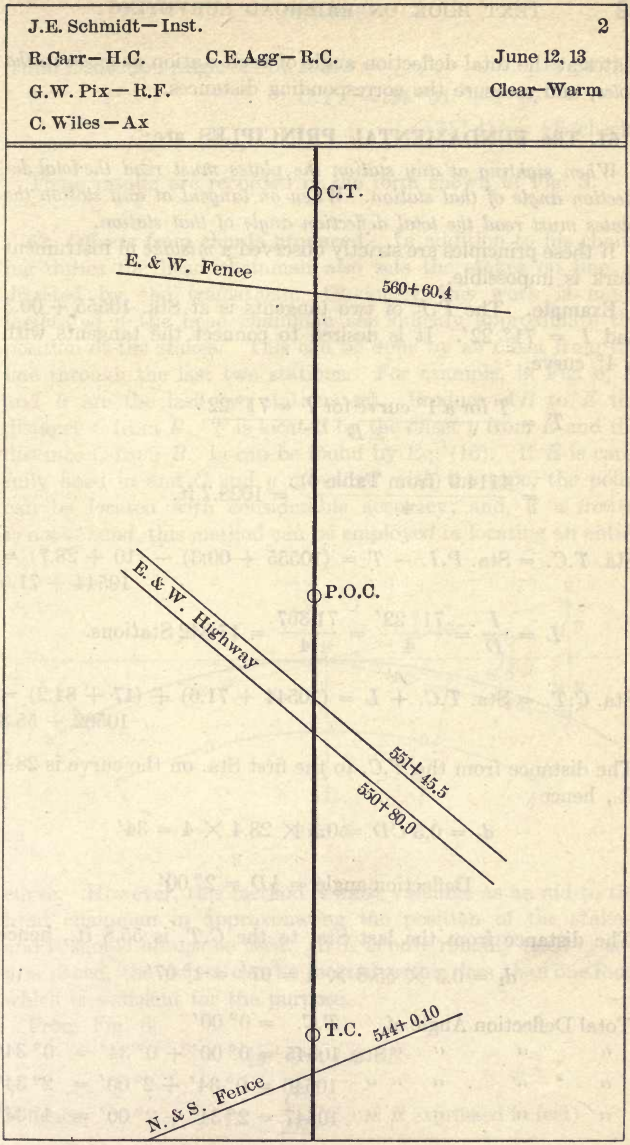
J.E. Schmidt—Inst.
2
R.Carr—H.C.
C.E.Agg—R.C.
June 12, 13
G.W. Pix—R.F.
Clear–Warm
C. Wiles—Ax
C.T.
E. & W. Fence
560+60.4
P.O.C.
E. & W. Highway
551+45.5
550+80.0
T.C.
544+0.10
N. & S. Fence

FIG. 5.

plates at the total deflection angle of each station *as given in the notes,* and measure the corresponding distances.

61. The FUNDAMENTAL PRINCIPLES are:

When sighting at any station the plates must read the total deflection angle of that station. When on tangent at any station the plates must read the total deflection angle of that station.

If these principles are strictly observed a *mistake* in instrument work is impossible.

Example. The *P.I.* of two tangents is at Sta. 10555 + 00.3 and $I = 71° 22'$. It is desired to connect the tangents with a 4° curve.

$$T = \frac{T \text{ for a } 1° \text{ curve for } I = 71° 22'}{D}$$

$$= \frac{4114.9 \text{ (from Table 6)}}{4} = 1028.7 \text{ ft.}$$

Sta. *T.C.* = Sta. *P.I.* − *T* = (10555 + 00.3) − (10 + 28.7) = 10544 + 71.6

$$L = \frac{I}{D} = \frac{71° 22'}{4} = \frac{71.367}{4} = 17.842 \text{ Stations.}$$

Sta. *C.T.* = Sta. *T.C.* + *L* = (10544 + 71.6) + (17 + 84.2) = 10562 + 55.8

The distance from the *T.C.* to the first Sta. on the curve is 28.4 ft., hence

$$d_1 = 0.3\, CD = 0.3 \times 28.4 \times 4 = 34'$$

$$\text{Deflection angle} = \tfrac{1}{2}D = 2° 00'$$

The distance from the last Sta. to the *C.T.* is 55.8 ft., hence

$$d_2 = 0.3 \times 55.8 \times 4 = 67' = 1° 07'$$

Total Deflection Angle of				*T.C.*	= 0° 00′	
"	"	"	" Sta.	10545	= 0° 00′ + 0° 34′ =	0° 34′
"	"	"	" "	10546	= 0° 34′ + 2° 00′ =	2° 34′
"	"	"	" "	10547	= 2° 34′ + 2° 00′ =	4° 34′

Total Deflection Angle of Sta. 10562 = = 34° 34′
" " " " $C.T.$ = 34° 34′ + 1° 07′ =
35° 41′ = $\frac{1}{2}I$ (check)

These results are recorded in the form shown in Fig. 5.

62. Offsets from chords produced. In addition to his chaining duties the head chainman also sets the stakes on line as directed by the transitman. Obviously this work is much facilitated if the head chainman can quickly approximate the position of the stakes. This can be done by an offset from the line through the last two stations. For example, in Fig. 6, A and B are the last two stations set. Produce AB to E the distance C from B. F is located by the offset y from E and the distance C from B. y can be found by Eq. (16). If E is carefully lined in and C and y measured with the tape, the point can be located with considerable accuracy; and, if a *transit is not at hand*, this method can be employed in locating an entire

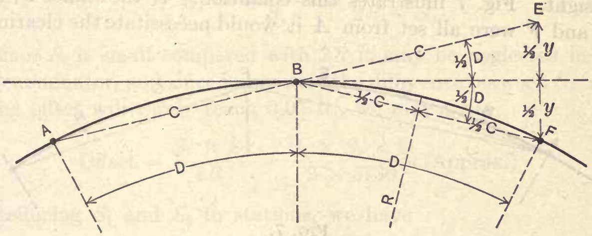

FIG. 6.

curve. However, this method is most valuable as an aid to the head chainman in approximating the position of the stakes, and it should *always* be used. If E is only roughly lined in and y is paced, the points can be located within less than one foot, which is sufficient for the purpose.

From Fig. 6,

$$\tfrac{1}{2}y : C :: \tfrac{1}{2}C : R$$

Whence $$\tfrac{1}{2}y = \frac{C^2}{2R} \text{ (}C\text{ and }R\text{ expressed in feet)}$$

Expressing R in terms of D, we have

$$\tfrac{1}{2}y = \frac{C^2D}{11460}$$

If n represents C expressed in stations, then

$$\tfrac{1}{2}y = 0.873\, n^2D \quad . \quad . \quad . \quad . \quad . \quad (15)$$

$\frac{1}{2}y$ is the *tangent offset* to the point F.

For $C = 100$ ft., $n = 1$,

and $\quad \frac{1}{2}y = 0.873\, D$, and $y = 1.746\, D = 1\frac{3}{4}\, D$ (approx.) (16,)

For $C = 50$ ft., $n = \frac{1}{2}$,

and $\frac{1}{2}y = 0.22\, D$, and $y = 0.44\, D$

63. Chord Offset Method. There are some cases in which the deflection angle method of running in curves can not be used to advantage. For instance, in heavily wooded country it may not be economical to locate every station by the deflection method on account of the large amount of clearing necessary for the lines of sight. Fig. 7 illustrates this condition. If the stakes B, C, E, and F were all set from A it would necessitate the clearing

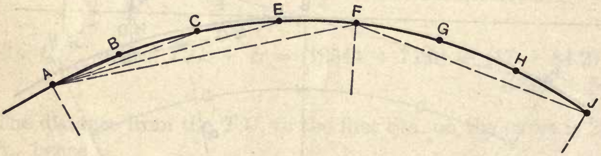

FIG. 7.

of a line to each or practically the entire area between the curve and the chord AF. If, on the other hand, F were set from A by its total deflection angle and the chord AF, and B, C, and E located by offsets from this chord, the only clearing required would be along AF and the short offsets. The transit would then be moved to F and the process repeated to J, and so on.

The chord AF is the $L.C.$ of a curve whose value of I is the central angle of the curve $ABCEF$, and therefore can be determined from Eq. (3) or from Table 6. In chaining this chord, temporary stakes are set at the full station distances, although perpendicular offsets from these will not give the exact location of the curve stations since the chord AF is shorter than the line $ABCEF$. This error may be neglected for the following reasons: (1) the error at any point in practice will rarely exceed one foot; (2) the perpendicularity of the offsets is established by eye, hence is not exact; and (3) the approximate location of these stations is sufficient since this method would be used only on first location to determine the profile. The offsets are computed as follows:

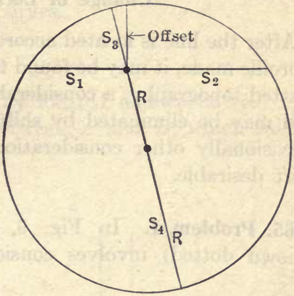

FIG. 8.

From geometry the products of the segments of two intersecting chords are equal. Then from Fig. 8,

$$S_1 \times S_2 = S_3 \times S_4$$

or

$$S_3 = \frac{S_1 \times S_2}{S_4} = \frac{S_1 \times S_2}{2R - S_3}$$

Since S_3 is small compared with $2R$ it may be neglected in the denominator, and since in practice the difference between S_3 and the offset will rarely reach 0.05 ft., we may write

$$\text{Offset} = \frac{S_1 \times S_2}{2R} = \frac{S_1 \times S_2 \times D}{2 \times 5730} \text{ (Approx.)}$$

Reducing S_1 and S_2 to stations, we have

$$\text{Offset (in feet)} = 0.873\, S_1 S_2 D \quad \text{(Slide Rule)} \quad . \quad . \quad (17)$$

64. Example. The $T.C.$ of a 4° curve is at Sta. 67 + 82.7. Sta. 72 is set by its total deflection angle (8° 21′) and the $L.C.$ of a 4° curve for $I = LD = 4.173 \times 4 = 16° 41.5'$, which from Table 6 = 415.8 ft. While chaining this chord, temporary stakes are set at 17.3, 117.3, 217.3, and 317.3 ft. from the $T.C.$ From Eq. (17),

The offset at Sta. 68 = 0.873 × 0.173 × 4 × 4 = 2.4 ft.
" " " " 69 = 0.873 × 1.173 × 3 × 4 = 12.3 ft.
" " " " 70 = 0.873 × 2.173 × 2 × 4 = 15.2 ft.
" " " " 71 = 0.873 × 3.173 × 1 × 4 = 11.1 ft.

The stations on the curve are located by measuring these offsets from the temporary stakes already set.

Change of Location Problems

After the line is located according to the paper projection and a profile made, it may be found that, owing to inaccuracies in the platted topography, a considerable cut or fill comes on a hillside and may be eliminated by shifting a portion of the alinement. Occasionally other considerations than earthwork make such a shift desirable.

65. Problem 1. In Fig. 9, the line as originally located (shown dotted) involves considerable earthwork which could

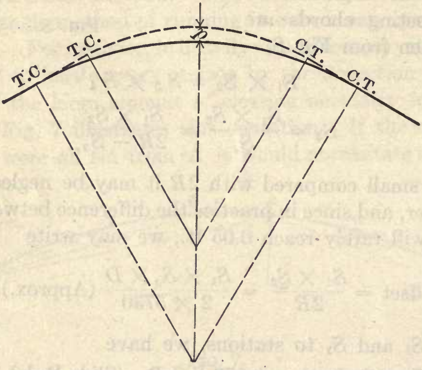

FIG. 9.

be eliminated by shifting the curve the distance p at or near its middle point.

The problem is to find the new degree of curve and the change in the position of the *T.C.* and the *C.T.* p is the difference in the external distances of the two curves, or

$$E_{new\ curve} = E_{old\ curve} + p$$

The new degree of curve may be computed from the new external by Eq. (5) or by means of Table 6, which is the quicker and more common method. The estimated value of p will usually give an odd value of D which is undesirable; hence the value of D to be used is taken only to the nearest ten minutes. The distance that the $T.C.$ and the $C.T.$ are shifted is equal to the difference in T for the two curves.

66. Problem 2, Case 1.

In Fig. 10, the line as originally located (shown dotted) involved considerable earthwork between A and B, which could

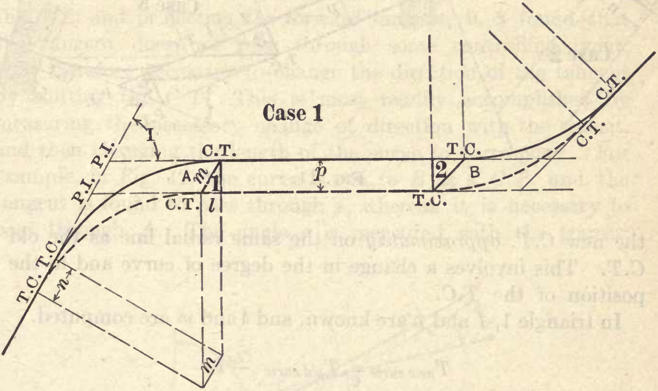

FIG. 10.

largely be eliminated by shifting the tangent the distance p parallel to its original position, which involves a change in the location of *TWO* curves.

The problem is to find the change in the $T.C.$s and the $C.T.$s of the two curves, the degree of curve remaining unchanged. In triangle 1, the sides m and l can be readily computed since I and p are known. $m = n =$ the required change in the $T.C.$ and $P.I.$ p will rarely exceed 100 feet, hence the new tangent is best located by offsets from the old tangent. The new $C.T.$ is then located from the old $C.T.$ by rectangular coordinates one of which is p and the other is the side l of triangle 1.

The second curve is located similarly using triangle 2.

67. Problem 2, Case 2.

Owing to some special cause, for example a stream-crossing as shown in Fig. 11, it may be undesirable to move the *C.T.* forward as in Case 1. This condition can usually be met by placing

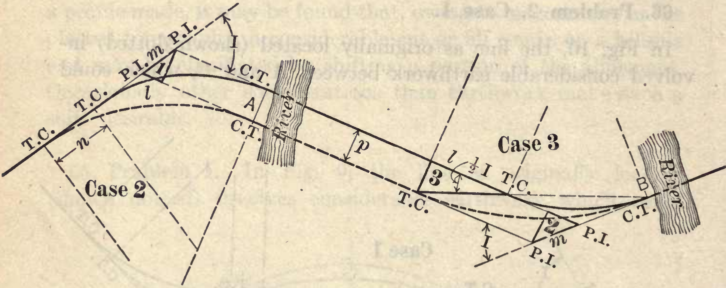

FIG. 11.

the new *C.T. approximately* on the same radial line as the old *C.T.* This involves a change in the degree of curve and in the position of the *T.C.*

In triangle 1, I and p are known, and l and m are computed.

$$T_{new\ curve} = T_{old\ curve} - l$$

whence the new D is easily found from Table 6 and, as in Problem 1, is taken only to the nearest 10 minutes. (The approximation in the position of the *C.T.* is due to thus not using the exact value of D.) A new value of T is then found which agrees with the D that is used. Then

$$n = T_{old\ curve} + m - T_{new\ curve}$$

68. Problem 2, Case 3. This case is similar to Case 2, except that the *C.T.* is on the fixed tangent instead of the one being changed, hence the solution is somewhat different.

Solve triangle 2 for the side m, then

$$T_{new\ curve} = T_{old\ curve} - m$$

whence the new degree of curve is obtained from Table 6.

Solve triangle 3 for the side l. Then the new *T.C.* can be located from the old *T.C.* by the co-ordinates l and p.

As in the previous problem, D should be taken only to the nearest ten minutes. This necessitates a slight change in both the *T.C.* and the *C.T.*, since T for this value of D is not the same as that used in the above computations. It must be remembered that the *T.C.* becomes the *C.T.*, or vice versa, when the line is run in the opposite direction.

69. Problem 3. Sometimes curves are run in beginning at the *T.C.* without previously locating the *P.I.* and the *C.T.*, and checking the direction of the forward tangent. On reaching the *C.T.* and projecting the forward tangent, it is found that the tangent does not pass through some controlling point. It is therefore necessary to change the direction of the tangent by shifting the *C.T.* This is most readily accomplished by measuring the necessary change of direction with the transit, and then changing the length of the curve to correspond. For example, in Fig. 12, the curve is run to B as a *C.T.* and the tangent is found to pass through x, whereas it is necessary to pass through A. The angle e is measured with the transit.

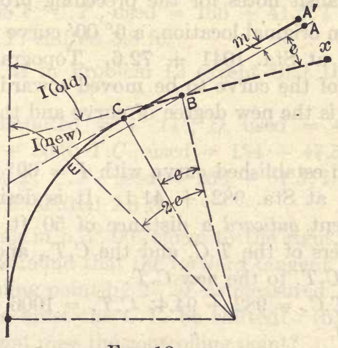

FIG. 12.

The length of curve corresponding to e is BC, whence the *C.T.* is moved back to C. The forward tangent then takes the position CA', parallel to BA, and misses A by the distance m, which is the middle ordinate of the curve BE.

$$BE = 2BC = \frac{2e}{D}$$

$$m = \frac{7}{8} \times \frac{\overline{BE}^2}{4} \times D = 0.875 \frac{e^2}{D}$$

m will rarely reach 5 ft., hence the line CA' meets the requirements.

Problems

1. If the *P.I.* is in a stream or is otherwise inaccessible, how can I and the positions of the *T.C.* and the *C.T.* be determined?

2. If the *T.C.* is inaccessible, how can the curve be run in and checked?

3. If the line of a curve passed through a building or similar obstruction, how can the curve be run in and checked?

4. Given $I = 63° 43'$. Find T, L, R, and E for each of the following values of D:—0° 30′, 2° 00′, 5° 00′, and 7° 30′. Solve by equation and check by Table 6.

5. Given the *P.I.* at Sta. 118 + 60.0, $I = 57° 48'$, and $D = 5° 00'$. Find the station numbers of the *T.C.* and the *C.T.*

6. Write transit notes for the preceding problem.

7. Given, on original location, a 6° 00′ curve with $I = 78° 21'$ and the *T.C.* at Sta. 1041 + 72.6. Topography requires the middle point of the curve to be moved toward the center *about* 45 ft. What is the new degree of curve and the station number of its *T.C.*?

8. Given an established curve with $I = 69° 38'$, $D = 3° 00'$, and the *T.C.* at Sta. 982 + 41.1. It is desired to move the forward tangent *outward* a distance of 50 ft. Find the new station numbers of the *T.C.* and the *C.T.*, and the coordinates from the old *C.T.* to the new *C.T.*

Answer. *T.C.* = 982 + 94.4; *C.T.* = 1006 + 15.5; $l = 18.6$, and $p = 50.0$.

9. Data same as in Problem 8, except that the forward tangent is moved *inward*.

Answer. *T.C.* = 981 + 87.8; *C.T.* = 1005 + 08.9; $l = 18.6$, and $p = 50.0$.

10. Given an established curve with $I = 47° 23'$, $D = 2° 30'$, and the *T.C.* at Sta. 1841 + 83.7. It is desired to move the

forward tangent *outward* a distance of 60 ft., keeping the *C.T.* on the same radial line *approximately*. Find the new degree of curve, the station number of the *T.C.*, and the distance that the *C.T.* moves forward or backward due to using *D* to the nearest ten minutes only.

Answer. *D*, computed = 2° 38.7′; *D*, used = 2° 40′; *T.C.* = 1843 + 28.0; *C.T.* moves 7.6 ft. backward.

11. Data same as in Problem 10, except that the forward tangent is moved *inward*.

Answer. *D*, computed = 2° 22.2′; *D*, used = 2° 20′; *T.C.* = 1840 + 30.3; *C.T.* moves 16.7 ft. forward.

12. Given an established curve with $I = 50° 35'$, $D = 4° 30'$, and the *T.C.* at Sta. 155 + 24.5. It is desired to move the initial tangent 35 ft. *inward* without changing the position of the *C.T.* (except the small amount due to using approx. value of *D*). Find the new degree of curve, the station numbers of the new *T.C.* and *C.T.*, the coordinates of the new *T.C.* from the old *T.C.*, and the small amount that the *T.C.* and the *C.T.* must shift due to the approx. value of *D* used.

Answer. *D*, computed = 4° 52′; *D*, used = 4° 50′; *T.C.*, computed = 155 + 98.7; *T.C.*, used = 155 + 94.9; *C.T.*, computed = 166 + 38.1; *C.T.*, used = 166 + 41.5; $l = 70.3$; $p = 35.0$; *T.C.* and *C.T.* shifted 3.8 ft.

13. Data same as in Problem 12 except that the tangent is moved *outward*.

Answer. *D*, computed = 4° 11′; *D*, used = 4° 10′; *T.C.*, computed = 154 + 50.3; *T.C.*, used = 154 + 47.5; *C.T.*, computed = 166 + 59.2; *C.T.*, used = 166 + 61.5; $l = 77.0$; $p = 35.0$; *T.C.* and *C.T.* shifted 2.8 ft.

14. After running in a 3° 00′ curve to the right, using paper location notes, it is found that the forward tangent passes to the right of the governing point by 2° 20′ as measured at the *C.T.* (a) What distance must the *C.T.* be shifted? (b) How much does the new tangent miss the controlling point?

Answer. (a) = 77.8 ft.; (b) = 1.6 ft.

Compound Curves

70. A compound curve is a combination of two or more simple curves in the same direction with a common tangent at the point of junction. *A compound curve should never be used except under conditions where a simple curve will not meet the requirements.* In rough country it may happen that a large volume of earthwork can be avoided by making one part of a curve sharper than another, resulting in a compound curve.

For example, in Fig. 13, the line is located as a compound curve *ABC*, requiring little earthwork and keeping on the bank of the stream. If the simple curve *AB* had been produced to *F* to

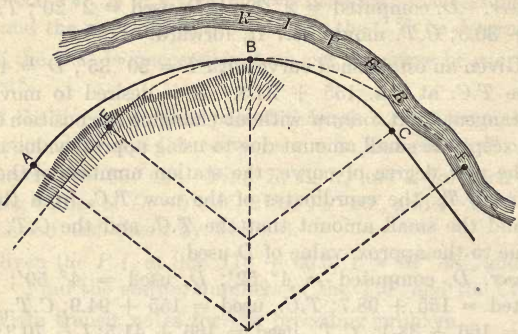

FIG. 13.

end in a parallel tangent, it would have fallen in the river. Or if the simple curve *CB* had been prolonged to *E*, it would have pierced the cliff.

The degree of curve and the point of compound curve, *C.C.*, are chosen to fit the contours and other governing conditions, and the central angles of the branches are scaled from the map.

This is one of many cases where a compound curve is applicable.

From the standpoint of operation a compound curve is better than two simple curves separated by a short tangent, hence it should be used in such cases. *In flat country a compound curve is inexcusable on main line.* If the degrees of curve of two adjacent branches of a compound curve differ by more than 2°00′, an easement curve should be inserted between the branches, and provision for this should be made in locating the curve. (See Spirals, paragraph 84.)

The nomenclature and positions of the functions are shown in Fig. 14.

71. Problem 1.

In new work I will be measured and I_1, I_2, D_1, and D_2 will be determined from the preliminary maps. It is desired to know

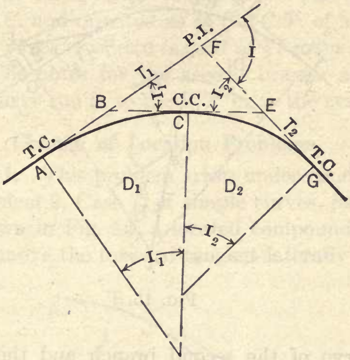

FIG. 14.

the value of T_1 and T_2 in order to set the $T.C.$ and the $C.T.$ and to run in the curve.

In Fig. 14, BE is the common tangent at the $C.C.$

$$BE = BC + CE$$

$BC = AB$ is the tangent distance for a D_1 curve for an intersection angle I_1; and $CE = EG$ is the tangent distance for a D_2 curve for an intersection angle I_2 and are computed by Table 6.

Then in the triangle BEF, one side and the adjacent angles are known from which the sides BF and EF are computed.

$$T_1 = AB + BF, \text{ and } T_2 = EF + EG$$

72. Problem 2. Occasionally the positions of the $T.C.$ and the $C.T.$ are fixed within narrow limits, giving unequal tangent distances, which necessitates a compound curve.

The degree of curve of one branch must be chosen before the problem can be solved. The problem then is to determine the

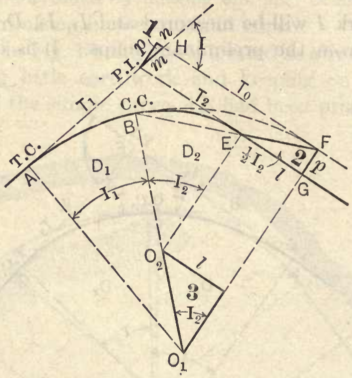

FIG. 15.

degree of curve of the second branch and the central angles I_1 and I_2.

In Fig. 15, I, T_1, T_2, and D_1 are known. $AH = HF = T_0 =$ the tangent of D_1 curve for the intersection angle I.

In triangle 1,

$$m = T_0 - T_1$$

and hence the triangle can be solved for p and n.

In triangle 2,

$$l = T_0 + n - T_2$$

Since p is known, the triangle can be solved for the angle at E, which is $\frac{1}{2}I_2$.

$$I_1 = I - I_2$$

In triangle 3, since l and I_2 are known, the side $O_1O_2 = R_1 - R_2$ can be solved for, whence D_2 is determined from Table 5.

73. Field Work.

A point on one branch of a compound curve can not be located with the transit set on a point on another branch, since in order to run in a circular curve with the transit and tape, the transit and the points to be located must be on the same circumference. Therefore each branch of a compound curve is run in independently as a simple curve. Thus the notes for the first branch are computed and the curve run in to the *C.C.* The transit is then placed at the *C.C.* and oriented as at the *C.T.* of a simple curve except that the *plates read zero instead of $\frac{1}{2}I$ when sighting along the tangent.** The notes for the second branch are then computed and the curve run in to the *C.T.* or to the next *C.C.*

Change of Location Problems

74. Problem 1. This problem arises under conditions similar to those in Problem 2, Case 1, of simple curves, paragraph 66.

Given, as shown in Fig. 16, a located compound curve *ABC*. It is desired to move the forward tangent laterally a distance *p*.

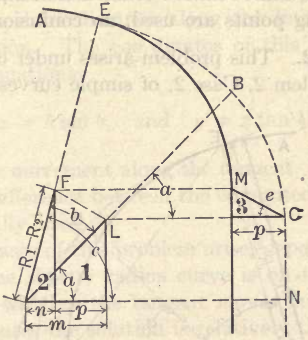

FIG. 16.

The simplest solution of this problem is to retain the same degrees of curve and to shift the *C.C.* from *B* to *E*.

$$BE \text{ (in feet)} = \frac{b}{D_1} 100$$

* To orient at the *C.C.*, back-sight on the last transit station with the plates set to read the difference between the total deflection angle of the *C.C.*, ½ I_1, and the total deflection angle of the back-sight station; turn the plates to zero and the line of sight is on tangent.

Therefore the problem resolves itself into solving for the angle b.

In triangle 1, since a is known and the hypotenuse is the difference in the two radii, the base m can be computed. Then $n = m - p$.

In triangle 2, the hypotenuse and the base are known, whence the angle c is computed.

$$b = c - a$$

In triangle 3, $e = 90° - \frac{1}{2}b - a$ (prove)

whence the coordinates of M, the new $C.T.$, from the old $C.T.$ can be determined.

Three other cases of this problem arise, viz.: (1) the same as above, except that the tangent is moved *outward;* (2) the curve of longer radius may fall on the tangent to be moved *inward;* and (3) the curve of longer radius may fall on the tangent to be moved *outward.*

The solution of each of these cases is the same as that given above except that the various points take different relative positions. If the same relative construction lines are drawn and the corresponding points are used, no confusion should arise.

75. Problem 2. This problem arises under conditions similar to those in Problem 2, Case 2, of simple curves, paragraph 67.

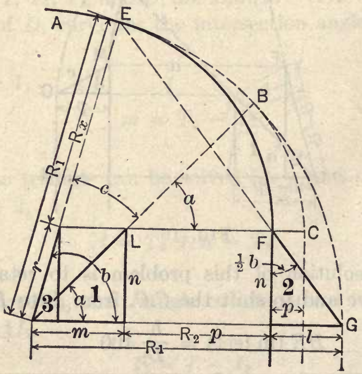

FIG. 17.

Given, as shown in Fig. 17, a located compound curve ABC. It is desired to move the forward tangent laterally a distance p, and to keep the $C.T.$ approximately on the same radial line, which involves a change in the degree of curve of the second branch and in the position of the $C.C.$

In triangle 1, a is known and the hypotenuse is the difference in the two given radii. Therefore the base m and the altitude n can be computed.

In triangle 2, the base n is now known and the altitude l can be determined since R_1, R_2, p, and m are known. The angle at $F = \frac{1}{2}b$ (Why?) can therefore be determined. Then

$$c = b - a$$

and the $C.C.$ is shifted the distance BE (in feet) $= \dfrac{c}{D_1} 100.$

In triangle 3, the angle b and the altitude n being known, the hypotenuse r can be computed from which R_x is determined, and the corresponding degree of curve D_x is found from Table 5, and is taken to the nearest ten minutes. Then since E and b are already fixed, this will change the value of p slightly and will shift the $C.T.$ a short distance along the line EG from F, its theoretical location. The coordinates of this new position are given by the equations

$$x = h \sin b, \quad \text{and} \quad y = x \tan \tfrac{1}{2}b,$$

in which x is the movement along the tangent, y is the change in p, and h is the difference between the computed value of R_x and the value actually used.

Three other cases of this problem arise, depending on whether the longer or the shorter radius curve is on the tangent to be moved, and on whether the tangent moves inward or outward. In all of these cases the solution is relatively the same.

Problems

1. Given the $P.I.$ at Sta. 837 + 00, $I = 64° 44'$, $I_1 = 29° 00'$, $I_2 = 35° 44'$, $D_1 = 4° 00'$, and $D_2 = 5° 30'$. Find the station numbers of the $T.C.$, $C.C.$, and $C.T.$

Answer. $T.C. = 828 + 73.4$; $C.C. = 835 + 98.4$; $C.T. = 842 + 73.4$.

2. Given the $P.I.$ at Sta. 1846 + 50.0, $I = 57° 18'$, $T_1 = 835.0$,

T_2 = 687.0, and D_1 = 3° 00′. Find I_1, I_2, D_2, and the station numbers of the *T.C.*, *C.C.*, and *C.T.*

Answer. I_1 = 16° 17′; I_2 = 41° 01′; D_2 = 4° 47.5′; *T.C.* = 1838 + 15.0; *C.C.* = 1843 + 57.8; *C.T.* = 1852 + 13.5.

3. A 2° 30′ curve compounds with a 4° 00′ curve at Sta. 8792 + 27.6. The central angle of the 4° 00′ curve = 26° 45′. It is desired to move the forward tangent *inward* 30 ft., but to retain the same degree of curve. Find the station number of the new *C.C.* and the coordinates of the new *C.T.* referred to the old *C.T.*

Answer. *C.C.* = 8790 + 61.6; l = 54.5 ft.; p = 30.0 ft.

4. Data the same as in Problem 3, except that the tangent is to be moved *outward.*

Answer. *C.C.* = 8794 + 22.0; l = 66.4 ft.; p = 30.0 ft.

5. A 5° 00′ curve compounds with a 3° 00′ curve at Sta. 147 + 63.3. The central angle of the 3° 00′ curve is 19° 00′. The forward tangent is to be moved 25 ft. *inward,* but the same degree of curve is to be retained. Find the station number of the new *C.C.* and the coordinates of the new *C.T.* referred to the old *C.T.*

Answer. *C.C.* = 149 + 04.0; l = 90.2 ft.; p = 25.0 ft.

6. Data same as in Problem 5, except that the tangent is to be moved *outward.*

Answer. *C.C.* = 146 + 61.3; l = 63.3 ft.; p = 25.0 ft.

7. A 4° 30′ curve compounds with a 7° 30′ curve at Sta. 999 + 67.0. The central angle of the 7° 30′ curve is 39° 24′. The forward tangent is to be moved *inward* 50 ft. and the *C.T.* is to be kept approximately on the same radial line. Find the new degree of curve for the second branch, the station number of the new *C.C.*, and the coordinates of the new *C.T.* (actual) referred to the old *C.T.*

Answer. D, computed = 6° 33′; D, used = 6° 30′; *C.C.* = 996 + 36.2; x = 5.4 ft. forward; p' = 47.2 ft.

8. Data same as in Problem 7, except that the tangent is to be moved *outward.*

Answer. D, computed = 12° 51.3′; D, used = 12° 50′; *C.C.* = 1003 + 31.4; x = 0.3 ft. forward; P' = 50.0.

9. A 5° 30′ curve compounds with a 3° 40′ curve at Sta. 1888 + 36.2. The central angle of the 3° 40′ curve is 27° 50′. The

forward tangent is to be moved *inward* 30 ft. and the *C.T.* is to be kept approximately on the same radial line. Find the new degree of curve for the second branch, the station number of the new *C.C.*, and the coordinates of the new *C.T.* (actual) referred to the old *C.T.*

Answer. D, computed = 2° 49.0′; D, used = 2° 50′; *C.C.* = 1890 + 84.4; x = 3 ft. backward; p' = 30.4 ft.

10. Data the same as in Problem 9, except that the tangent is to be moved *outward.*

Answer. D, computed = 4° 03.0′; D, used = 4° 00′; *C.C.* = 1886 + 01.5; x = 11.7 ft. forward; p' = 34.3 ft.

Reversed Curves

76. A reversed curve is a combination of two simple curves of opposite curvature with a common tangent at the point of junction.

A reversed curve should never be used on main lines on account of the shock due to the sudden reversal of curvature and also due to the fact that it is impossible to superelevate properly the outer rail at or near the point of reversal. If conditions require two curves of contrary curvature close together, they should be separated by sufficient tangent to run out the superelevation of each, or it should be provided with easement curves in which case the "points of spiral" may be coincident.

In yards and connections, reversed curves may be permissible, since the speed is low, and in some cases may be imperative. In nearly every case, however, they should be employed in conjunction with turnouts, therefore further discussion of reversed curves will be included with the problems of turnouts and connections in Chapter VI.

Part 2. Spirals

77. A spiral is a curve of varying radius which is used at the ends of circular curves in order that the change from rectilinear to circular motion, or vice versa, may be gradual and without shock. It is also used between the branches of a compound curve for similar reasons.

On tangents the track should be level transversely, but on curves the outer rail is elevated above the inner one to counteract the effect of centrifugal force. If this were carried out literally, there would be a vertical jog in the outer rail at the *T.C.* and the *C.T.*, which is impossible from the standpoint of operation. It is evident then that the superelevation must be attained gradually; the distance in which this is done is called the "run-off." It is the custom on unspiraled curves to have the run-off either wholly or in part on the tangent with the result that there is a disagreeable tipping of the train upon entering and leaving curves. When a spiral is used this objection is overcome since the superelevation is attained in its length, and at every point is correct for the degree of curve at that point.

Thus the spiral may be defined as *a curve whose degree of curve increases uniformly from zero at its beginning to the degree of the main curve at its end.*

Application to Simple Curves

78. The functions of the spiral are shown in Fig. 18, and are defined as follows:

T.S.—the point of change from tangent to spiral.

S.C.—the point of change from spiral to circular curve.

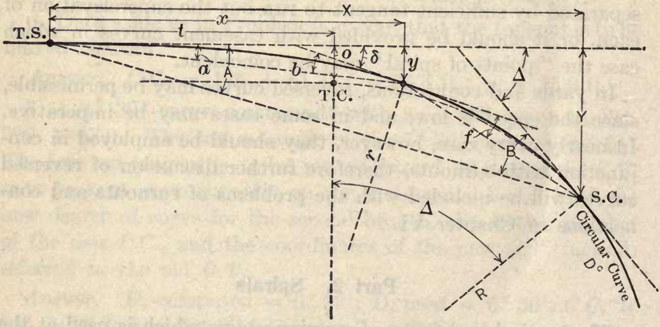

FIG. 18.

C.S.—the point of change from circular curve to spiral.

S.T.—the point of change from spiral to tangent.

a —the angle between the tangent at the *T.S.* and a chord to any point on the spiral—*the spiral deflection angle.*

A—a for the *S.C.*—*the spiral total deflection angle.*

b—the angle at any point on the spiral between a tangent at that point and a chord to the *T.S.*

B—b at the *S.C.*

d—degree of curve of the spiral at any point.

D—degree of curve of the central circular curve.

f—the angle at any point on the spiral between a tangent at that point and a chord to any other point (b is a special case of f).

I—the total central angle of the spiraled curve.

δ—the central angle of the spiral from the *T.S.* to any point.

Δ—the central angle of the spiral from the *T.S.* to the *S.C.*

k—the rate of change in the degree of curve of the spiral per station.

l—the length of the spiral in feet from the *T.S.* to any point.

L—the length of the spiral in feet from the *T.S.* to the *S.C.*

s—the length of the spiral in stations from the *T.S.* to any point $= \frac{l}{100}$.

S—the length of the spiral in stations from the *T.S.* to the *S.C.* $= \frac{L}{100}$.

r—the radius of curvature of the spiral at any point (radius corresponding to d).

R—the radius of curvature of the central circular curve.

x—the abscissa of any point referred to the *T.S.*

X—the abscissa of the *S.C.* referred to the *T.S.*

y—the ordinate, or tangent offset, of any point.

Y—the ordinate, or tangent offset, of the *S.C.*

T.C.—the point of curve of central curve produced back to a tangent parallel to the tangent at the *T.S.*

o—the ordinate of the *T.C.*

t—the abscissa of the *T.C.* referred to the *T.S.*

P.I.—the point of intersection of the tangents of the spiraled curve.

T_s—the tangent distance of the spiraled curve (*T.S.* to *P.I.*).

T—the tangent distance of an unspiraled curve of the same *D* and *I*.

E_s—the external distance of the spiraled curve.

E—the external distance of the unspiraled curve of the same *D* and *I*.

79. Formulas.

From definition,

$$\left.\begin{aligned} d &= ks = \frac{kl}{100} \\ D &= kS = \frac{kL}{100} \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (18)$$

The derivations of the following formulas require the use of the calculus and are given in the Appendix.

$$\delta \text{ (in degrees)} = \tfrac{1}{2}ks^2, \ \Delta = \tfrac{1}{2}kS^2 \quad \ldots\ldots \quad (19)$$

$$\left.\begin{aligned} a \text{ (in degrees)} &= \tfrac{1}{3}\,\delta = \tfrac{1}{6}\,ks^2 \\ a \text{ (in minutes)} &= 10ks^2, \\ &\quad A \text{ (in degrees)} = \tfrac{1}{3}\,\Delta = \tfrac{1}{6}\,kS^2 \end{aligned}\right\} \quad (20)$$

$$\begin{aligned} b \text{ (in degrees)} &= \tfrac{2}{3}\,\delta = 2a, \\ &\quad B \text{ (in degrees)} = \tfrac{2}{3}\Delta = 2A \end{aligned} \quad \ldots \quad (21)$$

$$\left.\begin{aligned} y &= 0.291\ ks^3 - .00000158k^3s^7 \\ Y &= 0.291\ kS^3 - .00000158\ k^3S^7 \end{aligned}\right\} \quad \ldots\ldots \quad (22)$$

$$\left.\begin{aligned} x &= l - .000762\ k^2s \\ X &= L - .000762\ k^2S^5 \end{aligned}\right\} \quad \ldots\ldots \quad (23)$$

$$o = 0.0727\ kS^3 \quad \ldots\ldots \quad (24)$$

$$t = \tfrac{1}{2}L - .000127\ k^2S^5 \quad \ldots\ldots \quad (25)$$

$$T_s = T + o \tan \tfrac{1}{2}I + t = (R + o) \tan \tfrac{1}{2}I + t \quad \ldots \quad (26)$$

$$E_s = E + \frac{o}{\cos \frac{1}{2}I} = (R + o) \operatorname{exsec} \tfrac{1}{2}I + o \quad \ldots \quad (27)$$

80. Length of Spiral.

Since the function of a spiral is to ease the entrance to a circular curve, *D* will always be known. Then from Eq. 18 it is only necessary to choose a value of *k* or *L*, and the spiral is fixed. Obviously any value of *k* could be chosen and the spiral would fit, but such a spiral may be so short as to require an excessive rate of superelevation, or, on the other hand, it may be needlessly long. It is therefore more logical to determine the length of spiral necessary to give the desired rate of superelevation and to make k to correspond.

The length of the spiral is a direct function of the rate of superelevation. The total superelevation depends upon the speed and the degree of curve and is found from the formula,

$$*e = 0.00069\,DV^2 \quad . \quad . \quad . \quad . \quad . \quad (28)$$

in which e is the superelevation in inches and V the velocity in miles per hour. e should never exceed 8 inches on account of the effect on slowly moving trains, but the track should be superelevated for the fastest train up to this limit. Therefore the maximum train speed for any given curve is limited by this maximum superelevation. According to the American Railway Engineering Association, curves requiring less than 2 inches of superelevation are not generally spiraled, as the run-off may be placed on the tangent without objection.

The maximum rate at which the superelevation may be attained without discomfort to passengers is about 1 1-6 inches per second.† Therefore the minimum length of spiral is,

$$L = 6/7\,ev$$

where v is in feet per second. Reducing v to miles per hour,

$$L = 1.26\,eV$$

Substituting the value of e from Eq. 28,

$$L = .00087\,DV^3 \quad . \quad . \quad . \quad . \quad (29)$$

Substituting the value of D from Eq. 18, and solving for k, we have

$$k = \frac{115000}{V^3}\ \text{(Approx.)} \quad . \quad . \quad . \quad . \quad (30)$$

The diagram, Fig. 19, is platted from values computed by the above formulas, and gives the length, superelevation, and k for

* For derivation, see Appendix, paragraph 143.

† American Railway Engineering Association, Bulletin 108, Feb., 1911.

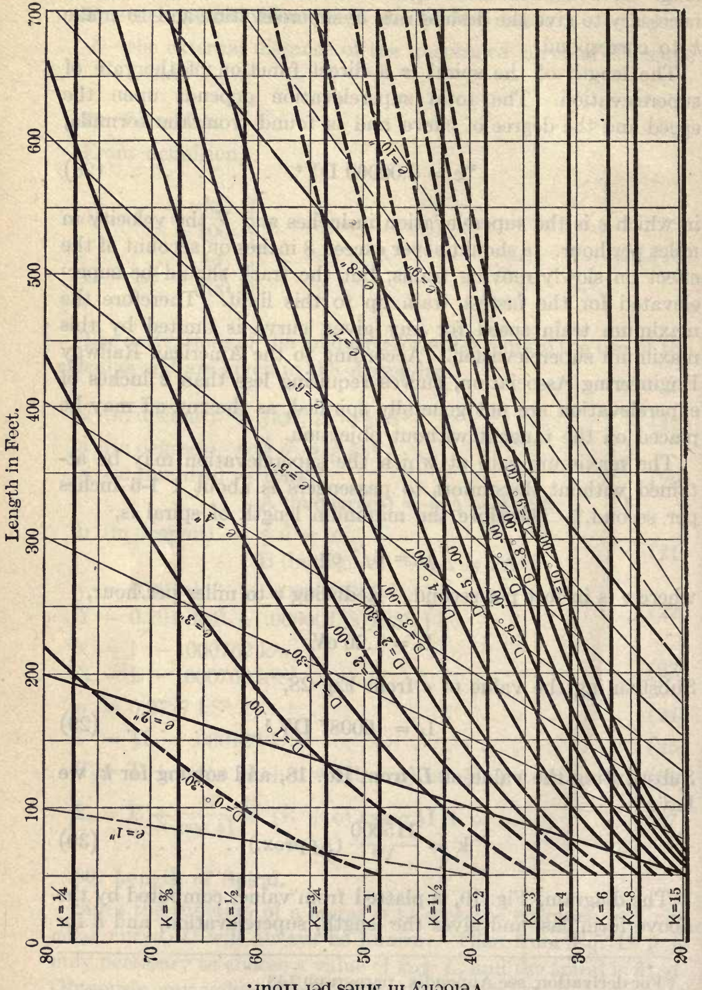

FIG. 19. SPIRAL DIAGRAM.
Rate of superelevation = 1½ inches per second.

curves from 0° 30′ to 10° 00′, and for speeds from 20 to 80 miles per hour. In this diagram, with any given value of D and V, the length of spiral, the corresponding value of k, and the required superelevation can be readily determined.

The consensus of opinion of 31 railroads of the United States as reported to the American Railway Engineering Association is that the theoretical speed for which the outer rail is superelevated, or the curve spiraled, may be exceeded about 20 per cent. without discomfort to passengers. Further, the maximum speed is never accurately known. Therefore, it is not necessary to use the exact values of k and L as determined for the assumed speed. Obviously, even values of k are desirable, and since considerable variation is permissible, such values may be chosen, provided the change does not increase the speed more than 20 per cent. An examination of the diagram, Fig. 19, will show that values of k of $\frac{1}{2}$, 1, 2, and 4 will give a satisfactory length of spiral for practically all cases met in practice.

81. Field Work.

The first step in the field work is to determine the station numbers of the *T.S.*, *S.C.*, *C.S.*, and *S.T.* The *T.S.* and the

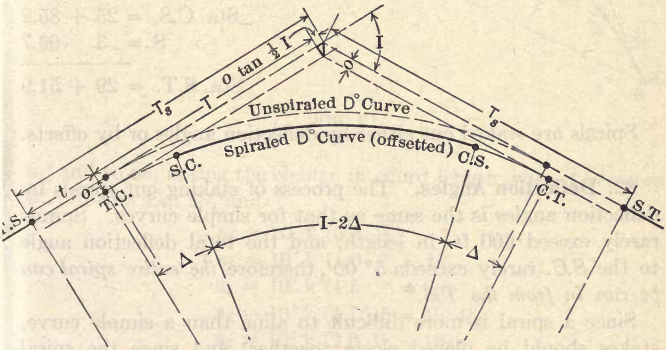

FIG. 20.

S.T. are located on the ground by measuring the distance T_s from the *P.I.*

From Fig. 20,

$$T_s = T + o \tan \tfrac{1}{2}I + t \qquad (31)$$

T is found from Table 6 (or Eq. 2); o is found from Table 1 (or Eq. 24); and t is found from Table 1 (or Eq. 25).

Example. Given:—*P.I.* = 21 + 21.1, $D = 3° 40'$, $I = 51° 20'$, and maximum speed about 45 miles per hour.

From diagram, Fig. 19.

Superelevation = 5 inches, $k = 1$, and $L = 366.7$ ft.

	Sta. P.I =		21 + 21.1
From Table 6,		T = 750.9	
From Table 1, o = 3.58,		o tan $\frac{1}{2}$I = 1.7	
From Table 1,		t = 183.3	
		T_s =	9 35.9
		Sta. T.S. =	11 + 85.2
		S =	3 66.7
		Sta. S.C. =	15 + 51.9

$$\text{Length of circular curve} = \frac{I - 2\Delta}{D} = \frac{I}{D} - S = 10 \quad 33.3$$

Sta. C.S. =	25 + 85.2
S =	3 66.7
Sta. S.T. =	29 + 51.9

Spirals are staked out either by deflection angles or by offsets.

82. Deflection Angles. The process of staking out spirals by deflection angles is the same as that for simple curves. Spirals rarely exceed 600 ft. in length, and the total deflection angle to the *S.C.* rarely exceeds 5° 00′, therefore *the entire spiral can be run in from the T.S.**

Since a spiral is more difficult to aline than a simple curve, stakes should be placed closer together; and since the spiral becomes sharper as it increases in length, stakes should be placed more closely together at the end than at the beginning.

* For running in spiral from an intermediate point on spiral, see paragraph 85.

RULE:—*Place stakes 50 ft. apart on all spirals up to the point where the degree of curve (d) becomes about 3°; beyond this point place them 25 ft. apart.*

For ease in computation, stakes are placed the above distances apart *beginning at the T.S.*; hence in general *all* the stakes will fall at plusses.

The spiral deflection angles are

$$a \text{ (in minutes)} = 10\,ks^2 \qquad (20)$$

Note that the spiral deflection angles vary with the *square* of the distance instead of the first power as in simple curves.

In Fig. 21 point 1 is located by a 50-ft. chord from the *T.S.* and the angle a_1; point 2 by a 50-ft. chord from 1 and the angle

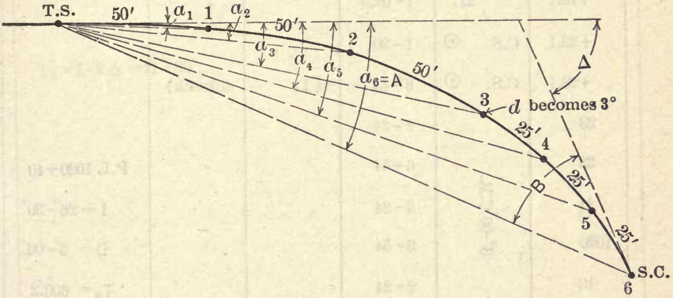

FIG. 21.

a_2; and so on, noting the change in chord length when d becomes 3°. From Eq. 20, and

$$a_1 = 10'\,k\,(0.5\;)^2$$
$$a_2 = 10'\,k\,(1.0\;)^2 = 4a_1$$
$$a_3 = 10'\,k\,(1.5\;)^2 = 9a_1$$
$$a_4 = 10'\,k\,(1.75)^2 = 49/4a_1$$
$$a_5 = 10'\,k\,(2.0\;)^2 = 16a_1$$
$$A = a_6 = 10'\,k\,(2.25)^2 = 81/4a_1 = 1/3\Delta$$

It is thus seen that the deflection angle for the first station only needs to be determined from Eq. 20. The other values are found by multiplying this value by the square of the ratio of the first distance to the other distances.

TRANSIT NOTES FOR LINE L

STATION	ALINEMENT	TOTAL DEFL. ANGLE	CALC. BEAR	MAG. BEAR	REMARKS
1027	Tan.		S 64°-14′W	S 64°-10′W	
26+23.1	S.T. ⊙	0°-00′			
+73.1		0°-02′.5			
25+23.1		0-10			
+73.1	Spiral $k = 1°$- Backed in from S.T.	0-22.5			
24+23.1		0-40			
+73.1		1-02.5			
+23.1	C.S. ⊙	1-30			
+23.1	C.S. ⊙	8°-45′	$= \frac{1}{2} I_c$	(check)	
23		8-24			
22		6-54			P.I. 1020+40
21	3°-00′ C.R.	5-24			I = 26°-30′
1020		3-54			D = 3°-00′
19		2-24			T_s = 600′.2
18		0-54			
17+39.8	S.C. ⊙	0°-00′			
17+39.8		1-30			$k = 1°$-
+89.8		1-02.5			L = 300′.0
16+39.8		0-40			Δ = 4°-30′
+89.8	Spiral $k = 1°$-	0-22.5			A = 1°-30′
15+39.8		0-10			B = 3°-00′
+89.8		0-02.5			
+39.8	T.S. ⊙	0°-00′			
1014	Tan.		S 37°-44′W	S 37°-50′W	

FIG. 22.

28

Mike McCarthy-Inst.
Heine Heinrichson-H.C.
Oley Olsen-R.C.
S.Garibaldi-R.F.

June 17, 1913
Clear-Hot

Set up at S.T.plates at 0°00′; B.S.along Tangent;
Back in Spiral to C.S.

$I_c = I - 2\Delta = 17°\text{-}30'$

B.S. at T.S., Plates at 3°-00′. Plunge and turn to
0°-00′ for Tangent.

FIG. 22.

Example. Assume that in Fig. 21, *T.S.* is at Sta. 711 + 44.0, $k = 2$, and $S = 2.25$. Then $D = 4° 30'$.

Deflection angle of *T.S.*,	Sta.	711 + 44.0	= 0° 00′
" " " 1	"	711 + 94.0	= 0° 05′
" " " 2	"	712 + 44.0	= 0° 20′
" " " 3	"	712 + 94.0	= 0° 45′
" " " 4	"	713 + 19.0	= 1° 01′ (1° 01.25′ exact)
" " " 5	"	713 + 44.0	= 1° 20′
" " "*S.C.*(A)"	"	713 + 69.0	= 1° 41′ (1° 41.25′ exact)

$$A = 1/3\Delta,\ \Delta = 5°\text{–}04' \quad (5°\ 03.75'\ \text{exact})$$

$$B = 2/3\Delta = 2A = 3°\ 22.5'$$

To orient the transit at the *S.C.*, back-sight on the *T.S.* with the plates set at 3° 22.5′ (angle *B*); then turn the plates to zero and the telescope is on tangent and the circular curve is run in as from the *T.C.* of a simple curve, *stakes being placed at the regular stations* (in the above problem at 714 + 00, 714 + 50, etc.). After running in about half of the circular curve, move the transit to the *S.T.* and run in the second spiral with the same deflection angles. Then move to the *C.S.* and *back-in* the remainder of the circular curve, thus placing the adjustment of the *errors of surveying* at the center of the curve instead of at the end of the spiral as is usually but *unwisely* done. The form of notes is shown in Fig. 22.

This method is particularly applicable for locating spirals after the construction is completed and the track is to be brought to exact line and surface. For setting stakes during construction the offset method is preferable.

83. Offsets. Evidently the entire spiral can be located by means of the coordinates x and y (tangent offsets), and this is a satisfactory method for short flat spirals where y is less than about 10 feet. When y becomes greater than this, the spiral can not be located with sufficient accuracy unless the offsets are turned off with an instrument.

On location, since it is usually desirable to advance the line as rapidly as possible, the best method is to run-in the circular curve from the *T.C.* to the *C.T.* (offsetted curve, see Fig. 20), and to insert the spiral later by offsets from both the tangent and the circular curve.

Since the spiral departs from an osculating circle at any point at the same rate that it departs from the tangent at the *T.S.* (see Appendix, paragraph 142), it follows that the offsets from the circular curve to the spiral are the same as the offsets from the tangent at the *T.S.* for the same distances. Since the offset *o* and the spiral bisect each other (see Appendix, paragraph 141), it is evident that the maximum offset is $\frac{1}{2}o$, and therefore will be small, and also that it is necessary to compute offsets for half the spiral only. Half of the spiral is then located by offsets *y* from the tangent at the *T.S.*, and the other half by the same offsets measured normal to the circular curve.

From Eq. 22 it is seen that the offsets vary approximately as the cube of the distances, and for this method of location can be taken so with inappreciable error. Since the maximum ordinate is $\frac{1}{2}o$, and *o* is determined to offset the *T.C.*, it is seen that the offsets can be determined directly from *o* instead of from Eq. 22.

Application to Compound Curves

At the *C.C.* of a compound curve—as at the *T.C.* of a simple curve—there is a change in the rate of curvature and in the amount of superelevation, and if this is great enough to be objectionable, a spiral should be inserted between the two branches.

Evidently only that part of the spiral of curvature intermediate between the degrees of the two curves is required, and—as at the *T.C.* of a simple curve—the two curves must be offsetted at the *C.C.*

84. Problem 1. In Fig. 23, *HBC* is a D_1 curve and *EFJ* is a D_2 curve having parallel tangents at *C* and *E* (the position of the *C.C.* if the curve were unspiraled). It is desired to connect the two curves by the spiral *BF*. Consider the spiral run backwards to its *T.S.* at *A*. Since the degree of curve of the spiral at *B* must be D_1 and at *F* must be D_2, then the spiral from *B* to *F* is that part of a regular spiral from where $d = D_1$ to where $d = D_2$. The value of *k* depends upon the maximum speed permissible on the *sharper* curve and upon the difference in the two degrees of curve.

Since the spiral departs from every osculating circle at the same rate as from the tangent at the *T.S.*, $BC = CF$, the spiral bisects CE, and CE is equal to o for a spiral whose $D = D_2 - D_1$ for the chosen value of k.

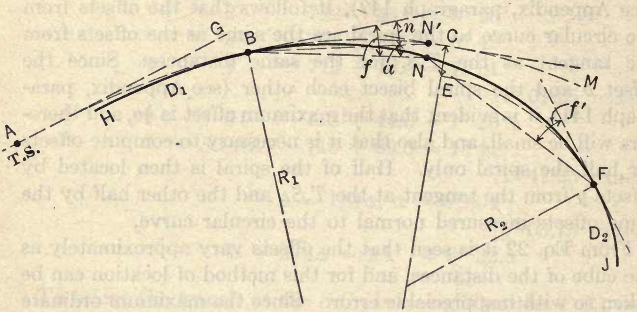

FIG. 23.

To insert a spiral between the curves, find o for a $D_2 - D_1$ curve and make the offset from C to E. The length of the spiral in stations is

$$S_1 = \frac{D_2 - D_1}{k}$$

Locate B and F by measuring $\frac{1}{2}S_1$ from C and E.

The curves may be staked out by continuing the first branch to C, offsetting to E, and running-in the second branch; and then inserting the spiral by offsets from the circular curves in exactly the same way as explained in paragraph 83.

85. Deflection angles may also be used; but, since the transit is at a point on the spiral, B or F, and not at the *T.S.*, the reflection angles to be used are values of f instead of a. From a tangent at B in Fig. 23, the deflection angle n to any point N' on the circular curve BCM is $\frac{1}{2}D_1 \times BN'$. Since the spiral departs from the osculating circle at the same rate as from the tangent at the *T.S.*, the angle between the circular curve and a point N on the spiral is $a = 1/6\ k(BN)^2$. But BN and BN' are equal. Then

$$f = n + a = \tfrac{1}{2}D_1\ (BN) + 1/6\ k\ (BN)^2.$$

If the transit were set at F, the deflection angle to N would be

$$f' = \tfrac{1}{2}D_2\,(FN) - 1/6\,k\,(FN)^2$$

86. Problem 2. Fig. 24 shows a compound curve to be spiraled at each end and between the two branches. The

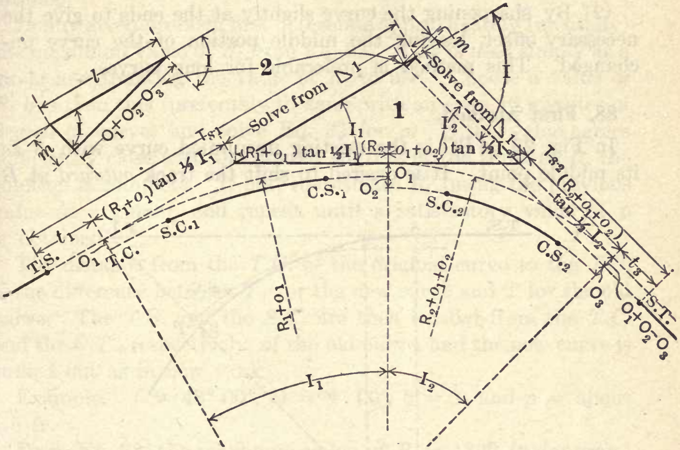

FIG. 24.

tangent distances T_{s1} and T_{s2} are required, and the solution is fully indicated in the figure.

Application to Existing Curves

To insert a spiral in an existing track, it is necessary to shift the ends of the curve inward to provide room for the spiral. If the same degree of circular curve were retained, this would shift the *entire curve* inward. Since the amount of such shifting may be considerable (o sec. $\tfrac{1}{2}I$ at its center) the new alinement may not be on the old roadbed and considerable cost of earthwork would be entailed in making the change. To obviate this, the degree of curve may be changed in such a way that the new alinement will permit the insertion of the spiral and at the same time require little or no additional earthwork.

87. SIMPLE CURVES. Existing simple curves may be spiraled in two ways.

(1) By shifting the center of the curve *outward* * a small amount, and by sharpening the curve sufficiently to give the desired offset. This method is particularly applicable for curves whose lengths are less than about four times the length of the spiral to be used.

(2) By sharpening the curve slightly at the ends to give the necessary offset, leaving the middle portion of the curve unchanged. This method is preferable for long curves.

88. First Method.

In Fig. 25, *ABC* is the existing unspiraled curve with *B* as its middle point. It is desired to shift the track *outward* at *B*

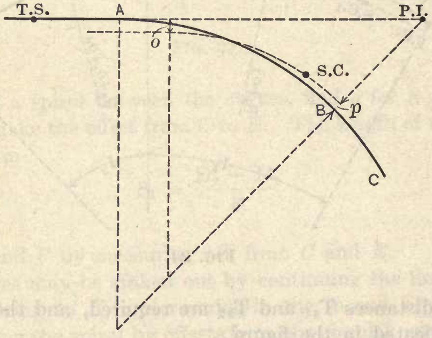

FIG. 25.

the *assumed* distance *p*, and to sharpen the curve to give the necessary offset *o*.

From the figure, *p* is the difference between the external distances of the existing curve and the spiraled curve. Therefore from Eqs. 5 and 27, we have

$$p = R \text{ exsec } \tfrac{1}{2}I - [(R_1 + o)\text{exsec } \tfrac{1}{2}I + o]$$

$$= (R - R_1 - o) \text{ exsec } \tfrac{1}{2}I - o \quad . \quad . \quad . \quad (32)$$

* The shifting must be *outward* to make the change in alinement a minimum.

The minimum change in radius ($R - R_1$) is that which will make p equal to zero. Then from Eq. 32,

$$R_1 = R - \frac{o^*}{\text{vers } \frac{1}{2}I} \quad \ldots \ldots \quad (33)$$

(This is the maximum value of R_1 that will satisfy the conditions.)

In any given problem first determine approximately (mentally) the maximum value of R_1 from Eq. 33. This is used simply as a guide in estimating the value of R_1 to use. Choose a value of R_1 less than this (preferably to agree with an even 10 minutes of degree of curve) and solve Eq. 32 for p. If this value agrees sufficiently close with the desired shifting of the track at B, the solution is complete. If not, re-estimate R_1 (using the previous value as a guide), and repeat until a satisfactory value of p is obtained.

The distance from the *T.C.* of the original curve to the *T.S.* is the difference between T_s for the new curve and T for the old curve. The *T.S.* and the *S.T.* are then located from the *T.C.* and the *C.T.*, respectively, of the old curve, and the new curve is staked out as in new work.

Example. $I = 40° 00'$, $D = 4° 00'$, $k = 1$, and $p =$ about 1.5 ft.

From Eq. 33, the maximum value of $R_1 = 1330$ ft. (approx.) corresponding to $D_1 = 4° 18'$ (approx.). Choose a trial value of $R_1 = 1322.2$ ft. for $D_1 = 4° 20'$. Then from Eq. 32, $p = 0.8$ ft. Choosing $R_1 = 1312.1$ ft. for $D_1 = 4° 22'$, p becomes 1.3 ft., showing that a change of 2′ in D_1 increases p about 0.5 ft. Then to make $p = 1.5$ ft., D_1 would have to be about 4° 23′. Since an odd value of D_1 is undesirable, and since it is not necessary to make p exactly 1.5 ft., it is sufficient to take $D_1 = 4° 22'$.

In the foregoing discussion it was assumed that the degee of the existing curve was known and that the *T.C.* and *C.T.* were monumented. It will generally happen, however, that the degree of curve is unknown, that the track is in poor alinement, and that the *T.C.* and *C.T.* are not monumented. In this case, run out the tangents to an intersection and measure the intersection angle. Then measure the external distance of the

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* o should correspond with R_1 which is unknown, therefore use a value of o corresponding to about 0.9 R.

existing curve and from it determine the degree of the curve that will connect the tangents and pass through the middle point of the existing curve. Use the value of R corresponding to this value of D in solving Eqs. 32 and 33.

89. Second Method. Case 1. In Fig. 26, *ABC* is the existing unspiraled curve, whose degree of curve, D, is known, whose alinement is good, and whose *T.C.* and *C.T.* are monumented. At some point on this curve, such as B, it is desired to compound with an assumed curve of slightly shorter radius, R_1, which, when run to a tangent parallel to the initial tangent, will be a distance from it equal to o for a R_1 curve, thus providing room for the spiral.

In the figure, *EFB* is the R_1 curve, and *EG* is o corresponding to

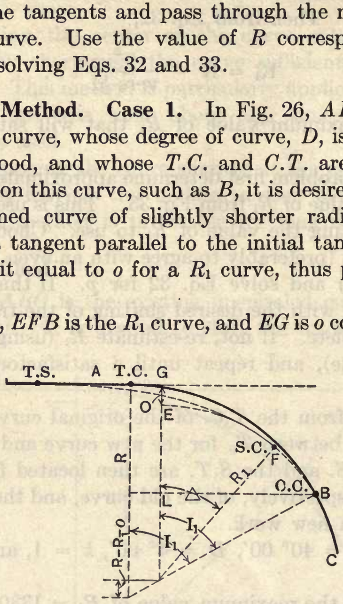

FIG. 26.

it. It is required to find the location of the *T.S.*, of the *S.C.*, and of the *C.C.*, B.

From the figure,

$$o = EG = GL - EL = (R - R_1) \text{ vers } I_1$$

$$\text{vers } I_1 = \frac{o}{R - R_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (34)$$

The *T.S.* is located by measuring back from the old *T.C.*

$$T.C. \text{ to } T.S. = t - (R - R_1 - o) \tan I_1. \quad . \quad . \quad (35)$$

The *S.C.* is located by measuring the spiral length from the *T.S.* The *C.C.*, B, is located by measuring the distance *FB* from the *S.C.*

$$FB \text{ (in feet)} = \frac{I_1 - \Delta}{D_1} 100 \quad . \quad . \quad . \quad . \quad (36)$$

The location of the point B may be checked by measuring the distance AB along the old curve.

$$AB \text{ (in feet)} = \frac{I_1}{D} 100$$

The distance from the $T.S.$ to the $C.C.$ along the new alinement is shorter than along the old alinement which will require the rails to be cut. This shortening is equal to the difference in the Sta. numbers of the $C.C.$ as computed along the respective alinements.

The limits of R_1 are such as will make the point B come at the middle of the original curve, or will make B and F coincide. In general, R_1 should be chosen between 0.8 R and 0.9 R.

Example. $D = 3° 00'$, D_1 (assumed) $= 4° 00'$, $k = 1$, and $o = 4.65$. From Eq. 34, $I_1 = 12° 14.3'$. From Eq. 35, the distance from the old $T.C.$ to the $T.S.$ is 156.5 ft. The spiral is 400 ft. long. From Eq. 36, the distance from the $S.C.$ to the $C.C.$ is 121.1 ft.

90. Second Method. Case 2. In Fig. 27, ABC is the existing unspiraled curve, whose degree of curve is unknown, whose alinement may be poor, and whose $T.C.$ and $C.T.$ are not monumented. First set-up in the center of the track at some

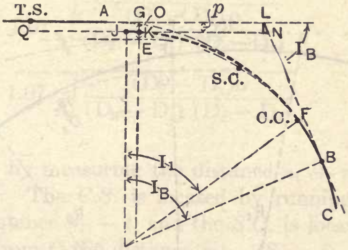

FIG. 27.

point C near the middle of the curve and by trial deflection angles find the degree of the curve, D, that will most nearly conform to the existing track. Then run-in this D curve to a point B which is about 500 ft. from the end of the curve. If this curve were continued, its $T.C.$ would fall at J on a tangent parallel to the initial tangent QL and at a distance p from it.

At *B* run-out the tangent to the *D* curve to an intersection with the initial tangent at *L* and measure the intersection angle I_B and the distance *BL*. *BN* is the tangent distance of the curve corresponding to I_B. Then,

$$p = NL \sin I_B$$

The *D* curve is to be compounded with a chosen D_1 curve at some point *F* to give the required offset *o*.

$$EK = o - p = (R - R_1) \text{ vers } I_B, \text{ whence}$$

$$\text{vers } I_B = \frac{o - p}{R - R_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (37)$$

The *T.S.* is located at *Q* by measurement from *L*.

$$QL = QG + GL = t + JN - JK - NL \cos I_B$$

The *S.C.* and the *C.C.* are located as in Case 1, and the spirals are staked out as in new work.

J may fall outside of *QL*, in which case *p* and *o* are numerically added; again, *p* may be greater than *o*, and in this case R_1 must be greater than *R*.

91. COMPOUND CURVES.

An existing compound curve can be spiraled in the following manner.

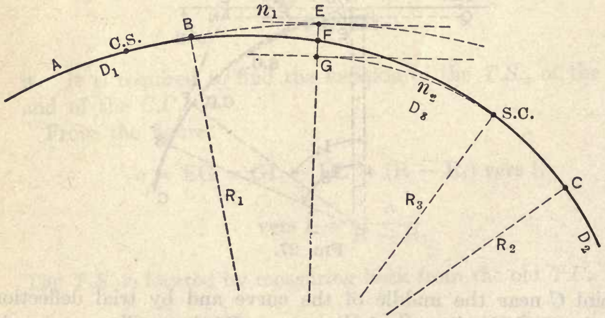

FIG. 28.

In Fig. 28, *ABC* is the existing compound curve with its *C.C.* at *B*. To make room for the spiral it is necessary to compound the sharper branch, D_2, at some point C with a still sharper curve of chosen degree, D_3, and to continue the first branch, D_1, to the point E where its tangent is parallel to the tangent of the D_3 curve at G. EG is the offset o for a spiral whose $D = D_3 - D_1$. The problem is to find $BE = n_1$ and $CG = n_2$.

For small central angles the ordinates between two circular curves are equal to the difference in their tangent offsets. Therefore EF can be considered as the difference in the tangent offsets of the D_1 and D_2 curves in the distance n_1; similarly FG is the difference in the tangent offsets of the D_2 and D_3 curves for the distance n_2.

Then from Eq. 15,

$$o = EF + FG = 0.873\ (D_2 - D_1)\ n_1^2 + 0.873\ (D_3 - D_2)\ n_2^2.$$

Since the central angle of the arc BC equals the sum of the central angles of the arcs BE and CG,

$$D_2\ (n_1 + n_2) = D_1 n_1 + D_3 n_2$$

or

$$(D_2 - D_1)\ n_1 = (D_3 - D_2)\ n_2.$$

Solving these simultaneous equations for n_1 and n_2 we have

$$n_1 = 1.07 \sqrt{\frac{(D_3 - D_2)\ o}{(D_2 - D_1)\ (D_3 - D_1)}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (38)$$

$$n_2 = 1.07 \sqrt{\frac{(D_2 - D_1)\ o}{(D_3 - D_2)\ (D_3 - D_1)}} \quad . \quad . \quad . \quad . \quad . \quad (39)$$

C is located by measuring the distance $n_1 + n_2$ along the D_2 curve from B. The $C.S.$ is located by running the D_1 curve from B the distance $n_1 - t$, and the $S.C.$ is located by running the D_3 curve from C the distance $n_2 - (S_1 - t)$. The spiral is staked out as usual for compound curves.

TABLE 1.—SPIRAL DATA.

D	k = 1°		k = ½°				k = 1°				k = 2°			
	L For other values of k, multiply by $\frac{1}{k}$	Δ For other values of k, multiply by $\frac{1}{k}$	o	X	Y	t	o	X	Y	t	o	X	Y	t
0° 30′	50.0	0° 07.5′	0.04	100.0	0.15	50.0	0.01	50.0	0.04	25.0	0.00	25.0	0.01	12.5
40′	66.7	0° 13.3′	0.09	133.3	0.35	66.7	0.02	66.7	0.09	33.3	0.00	33.3	0.02	16.7
50′	83.3	0° 20.8′	0.17	166.7	0.67	83.3	0.04	83.3	0.17	41.7	0.01	41.7	0.04	20.8
1° 00′	100.0	0° 30.0′	0.29	200.0	1.16	100.0	0.07	100.0	0.29	50.0	0.02	50.0	0.07	25.0
10′	116.7	0° 40.8′	0.46	233.3	1.85	116.7	0.11	116.7	0.46	58.3	0.03	58.3	0.11	29.1
20′	133.3	0° 53.3′	0.70	266.7	2.82	133.3	0.17	133.3	0.70	66.7	0.04	66.7	0.17	33.3
30′	150.0	1° 07.5′	0.98	299.9	3.93	150.0	0.24	150.0	0.98	75.0	0.06	75.0	0.24	37.5
40′	166.7	1° 23.3′	1.35	333.2	5.39	166.7	0.34	166.7	1.35	83.3	0.08	83.3	0.34	41.7
50′	183.3	1° 40.8′	1.80	366.6	7.19	183.3	0.45	183.3	1.80	91.7	0.11	91.7	0.45	45.8
2° 00′	200.0	2° 00.0′	2.33	399.8	9.31	200.0	0.58	200.0	2.33	100.0	0.15	100.0	0.58	50.0
10′	216.7	2° 20.8′	2.96	433.0	11.83	216.7	0.74	216.7	2.96	108.3	0.18	108.3	0.74	54.1
20′	233.3	2° 43.3′	3.69	466.3	14.77	233.2	0.92	233.2	3.69	116.7	0.23	116.7	0.92	58.3
30′	250.0	3° 07.5′	4.54	499.4	18.16	249.9	1.14	249.9	4.54	125.0	0.28	125.0	1.14	62.5
40′	266.7	3° 33.3′	5.51	532.5	22.06	266.6	1.38	266.6	5.51	133.3	0.34	133.3	1.38	66.7
50′	283.3	4° 00.8′	6.61	565.6	26.45	283.1	1.65	283.2	6.61	141.7	0.41	141.7	1.65	70.8
3° 00′	300.0	4° 30.0′	7.84	598.5	31.36	299.8	1.96	299.8	7.85	150.0	0.49	150.0	1.96	75.0
10′	316.7	5° 00.8′	9.22	631.4	36.88	316.4	2.31	316.5	9.22	158.3	0.58	158.3	2.31	79.2
20′	333.3	5° 33.3′	10.75	664.2	43.00	332.9	2.69	333.0	10.75	166.6	0.67	166.7	2.69	83.3
30′	350.0	6° 07.5′	12.45	696.8	49.73	349.5	3.12	349.6	12.46	174.9	0.78	175.0	3.12	87.5
40′	366.7	6° 43.3′					3.58	366.2	14.33	183.2	0.89	183.2	3.58	91.6
50′	383.3	7° 20.8′					4.09	382.7	16.37	191.6	1.02	191.6	4.09	95.8

4° 00′	400.0	8° 00.0′	4.65	399.2	18.59	199.9	1.16	199.9	4.65	100.0
10′	416.7	8° 40.8′	5.26	415.7	21.06	208.1	1.31	208.2	5.26	104.1
20′	433.3	9° 23.3′	5.91	432.1	23.64	216.5	1.48	216.5	5.91	108.3
30′	450.0	10° 07.5′	6.61	448.6	26.45	224.8	1.65	224.8	6.61	112.5
40′	466.7	10° 53.3′	7.37	465.0	29.49	233.0	1.84	233.1	7.37	116.6
50′	483.3	11° 40.8′	8.19	481.2	32.76	241.4	2.05	241.5	8.19	120.8
5° 00′	500.0	12° 30.0′	9.06	497.6	36.25	249.6	2.27	249.7	9.09	125.0
10′	516.7	13° 20.8′	9.99	513.9	39.98	257.8	2.50	257.9	10.02	129.1
20′	533.3	14° 13.3′	10.99	530.0	43.95	266.1	2.76	266.3	11.04	133.3
30′	550.0	15° 07.5′	12.06	546.2	48.15	274.4	3.02	274.6	12.09	137.5
40′	566.7	16° 03.3′	13.16	562.3	52.65	282.6	3.33	282.8	13.32	141.7
50′	583.3	17° 00.8′	14.35	578.0	57.38	290.8	3.60	291.1	14.42	145.7
6° 00′	600.0	18° 00.0′	15.65	594.1	62.41	299.0	3.91	299.3	15.69	149.9
10′	616.7	19° 00.8′					4.26	307.4	17.03	154.0
20′	633.3	20° 03.3′					4.61	315.7	18.44	158.1
30′	650.0	21° 07.5′					4.98	323.9	19.93	162.3
40′	666.7	22° 13.3′					5.37	332.0	21.50	166.4
50′	683.3	23° 20.8′					5.78	340.3	23.14	170.6
7° 00′	700.0	24° 30.0′					6.22	348.4	24.87	174.7
10′	716.7	25° 40.8′					6.67	356.5	26.67	178.9
20′	733.3	26° 53.3′					7.15	364.7	28.58	183.0
30′	750.0	28° 07.5′					7.65	372.8	30.56	187.2
40′	766.7	29° 23.3′					8.16	380.8	32.63	191.3
50′	783.3	30° 40.8′					8.71	389.0	34.81	195.4
8° 00′	800.0	32° 00.0′					9.28	396.9	37.04	199.5
10′	816.7	33° 20.8′					9.89	404.9	39.39	203.6
20′	833.3	34° 43.3′					10.50	412.9	41.83	207.7
30′	850.0	36° 07.5′					11.14	420.8	44.36	211.8
40′	866.7	37° 33.3′					11.81	428.7	47.00	215.9
50′	883.3	39° 00.8′					12.49	436.6	49.73	220.0
9° 00′	900.0	40° 30.0′					13.20	444.4	52.56	224.1
10′	916.7	42° 00.8′					13.94	452.1	55.50	228.2
20′	933.3	43° 33.3′					14.64	460.0	58.55	232.1
30′	950.0	45° 07.5′					15.50	467.7	61.68	236.3
40′	966.7	46° 43.3′					16.33	475.3	64.94	240.4
50′	983.3	48° 20.8′					17.18	483.1	68.29	244.4
10° 00′	1000.0	50° 00.0′					18.05	490.6	71.76	248.4

Problems

1. What is the maximum speed for 10°, 7°, 3°, and 2° curves?

2. Given. *P.I.* at Sta. 741 + 60.0; $I = 35° 42'$; $k = 2°$; and $D = 5° 00'$. Determine the station numbers of the *T.S.*, *S.C.*, *C.S.*, and *S.T.*, and the external distance of the curve.

Answer. *T.S.* = 736 + 65.3, *S.C.* = 739 + 15.3, *C.S.* = 743 + 79.3, *S.T.* = 746 + 29.3.

3. Write transit notes for Problem 4.

4. Compute notes for locating the spiral in Problem 4 by offsets.

5. On new location a 5° 00′ curve is to be offsetted from a 2° 00′ curve at station 333 + 00.0 for a $k = 1°$ spiral. Find the station numbers of the *C.S.* and the *S.C.* and the required offsets. Write notes for spiral.

6. Write notes to locate spiral in Problem 7 by offsets.

7. Given. *P.I.* at Sta. 267 + 00.0; $I = 69° 20'$; $I_1 = 21° 40'$; $I_2 = 47° 40'$; $D_1 = 1° 30'$; $D_2 = 4° 00'$; $k_1 = k_2 = 1°$; $k_3 = 2°$. Find T_{s1}, T_{s2}, and the Sta. numbers of the *T.S.*, *S.C.*, *C.S.*, *S.C.*, *C.S.*, and *S.T.*

Answer. $T_{s1} = 1883.3$, $T_{s2} = 1272.3$, *T.S.* = 248 + 16.7, *S.C.* = 249 + 66.7, *C.S.* = 262 + 11.1, *S.C.* = 264 + 61.1, *C.S.* = 274 + 27.8, *S.T.* = 276 + 27.8.

8. Write transit notes for Problem 9.

11. An existing curve is to be spiraled. $I = 39° 18'$, $D = 3° 20'$, $k = 1°$. The track is to be shifted outward at the middle about 1.0 ft. Find D_1 and the actual value of p.

Answer. $D_1 = 3° 30'$; $p = 1.24$ ft.

9. Given an existing 2° 40′ curve to be spiraled by compounding near the ends with a 3° 00′ curve. The *T.C.* is at Sta. 66 + 66.6 and $k = 1°$. Find the station number of the *T.S.*, *S.C.*, and *C.C.*, and the amount that the track will be shortened.

Answer. *T.S.* = 65 + 47.1, *S.C.* = 68 + 47.1, *C.C.* = 69 + 42.0. The track is shortened 0.1 ft.

10. An existing compound curve has its *C.C.* at Sta. 488+ 50.0. $D_1 = 4° 00'$, $D_2 = 7° 00'$, $D_3 = 7° 40'$, and $k = 1°$. Find the station numbers of the *C.S.*, *S.C.*, and *C.C.*

Answer. *C.S.* = 487 + 16.5, *S.C.* = 490 + 83.3, *C.C.* = 491 + 24.3.

CHAPTER V

EARTHWORK

Introduction

92. Railroad Cross-Sections. The forms of earthwork cross-sections in cut, fill, and side-hill work (both cut and fill) are shown in Figs. 29, 30, and 31, respectively. Fig. 32 shows the form a section in cut should take when it consists partly of earth and partly of rock.

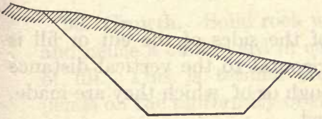

FIG. 29.

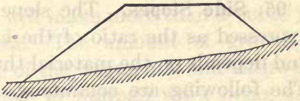

FIG. 30.

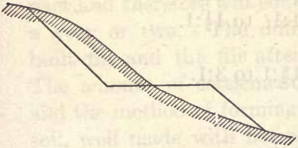

FIG. 31.

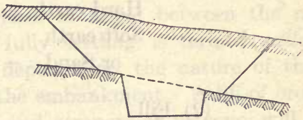

FIG. 32.

93. Width of Roadbed. The width of roadbed for single track on fill varies from 14 to 22 feet, and in cut from 20 to 33 feet. However, the best practice is 18 or 20 feet on fill and 28 or 30 feet in cut. The greater width in cut is required to allow for side ditches for drainage.

For double track add to the above quantities the distance between track centers.

94. Ditches. In order to provide drainage in cuts side ditches are constructed on each side of the track. The ditches should be of such cross-section that they can be easily constructed and maintained and not easily obstructed. For these reasons broad shallow ditches are better than narrow deep ones. The usual width of ditches is from 3 to 6 feet, depending on the size of the cut and the amount and rate of rainfall.

Where there is considerable ground water it may be necessary to construct tile sub-drains under one or both of the side ditches.

When there is likelihood of considerable surface water draining on to the roadbed, as for example in side-hill work, an open diversion ditch, termed a surface ditch, should be constructed outside the cut to carry this water to the end of the cut.

Side ditches are more expensive to excavate than the body of the cut, and therefore should preferably be included as a separate item in the contract.

95. Side Slopes. The slope of the sides of the cut or fill is expressed as the ratio of the horizontal to the vertical distance and depends on the material through or of which they are made. The following are commonly used.

(1) Cut

Solid rock – vertical or $\frac{1}{4}$:1.
Loose rock – $\frac{1}{4}$:1 to 1:1.
Hard earth – 1:1 to $1\frac{1}{2}$:1.
Soft earth
or Sand – $1\frac{1}{2}$:1 to 3:1.

(2) Fill

Loose rock – 1:1.
Earth – 1:1 to $1\frac{1}{2}$:1.
Sand – $1\frac{1}{2}$:1 to 2:1.

96. Borrow Pits. It frequently happens that the earth from the adjacent cuts is not sufficient to make the intervening fill. In this case the contractor is allowed to *borrow* earth from along the right of way. The pits thus dug are called *borrow pits,* and are staked out by the engineer before the work is started. In staking out borrow pits care should be taken to leave a berm of at least 5 ft. between the foot of the embankment and the edge of the borrow pit; a similar berm should also be left at the edge of the right of way. The contractor is required to leave all borrow pits in such a shape that water will not collect in them.

97. Shrinkage. Some soils become more compact when thoroughly compressed in an embankment than they were originally, and therefore a cubic yard of cut will *ultimately* make less than a cubic yard of fill. This does not take place until a year or two after the fill is made. This reduction of volume is called *shrinkage*. The amount of shrinkage varies with the kind of soil and hence the allowance for shrinkage should be left to the judgment of the engineer in the field and should not be made part of an arbitrary set of standards. *Very few soils will shrink as much as 3 per cent.*

98. Growth. Solid rock will increase in volume on excavation and hence a cubic yard in cut will make more than a cubic yard of fill. This is termed *growth*. The amount of growth depends on the uniformity of size of the fragments, and varies from 30 to 100 per cent., the average in railroad work being about 50 per cent.

99. Settlement. A newly built fill is never thoroughly compact and therefore will continue to settle for some time, possibly a year or two. The difference in *height* between the newly-built fill and the fill after fully settling is termed *settlement*. The amount of settlement depends on the nature of the soil and the method of forming the embankment. A fill of ordinary soil, well made with horses and scrapers or wagons, will settle about 5 per cent.; if simply dumped from a trestle, the settlement is greater and in some cases may reach 15 per cent. A rock fill will settle but little.

Allowance for settlement is made in the field by marking on the slope stake the theoretical fill plus the allowance for settlement. For example, if the fill is 10 feet and the settlement is 5 per cent., the slope stake is set at the proper point for a fill of 10 feet, *but is marked* F 10.5.

Shrinkage and settlement are frequently confused, but it is to be noted that *settlement includes shrinkage*, and that the allowance in the field is for settlement.

If a fill is short and high the full allowance for settlement may make a hump in the grade line which may be very objectionable from the standpoint of operation. Of course this hump would ultimately disappear, but it may be preferable to avoid the hump by reducing the allowance for settlement and later to bring the track up to grade by the addition of ballast.

In case a bridge is placed in a high fill, the full allowance for settlement can not be made at this point. Extra care should be taken to compact the fill immediately behind the abutments in order to reduce the amount of settlement, and the track should be carefully maintained at these points until the embankment is fully settled.

Cross-Sectioning

100. Slope Stakes. Before construction work can be commenced, slope stakes must be set for the guidance of the contractor (1) at every full station, (2) at those intermediate points where the longitudinal slope of the ground changes, and (3) at other points required by special structures.

A *slope stake* is a stake that is set on each side of the center line at the point where the side slope of the cut or fill will intersect the ground surface. It has the cut or fill at that point (see settlement) marked on one side and the station number on the other. The numbers are written lengthwise of the stake beginning at the top, and the cut or fill is given in feet and tenths, prefixing *C* for cut and *F* for fill (see Fig. 33). The stakes are driven with the tops slanting outward, and the sides upon which the cuts or fills are marked facing the roadbed, as shown in Fig. 33.

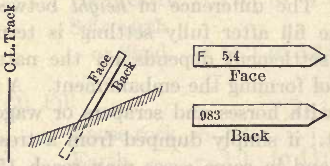

FIG. 33.

101. Cross-Sectioning. Cross-sectioning consists in setting the slope stakes, which mark the limits of excavation or embankment, and in taking sufficient elevations between the slope stakes to compute the area of the section to be excavated or filled in.

The data needed for cross-sectioning are the sub-grade elevation at every station, the width of the roadbed in both cut and fill, the side slopes for different materials, and the elevations of all bench marks. The sub-grade elevation for every station on the entire line can be obtained from the profile and should be written in the cross-section notebook opposite its station—as shown in the form of notes in Fig. 34—and carefully checked before any cross-sectioning is done. Also the description and elevation of every bench mark that was established during the location should be written in the back of the notebook.

102. Field Work. Starting with the nearest bench mark, differential levels are run to the part of the line that is to be cross-sectioned. The back sights, fore sights, heights of instrument, and elevations of turning points are recorded in the second column of the notes in such a way that the *H.I.* will be in the same line as the first station cross-sectioned from that set-up (see Fig. 34). The sub-grade elevation in the third column is subtracted *algebraically* from the *H.I.* elevation in the second column and the difference is the *grade rod* and is recorded in the fourth column. A rod reading is then taken to the nearest tenth of a foot *on the ground* at the foot of the center stake. *All the rod readings are considered negative.* The rod reading and the grade rod are added *algebraically* and the sum represents the cut or fill at the point where the reading is taken, *minus* indicating fill and *plus* indicating cut. The cut or fill is marked on the back of the center stake and is recorded in the notes as the numerator of a fraction whose denominator is zero.

If the ground is level transversely of the line, the cut or fill at the slope stake will be the same as at the center, and the distance from the center stake to the slope stake is found by multiplying the center cut or fill by the ratio of the side slopes and adding one half the width of the roadbed. Such a section is called a *level section* (see Fig. 35a).

If the ground is not level transversely, the cut or fill will be different for various points, and the problem is to find the point on each side of the center line whose distance from the center is

CROSS-SECTION NOTES.

Station.	Turning Points.	Grade.	Grade Rod.	L.	C.	R.
55	740.51 −11.63 728.88 +0.72	727.50	13.0	+9.0 / 27.5	+9.8 / 0	+10.2 / 29.3
56		727.00	13.5	+7.3 / 25.0	+7.3 / 0	+7.8 / 25.7
57		726.50	14.0	+5.5 / 22.3	+6.0 / 0	+6.4 / 23.6
58		726.00	14.5	+4.2 / 20.3	+4.4 / 0	+4.4 / 20.6
59	729.60 −10.54 719.06 +2.53	725.50	4.1	+2.2 / 17.3	+2.7 / 0	+ 3.4 / 19.1
10560		725.00	4.6	+1.0 / 15.5	+1.2 / 0	+ 1.4 / 16.1
				Grade Point +65		
61		724.50	5.1	−1.2 / 10.8	−0.6 / 0	− 0.8 / 10.2
62		724.00	5.6	−3.2 / 13.8	−2.4 / 0	− 2.1 / 12.2
63		723.50	6.1	−4.8 / 16.2	−3.8 / 0	− 3.5 / 14.3
64		723.00	6.6	−6.0 / 18.0	−5.2 / 0	− 5.0 / 16.5
65	721.69	722.50	0.8	−6.8 / 19.2	−6.6 / 0	− 6.6 / 18.9
66		722.00	0.3	−8.5 / 21.8	−7.8 / 0	− 7.0 / 19.5

FIG. 34.

End Areas.		Volumes.		Mass Curve Volumes.
Cut.	Fill.	Cut.	Fill.	
412.7				3653
		1303		
290.8				2350
		948		
221.0				1402
		687		
150.2				715
		442		
88.3				273
		230		
35.8				43
0.0	0.0	43		
			10	00
	15.3			
			130	10
	55.0			
				140
			278	
	95.3			418
			434	
	139.2			852
			602	
	186.0			1454
			772	
	230.8			2226

FIG. 34.

equal to the cut or fill at that point multiplied by the slope ratio and added to one-half the roadbed. This is necessarily a cut-and-try method, but proficiency is soon attained in approximating the correct position of the slope stake, and it is seldom that more than three trials are required. The cut or fill is marked

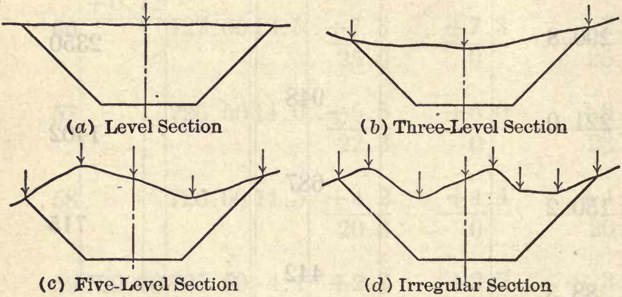

FIG. 35.

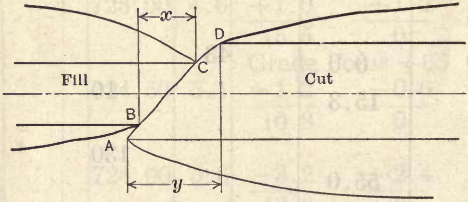

FIG. 36.

on the slope stake and is recorded in the notebook as the numerator of a fraction whose denominator is the distance out from the center. *Three-level, five-level,* and *irregular sections* come under this heading (see Figs. 35b-c-d).

103. Sections at Grade Points. Fig. 36 shows the junction between a cut and a fill. Stakes, marked "grade," are driven at *A*, *B*, *C*, and *D*, which are grade points. A cross-section is taken at *B* and *D*, and the distances x and y are measured.

Areas of Cross-Sections

Before the volume of earthwork can be computed, the area of each cross-section must be found. This is done as follows:

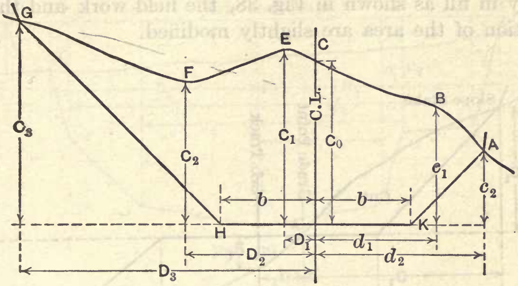

FIG. 37.

The cuts at *A*, *B*, *C*, *E*, *F*, and *G* (*i.e.*, the vertical distances from the ground surface to the level of the roadbed), and the distances of these several points from the center, *C*, have been recorded in the field notebook. To each section annex the fraction $\frac{0}{b}$ and write plus and minus signs on each side of each numerator, thus:

$$\frac{0}{b} \quad \frac{+C_3-}{D_3} \quad \frac{+C_2-}{D_2} \quad \frac{+C_1-}{D_1} \quad \frac{+C_0+}{0} \quad \frac{-c_1+}{d_1} \quad \frac{-c_2+}{d_2} \quad \frac{0}{b}$$

RULE 1.—To find the area (1) multiply each denominator by the algebraic sum of its adjacent numerators, using the sign facing the denominator; and (2) divide the algebraic sum of the resulting products by 2.

$$\text{or,} \quad \text{Area} = \frac{1}{2}\left[\begin{array}{l} b(C_3+c_2)+D_3C_2+D_2(C_1-C_3)+ \\ D_1(C_0-C_2)+d_1(C_0-c_2)+d_2c_1 \end{array}\right]. \quad (40)$$

(Let the student prove this equation.)

After the student becomes familiar with this formula, it will not be necessary for him to actually write down the plus and minus signs in the notes.

Eq. (40) can be used for either cut or fill, and for *level, three-level, five-level,* and *irregular sections.*

104. Side-hill Sections. When a section is partly in cut and partly in fill as shown in Fig. 38, the field work and the computation of the area are slightly modified.

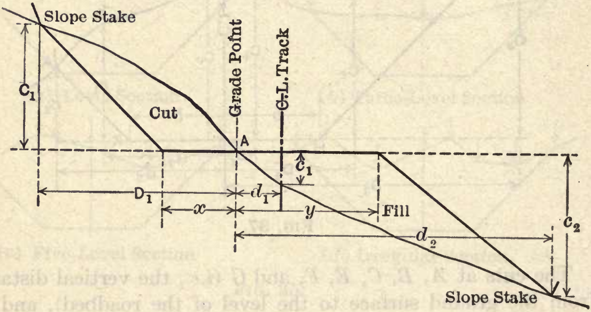

FIG. 38.

In this case, after the fill at the center has been determined, the *grade point, A,* is found by trial. Then *all horizontal distances are measured from A.* The notes would be recorded as follows:

$$\frac{0}{x} \qquad \frac{+C_1-}{D_1} \qquad \frac{+0+}{0} \qquad \frac{-c_1+}{d_1} \qquad \frac{-c_2+}{d_2} \qquad \frac{0}{y}$$

<- - - Cut - X - - - - - - - - - Fill - - - - - ->

Notice that x and y are used as the denominators of the annexed fractions instead of b as in the former case.

The areas of the cut and fill are computed separately, and are recorded *separately* in the notes (see Fig. 34).

105. Uncompleted Sections. It is sometimes necessary to find the area of an uncompleted section—for example, for monthly estimates—or of an irregular-shaped borrow pit. The field work for this does not require that elevations be carried from station to station, but *at each set-up the plane of the horizontal line of sight is taken as the reference plane.* For example, in Fig. 39, AB is the reference plane whose elevation is not

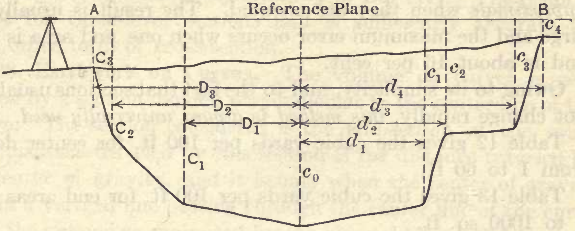

FIG. 39.

necessary for the determination of the area of the section. The notes should be written thus:

$$\frac{+c_4-}{0} \quad \frac{+C_3-}{D_3} \quad \frac{+C_2-}{D_2} \quad \frac{+C_1-}{D_1} \quad \frac{+C_0+}{0} \quad \frac{-c_1+}{d_1}$$

$$\frac{-c_2+}{d_2} \quad \frac{-c_3+}{d_3} \quad \frac{-c_4+}{d_4} \quad \frac{-C_3+}{0}$$

Notice carefully the end fractions annexed in this case. The area is found by Rule 1.

Volumes of Earthwork

Earthwork is paid for by the cubic yard, and in order to compute the cost it is necessary to find the volume of the material handled. The total volume is the sum of the volumes of the *prismoids* formed by adjacent cross-sections. The volume of the prismoid between two adjacent cross-sections may be found (1) by the end area method, and (2) by the prismoidal method.

106. End Area Method. In this method the prismoid is treated as a *prism*, whose cross-section is the mean of the two end areas of the prismoid.

$$v \text{ (cu. yds.)} = \frac{l}{27} \times \frac{A_1 + A_2}{2} \quad . \quad . \quad . \quad . \quad . \quad (41)$$

where v is the volume, A_1 and A_2 the end areas in sq. ft., and l is the distance between cross-sections in feet.

For l = 100 ft.,

$$v = 1.85\,(A_1 + A_2) \quad . \quad . \quad . \quad . \quad . \quad . (41a)$$

This method is *exact* when the end areas are equal, but is only *approximate* when they are unequal. The result is usually too large and the maximum error occurs when one end area is zero, and is about 16 per cent.

Owing to its simplicity, and to the fact that sections usually do not change rapidly, *this method is almost universally used.*

Table 12 gives the cubic yards per 100 ft. for center depths from 1 to 60 ft.

Table 13 gives the cubic yards per 100 ft. for end areas from 1 to 1000 sq. ft.

107. Prismoidal Method. When the changes from cut to fill are frequent and abrupt or the work is in rock, greater accuracy may be required; in this case the prismoidal method is used.

From Simpson's rule,

Mean area of a prismoid $= \dfrac{A_1 + 4A_m + A_2}{6}$, where A_1 and A_2 are the end areas and A_m the area of a section midway between the ends. Then,

$$v = \frac{l}{27} \times \frac{A_1 + 4\,A_m + A_2}{6} \quad . \quad . \quad . \quad . \quad . \quad . \quad (42)$$

This is called the *prismoidal formula.* This form however is inconvenient to use since it requires the area of a mid-section. It is therefore more convenient to find the difference between the prismoidal and end area formulas and to apply this difference to the latter. Subtracting the prismoidal formula from the end area formula and reducing,

$$\text{Prismoidal Correction} = \frac{l}{81}\,(A_1 - 2A_m + A_2)$$

Putting A_1, A_2, and A_m in terms of their slope stake dimensions—remembering that the dimensions of A_m are the average of those of A_1 and A_2—and reducing, we have

$$\text{Pris. Cor.} = \frac{l}{12 \times 27}\,(C_1 - C_2)\,(W_2 - W_1) \quad . \quad . \quad . \quad (43)$$

in which C_1 and C_2 are the center cuts or fills at A_1 and A_2, and W_1 and W_2 are the corresponding distances between slope stakes.

When $l = 100$ ft., Pris. Cor. $= 0.31\ (C_1 - C_2)\ (W_2 - W_1)$ (43a)

This correction is added *algebraically* to Eq. (41). The result is exact for three-level sections and is sufficiently accurate for any other form of cross-section.

108. Earthwork on Curves. The volume on curves is generated by a section moving perpendicular to the center line of the curve. The section considered is the *mid-section* of the solid. The distance traveled by this section is the distance traveled by its center of gravity, and it is only when the center of gravity lies in a vertical line passing through the center line of the curve that the volume as computed by the prismoidal method is exact. If the center of gravity is inside the center line, the results obtained by the prismoidal method are too large; if outside, they are too small. The difference between the true volume and the volume determined by the prismoidal method is called the *curvature correction.*

If the volumes are computed by the end area method, it is inconsistent to apply the curvature correction; but if the prismoidal method is used, the curvature correction should be applied, especially in rock work.

The curvature correction is computed as follows:

Fig. 40 represents the *mid-section* of the solid. Construct

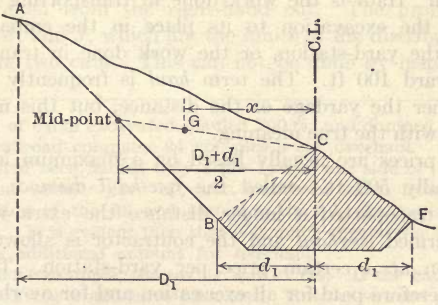

FIG. 40.

BC with the same slope as *CF*. Then the center of gravity of the part shown shaded is in a vertical line through *C* and therefore there is no correction to be applied to this portion. The center of gravity of the triangle *ABC* is at *G*, which is the distance *x* from the center, *C*.

The volume generated by the triangle *ABC* is

$$v = ABC \times (R + x) \times I$$

in which *I* is the angle at the center expressed in radians.

The volume computed by the prismoidal method is

$$v_1 = ABC \times R \times I$$

The curvature correction then is

$$C.\,C. = v - v_1 = ABC \times x \times I$$

But $x = \frac{2}{3} \times \frac{1}{2} \times (D_1 + d_1)$. Substituting this value of *x* and expressing *I* in degrees, we have

$$C.\,C. = 0.006\,ABC \times (D_1 + d_1) \times I°. \quad . \quad . \quad . \quad . \quad (44)$$

For 100 ft., *I* becomes *D*, the degree of the curve.

Haul and Overhaul

109. Haul. Haul is the work done in transporting the material from the excavation to its place in the embankment. Its unit is the yard-station, or the work done in transporting one cubic yard 100 ft. The term *haul* is frequently used to indicate either the yardage or the distance, but this must not be confused with the true meaning.

Contract prices are usually based on a maximum length of haul—generally 500 ft.—called the *free-haul distance.* If the material is transported a longer distance the extra work involved is termed *overhaul* and the contractor is allowed extra compensation at a certain price per yard-station. The contractor is therefore paid for all excavation and for overhaul, but *he is not paid for making the fills nor for haul inside the free-haul distance.*

The amount of excavation is readily determined from the cross-section notes, hence this portion of the contractor's remuneration presents no particular difficulties except when the excavation involves several different kinds of materials to be paid for at different prices. The amount of overhaul, however, depends on the plan of distributing the excavated material, and the problem is to determine an economical distribution. This problem is not of great difficulty, but unfortunately it has often been neglected, resulting in uneconomical work, misunderstandings with the contractor, and frequent law-suits.

The limit of *profitable haul* is that distance at which the cost of overhaul equals the cost of excavating a yard of earth. For example, if the contract price is 24 cents a yard for excavation and $1\frac{1}{2}$ cents a yard-sta. for overhaul, and the free-haul distance is 500 ft., the limit of profitable haul is $\frac{24}{1\frac{1}{2}} + 5 = 21$ Sta.*

110. Case 1. Fig. 41 represents a fill between two cuts. It is readily seen that there is more than enough earth in the cuts to make the fill, and the question is how much of the fill shall be made from each cut.

The points *B* and *D* are the free-haul distance apart and are located on the profile so that the volume of cut between *B* and *C* equals the volume of fill between *C* and *D*. *F* and *H* are similarly located with respect to *G*.

Since the cut to the right is the deeper, it is evident that the fill can be made with the minimum haul if the greater volume of earth is taken from the right-hand cut. The problem is to locate *A*, *E*, and *J*, which are the limits of the distribution from each of the two cuts. This can not be done by inspection nor

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* A yard of earth excavated, hauled 700 ft., and dumped into the fill costs the railroad company 24 cts. plus 3 cts. overhaul. If the yard excavated had been hauled only a few feet to one side of the cut and dumped, and *another* yard of earth had been taken from a borrow pit along side of the fill and placed in the fill, the cost would have been 48 cts. It is evident then that it is much cheaper for the railroad to pay the additional amount for overhaul.

In the above example, the saving was 21 cts. If the haul had been longer, the saving would have been less. But *the railroad saves money up to the point where the cost of overhaul equals the cost of making a yard of fill from a borrow pit.* Beyond this point there is an increasing loss, and when twice the limit of *profitable haul* is reached, this loss equals the previous saving. *The limit of profitable haul is considered as that distance at which the profit is the largest.*

can it be accomplished easily from the cross-section notes. It can be done most easily and accurately by constructing a *distribution diagram.*

The first step in making the distribution diagram is to construct the *mass curve,* which is done in the following manner:

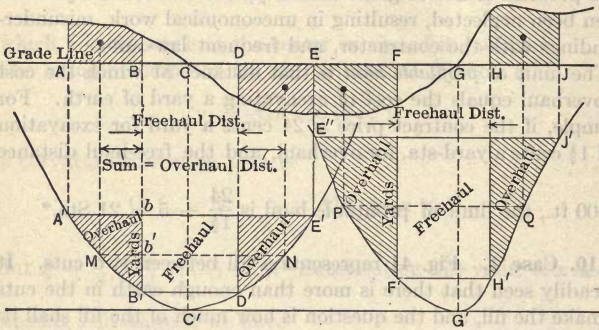


FIG. 41.

Choose a horizontal base line near the bottom of the profile sheet, and project the grade points C and G onto it at C' and G' as shown in Fig. 41.

Then beginning at C' plat to the chosen scale—usually 1,000 cu. yds. to the inch—a curve such that the ordinate to it at any point is equal to the total volume of earthwork between that point and C'. From G' plat a similar curve to the same scale. The ordinates to these curves are computed at the regular stations from the cross-section notes. Allowance for shrinkage or growth must be made by increasing the fill volumes by the amount of shrinkage or decreasing them by the amount of growth.

The second step is to determine the limits of free haul. This is done by locating a horizontal line equal in length to the free-haul distance in such a position that its ends are in the mass curve as at $B'D'$ and $F'H'$. These points are projected up to locate B, D, F, and H. The ordinate to $B'D'$ is the free-haul yardage past C, and the ordinate to $F'H'$ is the free-haul yardage past G.

The third step is to find the positions of A, E, and J so that the haul will be a minimum. For all practical purposes this occurs when $AE = EJ$. Therefore in the distribution diagram find by trial the positions of the two horizontal lines $A'E'$ and $E''J'$ of equal length, with E' and E'' on the same vertical line. These points are projected onto the profile to locate A, E, and J. These points should be located in the field and distinctly marked for the guidance of the contractor.

The ordinates between $B'D'$ and $A'E'$ and also between $F'H'$ and $E''J'$ give the total volumes on which there is an overhaul charge. The total volume moved is given by the ordinates from the base line to $A'E'$ and $E''J'$.

Since the mass curve is a curve between distance and total volumes, it follows that the area inside the curve represents *haul* in yard-stations. Consequently the *overhaul* is given by the shaded portion between the curves and the lines $A'E'$ and $E''J'$.

If the ordinate $B'b$ is bisected—dividing the overhaul yardage into two equal parts—and the horizontal line MN is drawn, the two points M and N will be directly under the centers of mass of the cut and the fill. Therefore MN minus the free-haul distance is the overhaul distance corresponding to $B'b$; and the overhaul can be found by multiplying $B'b$ by this distance. This method is frequently easier of application than that of determining the areas direct. The overhaul past G can be determined similarly.

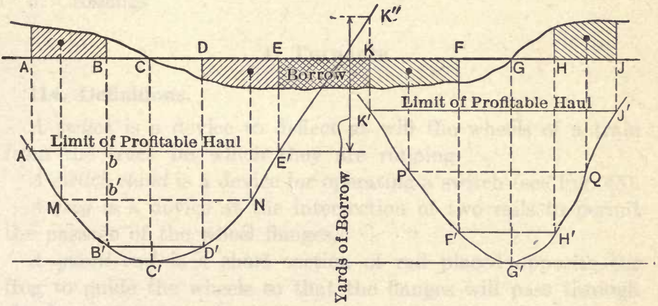


FIG. 42.

111. Case 2. In Fig. 42, C and G are so far apart and the cuts are so long that it is evident that the limit of profitable haul will be reached. Construct the mass curve and locate the free-haul limits as before. Lay of $A'E'$ and $K'J'$ each equal to the limit of profitable haul. The centers of mass, M, N, P, and Q, are found as in Case 1. The points A', E', K', and J' projected onto the profile give the points A, E, K, and J, which should be marked in the field.

The fill between E and K must be borrowed and the yardage required is given by the difference of the ordinates to E' and K''. The amount of overhaul is determined as in the former case. The complement of this case is the determination of waste in a long cut.

112. Case 3. In case earth can not be moved past some point, the distribution diagram is constructed as before except that the horizontal distribution lines ($A'E'$ and $E''J'$ in Fig. 41) must start at the fixed point. The remainder of the work is done as before. This condition frequently occurs—usually at stream crossings.

CHAPTER VI

TURNOUTS, CONNECTIONS, AND CROSSINGS

113. The subjects treated in this chapter are as follows.

1. Turnouts
   - Switches
   - Frogs
2. Connections
   - Diverging Tracks
     - From Tangents
     - From Curves
   - Parallel Tracks
     - Sidings
       - From Tangents
       - From Curves
     - Crossovers
       - From Tangents
       - From Curves
   - Intersecting Tracks
     - Tangents
     - Curves
3. Crossings

1. Turnouts

114. Definitions.

A switch is a device to deflect at will the wheels of a train from the track on which they are running.

A switch stand is a device for operating a switch (see Fig. 45).

A frog is a device at the intersection of two rails to permit the passage of the wheel flanges.

A guard rail is a short section of rail placed opposite the frog to guide the wheels so that the flanges will pass through the frog properly.

A turnout is a combination of a switch, a frog, and the necessary connecting rails, etc., to permit rolling stock to pass from one track to another (see Fig. 45).

A siding is a secondary track parallel to the main track which is used for the storage of rolling stock or for the passing of trains.

It is connected to the main track by a turnout at one or both ends.

A crossover is a connection at an intermediate point between two parallel adjacent tracks (see Fig. 45).

115. Switches. Switches are of three types, viz., Split Switches, Tongue Switches, and Stub Switches.

The *Split Switch*, Fig. 43a, is the form universally used on steam roads. It consists of two wedge-shaped sections of rails connected by tie rods and sliding on metal plates placed on the ties. The broad end or *heel* of each point rail acts as a pivot by being fastened to the lead rails by means of the usual splice bars. The *point* moves through a distance of about $5\frac{1}{2}$ inches, which is called the *throw* (t), and is controlled by a switch stand placed outside the track on a long tie (sometimes two) called a *head-block.* The distance between the gage lines at the heel is called the *heel spread* (h). The angle between the gage lines of the switch and the main rail is called the *switch angle* (s). The width of the point is usually $\frac{1}{4}''$ (when new). From Fig. 43a it is seen that

$$\sin s = \frac{h - p}{l} \qquad (45)$$

where p is the width of the point, and l the length of the switch rail. Split switches vary in length from 10 to 33 feet, depending on the flatness of the turnout desired. The point rails are cut from rails of standard length so as to have no waste. For 30-ft. rails, 10, 12, 15, 18, 20, and 30-ft. switch points are used, and for 33-ft. rails, 11, 13, $16\frac{1}{2}$, 20, 22, and 33-ft. The most common lengths are 15 and $16\frac{1}{2}$ ft.

The *Tongue Switch*, Fig. 43b, consists of a steel wedge or tongue pivoted at one end and moving in a heavy cast-iron frame so arranged that pavement may be built around it. This is the common form on street railways, where it is usually used singly with a rigid fitting called a *mate* in the opposite rail. Steam roads use them only for turnouts in pavement, and then usually in pairs, where the action is the same as in a split switch.

A *Stub Switch*, Fig. 43c, consists of a pair of ordinary rails fastened together with tie rods. The rails are spiked for part of their length, the remainder being thrown to match the stub ends of the lead rails. A stub switch differs from a split switch in that the toe is fixed and the heel moves. This form of switch may be

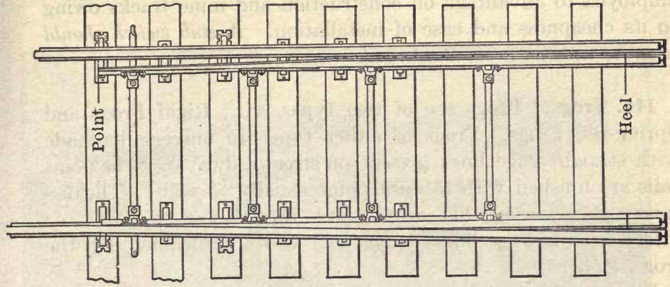


FIG. 43a.

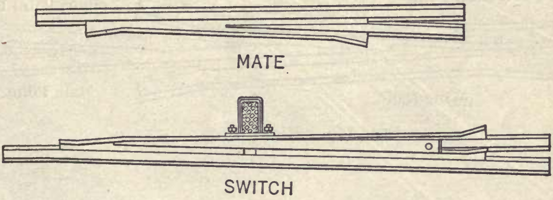


FIG. 43b.

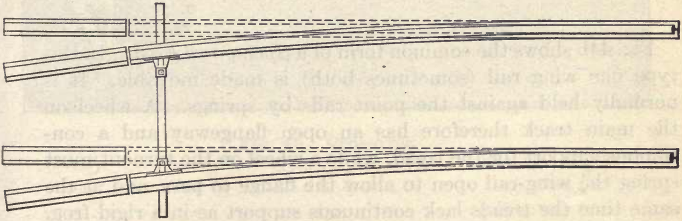


FIG. 43c.

employed to advantage on construction and mine tracks owing to its cheapness and ease of installation. *A stub switch should never be used on a standard road.*

116. Frogs. Frogs are of two types, viz., Rigid Frogs and Spring-rail Frogs. Frogs of either type are universally made with straight gage lines (except on street railways). The point rails are finished with a blunt point usually $\frac{1}{2}''$ wide. The distance P between this *actual* and the *theoretical point* or intersection of gage lines equals the width multiplied by the frog number.

Fig. 44a shows the common form of *rigid frog* and the names of the various parts. The essential feature of the rigid frog is that both flangeways are open and must be jumped by passing wheel treads.

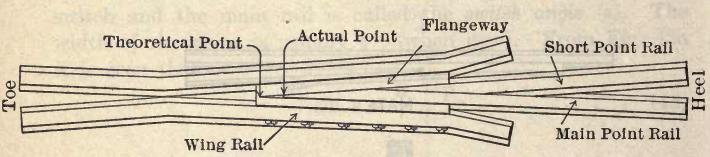


FIG. 44a. Rigid Frog.

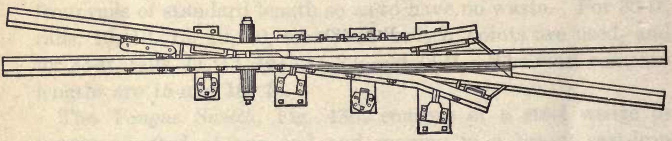


FIG. 44b. Spring-rail Frog.

Fig. 44b shows the common form of a *Spring-rail Frog.* In this type one wing rail (sometimes both) is made movable. It is normally held against the point rails by springs. A wheel on the main track therefore has an open flangeway and a continuous support for the tread, while a wheel on the turnout must spring the wing-rail open to allow the flange to pass, and at the same time the treads lack continuous support as in a rigid frog. *Guard rails are absolutely essential to the safe operation of a spring-*

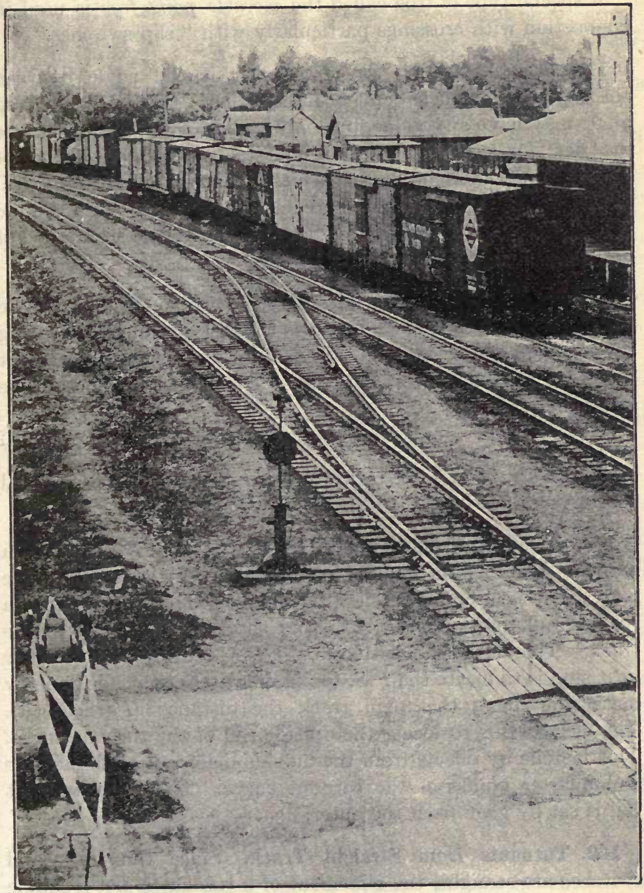


FIG. 45. Crossover.

rail frog. Spring-rail frogs are used on main track turnouts, and rigid frogs in yards.

A special type of frog called the *movable point frog* is used in connection with crossings particularly with "slip switches."

117. Frog Angle, F. The *frog angle* is the angle between the gage lines at their point of intersection. Obviously the frog angle may have any value, but only values of about 2° to 8° are practical for turnouts. For turnouts a few standard values of the frog angle can be chosen which will meet all the practical requirements. These angles are chosen to agree with simple values of the *Frog Number* which is a more convenient method of designating frogs than by their angles.

118. Frog Number, N. The *Frog Number* is the ratio of the axial length to the spread, *i.e.*, it is the distance measured along the bisector of the angle in which the gage lines diverge a unit distance. Reducing this ratio to a trigonometric function we have,

$$N = \tfrac{1}{2} \cot \tfrac{1}{2}F \quad . \quad . \quad . \quad . \quad . \quad (46)$$

Values of N from 7 to 15 are commonly used, but for special purposes values from 3 to 27 are occasionally used.

119. Location of Turnouts. The first step in staking out a turnout (whether on straight or curved track) is to locate the frog. The heel or toe of the frog should come, if possible, at a regular rail joint in order to avoid short pieces of rail in the track. This fixes the position of the *P.F.* (point of frog). The next step is to locate the *P.S.* (point of switch), which is done by measuring along the main track the distance L (the lead). The next step is to locate the outside rail of the turnout curve. This is done by offsets from the outside main rail at the middle and quarter points of the turnout curve. The inner turnout rail is set by gage from the outer.

120. Turnouts from Straight Track. Since the frogs and switches are straight, the alinement of a turnout is not a simple curve from a tangent, but consists of two short pieces of tangent making a fixed angle with the main track rails connected by a curve.

In triangle 1, Fig. 46, the hypotenuse and angles are known. Solve for m and n. In triangle 2, $q = g - h - n$ and the angles are known. Solve for j and c. c is the chord of the outside lead rail and the central angle $(F-s)$ is known, hence the radius of the outside rail is

$$R + \tfrac{1}{2}g = \frac{c}{2 \sin \frac{1}{2}(F-s)} \quad . \quad . \quad . \quad . \quad . \quad (47)$$

The distance along the straight track from the *P.F.* to the *P.S.* is called the *lead*, *L*. From the figure

$$L = l + j + m + P \quad . \quad . \quad . \quad . \quad . \quad (48)$$

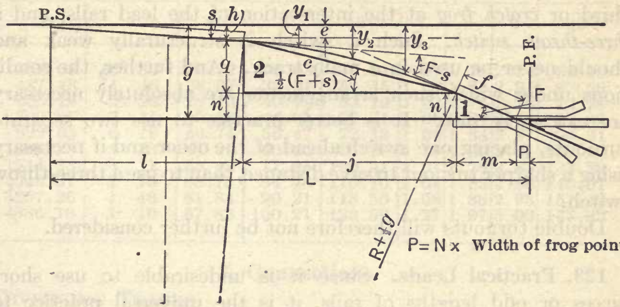


FIG. 46.

To compute the offsets for the lead rail, consider its gage line produced back to a tangent parallel to the main rail. The distance between these tangents is

$$e = h - (R + \tfrac{1}{2}g) \text{ vers } s$$

The offset from the main rail to the quarter point of the lead rail is then,

$$\left.\begin{array}{ll} y_1 = e + (R + \frac{1}{2}g) \text{ vers } [s + \frac{1}{4}(F - s)] & \text{(Slide Rule)} \\ \text{For the middle point,} & \\ y_2 = e + (R + \frac{1}{2}g) \text{ vers } [s + \frac{1}{2}(F - s)] & \text{“ \quad “} \\ \text{For the three-quarters point,} & \\ y_3 = e + (R + \frac{1}{2}g) \text{ vers } [s + \frac{3}{4}(F - s)] & \text{“ \quad “} \end{array}\right\} (49)$$

121. Turnouts from Curved Track. It can be shown (the solution is too involved to be included here) that the lead of a turnout from a curved track is almost identical with the lead of a turnout from straight track with the same frog number. And further, that the degree of curve of the lead rails is equal to the degree of curve of the turnout from straight track increased or diminished by the degree of the main curve depending on whether the turnout is on the inside or the outside of the main curve.

Therefore a turnout on a curve is staked out with the same dimensions as one with the same frog number on straight track.

122. Double Turnouts. Occasionally two turnouts to opposite sides of the main track are located at the same point. This involves the use of two regular frogs in the main rails, a third or *crotch frog* at the intersection of the lead rails, and a *three-throw switch.* Such a switch is structurally weak and should never be used in a main track. And further, the conditions under which such arrangements are absolutely necessary are extremely rare. It is better practice to use two separate turnouts, placing one switch ahead of the other and if necessary using a sharper turnout to save distance, than to use a three-throw switch.

Double turnouts will therefore not be further considered.

123. Practical Leads. Since it is undesirable to use short pieces or odd lengths of rails, it is the universal practice to modify the theoretical leads as computed above (Eq. 48), so as to use convenient lengths of lead rails. The difference between the theoretical leads and the practical leads is never very great, and the turnout is located as above except for this modification in the lead. This has the effect of changing the turnout curve from a true circle, but the amount is inappreciable. There is also a difference in the length of the straight and the curved lead rails. The best practice is to correct this by making the toe length of the frog on the turnout side longer than on the main-track side.

Every railroad has its standard turnouts, all dimensions of which are worked out and tabulated. The turnouts are then installed by the trackmen, the only duty required of the engineer being to locate the *P.F.* and occasionally the *P.S.* The engineer therefore has little occasion to use the functions of the turnout proper. His problem is to connect the turnout to the required track.

Table 2 gives the practical switch leads recommended by the American Railway Engineering Association; also the rectangular co-ordinates to the quarter and center points on the gage side of the curved rail, referred to the point of switch as origin.

TABLE 2

Practical Leads as Recommended by the American Railway Engineering Association

Frog Number	Radius of Center Line	Degree of Lead Curve	Rectangular Co-ordinates to the Quarter and Center Points on Gage Side of Curved Rail, Referred to Point of Switch as Origin						Lead—Distance from Actual P.S. to Actual P.F.
1	2	3	4	5	6	7	8	9	10
7	362.08	15° 52′	26.72	36.93	47.11	0.97	1.71	2.74	62.10
8	487.48	11 46	28.37	39.91	51.45	1.02	1.78	2.91	67.98
9	605.18	9 29	28.75	40.98	53.19	1.02	1.76	2.75	72.28
10	790.25	7 15	30.28	44.05	57.81	1.06	1.84	2.85	77.93
11	922.65	6 13	40.74	56.47	72.19	1.08	1.84	2.87	94.31
13	1098.73	5 13	43.99	60.65	77.28	1.15	1.90	2.91	100.90
15	1744.38	3 17	55.49	77.95	100.41	1.01	1.78	2.85	133.28
18	2546.31	2 15	58.73	84.46	110.10	1.04	1.82	2.86	146.51
20	3257.26	1 46	61.84	90.21	118.50	1.08	1.88	2.93	157.42
24	4886.16	1 10	67.82	100.21	132.59	1.27	1.97	3.00	177.22

2. Connections

DIVERGING TRACKS.

124. Case 1. From Straight Track.

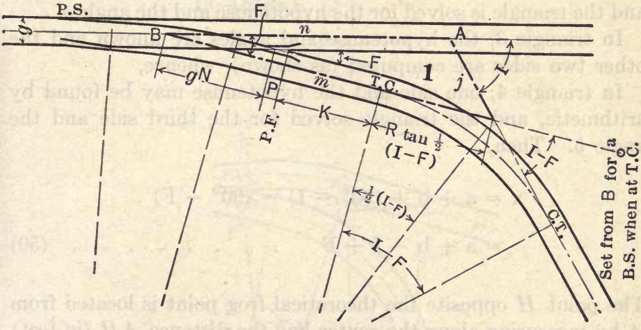


FIG. 47.

Given:

I = the intersection angle between a diverging track and a straight main track.

N = the frog number chosen for the turnout.

R = the chosen radius of the connecting curve.

K = the frog tangent, *i.e.*, the distance from the actual *P.F.* to the *T.C.* of the connecting curve.

P = the distance between the theoretical and the actual point of frog.

It is required to locate the *P.F.*, the *T.C.*, and the *C.T.*

In triangle 1, Fig. 47, all the angles are known and the side $m = gN + P + K + R \tan \frac{1}{2}(I - F)$, whence the sides n and j can be computed.

The point B and the *C.T.* of the connecting curve are located from A by the distances n and $j + R \tan \frac{1}{2}(I - F)$, respectively. The *P.F.* is located from B by the co-ordinates $gN + P$ and $\frac{1}{2}g = 2.35$. The *T.C.* of the connecting curve is located from B by the angle F and the distance $gN + P + K$.

125. Case 2. From Curved Track.

(*a*) *Turnout from the inside of a curved main track.*

The data and requirements of this problem are the same as in the preceding problem except that the main track is on a $D°$ curve.

In triangle 1, Fig. 48, the hypotenuse and the angles are known and the other two sides are computed (as shown), whence,

In triangle 2, the base and altitude are found by arithmetic, and the triangle is solved for the hypotenuse and the angle a.

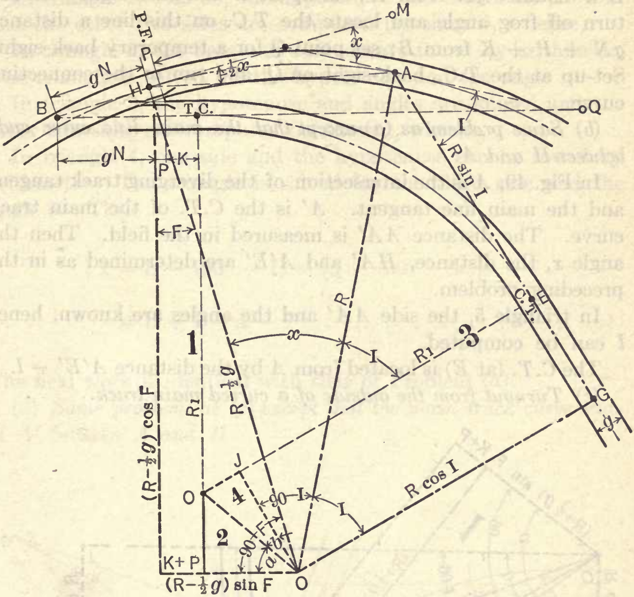
In triangle 3, the hypotenuse and angles are known and the other two sides are computed (as shown), whence,

In triangle 4, one side and the hypotenuse may be found by arithmetic, and the triangle solved for the third side and the angle b. Then,

$$x = a + b + (90° - I) - (90° - F)$$

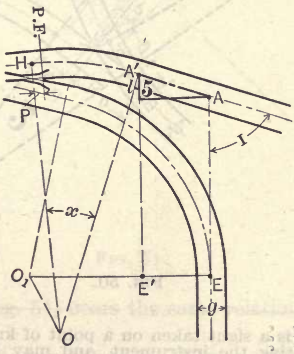
$$= a + b - I + F \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (50)$$

The point H opposite the theoretical frog point is located from A by measuring along the center line the distance AH (in feet) $= \frac{x}{D} 100$. The *C.T.* is located from A by the distance $AE = AG - EG$. ($EG = JO$.) The *T.C.* is best located as follows: set-up at H; back-sight on A; turn off $\frac{1}{2}x$ to get on tangent; locate M for a temporary back-sight; plunge telescope and set point



P.F.
M
x
P
gN
H
½x
A
B
T.C.
Q
I
R sin I
gN
P
K
F
C.T.
E
1
x
R
I
R1
3
R−½g
R1
(R−½g) cos F
G
g
J
O
4
90−I
I
R cos I
2
90+F
a
b
K+P
(R−½g) sin F
O

FIG. 48.



P.F.
H
A′
l
5
A
P
I
x
O1
E′
E
g
O

FIG. 49.

B a distance gN from H; set-up at B and back-sight * on M; turn off frog angle and locate the $T.C.$ on this line a distance $gN + P + K$ from B; set point Q for a temporary back-sight. Set-up at the $T.C.$, back-sight on Q, and run in the connecting curve.

(*b*) *Same problem as* (*a*) *except that the main line curve ends between* H *and* A.

In Fig. 49, A is the intersection of the diverging track tangent and the main line tangent. A' is the $C.T.$ of the main track curve. The distance AA' is measured in the field. Then the angle x, the distance, HA' and $A'E'$ are determined as in the preceding problem.

In triangle 5, the side AA' and the angles are known, hence l can be computed.

The $C.T.$ (at E) is located from A by the distance $A'E' - l$.

(*c*) *Turnout from the outside of a curved main track.*

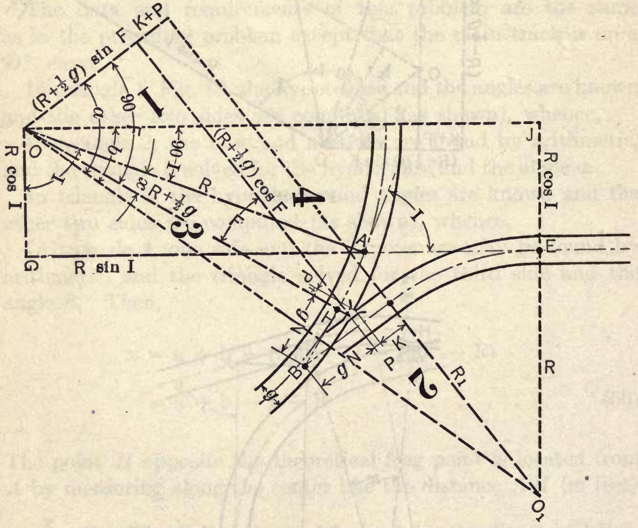


FIG. 50.

*A back-sight is a sight taken on a point of known position for the purpose of orienting the instrument, and may be either back of or in front of the instrument.

In triangle 1, Fig. 50, the hypotenuse and angles are known, and the other two sides are computed (as shown), whence,

In triangle 2, the base and altitude are found by arithmetic. The triangle is solved for the hypotenuse and the angle *a*.

In triangle 3, the hypotenuse and angles are known and the other two sides are computed (as shown), whence,

In triangle 4, one side and the hypotenuse can be found by arithmetic. The triangle is solved for the third side and the angle *b*. Then

$$x = b - (90° - I) - [a - (90° - F)]$$

$$= b + I - a - F \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (51)$$

The field work is identical with that of Problem (*a*).

(*d*) *Same problem as* (*c*) *except that the main track curve ends at A′ between A and H.*

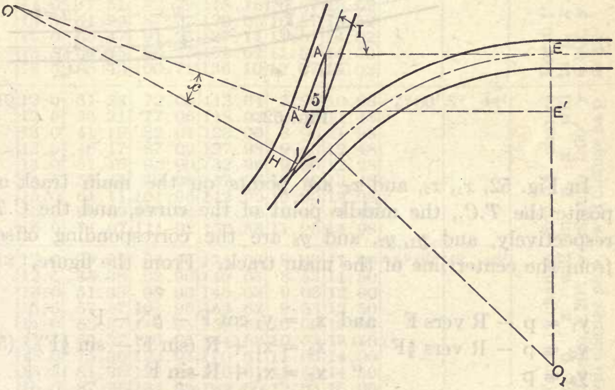


FIG. 51.

This problem, Fig. 51, bears the same relation to (*c*) that (*b*) bears to (*a*).

If *I* is greater than 90° in any of these four problems, the various lines used in the solution will have relatively different positions, but the general order of solution is the same, and if followed out no difficulty should arise.

PARALLEL TRACKS. SIDINGS.

126. Case 1. Straight Tracks.

(*a*) *Tangent and simple curve.*

The best way to connect a turnout to a parallel siding is to make the frog tangent of such a length that it can be connected to the siding by a simple curve of about the same radius as that of the lead rails. A connecting track of this kind is most easily located by co-ordinates from the actual point of frog.

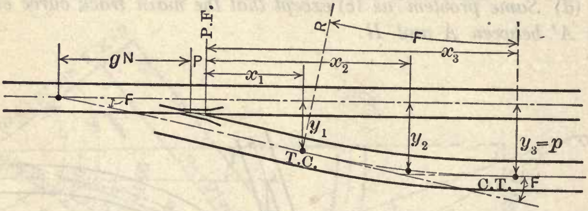


FIG. 52.

In Fig. 52, x_1, x_2, and x_3 are points on the main track opposite the *T.C.*, the middle point of the curve, and the *C.T.*, respectively, and y_1, y_2, and y_3 are the corresponding offsets from the center line of the main track. From the figure,

$$\left.\begin{array}{lll} y_1 = p - R \text{ vers } F & \text{and} & x_1 = y_1 \cot F - gN - P \\ y_2 = p - R \text{ vers } \tfrac{1}{2}F & \text{"} & x_2 = x_1 + R(\sin F - \sin \tfrac{1}{2}F) \\ y_3 = p & \text{"} & x_3 = x_1 + R \sin F \end{array}\right\} \quad (52)$$

Table 3 gives the values of x and y for track centers from 12 to 16 ft. and for frog numbers from 7 to 15.

(b) Sometimes the connecting curve is commenced at the heel of the frog or a fixed distance beyond it. In this case x_1

TABLE 3

Co-ordinates for Locating Parallel Sidings with Tape

Frog No. N	Track Centers $p = y_3$	x_1	x_2	x_3	y_1	y_2	Connecting curve, D	Frog Ang. F	Variation
7	12.0	23.31	50.45	77.73	8.12	11.03	15° 00′	8° 10′	For 0.1′ change in p, x change 0.70′. y change as p.
	12.5	26.79	53.93	81.21	8.62	11.53			
	13.0	30.28	57.42	84.70	9.12	12.03			
	13.5	33.76	60.90	88.18	9.62	12.53			
	14.0	37.24	64.38	91.66	10.12	13.03			
	14.5	40.73	67.87	95.15	10.62	13.53			
	15.0	44.21	71.35	98.63	11.12	14.03			
	15.5	47.70	74.84	102.12	11.62	14.53			
	16.0	51.18	78.32	105.60	12.12	15.03			
8	12.0	25.33	57.73	90.26	7.94	10.98	11° 00′	7° 09′	For 0.1′ change in p, x change 0.80′. y change as p.
	12.5	29.32	61.72	94.25	8.44	11.48			
	13.0	33.31	65.71	98.24	8.94	11.98			
	13.5	37.29	69.69	102.22	9.44	12.48			
	14.0	41.28	73.68	106.21	9.94	12.98			
	14.5	45.26	77.66	110.19	10.44	13.48			
	15.0	49.25	81.65	114.18	10.94	13.98			
	15.5	53.24	85.64	118.17	11.44	14.48			
	16.0	57.22	89.62	122.15	11.94	14.98			
9	12.0	29.59	64.87	100.26	8.07	11.02	9° 00′	6° 22′	For 0.1′ change in p, x change 0.90′. y change as p.
	12.5	34.07	69.35	104.74	8.57	11.52			
	13.0	38.55	73.83	109.22	9.07	12.02			
	13.5	43.03	78.31	113.70	9.57	12.52			
	14.0	47.51	82.79	118.18	10.07	13.02			
	14.5	51.99	87.27	122.66	10.57	13.52			
	15.0	56.47	91.75	127.14	11.07	14.02			
	15.5	60.95	96.23	131.62	11.57	14.52			
	16.0	65.43	100.71	136.10	12.07	15.02			
10	12.0	31.23	72.08	113.04	7.90	10.98	7° 00′	5° 44′	For 0.1′ change in p, x will change 1.00′. y will change as p.
	12.5	36.21	77.06	118.02	8.40	11.48			
	13.0	41.19	82.04	123.00	8.90	11.98			
	13.5	46.17	87.02	127.98	9.40	12.48			
	14.0	51.15	92.00	132.96	9.90	12.98			
	14.5	56.13	96.98	137.94	10.40	13.48			
	15.0	61.11	101.96	142.92	10.90	13.98			
	15.5	66.09	106.94	147.90	11.40	14.48			
	16.0	71.07	111.92	152.88	11.90	14.98			
12	12.0	39.38	86.96	134.63	8.03	11.00	5° 00′	4° 46′	For 0.1′ change in p, x will change 1.20′. y will change as p.
	12.5	45.38	92.96	140.63	8.53	11.50			
	13.0	51.38	98.96	146.63	9.03	12.00			
	13.5	57.37	104.95	152.62	9.53	12.50			
	14.0	63.37	110.95	158.62	10.03	13.00			
	14.5	69.37	116.95	164.62	10.53	13.50			
	15.0	75.36	122.94	170.61	11.03	14.00			
	15.5	81.36	128.94	176.61	11.53	14.50			
	16.0	87.35	134.93	182.60	12.03	15.00			
15	12.0	48.38	111.08	173.85	7.87	10.97	3° 00′	3° 46′	For 0.1′ change in p, x will change 1.52′. y will change as p.
	12.5	55.97	118.67	181.44	8.37	11.47			
	13.0	63.57	126.27	189.04	8.87	11.97			
	13.5	71.16	133.86	196.63	9.37	12.47			
	14.0	78.76	141.46	204.23	9.87	12.97			
	14.5	86.35	149.05	211.82	10.37	13.47			
	15.0	93.95	156.65	219.42	10.87	13.97			
	15.5	101.54	164.24	227.01	11.37	14.47			
	16.0	109.14	171.84	234.61	11.87	14.97			

and y_1 are known and the radius of the connecting curve must be computed. The other dimensions are then computed as before. Although this method flattens the connecting curve, it increases the distance from the *P.F.* to the *T.C.* There is nothing gained by making the connecting curve flatter than that of the turnout itself, and also the greater length of tangent is advantageous.

(c) Sometimes the connection is made in the form of a reversed curve with radii about the same as the radius of the turnout curve under the false idea that this saves distance between the *P.F.* and the *T.C.* The actual difference in x_3 for such a connection and for one of the form first given for a No. 10 turnout is only about 1.1 ft., an inappreciable amount considering the relative riding qualities of the two layouts for heavy road engines.

127. Case 2. Curved Tracks.

A turnout and a connection to a parallel track on a curve may be staked out by the co-ordinates given in Table 3. Such a layout will have the following characteristics.

1. The degree of curve of the turnout will be increased or diminished by the degree of the main curve, depending on

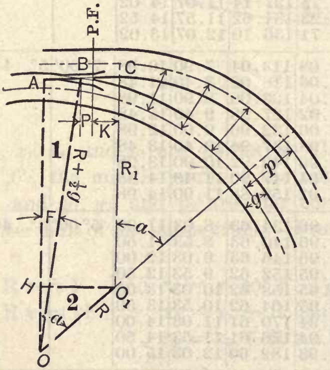


FIG. 53.

whether the siding is inside or outside of the main track curve.

2. The degree of the connecting curve will be diminished or increased by the degree of the main curve (approx.), depending

on whether the siding is inside or outside of the main track curve.

3. The track between the frog point and the beginning of the connecting curve will become a curve of the same degree (approx.) as the main curve.

On curves of about 1° this method is both satisfactory and convenient, but on sharper curves, or in case it is desired to maintain a frog tangent, it will be necessary to compute the connection for the particular case. Two general cases arise:

(*a*) *Sidings on the outside of the main curve.*

In Fig. 53,

$$OA = (R + \tfrac{1}{2}g) \cos F$$
$$AB = (R + \tfrac{1}{2}g) \sin F$$
$$AC = AB + P + K = O_1H$$
$$OO_1 = R + p - R_1$$
$$OH = OA - (R_1 - \tfrac{1}{2}g)$$

In triangle 2, $(OO_1)^2 = (O_1H)^2 + (OH)^2$

$$(R + p - R_1)^2 = (AC)^2 + (OA + \tfrac{1}{2}g - R_1)^2$$

expanding and reducing,

$$R_1 = \frac{(AC)^2}{2(OA + \tfrac{1}{2}g - R - p)} + (OA + \tfrac{1}{2}g + R + p) \quad . \quad (53)$$

then

$$\sin a = \frac{AC}{OO_1}$$

Since the central angle *a* and the radius R_1 are now known, the length of the connecting curve can be computed.

The curve may be staked out either by deflection angles from either end (orient how?) or by offsets from the main track. The latter method is the more rapid and convenient.

Since the connecting curve and the siding curve have a common tangent and since the angles are small, the offset between them at any point is equal to the difference of their tangent offsets. Then the offset from the center line of the main track to the center line of the connecting curve at any point is

$p - \frac{7}{8} n^2 (D_1 - D_s)$, in which D_1 and D_s are the degrees of curve of the connecting track and the siding, respectively, and *n* is the distance in stations along the connecting curve from the point where it joins the siding. These offsets should be measured radially to the main curve and the distances should be measured along the connecting curve.

(*b*) *Sidings on the inside of the main curve.*

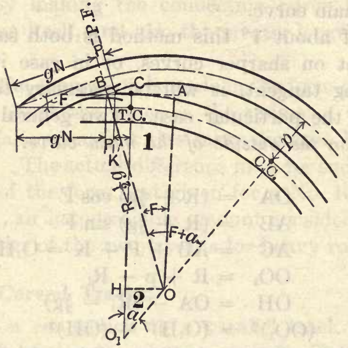


FIG. 54a.

In Fig. 54a,

$$OA = (R - \tfrac{1}{2}g)\cos F$$
$$AB = (R - \tfrac{1}{2}g)\sin F$$
$$AC = AB - K - P = OH$$
$$OO_1 = R_1 + p - R$$
$$O_1H = R_1 + \tfrac{1}{2}g - OA$$

In triangle 2, $(OO_1)^2 = (OH)^2 + (O_1H)^2$

$$(R_1 + p - R)^2 = (AC)^2 + (R_1 + \tfrac{1}{2}g - OA)^2$$

expanding and reducing,

$$R_1 = \frac{(AC)^2}{2(OA - \frac{1}{2}g - R + p)} + (OA - \tfrac{1}{2}g + R - p) \quad . \quad (54)$$

then

$$\sin a = \frac{AC}{OO_1}$$

If Eq. 54 gives a positive value of R_1, the layout is as shown in Fig. 54a.

If a negative value of R_1 is obtained, the layout is as shown in Fig. 54b and the value of R_1 is numerically correct.

If $(OA - \frac{1}{2}g) = R - p$, Eq. 54 gives R_1 = infinity, and the frog tangent produced is tangent to the siding as shown in Fig. 54c.

These connections can be staked out by offsets as explained under case (a). It is to be noted, however, that if the layout is

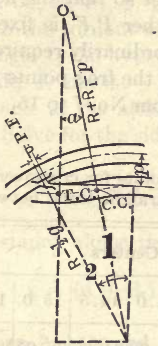


FIG. 54b.

FIG. 54c.

as shown in Fig. 54b, the *sum* of the tangent offsets must be used.

PARALLEL TRACKS. CROSSOVERS.

Since a crossover is equivalent to an entry to a siding, and therefore both turnouts will be run over at practically the same speed, there is no valid reason for making one turnout flatter than the other, even when the crossover is between a main track

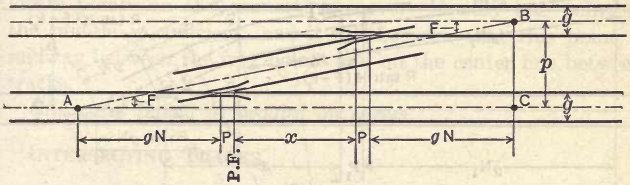


FIG. 55.

and a siding. A crossover should therefore always have frogs of the same number at both ends.

128. Case 1. Straight Tracks.

(a) Straight track between frogs of the same number.

From Fig. 55, $AC = P \cot F$

then $x = AC - 2gN - 2P$ . . . . (55)

To locate the crossover one *P.F.* is set so that the heel or toe will be at a regular rail joint. The other *P.F.* is fixed by the distance x. These are the only stakes ordinarily required.

Table 4 gives the distance x between the frog points for track centers from 12 to 16 ft. for turnouts from No. 7 to 15.

TABLE 4

Distances along main track between frog points for crossovers between parallel tracks. Frogs of same number, straight track between frogs.

N	F	Track Centers								
		12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0
7	8° 10′	17.14	20.63	24.11	27.59	31.08	34.66	38.05	41.53	45.02
8	7° 09′	19.66	23.64	27.61	31.62	35.60	39.59	43.57	47.56	51.55
9	6° 22′	22.05	26.53	31.05	35.49	39.97	44.45	48.93	53.42	57.90
10	5° 44′	24.52	29.50	34.48	39.46	44.45	49.43	54.41	59.39	64.37
12	4° 46′	29.90	35.90	41.90	47.90	53.89	59.89	65.89	71.88	77.88
15	3° 49′	37.38	44.88	52.37	59.86	67.36	74.85	82.35	89.84	97.34

(*b*) *Simple curve between frogs of different number.*

Sometimes unequal frogs are used on crossovers, and in this

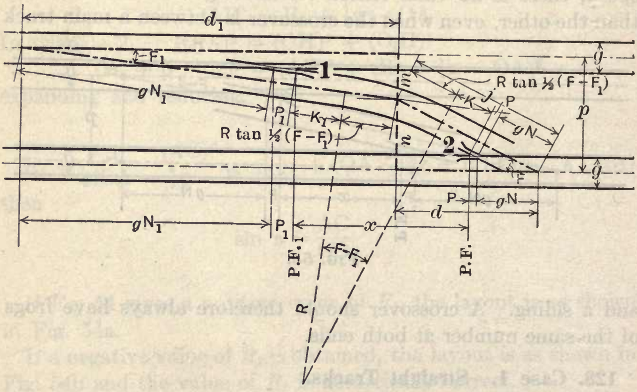


FIG. 56.

case the best form of layout to use is a connecting curve of about the same degree as the *sharper* turnout, tangent at the heel of the *flatter* frog. This will place a short piece of tangent between the curve and the heel of the sharper frog which is desirable.

In Fig. 56, F, F_1, p, g, and K_1 are known. R is chosen to agree with the turnout curve of F.

In triangle 1, the hypotenuse and angle F_1 are known. Solve for the sides d_1 and m.

In triangle 2, the altitude $n = p - m$ and the angle F are known. Solve for the sides d and j. Then

$$K = j - gN - R \tan \tfrac{1}{2} (F - F_1)$$

The distance along the main tracks between frog points is

$$x = (d + d_1) - (gN + P + gN_1 + P_1) \quad . \quad . \quad (56)$$

129. Case 2. Curved Tracks.

It can be shown that, if a crossover is located between curved tracks with the same frog numbers and a simple curve tangent to the heels of the frogs, the distance along the main tracks between frog points is practically the same as for a straight crossover between straight tracks; and also that the degree of curve of the connection is practically the same as that of the main tracks.

Therefore, a crossover on a curve is located with the same dimensions as one on tangent. It may be desirable, however, to locate points on the connecting curve. Usually one point at the middle is sufficient, and it will be seen that this point is midway between the frog points and on the center line between tracks.

Crossovers should be avoided on curves.

Intersecting Tracks.

130. Case 1. Both Tracks Straight.

(*a*) *Connection in form of simple curve.*

Given in Fig. 57, the intersection angle, I; the frog angles, F and F_1; and the radius of the connecting curve.

Required: The distances, A and B, from the intersection of the center lines to points opposite the frog points.

In triangle 1, the angles are known and one side, n, is readily obtainable. Solve for r and m.

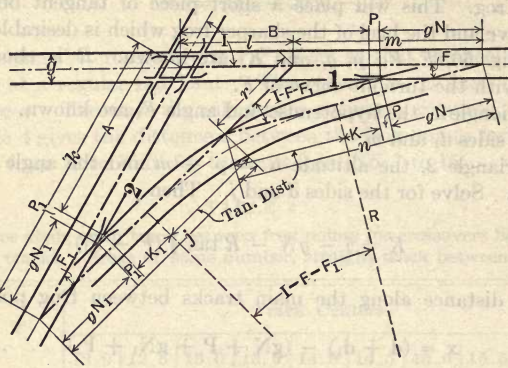


FIG. 57.

In triangle 2, one side, $j + r$, and the angles are now known, whence k and l can be computed.

Then

$$\left.\begin{aligned} A &= k - gN_1 - P_1 \\ B &= l + m \quad - gN - P \end{aligned}\right\} \quad . \quad . \quad (57)$$

(b) *Connection in form of reversed curve.*

Given in Fig. 58, the intersection angle, I; the frog angles, F and F_1; the radii of the reversed curve, R and R_1; and the location of one frog point, which is the distance, T, from the *P.I.* at A.

Required: The central angles, a and b, of the reversed curve, the distance, T_1, from the *P.I.* to the unknown frog point, and the distance x between frog points measured along the straight track.

In triangle 1 (CDB) CD and angle F are given. Solve for CB and DB, whence AB and OB can be found.

In triangle 2 (ABE) AB and the angles are known. Solve for BE and AE.

In triangle 3 (OEG) OE and the angles are known. Solve for OG and GE.

In triangle 4 (LHQ) LH and the angles are known. Solve for HQ and $LQ = JM$.

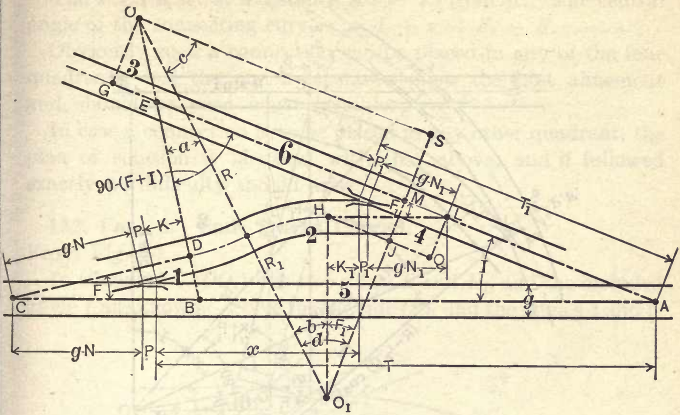


FIG. 58.

In triangle 5 (HJO_1) HO_1 and the angle F_1 are known. Solve for O_1J and HJ.

In triangle 6 (O_1OS) $O_1O = R + R_1$ and $O_1S = O_1J + JM + GO$ are known. Solve for angles c and d, whence angles a and b are readily determined.

$$T_1 = AE + EG - OS - LM + gN_1 + P_1 \quad . \quad (58)$$

$$x = T - AL \cos I - gN_1 - P_1 \quad . \quad . \quad . \quad (59)$$

If T_1 instead of T is known the plan of solution is the same.

If the tracks do not run to an intersection or if it is inadvisable to run out the tangents and determine I, locate the point D, set-up and turn off 90° from the frog tangent, and measure DE. Then set-up at E and measure DEL. With these data the problem can be solved in the same manner as before.

131. Case 2. One Straight and One Curved Track. From Fig. 59,

In triangle 1, the hypotenuse and the angle F are known. Solve for the two sides. Whence,

In triangle 2, the two sides can be obtained by arithmetic. Solve for the hypotenuse and the angle a.

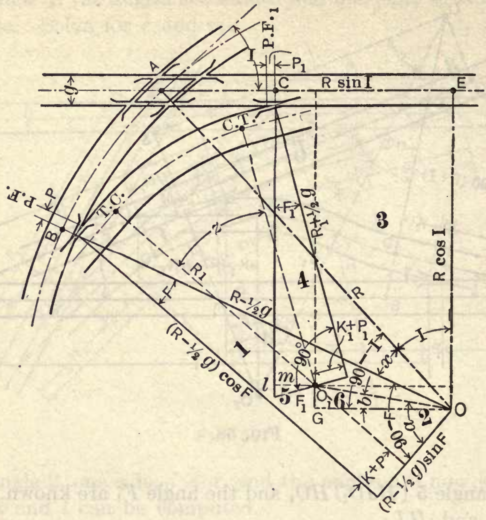


FIG. 59.

In triangle 3, the hypotenuse and the angle I are known. Solve for the two sides.

In triangle 4, the altitude $= R_1 + \frac{1}{2}g$ and the angle F_1 are known. Solve for the hypotenuse and the base.

In triangle 5, the hypotenuse and the angle F_1 are known. Solve for the sides l and m. Whence,

In triangle 6, the altitude is found by arithmetic and the hypotenuse is known from triangle 2. Solve for the angle b. Then

$$x = a - b + (90° - I) - (90° - F)$$

$$= a - b - I + F \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (60)$$

and

$$\text{(curve) AB (in feet)} = \frac{100\,x}{D}$$

The $P.F.$ is set at the distance $AB - P$ from A.

From triangles 3, 5, and 6, the distances AE, m, and OG are known. Then AC is found by arithmetic.

The $P.F._1$ is set at a distance $AC - P_1$ from A. The central angle of the connecting curve $z = I + x - F_1 - F$.

Obviously such a connection can be placed in any of the four quadrants, but the one here shown gives the best alinement and should be used when possible.

In case a connection is to be placed in any other quadrant, the plan of solution is identical with that above, and if followed exactly no difficulty should arise.

132. Case 3. Both Tracks Curved.

From Fig. 60,

In triangle 1 (AOO_1), the two sides, R and R_1, and the included angle I are known. Solve for the side OO_1 and the angles a and b.

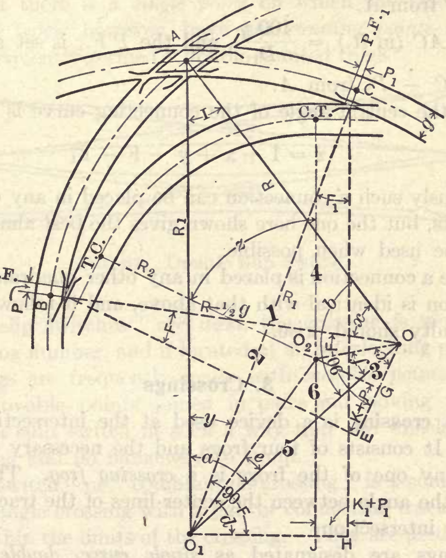


FIG. 60.

In triangle 2 (BEO), the hypotenuse and angle F are known. Solve for the sides BE and EO.

Then in triangle 3 (OO_2G), the two sides are found by arithmetic. Solve for the angle c and the side OO_2.

In triangle 4 (CO_1H) the hypotenuse and the angle F_1 are known. Solve for the sides, CH and HO_1.

Then in triangle 5 (O_1O_2J), the two sides are found by arithmetic. Solve for the angle d and the side O_1O_2.

In triangle 6 (OO_1O_2), the three sides are now known. Solve for the angles e and f. Then

$$x = b - f + c - (90° - F)$$
$$= b - f + c + F - 90° \quad . \ . \ . \ . \ . \quad (61)$$

and

$$y = a - e + d + F_1 - 90° \quad . \ . \ . \quad (62)$$

curve AB (in ft.) $= \dfrac{100\,x}{D}$, and the $P.F.$ is set at a distance $AB - P$ from A.

curve AC (in ft.) $= \dfrac{100\,y}{D_1}$, and the $P.F._1$ is set at the distance $AC - P_1$ from A.

Then the central angle of the connecting curve is

$$z = I + x + y - F - F_1 \quad . \ . \ . \quad (63)$$

Obviously such a connection can be placed in any of the four quadrants, but the one here shown gives the best alinement and should be used when possible.

In case a connection is placed in any other quadrant the plan of solution is identical with that above, and if followed exactly no difficulty should arise.

3. Crossings

133. A crossing is a device used at the intersection of two tracks. It consists of four frogs and the necessary connecting rails. Any one of the frogs is a *crossing frog*. The *crossing angle* is the angle between the center lines of the tracks at their point of intersection.

Crossings are designated as *single curve*, *double curve*, or *straight* according as one, both, or neither of the tracks are curved.

Crossings are usually made of rolled rails fitted together. When the crossing angle is greater than about 25°, the various pieces are cut to fit against each other and are united by filling blocks and heavy straps well bolted. This is frequently termed *solid construction.* For angles under about 25°, regular frog point construction is used, and such crossings are termed *frog crossings.* Distinguish between *frog crossing* and *crossing frog.*

On street railway work hard steel (manganese) centers for frogs have been used for many years, and since 1905 such construction has been growing in use on steam roads both for standard frogs and for crossings. (This type is usually designated as "manganese frogs or crossings.")

There have been numerous attempts to construct crossings with a revolving section or turntable at each frog so that the wheels will have no flangeway to jump; but only one of these seems to give much promise of success.

The end frogs of a frog crossing are similar to a standard rigid frog in that there is a *single point* on which the wheels run. The middle frogs, however, have *two running points* and are therefore frequently termed "double-pointed frogs."

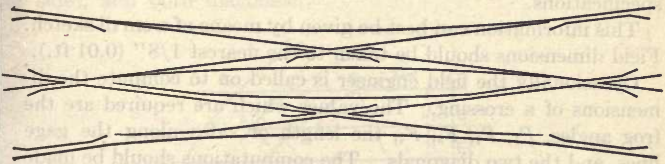


FIG. 61. Double Slip Switch.

When "slip switches" are used, the crossing is made to a standard frog number, and if located at an interlocking plant the middle frogs are frequently made with *movable points.* That is, with movable points joined in pairs and moving together similar to a split switch in such a way that the wheels have a solid bearing and no flangeway to jump.

A "slip switch" or "combination crossing" is a combination of a small angle crossing with a pair of connecting tracks placed entirely within the limits of the crossing. They are used in large yards and terminals (Fig. 61).

134. Crossing Data. Very few railroads construct their own crossings, but have them built by manufacturers who make a specialty of such work. The field engineer is rarely called on to compute the dimensions of a crossing, and to do so is a waste of time if the crossing is ordered from a manufacturer.

It is far more important that the makers have *all* the data, and the field engineer is frequently required to furnish the data. The information required is:

1. The crossing angle.
2. The gage of each track.
3. The curvature—degree of curve, radii, or the equivalent.
4. The direction of curvature.
5. The length along each gage line from one gage line intersection (theoretical *P.F.*) to the nearest rail joint.
6. Length over all along each gage line.
7. The height, weight, and style of rail of which the crossing is to be made.
8. The height, weight, and style of rail in intersecting track if offset splices are to be furnished.
9. The spacing and size of holes for splice bars.
10. The type of crossing, etc., unless covered by general specifications.

This information can best be given by means of a small sketch. Field dimensions should be taken to the nearest 1/8″ (0.01 ft.).

Occasionally the field engineer is called on to compute the dimensions of a crossing. The values which are required are the frog angles, F_1, F_2, F_3, F_4, the length of sides along the gage lines, and the two diagonals. The computations should be made with sufficient accuracy to give results which are correct to the nearest 1/16″, which is the working limit of the manufacturers.

The solutions of the three kinds of crossings are outlined as follows:

135. Straight Crossings.

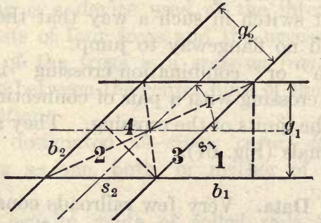


FIG. 62.

(*a*) *Unequal Gages.* In Fig. 62, g_1, g_2, and I are given, and the sides and diagonals are required.

In triangle 1, the altitude g_1 and the angle I are known. Solve for s_1 and b_1.

Similarly solve for s_2 and b_2 in triangle 2.

In triangle 3, the altitude g_1 and the base $s_2 + b_1$ are known. Solve for the hypotenuse, which is the long diagonal of the crossing.

In triangle 4, the altitude g_2 and the base $s_1 - b_2$ are known. Solve for the hypotenuse, which is the short diagonal of the crossing.

(b) *Equal Gages.* In this case, triangles 1 and 2 are identical and all four sides are equal. The angle between the hypotenuse and the base of triangle 3 becomes $\frac{1}{2}I$, and of triangle 4 becomes $90 - \frac{1}{2}I$ which simplifies the solution.

136. Single-curve Crossings.

Given, in Fig. 63, g_1, g_2, and I to find the frog angles, length of sides, and both diagonals.

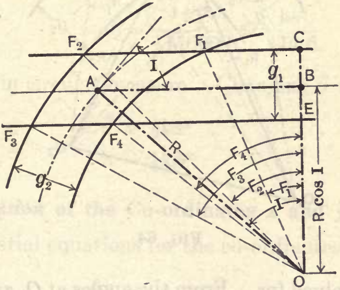


FIG. 63

Project the radius on a perpendicular to the straight track. Then $OB = R \cos I$, whence OE and OC are known.

In triangle F_1CO, the base and hypotenuse are known. Solve for F_1C and the angle F_1.

Similarly solve for F_2 and F_2C, F_3 and F_3E, and F_4 and F_4E from corresponding triangles. Then the straight sides F_1F_2 and F_3F_4 can be found by subtraction. The curved sides F_1F_4 and F_2F_3 can be determined since their radii are known and their central angles can be found by subtraction.

The long diagonal is the hypotenuse of a triangle whose altitude is g_1 and whose base is $F_3E - F_1C$, and the short diagonal is the hypotenuse of a triangle whose altitude is g_1 and whose base is $F_2C - F_4E$.

137. Double-curve Crossings.

In Fig. 64, R_1, R_2, g_1, g_2, and I are given, and it is required to find the frog angles, length of sides, and both diagonals.

In triangle AO_1O_2, two sides and the included angle are known. Solve for the distance between centers, O_1O_2.

Then in the four triangles formed on O_1O_2 by the radii from F_1, F_2, F_3, and F_4 the three sides of each are known, and the

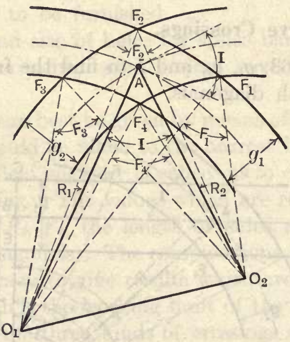


FIG. 64.

angles can be solved for. From the angles at O_1 and O_2 determine the central angles of the arcs, F_1F_2, F_2F_3, F_3F_4, and F_4F_1, from which the lengths of the arcs can be computed since their radii are known. The long diagonal is found from the triangles $F_1O_1F_3$ or $F_1O_2F_3$, and the short diagonal from the triangles $F_2O_1F_4$ or $F_2O_2F_4$.

APPENDIX

THEORY OF SPIRAL

138. Derivation of δ and Δ.

From definition, $d = ks$; for the *S.C.*, $D = kS$ . . . . (18)

The radius of curvature, $r = \dfrac{dl}{d\delta}$

Substituting for r its value, $\dfrac{5730}{d}$, and then for d its value from Eq. 18, and solving,

$$d\delta = \frac{kl\ dl}{5730}$$

Integrating, $$\delta = \frac{kl^2}{1146000} = \frac{ks^2}{114.6}$$

in which δ is in circular measure. Changing δ to degrees,

$$\delta = \tfrac{1}{2}ks^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

For the *S.C.*, $$\Delta = \tfrac{1}{2}kS^2$$

139. Derivation of the Co-ordinates *x* and *y*.

The differential equations for the co-ordinates of a spiral are:

$$dx = ds \cos \delta$$
$$dy = ds \sin \delta$$

Expanding the sin and cos into series,

$$dx = ds\left(1 - \frac{\delta^2}{\underline{|2}} + \frac{\delta^4}{\underline{|4}} - \text{etc.}\right)$$

$$dy = ds\left(\delta - \frac{\delta^3}{\underline{|3}} + \frac{\delta^5}{\underline{|5}} - \text{etc.}\right)$$

Substituting $\dfrac{ks^2}{114.6}$ for δ

$$dx = ds\left(1 - \frac{k^2s^4}{2(114.6)^2} + \text{etc.}\right)$$

$$dy = ds\left(\frac{ks^2}{114.6} - \frac{k^3s^6}{6(114.6)^3} - + \text{etc.}\right)$$

Integrating, $$x = s - \frac{k^2s^5}{10(114.6)^2} + \text{etc.}$$

$$y = \frac{ks^3}{3(114.6)} - \frac{k^3s^7}{42(114.6)^3} + \text{etc.}$$

in which x and y are in stations. Reducing to feet and dropping small terms,

$$x = 100\,s - 0.000762\,k^2s^5 \quad . \quad . \quad . \quad (23)$$

$$y = 0.291\,ks^3 - 0.00000158\,k^3s^7 \quad . \quad (22)$$

140. Derivation of *a*, *A*, *b*, and *B*.

$$\tan a = \frac{x}{y} = \frac{\dfrac{ks^3}{3\times 114.6} - \dfrac{k^3s^7}{42\times(114.6)^3} + \text{etc.}}{s - \dfrac{k^2s^5}{10\times(114.6)^2} + \text{etc.}}$$

$$= \frac{ks^2}{3\times 114.6} + \frac{k^3s^6}{(114.6)^3\times 105} + \text{etc.}$$

Substituting δ for $\frac{ks^2}{114.6}$

$$\tan a = \frac{\delta}{3} + \frac{1}{105}\delta^3 + \text{etc.}$$

$$\tan\frac{\delta}{3} = \frac{\delta}{3} + \frac{1}{81}\delta^3 + \text{etc. (tangent series).}$$

Whence, $\tan a = \tan\frac{1}{3}\delta - \frac{24}{8505}\delta^3$

Reducing to degrees,

$$\tan a = \tan\frac{1}{3}\delta - 0.000000015\,\delta^3$$

Investigating the second term, it is found that δ must be about 25° before there is an error of *one minute* in a by considering it as $\frac{1}{3}\delta$; and since δ rarely reaches 25° and any error of direction is corrected at the *S.C.*, it is sufficient to write

$$\left.\begin{aligned} a &= \frac{1}{3}\delta = 10ks^2 \text{ (in minutes)} \\ A &= \frac{1}{3}\Delta = 10kS^2 \text{ (in minutes)} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (20)$$

and,

$$b = \frac{2}{3}\,\delta = 2a, \text{ and } B = \frac{2}{3}\,\Delta = 2A \quad . \quad . \quad (21)$$

141. Derivation of *O*.

From Fig. 65,

$$o = Y - R \text{ vers } \Delta$$

Substituting for Y its value, $0.291\,kS^3$, for R its value, $\frac{5730}{kS}$, and expanding the vers series,

$$o = 0.291\,kS^3 - 0.00000158\,k^3S^7 -$$

$$\frac{5730}{kS}\left(\frac{k^2S^4}{2 \times (114.6)^2} - \frac{k^4S^8}{24(114.6)^4}\right)$$

$$o = 0.291\,kS^3 - 0.00000158\,k^3S^7 - 5730$$

$$\left(\frac{kS^3}{2(114.6)^2} - \frac{k^3S^7}{24(114.6)^4}\right)$$

Reducing,

$$o = 0.0727\,kS^3 - 0.0000002\,k^3\,S^7$$

Evidently the second term is very small, hence,

$$o = 0.0727\,kS^3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (24)$$

From figure,

$$t = X - R \sin \Delta$$

Substituting for X its value from Eq. 23, and for R its value, $\frac{5730}{kS}$, and expanding the sin series,

$$t = 100\,s - 0.000762\,k^2S^5 - \frac{5730}{kS}\left(\Delta - \frac{\Delta^3}{3} + \text{etc.}\right)$$

$$= 100\,s - 0.000762\,k^2S^5 - \frac{5730}{kS}\left(\frac{kS^2}{114.6} - \frac{k^3S^6}{6\,(114.6)^3} + \text{etc.}\right)$$

Reducing,

$$t = 50\,S - 0.000127\,k^2S^5 \quad . \quad . \quad . \quad . \quad . \quad (25)$$

Substituting $\frac{1}{2}S$ in Eq. 23, the abscissa of the middle of the spiral is $50S - 0.000024\ k^2S^5$. The difference between this and Eq. 25 is only $0.0001\ k^2S^5$, showing that the spiral is practically bisected by the ordinate to the *T.C.*

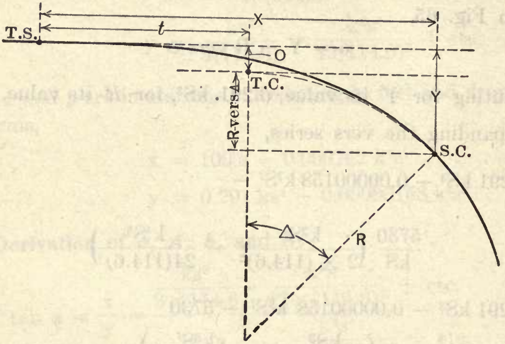


FIG. 65.

Substituting $\frac{1}{2}S$ in Eq. 24, the ordinate for the middle of the spiral is $0.0364\ kS^3$.

$$\tfrac{1}{2}o = 0.0363\ kS^3$$

showing that *o* is bisected by the spiral. If the second term of Eq. 24 had been used the difference would have been still less.

142. Osculating Circle.

The fact that *o* and the spiral mutually bisect shows that the deflection of the circle from the spiral between the *S.C.* and the *T.C.* is the same as the deflection of the spiral from the tangent in half its length. Since the *S.C.* can be at any point on a spiral of given *k*, and the circular curve has the same radius as the spiral at that point, it follows that in general the spiral departs from an osculating circle at the same rate as from the initial tangent.

143. Superelevation.

From mechanics,

$$F = \frac{Wv^2}{2gR}$$

where F is the centrifugal force, W is the weight, v is the velocity in feet per second, R is the radius of curvature, and g is the acceleration of gravity (equal to 16.08).

In Fig. 66, AB represents the horizontal distance between rail heads, which for standard gage is about 4.9 ft.; CB, the

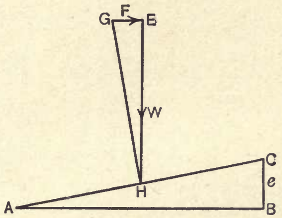


FIG. 66.

superelevation; EH, the weight W; and GE, the centrifugal force. Then from similar triangles,

$$F = W \frac{e}{AB}$$

Substituting the above value of F in this equation, we have

$$\frac{Wv^2}{2gR} = \frac{We}{AB}$$

whence,

$$e \text{ (in feet)} = \frac{ABv^2}{2gR} = \frac{4.9\ v^2}{32.16\ R}$$

Reducing v to miles per hour, substituting $\frac{5730}{D}$ for R, and reducing,

$$e \text{ (in inches)} = 0.00069\ D\ V^2 \quad . \quad . \quad . \quad . \quad (28)$$

where F is the centrifugal force, W is the weight, v is the velocity in feet per second, R is the radius of curvature, and g is the acceleration of gravity (equal to 32.16).

In Fig. 60, AB represents the horizontal distance between rail heads, which for standard gage is about 4.9 ft.; CB, the

Fig. 60.

superelevation; EW, the weight W; and GE, the centrifugal force. Then from similar triangles,

$$F = W\frac{e}{AB}$$

Substituting the above value of F in this equation, we have

$$\frac{Wv^2}{gR} = \frac{We}{AB}$$

whence,

$$e = \frac{ABv^2}{gR} = \frac{4.9\,v^2}{32.16\,R}\ \text{(in feet)}$$

Reducing v to miles per hour, substituting $\frac{5730}{D}$ for R, and reducing

$$e\ \text{(in inches)} = 0.00069\ D\ V^2, \qquad (28)$$

TABLES

Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.
0° 0′	Infinite	1° 0′	5729.65	2° 0′	2864.93	3° 0′	1910.08	4° 0′	1432.69
1	343775.	1	5635.72	1	2841.26	1	1899.53	1	1426.74
2	171887.	2	5544.83	2	2817.97	2	1889.09	2	1420.85
3	114592.	3	5456.82	3	2795.06	3	1878.77	3	1415.01
4	85943.7	4	5371.56	4	2772.53	4	1868.56	4	1409.21
5	68754.9	5	5288.92	5	2750.35	5	1858.47	5	1403.46
6	57295.8	6	5208.79	6	2728.52	6	1848.48	6	1397.76
7	49110.7	7	5131.05	7	2707.04	7	1838.59	7	1392.10
8	42971.8	8	5055.59	8	2685.89	8	1828.82	8	1386.49
9	38197.2	9	4982.33	9	2665.08	9	1819.14	9	1380.92
10	34377.5	10	4911.15	10	2644.58	10	1809.57	10	1375.40
11	31252.3	11	4841.98	11	2624.39	11	1800.10	11	1369.92
12	28647.8	12	4774.74	12	2604.51	12	1790.73	12	1364.49
13	26444.2	13	4709.33	13	2584.93	13	1781.45	13	1359.10
14	24555.4	14	4645.69	14	2565.65	14	1772.27	14	1353.75
15	22918.3	15	4583.75	15	2546.64	15	1763.18	15	1348.45
16	21485.9	16	4523.44	16	2527.92	16	1754.19	16	1343.15
17	20222.1	17	4464.70	17	2509.47	17	1745.26	17	1337.65
18	19098.6	18	4407.46	18	2491.29	18	1736.48	18	1332.77
19	18093.4	19	4351.67	19	2473.37	19	1727.75	19	1327.63
20	17188.8	20	4297.28	20	2455.70	20	1719.12	20	1322.53
21	16370.2	21	4244.23	21	2438.29	21	1710.56	21	1317.46
22	15626.1	22	4192.47	22	2421.12	22	1702.10	22	1312.43
23	14946.7	23	4141.96	23	2404.19	23	1693.72	23	1307.45
24	14323.6	24	4092.66	24	2387.50	24	1685.42	24	1302.50
25	13751.0	25	4044.51	25	2371.04	25	1677.20	25	1297.58
26	13222.1	26	3997.49	26	2354.80	26	1669.06	26	1292.71
27	12732.4	27	3951.54	27	2338.78	27	1661.00	27	1287.87
28	12277.7	28	3906.54	28	2322.98	28	1653.01	28	1283.07
29	11854.3	29	3862.74	29	2307.39	29	1645.11	29	1278.30
30	11459.2	30	3819.83	30	2292.01	30	1637.28	30	1273.57
31	11089.6	31	3777.85	31	2276.84	31	1629.52	31	1268.87
32	10743.0	32	3736.79	32	2261.86	32	1621.84	32	1264.21
33	10417.5	33	3696.61	33	2247.08	33	1614.22	33	1259.58
34	10111.1	34	3657.29	34	2232.49	34	1606.68	34	1254.98
35	9822.18	35	3618.80	35	2218.09	35	1599.21	35	1250.42
36	9549.34	36	3581.10	36	2203.87	36	1591.81	36	1245.89
37	9291.29	37	3544.19	37	2189.84	37	1584.48	37	1241.40
38	9046.75	38	3508.02	38	2175.98	38	1577.21	38	1236.94
39	8814.78	39	3472.59	39	2162.30	39	1570.01	39	1232.51
40	8594.42	40	3437.87	40	2148.79	40	1562.88	40	1228.11
41	8384.80	41	3403.83	41	2135.44	41	1555.81	41	1223.74
42	8185.16	42	3370.46	42	2122.26	42	1548.80	42	1219.40
43	7994.81	43	3337.74	43	2109.24	43	1541.86	43	1215.30
44	7813.11	44	3305.65	44	2096.39	44	1534.98	44	1210.82
45	7639.49	45	3274.17	45	2083.68	45	1528.16	45	1206.57
46	7473.42	46	3243.29	46	2071.13	46	1521.40	46	1202.36
47	7314.41	47	3212.98	47	2058.73	47	1514.70	47	1198.17
48	7162.03	48	3183.23	48	2046.48	48	1508.06	48	1194.01
49	7015.87	49	3154.03	49	2034.37	49	1501.48	49	1189.88
50	6875.55	50	3125.36	50	2022.41	50	1494.95	50	1185.78
51	6740.74	51	3097.20	51	2010.59	51	1488.48	51	1181.71
52	6611.12	52	3069.55	52	1998.90	52	1482.07	52	1177.66
53	6486.38	53	3042.39	53	1987.35	53	1475.71	53	1173.65
54	6366.26	54	3015.71	54	1975.93	54	1469.41	54	1169.66
55	6250.51	55	2989.48	55	1964.64	55	1463.16	55	1165.70
56	6138.90	56	2963.71	56	1953.48	56	1456.96	56	1161.76
57	6031.20	57	2938.39	57	1942.44	57	1450.81	57	1157.85
58	5927.22	58	2913.49	58	1931.53	58	1444.72	58	1153.97
59	5826.76	59	2889.01	59	1920.75	59	1438.68	59	1150.11
60	5729.65	60	2864.93	60	1910.08	60	1432.69	60	1146.28

Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.
5° 0′	1146.28	6° 0′	955.37	7° 0′	818.64	8° 0′	716.34	9° 0′	636.78
1	1142.47	1	952.72	1	816.70	1	714.85	1	635.61
2	1138.69	2	950.09	2	814.76	2	713.37	2	634.44
3	1134.94	3	947.48	3	812.83	3	711.90	3	633.27
4	1131.21	4	944.83	4	810.92	4	710.43	4	632.10
5	1127.50	5	942.29	5	809.01	5	708.96	5	630.94
6	1123.82	6	939.72	6	807.11	6	707.51	6	629.79
7	1120.16	7	937.16	7	805.22	7	706.05	7	628.64
8	1116.52	8	934.62	8	803.34	8	704.60	8	627.49
9	1112.91	9	932.09	9	801.47	9	703.16	9	626.35
10	1109.33	10	929.57	10	799.61	10	701.73	10	625.21
11	1105.76	11	927.07	11	797.75	11	700.30	11	624.08
12	1102.22	12	924.58	12	795.91	12	698.88	12	622.95
13	1098.70	13	922.10	13	794.07	13	697.46	13	621.82
14	1095.20	14	919.64	14	792.24	14	696.05	14	620.70
15	1091.73	15	917.19	15	790.42	15	694.65	15	619.58
16	1088.28	16	914.75	16	788.61	16	693.24	16	618.47
17	1084.85	17	912.33	17	786.80	17	691.85	17	617.36
18	1081.44	18	909.92	18	785.01	18	690.46	18	616.25
19	1078.05	19	907.52	19	783.22	19	689.08	19	615.15
20	1074.68	20	905.13	20	781.44	20	687.70	20	614.05
21	1071.34	21	902.76	21	779.67	21	686.33	21	612.96
22	1068.01	22	900.40	22	777.91	22	684.96	22	611.87
23	1064.71	23	898.05	23	776.15	23	683.60	23	610.78
24	1061.43	24	895.71	24	774.40	24	682.25	24	609.70
25	1058.16	25	893.39	25	772.66	25	680.89	25	608.62
26	1054.92	26	891.08	26	770.93	26	679.55	26	607.55
27	1051.70	27	888.78	27	769.21	27	678.21	27	606.48
28	1048.48	28	886.49	28	767.49	28	676.88	28	605.41
29	1045.31	29	884.21	29	765.78	29	675.54	29	604.35
30	1042.14	30	881.95	30	764.08	30	674.22	30	603.29
31	1039.00	31	879.69	31	762.39	31	672.90	31	602.23
32	1035.87	32	877.45	32	760.70	32	671.59	32	601.18
33	1032.76	33	875.22	33	759.02	33	670.28	33	600.13
34	1029.67	34	873.00	34	757.35	34	668.98	34	599.09
35	1026.60	35	870.80	35	755.69	35	667.68	35	598.04
36	1023.55	36	868.60	36	754.03	36	666.39	36	597.01
37	1020.51	37	866.41	37	752.38	37	665.10	37	595.97
38	1017.49	38	864.24	38	750.74	38	663.82	38	594.94
39	1014.50	39	862.08	39	749.10	39	662.54	39	593.91
40	1011.51	40	859.92	40	747.48	40	661.26	40	592.89
41	1008.55	41	857.78	41	745.86	41	659.99	41	591.87
42	1005.60	42	855.65	42	744.24	42	658.73	42	590.85
43	1002.67	43	853.53	43	742.63	43	657.47	43	589.84
44	999.76	44	851.42	44	741.03	44	656.22	44	588.83
45	996.87	45	849.32	45	739.44	45	654.97	45	587.83
46	993.99	46	847.23	46	737.86	46	653.72	46	586.82
47	991.13	47	845.15	47	736.28	47	652.48	47	585.83
48	988.28	48	843.08	48	734.70	48	651.25	48	584.83
49	985.45	49	841.02	49	733.14	49	650.02	49	583.84
50	982.64	50	838.97	50	731.58	50	648.79	50	582.85
51	979.84	51	836.93	51	730.03	51	647.57	51	581.86
52	977.06	52	834.90	52	728.48	52	646.35	52	580.88
53	974.29	53	832.89	53	726.94	53	645.14	53	579.90
54	971.54	54	830.88	54	725.41	54	643.94	54	578.92
55	968.81	55	828.88	55	723.88	55	642.73	55	577.95
56	966.09	56	826.89	56	722.36	56	641.53	56	576.98
57	963.39	57	824.91	57	720.85	57	640.34	57	576.02
58	960.70	58	822.93	58	719.34	58	639.15	58	575.06
59	958.03	59	820.97	59	717.84	59	637.96	59	574.10
60	955.37	60	819.02	60	716.34	60	636.78	60	573.14

Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.
10° 0′	573.14	**12° 0′**	477.68	**14° 0′**	409.32	**16° 0′**	358.17	**18° 0′**	318.39
2	571.24	2	476.36	2	408.35	2	357.43	2	317.80
4	569.35	4	475.05	4	407.38	4	356.69	4	317.22
6	567.47	6	473.74	6	406.42	6	355.95	6	316.63
8	565.60	8	472.44	8	405.46	8	355.21	8	316.05
10	563.75	10	471.15	10	404.51	10	354.48	10	315.47
12	561.91	12	469.86	12	403.56	12	353.75	12	314.89
14	560.08	14	468.58	14	402.61	14	353.03	14	314.32
16	558.26	16	467.31	16	401.67	16	352.30	16	313.75
18	556.45	18	466.04	18	400.74	18	351.58	18	313.18
20	554.66	20	464.78	20	399.80	20	350.86	20	312.61
22	552.88	22	463.53	22	398.88	22	350.15	22	312.04
24	551.11	24	462.29	24	397.95	24	349.44	24	311.47
26	549.35	26	461.05	26	397.03	26	348.72	26	310.91
28	547.60	28	459.82	28	396.13	28	348.02	28	310.35
30	545.87	30	458.59	30	395.21	30	347.32	30	309.79
32	544.14	32	457.38	32	394.30	32	346.62	32	309.23
34	542.42	34	456.16	34	393.40	34	345.93	34	308.68
36	540.72	36	454.96	36	392.50	36	345.23	36	308.13
38	539.03	38	453.76	38	391.61	38	344.54	38	307.58
40	537.34	40	452.57	40	390.72	40	343.85	40	307.03
42	535.67	42	451.38	42	389.83	42	343.16	42	306.48
44	534.01	44	450.20	44	388.95	44	342.48	44	305.93
46	532.36	46	449.02	46	388.07	46	341.80	46	305.39
48	530.71	48	447.86	48	387.20	48	341.12	48	304.85
50	529.08	50	446.69	50	386.33	50	340.45	50	304.31
52	527.46	52	445.54	52	385.47	52	339.78	52	303.77
54	525.85	54	444.39	54	384.60	54	339.11	54	303.24
56	524.25	56	443.24	56	383.75	56	338.44	56	302.70
58	522.65	58	442.11	58	382.89	58	337.77	58	302.17
11° 0′	521.07	**13° 0′**	440.97	**15° 0′**	382.04	**17° 0′**	337.11	**19° 0′**	301.64
2	519.50	2	439.85	2	381.19	2	336.45	2	301.12
4	517.93	4	438.73	4	380.35	4	335.80	4	300.59
6	516.38	6	437.61	6	379.51	6	335.14	6	300.07
8	514.84	8	436.50	8	378.68	8	334.49	8	299.54
10	513.30	10	435.40	10	377.84	10	333.84	10	299.02
12	511.77	12	434.30	12	377.02	12	333.19	12	298.50
14	510.26	14	433.21	14	376.19	14	332.55	14	297.99
16	508.75	16	432.12	16	375.37	16	331.91	16	297.47
18	507.25	18	431.04	18	374.55	18	331.27	18	296.96
20	505.76	20	429.96	20	373.74	20	330.63	20	296.45
22	504.28	22	428.98	22	372.93	22	330.00	22	295.94
24	502.80	24	427.82	24	372.12	24	329.37	24	295.43
26	501.34	26	426.76	26	371.32	26	328.74	26	294.92
28	499.88	28	425.71	28	370.52	28	328.11	28	294.42
30	498.43	30	424.66	30	369.72	30	327.48	30	293.91
32	496.99	32	423.61	32	368.93	32	326.86	32	293.41
34	495.56	34	422.57	34	368.14	34	326.24	34	292.91
36	494.14	36	421.54	36	367.35	36	325.62	36	292.41
38	492.73	38	420.51	38	366.57	38	325.01	38	291.92
40	491.32	40	419.49	40	365.79	40	324.40	40	291.42
42	489.92	42	418.47	42	365.01	42	323.79	42	290.93
44	488.53	44	417.45	44	364.24	44	323.18	44	290.44
46	487.15	46	416.44	46	363.47	46	322.57	46	289.95
48	485.77	48	415.44	48	362.70	48	321.97	48	289.46
50	484.40	50	414.44	50	361.94	50	321.37	50	288.98
52	483.05	52	413.44	52	361.18	52	320.77	52	288.49
54	481.69	54	412.45	54	360.42	54	320.17	54	288.01
56	480.35	56	411.47	56	359.67	56	319.57	56	287.53
58	479.01	58	410.49	58	358.92	58	318.98	58	287.05
60	477.68	60	409.51	60	358.17	60	318.39	60	286.57

TABLE 6.—FUNCTIONS OF A ONE-DEGREE CURVE.

The Long Chords, Mid-Ordinates, Externals, and Tangent Distances of this table are for a curve of 5730 feet radius. To find the corresponding functions of any other curve divide the tabular values by the degree of curve.

For metric curves having 20-metre chords, multiply tne degree by 5 and enter the table with the result as a value of D, the tabular values being taken as metres instead of feet

Thus for a 1° 30′ metric curve having $I = 45°$ the tangent distance is $T = \frac{2373.4}{1.5 \times 5} = 316.45$ metres. Again, suppose $I = 38°$ and the long chord = 373.1 m. known and D required. The tabular $L.\ C.$ is 3731 m.; therefore $D = \frac{3731.0}{373.1 \times 5} = 2°\ 0'$.

′	0° L. C.	0° M.	0° E.	0° T.	1° L. C.	1° M.	1° E.	1° T.	′
0	0.00	0.000	0.000	0.00	100.00	0.218	0.218	50.00	0
2	3.33	0 000	0.000	1.67	103.33	0.233	0.233	51.67	2
4	6.67	0 001	0.001	3.33	106.66	0.248	0.248	53.33	4
6	10.00	0.002	0.002	5.00	110.00	0.264	0.264	55.00	6
8	13.33	0.004	0.004	6.67	113.33	0.280	0.280	56.67	8
10	16.67	0.006	0.006	8.33	116.66	0.297	0.297	58.33	10
12	20.00	0.009	0.009	10.00	120.00	0.314	0.314	60.00	12
14	23.33	0.012	0.012	11.67	123.33	0.332	0.332	61.67	14
16	26.67	0.015	0.015	13.33	126.66	0.350	0.350	63.33	16
18	30.00	0.019	0.019	15.00	130.00	0.368	0.368	65.00	18
20	33.33	0.024	0.024	16.67	133.33	0.388	0.388	66.67	20
22	36.67	0.029	0.029	18.33	136.66	0.407	0.407	68.33	22
24	40.00	0.035	0.035	20.00	140.00	0.427	0.427	70.00	24
26	43.33	0.041	0.041	21.67	143.33	0.448	0.448	71.67	26
28	46.67	0.048	0.048	23.33	146.66	0.469	0.469	73.33	28
30	50.00	0.054	0.054	25.00	150.00	0.491	0.491	75.00	30
32	53 33	0.062	0.062	26.67	153.33	0.513	0.513	76.67	32
34	56 67	0 070	0.070	28.33	156.66	0.536	0.536	78.33	34
36	60.00	0.079	0.079	30.00	160.00	0.559	0.559	80.00	36
38	63.33	0.088	0.088	31.67	163.33	0.582	0.582	81.67	38
40	66.67	0.097	0.097	33 33	166 66	0.606	0.606	83.33	40
42	70.00	0.107	0.107	35.00	170.00	0.630	0.630	85.00	42
44	73.33	0.117	0.117	36.67	173.33	0.655	0.655	86.67	44
46	76.67	0.128	0.128	38.33	176.66	0.681	0.681	88.33	46
48	80.00	0.140	0.140	40.00	180.00	0.706	0.706	90.00	48
50	83.33	0.151	0.151	41.67	183.33	0 733	0.733	91.67	50
52	86 67	0.164	0.164	43.33	186.66	0.760	0.760	93.33	52
54	90.00	0 176	0.176	45.00	190.00	0.788	0.788	95.00	54
56	93 33	0.190	0.190	46.67	193.33	0.815	0.815	96.67	56
58	96.67	0.204	0.204	48.33	196.66	0.844	0.844	98.33	58
60	100.00	0.218	0.218	50.00	199.98	0.873	0 873	100.00	60

′	2°				3°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	199.98	0.873	0.873	100.00	299.96	1.964	1.964	150.07	0
2	203.31	0.902	0.902	101.67	303.29	2.008	2.009	151.74	2
4	206.64	0.932	0.932	103.34	306.62	2.053	2.054	153.41	4
6	209.97	0.962	0.962	105.01	309.95	2.098	2.099	155.08	6
8	213.31	0.993	0.993	106.68	313.29	2.143	2.144	156.75	8
10	216.64	1.024	1.024	108.35	316.62	2.188	2.189	158.42	10
12	219.97	1.056	1.056	110.02	319.95	2.235	2.236	160.09	12
14	223.30	1.088	1.088	111.69	323.28	2.282	2.283	161.76	14
16	226.64	1.121	1.121	113.36	326.62	2.329	2.330	163.43	16
18	229.97	1.154	1.154	115.02	329.95	2.376	2.377	165.09	18
20	233.30	1.188	1.188	116.69	333.28	2.424	2.425	166.76	20
22	236.63	1.222	1.222	118.36	336.61	2.473	2.474	168.43	22
24	239.97	1.256	1.256	120.03	339.95	2.523	2.523	170.10	24
26	243.30	1.292	1.292	121.70	343.28	2.572	2.573	171.77	26
28	246.63	1.328	1.328	123.37	346.61	2.622	2.623	173.44	28
30	249.96	1.364	1.364	125.03	349.94	2.672	2.673	175.10	30
32	253.29	1.399	1.399	126.70	353.27	2.724	2.725	176.72	32
34	256.62	1.437	1.437	128.37	356.60	2.776	2.777	178.39	34
36	259.96	1.475	1.475	130.04	359.94	2.828	2.829	180.06	36
38	263.29	1.513	1.513	131.71	363.27	2.880	2.881	181.73	38
40	266.62	1.552	1.552	133.38	366.60	2.933	2.934	183.40	40
42	269.96	1.592	1.592	135.05	369.94	2.987	2.988	185.07	42
44	273.29	1.632	1.632	136.72	373.27	3.042	3.043	186.74	44
46	276.62	1.672	1.672	138.38	376.60	3.096	3.097	188.40	46
48	279.96	1.712	1.712	140.05	379.94	3.151	3.152	190.07	48
50	283.29	1.752	1.752	141.72	383.27	3.206	3.207	191.74	50
52	286.62	1.794	1.794	143.39	386.60	3.263	3.264	193.41	52
54	289.96	1.836	1.836	145.06	389.94	3.320	3.321	195.08	54
56	293.29	1.878	1.878	146.73	393.27	3.377	3.378	196.75	56
58	296.62	1.921	1.921	148.40	396.60	3.434	3.435	198.42	58
60	299.96	1.964	1.964	150.07	399.94	3.491	3.492	200.09	60

′	4°				5°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	399.94	3.491	3.492	200.09	499.88	5.454	5.459	250.17	0
2	403.27	3.550	3.551	201.76	503.21	5.527	5.533	251.84	2
4	406.60	3.609	3.610	203.43	506.54	5.601	5.607	253.51	4
6	409.93	3.668	3.670	205.10	509.87	5.675	5.681	255.18	6
8	413.26	3.727	3.730	206.77	513.20	5.749	5.755	256.85	8
10	416.59	3.787	3.790	208.44	516.53	5.823	5.829	258.52	10
12	419.92	3.848	3.851	210.11	519.86	5.899	5.905	260.20	12
14	423.26	3.910	3.913	211.77	523.19	5.975	5.981	261.86	14
16	426.59	3.972	3.975	213.45	526.52	6.052	6.058	263.54	16
18	429.92	4.034	4.037	215.11	529.85	6.129	6.135	265.20	18
20	433.25	4.096	4.099	216.78	533.18	6.206	6.212	266.87	20
22	436.58	4.160	4.163	218.45	536.51	6.284	6.290	268.54	22
24	439.91	4.224	4.227	220.12	539.84	6.362	6.369	270.21	24
26	443.24	4.288	4.291	221.79	543.17	6.441	6.448	271.88	26
28	446.58	4.353	4.356	223.46	546.50	6.520	6.527	273.54	28
30	449.91	4.418	4.421	225.13	549.83	6.599	6.606	275.21	30
32	453.24	4.484	4.487	226.80	553.17	6.680	6.687	276.88	32
34	456.57	4.550	4.554	228.47	556.50	6.761	6.768	278.55	34
36	459.90	4.617	4.621	230.14	559.83	6.842	6.849	280.23	36
38	463.23	4.684	4.688	231.81	563.16	6.923	6.931	281.90	38
40	466.56	4.751	4.755	233.48	566.49	7.005	7.013	283.57	40
42	469.89	4.820	4.824	235.15	569.82	7.088	7.096	285.24	42
44	473.23	4.889	4.893	236.82	573.15	7.171	7.180	286.91	44
46	476.56	4.958	4.962	238.48	576.48	7.255	7.264	288.59	46
48	479.89	5.027	5.031	240.15	579.81	7.339	7.348	290.26	48
50	483.22	5.096	5.100	241.82	583.14	7.423	7.432	291.93	50
52	486.55	5.167	5.171	243.49	586.47	7.508	7.517	293.60	52
54	489.88	5.238	5.243	245.16	589.80	7.593	7.603	295.27	54
56	493.21	5.310	5.315	246.83	593.13	7.678	7.689	296.95	56
58	496.54	5.382	5.387	248.50	596.46	7.764	7.775	298.62	58
60	499.88	5.454	5.459	250.17	599.80	7.850	7.861	300.30	60

′	6° L. C.	6° M.	6° E.	6° T.	7° L. C.	7° M.	7° E.	7° T.	′
0	599.80	7.850	7.861	300.30	699.60	10.69	10.71	350.44	0
2	603.13	7.940	7.951	301.97	702.93	10.79	10.81	352.11	2
4	606 46	8.030	8.041	303.64	706.26	10.90	10.92	353.79	4
6	609.78	8.120	8.131	305.31	709.58	11.00	11.02	355.46	6
8	613.11	8.210	8.221	306.98	712.91	11.11	11.13	357.13	8
10	616.44	8.300	8.311	308.65	716.24	11.21	11.23	358.81	10
12	619.76	8.390	8.401	310.32	719.56	11.31	11.33	360.48	12
14	623.09	8.480	8.491	311.99	722.89	11.42	11.44	362.15	14
16	626.42	8.570	8.581	313.66	726.21	11.52	11.54	363 83	16
18	629.74	8.660	8.671	315.33	729.53	11.63	11.65	365.50	18
20	633.07	8.750	8.761	317.00	732.86	11.73	11.75	367.17	20
22	636.40	8.844	8.856	318.67	736.19	11.84	11.86	368.85	22
24	639.72	8.939	8.951	320.34	739.51	11.95	11.97	370.52	24
26	643.05	9.033	9.046	322.01	742.84	12.06	12.08	372.19	26
28	646.38	9.128	9.141	323.68	746.17	12.17	12.19	373.86	28
30	649.70	9.222	9.236	325.35	749.49	12.27	12.30	375.54	30
32	653.03	9.317	9.331	327.02	752.82	12.38	12.41	377.22	32
34	656.36	9.411	9.426	328.69	756.15	12.49	12.52	378.89	34
36	659.69	9.506	9.521	330.37	759.47	12.60	12.63	380 57	36
38	663.02	9.600	9.616	332.04	762.80	12.71	12.74	382.24	38
40	666.34	9.695	9.712	333.71	766.13	12.82	12.85	383.92	40
42	669.67	9.794	9.812	335.38	769.45	12.93	12.96	385.60	42
44	673.00	9.894	9.912	337.05	772.78	13.04	13.08	387.27	44
46	676.32	9.993	10.01	338.73	776.11	13.15	13.19	388.95	46
48	679.65	10.09	10.11	340.40	779.43	13.26	13.31	390.62	48
50	682.98	10.19	10.21	342.07	782.76	13.37	13.42	392.30	50
52	686.30	10.29	10.31	343.74	786.09	13.48	13.53	393.98	52
54	689.63	10.39	10.41	345.41	789.41	13.59	13.65	395.65	54
56	692.96	10.49	10.51	347.08	792.74	13.70	13.76	397.33	56
58	696.28	10.59	10.61	348.76	796.07	13.81	13.88	399.01	58
60	699 60	10.69	10.71	350.44	799.40	13.96	13.99	400.70	60

′	8° L. C.	8° M.	8° E.	8° T.	9° L. C.	9° M.	9° E.	9° T.	′
0	799.40	13.96	13.99	400.70	899.10	17.66	17.71	450.95	0
2	802.72	14.07	14.10	402.37	902.42	17.79	17.84	452.63	2
4	806.04	14.19	14.22	404.05	905.74	17.92	17.98	454.31	4
6	809.37	14.31	14.34	405.72	909.07	18.06	18.11	455.98	6
8	812.69	14 43	14.46	407.39	912.39	18.19	18.25	457.66	8
10	816.01	14.55	14.58	409.06	915.71	18.32	18.38	459.34	10
12	819.34	14.66	14.70	410.74	919.04	18.46	18.52	461.02	12
14	822.66	14.78	14.82	412.41	922.36	18.59	18.65	462.70	14
16	825.98	14.90	14.94	414.08	925.68	18.72	18.79	464.37	16
18	829.31	15.02	15.06	415.75	929.01	18.86	18.92	466.05	18
20	832.63	15.14	15.18	417.43	932.33	18.99	19.06	467.73	20
22	835.95	15.26	15.30	419.10	935.65	19.12	19.19	469.41	22
24	839.28	15.38	15.43	420.77	938.98	19.26	19.33	471.08	24
26	842.60	15.51	15.55	422.45	942.30	19.40	19.47	472.76	26
28	845.92	15.63	15.68	424.12	945.62	19.54	19.61	474.43	28
30	849.25	15.75	15.80	425.79	948.95	19.68	19.75	476.10	30
32	852.57	15.88	15.93	427.47	952.27	19.82	19.89	477.78	32
34	855.89	16.00	16.05	429.15	955.59	19.96	20.03	479.46	34
36	859.22	16.12	16.18	430.82	958.92	20.10	20.17	481.14	36
38	862.54	16.25	16.30	432.50	962.24	20.24	20.31	482.83	38
40	865.86	16.38	16.43	434.18	965.56	20.38	20.45	484.51	40
42	869.19	16.50	16.55	435.86	968.89	20.52	20.59	486.19	42
44	872.51	16.63	16.68	437.54	972.21	20.66	20.74	487.87	44
46	875.83	16.76	16.81	439.21	975.53	20.80	20.88	489.56	46
48	879.16	16.89	16.94	440.89	978.86	20.94	21.03	491.24	48
50	882.48	17.02	17.07	442.57	982.18	21.09	21.17	492.92	50
52	885.80	17.14	17.19	444.25	985.50	21.23	21.31	494.60	52
54	889.13	17.27	17.32	445.93	988.83	21.37	21.46	496.28	54
56	892.45	17.40	17.45	447.60	992.15	21.51	21.60	497.96	56
58	895.77	17.53	17.58	449.28	995.47	21.65	21.75	499.65	58
60	899.10	17.66	17.71	450.95	998.80	21.80	21.89	501.32	60

′	10°				11°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	998.8	21.80	21.89	501.32	1098.4	26.38	26.50	551.74	0
2	1002.1	21.94	22.03	503.00	1101.7	26.54	26.66	553.42	2
4	1005.4	22.09	22.18	504.68	1105.0	26.70	26.83	555.10	4
6	1008.8	22.24	22.33	506.36	1108.3	26.86	26.99	556.78	6
8	1012.1	22.39	22.48	508.04	1111.7	27.02	27.16	558.46	8
10	1015.4	22.54	22.63	509.72	1115.0	27.19	27.32	560.14	10
12	1018.7	22.68	22.78	511.40	1118.3	27.35	27.48	561.82	12
14	1022 0	22.83	22.93	513.08	1121.6	27.51	27.65	563.50	14
16	1025.4	22.98	23.08	514.76	1124.9	27.67	27.81	565.18	16
18	1028.7	23.13	23.23	516.44	1128.2	27.83	27.98	566.86	18
20	1032.0	23.28	23.38	518.12	1131.6	28.00	28.14	568.54	20
22	1035.3	23.43	23.53	519.80	1134.9	28.17	28.30	570.22	22
24	1038.6	23.58	23.68	521.48	1138.2	28.34	28.47	571.90	24
26	1042.0	23.73	23.84	523.16	1141.5	28.50	28.64	573.58	26
28	1045.3	23.88	23.99	524.85	1144.8	28.67	28.81	575.27	28
30	1048.6	24.04	24.14	526.53	1148.1	28.84	28.98	576.95	30
32	1051.9	24.19	24.30	528.21	1151.5	29.00	29.14	578.63	32
34	1055.2	24.34	24.45	529.89	1154.8	29.17	29.31	580.32	34
36	1058.6	24.49	24.60	531.57	1158.1	29.34	29.48	582.00	36
38	1061.9	24.64	24.76	533.25	1161.4	29.50	29.65	583.69	38
40	1065.2	24.80	24.91	534.93	1164.7	29.67	29.82	585.37	40
42	1068.5	24.95	25.06	536.61	1168.0	29.84	29.99	587.05	42
44	1071.8	25.11	25.22	538.29	1171.4	30.01	30.17	588.74	44
46	1075.2	25.27	25.38	539.97	1174.7	30.18	30.34	590.42	46
48	1078.5	25.43	25.54	541.65	1178.0	30.35	30.52	592.11	48
50	1081.8	25.59	25.70	543.33	1181.3	30.53	30.69	593.79	50
52	1085.1	25.74	25.86	545.01	1184.6	30.70	30.86	595.47	52
54	1088.4	25.90	26.02	546.69	1187.9	30.87	31.04	597.16	54
56	1091.8	26.06	26.18	548.37	1191.3	31.04	31.21	598.84	56
58	1095.1	26.22	26.34	550.06	1194.6	31.21	31.39	600.53	58
60	1098.4	26.38	26.50	551.74	1197.9	31.39	31.56	602.22	60

′	12°				13°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	1197.9	31.39	31.56	602.22	1297.3	36.83	37.07	652.87	0
2	1201.2	31.57	31.73	603.91	1300.6	37.02	37.26	654.56	2
4	1204.5	31.74	31.91	605.60	1303.9	37.21	37.46	656.25	4
6	1207.8	31.92	32.09	607.28	1307.2	37.40	37.65	657.93	6
8	1211.1	32.09	32.27	608.97	1310.5	37.59	37.85	659.62	8
10	1214.5	32.27	32.45	610.66	1313.8	37.79	38.04	661.31	10
12	1217.8	32.45	32.63	612.35	1317.2	37.98	38.23	663.00	12
14	1221.1	32.62	32.81	614.04	1320.5	38.17	38.43	664.69	14
16	1224.4	32.80	32.99	615.72	1323.8	38.36	38.62	666.37	16
18	1227.7	32.97	33.17	617.41	1327.1	38.55	38.82	668.06	18
20	1231.0	33.15	33.35	619.10	1330.4	38.75	39.01	669.75	20
22	1234.3	33.33	33.53	620.79	1333.7	38.95	39.20	671.44	22
24	1237.7	33.51	33.72	622.48	1337.0	39.15	39.40	673.13	24
26	1241.0	33.69	33.90	624.16	1340.3	39.35	39.60	674.81	26
28	1244.3	33.87	34.09	625.85	1343.6	39.54	39.80	676.51	28
30	1247.6	34.06	34.27	627.55	1346.9	39.74	40.00	678.20	30
32	1250.9	34.24	34.45	629.24	1350.3	39.94	40.19	679.89	32
34	1254.2	34.42	34.64	630.93	1353.6	40.13	40.39	681.58	34
36	1257.5	34.60	34.82	632.61	1356.9	40.33	40.59	683.26	36
38	1260.8	34.78	35.01	634.30	1360.2	40.52	40.79	684.95	38
40	1264.2	34.97	35.19	635.99	1363.5	40.71	40.99	686.64	40
42	1267.5	35.16	35.37	637.68	1366.8	40.91	41.19	688.33	42
44	1270.8	35.34	35.56	639.37	1370.1	41.11	41.40	690.02	44
46	1274.1	35.53	35.75	641.05	1373.4	41.31	41.60	691.70	46
48	1277.4	35.71	35.94	642.74	1376.7	41.51	41.81	693.39	48
50	1280.7	35.90	36.13	644.43	1380.0	41.71	42.01	695.08	50
52	1284.0	36.09	36.31	646.12	1383.4	41.91	42.21	696.77	52
54	1287.4	36.27	36.50	647.81	1386.7	42.11	42.42	698.46	54
56	1290.7	36.46	36.69	649.49	1390.0	42.31	42.62	700.14	56
58	1294.0	36.64	36.88	651.18	1393.3	42.51	42.83	701.83	58
60	1297.3	36.83	37.07	652.87	1396.6	42.71	43.03	703.53	60

′	14° L. C.	14° M.	14° E.	14° T.	15° L. C.	15° M.	15° E.	15° T.	′
0	1396.6	42.71	43.03	703.53	1495.9	49.02	49.44	754.35	0
2	1399.9	42.92	43.23	705.23	1499.2	49.24	49.66	756.05	2
4	1403.2	43.12	43.44	706.92	1502.5	49.46	49.89	757.74	4
6	1406.5	43.33	43.65	708.62	1505.8	49.68	50.11	759.44	6
8	1409.8	43.53	43.86	710.31	1509.1	49.90	50.34	761.13	8
10	1413.1	43.74	44.07	712.01	1512.4	50.12	50.56	762.83	10
12	1416.5	43.94	44.28	713.71	1515.7	50.34	50.78	764.53	12
14	1419.8	44.15	44.49	715.40	1519.0	50.56	51.01	766.22	14
16	1423.1	44.35	44.70	717.10	1522.3	50.78	51.23	767.92	16
18	1426.4	44.56	44.91	718.79	1525.6	51.00	51.46	769.61	18
20	1429.7	44.77	45.12	720.49	1528.9	51.22	51.68	771.31	20
22	1433.0	44.98	45.33	722.20	1532.2	51.44	51.90	773.01	22
24	1436.3	45.19	45.54	723.89	1535.5	51.67	52.13	774.70	24
26	1439.6	45.40	45.76	725.59	1538.8	51.89	52.36	776.40	26
28	1442.9	45.61	45.97	727.28	1542.1	52.12	52.59	778.09	28
30	1446.2	45.82	46.18	728.97	1545.4	52.34	52.82	779.79	30
32	1449.6	46.03	46.40	730.66	1548.7	52.57	53.05	781.49	32
34	1452.9	46.24	46.61	732.35	1552.0	52.79	53.28	783.19	34
36	1456.2	46.45	46.82	734.05	1555.3	53.02	53.51	784.89	36
38	1459.5	46.66	47.04	735.74	1558.6	53.24	53.74	786.59	38
40	1462.8	46.87	47.25	737.43	1561.9	53.47	53.97	788.29	40
42	1466.1	47.08	47.46	739.12	1565.2	53.69	54.20	789.99	42
44	1469.4	47.30	47.68	740.81	1568.5	53.92	54.44	791.69	44
46	1472.7	47.51	47.90	742.51	1571.8	54.15	54.67	793.39	46
48	1476.0	47.73	48.12	744.20	1575.1	54.38	54.91	795.09	48
50	1479.3	47.94	48.34	745.89	1578.4	54.61	55.14	796.79	50
52	1482.7	48.16	48.56	747.58	1581.7	54.84	55.37	798.49	52
54	1486.0	48.37	48.78	749.27	1585.0	55.07	55 61	800.19	54
56	1489.3	48.59	49.00	750.97	1588.3	55.30	55.84	801.89	56
58	1492.6	48.80	49.22	752.66	1591.6	55.53	56.08	803.59	58
60	1495.9	49.02	49.44	754.35	1594.9	55.76	56.31	805.29	60

′	16° L. C.	16° M.	16° E.	16° T.	17° L. C.	17° M.	17° E.	17° T.	′
0	1594.9	55.76	56.31	805.29	1693.9	62.94	63.64	856.35	0
2	1598.2	55.99	56.54	806.99	1697.2	63.18	63.89	858.05	2
4	1601.5	56.23	56.78	808.64	1700.5	63.43	64.15	859.76	4
6	1604.8	56.46	57.02	810.39	1703.8	63.68	64.40	861.46	6
8	1608.1	56.70	57.26	812.09	1707.1	63.93	64.66	863.16	8
10	1611.4	56.93	57.50	813.79	1710.4	64.18	64.91	864.87	10
12	1614.7	57.17	57.74	815.49	1713.7	64.42	65.16	866.57	12
14	1618.0	57.40	57.98	817.19	1716.9	64.67	65.42	868.27	14
16	1621.3	57.64	58.22	818.89	1720.2	64.92	65.67	869.98	16
18	1624.6	57.87	58.46	820.59	1723.5	65.17	65.93	871.68	18
20	1627.9	58.11	58.70	822.29	1726.8	65.42	66.18	873.38	20
22	1631.2	58.34	58.94	823.99	1730.1	65.67	66.43	875.09	22
24	1634.5	58.58	59.19	825.69	1733.4	65.93	66.69	876.79	24
26	1637.8	58.82	59.43	827.39	1736.7	66.18	66.95	878.49	26
28	1641.1	59.06	59.68	829.09	1740.0	66.44	67.21	880.20	28
30	1644.4	59.30	59.92	830.79	1743.3	66.69	67.47	881.90	30
32	1647.7	59.54	60.16	832.49	1746.6	66.94	67.72	883.61	32
34	1651.0	59.78	60.41	834.20	1749.9	67.20	67.98	885.32	34
36	1654.3	60.02	60.65	835.90	1753.2	67.45	68.24	887.02	36
38	1657.6	60.26	60.90	837.61	1756.5	67.71	68.50	888.73	38
40	1660.9	60.50	61.14	839.31	1759.8	67.96	68.76	890.44	40
42	1664.2	60.74	61.39	841.01	1763.1	68.21	69.03	892.15	42
44	1667.5	60.99	61.64	842.72	1766.3	68.47	69.29	893.86	44
46	1670.8	61.23	61.89	844.42	1769.6	68.73	69.56	895.56	46
48	1674.1	61.48	62.14	846.13	1772.9	68.99	69.82	897.27	48
50	1677.4	61.72	62.39	847.83	1776 2	69.25	70.09	898.98	50
52	1680.7	61.96	62.64	849.53	1779.5	69.50	70.36	900.69	52
54	1684.0	62.21	62.89	851.24	1782.8	69.76	70.62	902.40	54
56	1687.3	62.45	63.14	852.94	1786.1	70.02	70.89	904.10	56
58	1690.6	62.70	63.39	854.65	1789.4	70.28	71.17	905.81	58
60	1693.9	62.94	63.64	856.35	1792.7	70.54	71.42	907.52	60

′	18°				19°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	1792.7	70.54	71.42	907.52	1891.5	78.58	79.65	958.86	0
2	1796.0	70.80	71.69	909.23	1894.8	78.86	79.94	960.57	2
4	1799.3	71.06	71.96	910.94	1898.1	79.13	80.22	962.30	4
6	1802.6	71.33	72.23	912.65	1901.3	79.41	80.51	964.00	6
8	1805.9	71.59	72.50	914.36	1904.6	79.68	80.79	965.72	8
10	1809.2	71.85	72.77	916.07	1907.9	79.96	81.08	967.43	10
12	1812.5	72.12	73.04	917.78	1911.2	80.24	81.37	969.15	12
14	1815.7	72.38	73.31	919.49	1914.5	80.51	81.65	970.86	14
16	1819.0	72.64	73.58	921.20	1917.8	80.79	81.94	972.58	16
18	1822.3	72 91	73.85	922.91	1921.0	81.07	82.22	974.29	18
20	1825.6	73.17	74.12	924.63	1924.3	81.35	82.51	976.01	20
22	1828.9	73.43	74.39	926.34	1927.6	81.63	82.80	977.72	22
24	1832 2	73.70	74.67	928.05	1930.9	81.91	83.09	979.44	24
26	1835.5	73.97	74.94	929.76	1934.2	82.20	83.38	981.15	26
28	1838.8	74.24	75.22	931.47	1937.5	82.48	83.67	982.86	28
30	1842.1	74.51	75.49	933.18	1940.7	82.76	83.97	984.58	30
32	1845.4	74.77	75.77	934.89	1944.0	83.05	84.26	986.30	32
34	1848.7	75.04	76.04	936.60	1947.3	83.33	84.55	988.02	34
36	1852.0	75.31	76.32	938.32	1950.6	83.61	84.84	989.74	36
38	1855.3	75.58	76.59	940.03	1953.9	83.90	85.13	991.46	38
40	1858.6	75.85	76.87	941.74	1957.2	84.18	85.43	993.18	40
42	1861.9	76.12	77.14	943.45	1960 4	84.47	85.73	994.90	42
44	1865.1	76.39	77.42	945.16	1963.7	84.75	86.02	996.62	44
46	1868.4	76.67	77.70	946.88	1967.0	85.04	86.32	998.34	46
48	1871.7	76.94	77.98	948.59	1970.3	85.32	86.61	1000.0	48
50	1875.0	77.21	78.26	950.30	1973.6	85.61	86.91	1001.8	50
52	1878.3	77.49	78.53	952.01	1976.9	85.90	87.21	1003.5	52
54	1881.6	77.76	78.81	953.72	1980.1	86.19	87.50	1005.2	54
56	1884.9	78.03	79.09	955.44	1983.4	86.47	87.80	1006.9	56
58	1888.2	78.31	79.37	957.15	1986.7	86.76	88.09	1008.6	58
60	1891.5	78.58	79.65	958 86	1990.0	87.05	88.39	1010.4	60

′	20°				21°				′
	L. C.	M.	E.	T.	L. C.	M	E.	T.	
0	1990.0	87.05	88.39	1010.4	2088.5	95.95	97.58	1062.0	0
2	1993.3	87.34	88.69	1012.1	2091.8	96.26	97.90	1063.7	2
4	1996.6	87.63	88.99	1013.8	2095.0	96.56	98.21	1065.4	4
6	1999.8	87.92	89.29	1015.5	2098.3	96.87	98.53	1067.2	6
8	2003.1	88.21	89.59	1017.2	2101.6	97.17	98.84	1068.9	8
10	2006.4	88.50	89.89	1019.0	2104.9	97.48	99.16	1070.6	10
12	2009.7	88.79	90.19	1020.7	2108.1	97.79	99.48	1072.4	12
14	2013.0	89.08	90.49	1022 4	2111.4	98.09	99.79	1074.1	14
16	2016 3	89.37	90.79	1024.1	2114.7	98.40	100.1	1075.8	16
18	2019.5	89.66	91.09	1025.8	2118.0	98.70	100.4	1077.5	18
20	2022.8	89.96	91.40	1027.6	2121.2	99.00	100.7	1079.3	20
22	2026.1	90.25	91.71	1029.3	2124.5	99.30	101.1	1081.0	22
24	2029.4	90.55	92.01	1031.0	2127.8	99.60	101.4	1082.7	24
26	2032.7	90.85	92.32	1032.7	2131.0	99.90	101.7	1084.4	26
28	2036.0	91.15	92.62	1034.4	2134.3	100.2	102.0	1086.2	28
30	2039.2	91.45	92.93	1036 1	2137.6	100.5	102.3	1087.9	30
32	2042.5	91.74	93.24	1037.9	2140.9	100.8	102.7	1089.6	32
34	2045.8	92.04	93.54	1039.6	2144.1	101.1	103.0	1091.3	34
36	2049.1	92.34	93.85	1041.3	2147.4	101.4	103.3	1093.1	36
38	2052.4	92.64	94.15	1043.0	2150.7	101.7	103.6	1094.8	38
40	2055.7	92.94	94.46	1044.8	2154.0	102.1	104.0	1096.5	40
42	2058.9	93.24	94.78	1046.5	2157.2	102.4	104.3	1098.3	42
44	2062.2	93.54	95.09	1048.2	2160.5	102.7	104.6	1100.0	44
46	2065.5	93.84	95.40	1049.9	2163.8	103.0	104.9	1101.7	46
48	2068.8	94.14	95.71	1051.7	2167.1	103.3	105.3	1103.4	48
50	2072.1	94.44	96.03	1053.4	2170.3	103.6	105.6	1105.2	50
52	2075.4	94.74	96.34	1055.1	2173.6	103.9	105.9	1106.9	52
54	2078.6	95.04	96.65	1056.8	2176.9	104.2	106.3	1108.6	54
56	2081.9	95.34	96.96	1058.6	2180.1	104.5	106.6	1110.3	56
58	2085.2	95.64	97.27	1060.3	2183.4	104.8	106.9	1112.1	58
60	2088.5	95.95	97.58	1062.0	2186.7	105.2	107.2	1113.8	60

′	22°				23°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	2186.7	105.2	107.2	1113.8	2284.8	115.0	117.4	1165.8	0
2	2190.0	105.6	107.6	1115.5	2288.1	115.3	117.7	1167.5	2
4	2193.2	105.9	107.9	1117.3	2291.3	115.7	118.1	1169.2	4
6	2196.5	106.2	108.2	1119.0	2294.6	116.0	118.4	1171.0	6
8	2199.8	106.5	108.6	1120.7	2297.8	116.4	118.8	1172.7	8
10	2203.0	106.8	108.9	1122.4	2301.1	116.7	119.1	1174.4	10
12	2206.3	107.1	109.2	1124.2	2304.4	117.0	119.5	1176.2	12
14	2209.6	107.4	109.6	1125.9	2307.6	117.4	119.8	1177.9	14
16	2212.9	107.7	109.9	1127.6	2310.9	117.7	120.2	1179.7	16
18	2216.1	108.0	110.2	1129.4	2314.1	118.1	120.5	1181.4	18
20	2219.4	108.4	110.6	1131.1	2317.4	118.4	120.9	1183.1	20
22	2222.7	108.7	110.9	1132.8	2320.7	118.7	121.2	1184.9	22
24	2225.9	109.0	111.2	1134.6	2323.9	119.1	121.6	1186.6	24
26	2229.2	109.4	111.6	1136.3	2327.2	119.4	121.9	1188.4	26
28	2232.5	109.7	111.9	1138.0	2330.4	119.8	122.3	1190.1	28
30	2235.7	110.0	112.3	1139.7	2333.7	120.1	122.6	1191.8	30
32	2239.0	110.4	112.6	1141.5	2337.0	120.4	123.0	1193.6	32
34	2242.3	110.7	112.9	1143.2	2340.2	120.8	123.3	1195.3	34
36	2245.6	111.0	113.3	1144.9	2343.5	121.1	123.7	1197.1	36
38	2248.8	111.4	113.6	1146.7	2346.7	121.5	124.1	1198.8	38
40	2252.1	111.7	113.9	1148.4	2350.0	121.8	124.4	1200.5	40
42	2255.4	112.0	114.3	1150.1	2353.3	122.1	124.8	1202.3	42
44	2258.6	112.3	114.6	1151.9	2356.5	122.5	125.1	1204.0	44
46	2261.9	112.7	115.0	1153.6	2359.8	122.8	125.5	1205.8	46
48	2265.2	113.0	115.3	1155.4	2363.0	123.2	125.8	1207.5	48
50	2268.4	113.3	115.7	1157.1	2366.3	123.5	126.2	1209.2	50
52	2271.7	113.7	116.0	1158.8	2369.6	123.8	126.6	1211.0	52
54	2275.0	114.0	116.3	1160.6	2372.8	124.2	126.9	1212.7	54
56	2278.3	114.3	116.7	1162.3	2376.1	124.5	127.3	1214.5	56
58	2281.5	114.7	117.0	1164.0	2379.3	124.9	127.6	1216.2	58
60	2284.8	115.0	117.4	1165.8	2382.6	125.2	128.0	1218.0	60

′	24°				25°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	2382.6	125.2	128.0	1218.0	2480.4	135.8	139.1	1270.3	0
2	2385.9	125.5	128.4	1219.7	2483.6	136.2	139.5	1272.0	2
4	2389.1	125.9	128.7	1221.4	2486.9	136.5	139.9	1273.8	4
6	2392.4	126.2	129.1	1223.2	2490.1	136.9	140.3	1275.5	6
8	2395.6	126.6	129.5	1224.9	2493.4	137.2	140.6	1277.3	8
10	2398.9	126.9	129.8	1226.7	2496.6	137.6	141.0	1279.0	10
12	2402.2	127.3	130.2	1228.4	2499.9	138.0	141.4	1280.8	12
14	2405.4	127.6	130.6	1230.2	2503.1	138.3	141.8	1282.5	14
16	2408.7	128.0	130.9	1231.9	2506.4	138.7	142.2	1284.3	16
18	2411.9	128.3	131.3	1233.6	2509.6	139.0	142.5	1286.1	18
20	2415.2	128.7	131.7	1235.4	2512.9	139.4	142.9	1287.8	20
22	2418.5	129.0	132.0	1237.1	2516.1	139.8	143.3	1289.6	22
24	2421.7	129.4	132.4	1238.9	2519.4	140.1	143.7	1291.3	24
26	2425.0	129.7	132.8	1240.6	2522.6	140.5	144.1	1293.1	26
28	2428.2	130.1	133.1	1242.4	2525.9	140.8	144.5	1294.8	28
30	2431.5	130.4	133.5	1244.1	2529.1	141.2	144.9	1296.6	30
32	2434.8	130.8	133.9	1245.8	2532.4	141.6	145.3	1298.3	32
34	2438.0	131.1	134.2	1247.6	2535.6	142.0	145.6	1300.1	34
36	2441.3	131.5	134.6	1249.3	2538.9	142.3	146.0	1301.8	36
38	2444.5	131.8	135.0	1251.1	2542.1	142.7	146.4	1303.6	38
40	2447.8	132.2	135.4	1252.8	2545.4	143.1	146.8	1305.3	40
42	2451.1	132.6	135.7	1254.6	2548.6	143.5	147.2	1307.1	42
44	2454.3	132.9	136.1	1256.3	2551.9	143.8	147.6	1308.8	44
46	2457.6	133.3	136.5	1258.1	2555.1	144.2	148.0	1310.6	46
48	2460.8	133.6	136.9	1259.8	2558.4	144.5	148.4	1312.4	48
50	2464.1	134.0	137.2	1261.5	2561.6	144.9	148.8	1314.1	50
52	2467.4	134.4	137.6	1263.3	2564.9	145.3	149.2	1315.9	52
54	2470.6	134.7	138.0	1265.0	2568.1	145.7	149.5	1317.6	54
56	2473.9	135.1	138.4	1266.8	2571.4	146.0	149.9	1319.4	56
58	2477.1	135.4	138.7	1268.5	2574.6	146.4	150.3	1321.1	58
60	2480.4	135.8	139.1	1270.3	2577.9	146.8	150.7	1322.9	60

′	26°				27°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	2577.9	146.8	150.7	1322.9	2675.3	158.3	162.8	1375.6	0
2	2581.1	147.1	151.1	1324.6	2678.5	158.6	163.2	1377.4	2
4	2584.4	147.5	151.5	1326.4	2681.8	159.0	163.7	1379.2	4
6	2587.6	147.9	151.9	1328.1	2685.0	159.4	164.1	1380.9	6
8	2590.9	148.3	152.3	1329.9	2688.2	159.8	164.5	1382.7	8
10	2594.1	148.7	152.7	1331.6	2691.5	160.2	164.9	1384.5	10
12	2597.4	149.1	153.1	1333.4	2694.7	160.6	165.3	1386.2	12
14	2600.6	149.4	153.5	1335.2	2698.0	161.0	165.7	1388.0	14
16	2603.9	149.8	153.9	1336.9	2701.2	161.4	166.1	1389.8	16
18	2607.1	150.2	154.3	1338.7	2704.4	161.8	166.5	1391.5	18
20	2610.4	150 6	154.7	1340.4	2707.7	162.2	167.0	1393.3	20
22	2613.6	151.0	155.1	1342.2	2710.9	162.6	167.4	1395.0	22
24	2616.9	151.4	155.5	1343.9	2714.1	163.0	167.8	1396.8	24
26	2620.1	151.7	155.9	1345.7	2717.4	163.4	168.2	1398.6	26
28	2623.4	152.1	156.3	1347.4	2720.6	163.8	168.6	1400.3	28
30	2626.6	152.5	156.7	1349.2	2723.8	164.2	169.1	1402.1	30
32	2629.8	152.9	157.1	1351.0	2727.1	164.6	169.5	1403.9	32
34	2633.1	153.3	157.5	1352.7	2730.3	165.0	169.9	1405.6	34
36	2636.3	153.7	157.9	1354 5	2733.6	165.4	170.3	1407.4	36
38	2639.6	154.0	158.3	1356.2	2736.8	165.8	170.8	1409.2	38
40	2642.8	154.4	158.7	1358.0	2740.0	166.2	171.2	1410.9	40
42	2646.1	154.8	159.1	1359.8	2743.3	166.6	171.6	1412.7	42
44	2649.3	155.2	159.5	1361.5	2746.5	167.0	172.0	1414.5	44
46	2652.6	155.6	160.0	1363.3	2749.7	167.4	172.5	1416.3	46
48	2655.8	156.0	160.4	1365.1	2753.0	167.8	172.9	1418.0	48
50	2659.1	156.3	160.8	1366.8	2756.2	168.2	173.3	1419.8	50
52	2662.3	156.7	161.2	1368.6	2759.5	168.6	173.7	1421.6	52
54	2665.6	157.1	161.6	1370.4	2762.7	169.0	174.1	1423.3	54
56	2668.8	157 5	162.0	1372.1	2765.9	169.4	174.6	1425.1	56
58	2672.1	157.9	162.4	1373.9	2769.2	169.8	175.0	1426.9	58
60	2675.3	158.3	162.8	1375.6	2772.4	170.2	175.4	1428.6	60

′	28°				29°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	2772.4	170.2	175.4	1428.6	2869.4	182.5	188.5	1481.9	0
2	2775.6	170.6	175.8	1430.4	2872.6	182.9	189.0	1483.7	2
4	2778.9	171.0	176.3	1432.2	2875.8	183 3	189.4	1485.4	4
6	2782.1	171.4	176.7	1434.0	2879.1	183.7	189.9	1487.2	6
8	2785.3	171.8	177.1	1435.7	2882.3	184.2	190.3	1489.0	8
10	2788.6	172.2	177.6	1437.5	2885.5	184.6	190.8	1490.8	10
12	2791.8	172.6	178.0	1439.3	2888.7	185.0	191.2	1492.6	12
14	2795.0	173.0	178.4	1441.1	2892.0	185.4	191.7	1494.3	14
16	2798.3	173.4	178.9	1442.8	2895.2	185.8	192.1	1496.1	16
18	2801.5	173.8	179.3	1444.6	2898.4	186.3	192.5	1497.9	18
20	2804.7	174.3	179.7	1446.4	2901.6	186.7	193.0	1499.7	20
22	2808.0	174.7	180.2	1448.2	2904.8	187.1	193.5	1501.5	22
24	2811.2	175.1	180.6	1449.9	2908.1	187.5	193.9	1503.2	24
26	2814.4	175.5	181.0	1451.7	2911.3	188.0	194.4	1505.0	26
28	2817.7	175.9	181.5	1453.5	2914.5	188.4	194.8	1506.8	28
30	2820.9	176.3	181.9	1455.2	2917.7	188.8	195.3	1508.6	30
32	2824.1	176.7	182.3	1457.0	2921.0	189.2	195.7	1510.4	32
34	2827.4	177.1	182.8	1458.8	2924.2	189.7	196.2	1512.1	34
36	2830.6	177.5	183.2	1460.6	2927.4	190.1	196.7	1513.9	36
38	2833.8	177.9	183.6	1462.3	2930.6	190.5	197.1	1515.7	38
40	2837.1	178.4	184.1	1464.1	2933.9	190.9	197.6	1517.5	40
42	2840.3	178.8	184.5	1465.9	2937.1	191.4	198.0	1519.3	42
44	2843.5	179.2	185.0	1467.7	2940.3	191.9	198.5	1521.0	44
46	2846.8	179.6	185.4	1469.5	2943.5	192.4	198.9	1522.8	46
48	2850.0	180.0	185.9	1471.2	2946.8	192.8	199.4	1524.6	48
50	2853.2	180.4	186.3	1473.0	2950.0	193.2	199.8	1526.4	50
52	2856.5	180.8	186.8	1474.8	2953.2	193.6	200.3	1528.2	52
54	2859.7	181.2	187.2	1476.6	2956.4	194.0	200.8	1530.0	54
56	2862.9	181.6	187.6	1478.3	2959.6	194.4	201.2	1531.7	56
58	2866.2	182.0	188.1	1480.1	2962.9	194.8	201.7	1533.5	58
60	2869.4	182 5	188.5	1481.9	2966.1	195.2	202.1	1535 3	60

′	30°				31°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	2966.1	195.2	202.1	1535.3	3062.6	208.4	216 3	1589.0	0
2	2969.3	195.6	202.6	1537.1	3065.8	208.8	216.8	1590.8	2
4	2972.5	196.1	203.1	1538.9	3069.0	209.3	217.2	1592.6	4
6	2975.7	196.5	203.5	1540.7	3072.2	209.7	217.7	1594.4	6
8	2979.0	197.0	204.0	1542.5	3075.4	210.2	218.2	1596.2	8
10	2982.2	197.4	204.5	1544.3	3078.6	210.6	218.7	1598.0	10
12	2985.4	197.8	204.9	1546.0	3081.8	211.1	219.2	1599.8	12
14	2988.6	198.2	205.4	1547.8	3085.0	211.5	219.6	1601.6	14
16	2991.8	198.6	205.9	1549.6	3088.3	212.0	220.1	1603.4	16
18	2995.0	199.1	206.3	1551.4	3091.5	212.4	220.6	1605.2	18
20	2998.3	199.5	206.8	1553.2	3094.7	212.9	221.1	1607.0	20
22	3001.5	199.9	207.3	1555.0	3097.9	213.3	221.6	1608.8	22
24	3004.7	200.4	207.7	1556.8	3101.1	213.8	222.1	1610.6	24
26	3007.9	200.8	208.2	1558.6	3104.3	214.2	222.6	1612.4	26
28	3011.1	201.3	208.7	1560.4	3107.5	214.7	223.0	1614.2	28
30	3014.3	201.7	209.1	1562.2	3110.7	215.1	223.5	1616.0	30
32	3017.6	202.1	209.6	1564.0	3113.9	215.6	224.0	1617.8	32
34	3020.8	202.6	210 1	1565.7	3117.1	216.0	224.5	1619.6	34
36	3024.0	203.0	210.5	1567.5	3120.3	216.5	225.0	1621.4	36
38	3027.2	203.5	211.0	1569.3	3123.5	216.9	225.5	1623.2	38
40	3030.4	203.9	211 5	1571.1	3126.7	217.4	226.0	1625.0	40
42	3033.6	204.3	212.0	1572.9	3129.9	217.8	226.5	1626.8	42
44	3036.9	204.8	212.4	1574.7	3133.1	218.3	227.0	1628.6	44
46	3040.1	205.2	212.9	1576.5	3136.4	218.7	227.5	1630.5	46
48	3043.3	205.7	213.4	1578.3	3139.6	219.2	228.0	1632.3	48
50	3046.5	206.1	213.9	1580.1	3142.8	219.6	228.4	1634.1	50
52	3049.7	206.5	214.4	1581.9	3146.0	220.1	228.9	1635.9	52
54	3052.9	207.0	214.8	1583.7	3149.2	220.5	229.4	1637.7	54
56	3056.2	207.4	215.3	1585.5	3152.4	221.0	229.9	1639.5	56
58	3059.4	207.9	215.8	1587.2	3155.6	221.5	230.4	1641.3	58
60	3062.6	208.4	216 3	1589.0	3158.8	222.0	230.9	1643.1	60

′	32°				33°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	3158.8	222.0	230.9	1643.1	3254.9	236.0	246.1	1697 3	0
2	3162.0	222 5	231.4	1644 9	3258.1	236.4	246.6	1699.1	2
4	3165.2	222.9	231.9	1646.7	3261.3	236.9	247.1	1700.9	4
6	3168.4	223.4	232.4	1648.5	3264.5	237.4	247.7	1702.7	6
8	3171.6	223.8	232.9	1650.3	3267.7	237.9	248.2	1704.5	8
10	3174.8	224.3	233.4	1652.1	3270.8	238.4	248.7	1706.4	10
12	3178.0	224 8	233.9	1653.9	3274 0	238.9	249.2	1708.2	12
14	3181.2	225.2	234.4	1655.7	3277.2	239 3	249.7	1710.0	14
16	3184.4	225.7	234.9	1657.5	3280.4	239.8	250.2	1711.8	16
18	3187.6	226.1	235.4	1659.3	3283.6	240.3	250.8	1713.6	18
20	3190.8	226.6	235.9	1661.1	3286.8	240.8	251.3	1715.5	20
22	3194.0	227.1	236.4	1662.9	3290 0	241.2	251.8	1717.3	22
24	3197 2	227.5	236 9	1664.7	3293.2	241 7	252.3	1719.1	24
26	3200.4	228.0	237.4	1666 5	3296.4	242.2	252.9	1720.9	26
28	3203.6	228.4	237.9	1668.3	3299.6	242.7	253.4	1722.7	28
30	3206.8	228 9	238.4	1670.1	3302.7	243.2	253.9	1724.6	30
32	3210.0	229.4	239.0	1671.9	3305 9	243.6	254.4	1726.4	32
34	3213.2	229 8	239.5	1673.7	3309 1	244.1	255.0	1728.2	34
36	3216.5	230.3	240.0	1675.5	3312.3	244.6	255.5	1730.0	36
38	3219.7	230.7	240.5	1677.4	3315.5	245.1	256.0	1731.8	38
40	3222.9	231.2	241.0	1679.2	3318.7	245.6	256.5	1733.6	40
42	3226 1	231.7	241.5	1681.0	3321.9	246.0	257.1	1735.5	42
44	3629.3	232.2	242.0	1682.8	3325.1	246.5	257.6	1737.3	44
46	3232.5	232.6	242.5	1684.6	3328.3	247.0	258.1	1739.1	46
48	3235.7	233.1	243.0	1686.4	3331.5	247 5	258.6	1740.9	48
50	3238.9	233.5	243.5	1688.2	3334.6	248.0	259.2	1742.7	50
52	3242.1	234.0	244.1	1690.0	3337.8	248.4	259.7	1744.6	52
54	3245 3	234.5	244.6	1691.8	3341.0	248.9	260 2	1746.4	54
56	3248.5	235.0	245.1	1693.7	3344.2	249.4	260.8	1748.2	56
58	3251.7	235.5	245.6	1695 5	3347.4	249.9	261.3	1750,0	58
60	3254.9	236.0	246.1	1697.3	3350.6	250.4	261 8	1751.8	60

′	34° L. C.	34° M.	34° E.	34° T.	35° L. C.	35° M.	35° E.	35° T.	′
0	3350.6	250.4	261.8	1751.8	3446.1	265.2	278.1	1806.7	0
2	3353.8	250.8	262.3	1753.7	3449.3	265.7	278.6	1808.5	2
4	3357.0	251.2	262.9	1755.5	3452.5	266.2	279.2	1810.3	4
6	3360.1	251.7	263.4	1757.3	3455.6	266.7	279.7	1812.2	6
8	3363.3	252.2	264.0	1759.1	3458.8	267.2	280.3	1814.0	8
10	3366.5	252.7	264.5	1761.0	3462.0	267.7	280.8	1815.8	10
12	3369.7	253.2	265.0	1762.8	3465.2	268.2	281.4	1817.7	12
14	3372.9	253.7	265.6	1764.6	3468.3	268.7	281.9	1819.5	14
16	3376.1	254.2	266.1	1766.4	3471.5	269.2	282.5	1821.3	16
18	3379.2	254.7	266.7	1768.3	3474.7	269.7	283.0	1823.2	18
20	3382.4	255.2	267.2	1770.1	3477.9	270.2	283.6	1825.0	20
22	3385.6	255.7	267.7	1771.9	3481.0	270.7	284.2	1826.8	22
24	3388.8	256.2	268.3	1773.7	3484.2	271.2	284.7	1828.7	24
26	3392.0	256.7	268.8	1775.6	3487.4	271.7	285.3	1830.5	26
28	3395.2	257.2	269.3	1777.4	3490.6	272.2	285.9	1832.3	28
30	3398.3	257.7	269.9	1779.2	3493.7	272.7	286.4	1834.2	30
32	3401.5	258.2	270.4	1781.0	3496.9	273.2	287.0	1836.0	32
34	3404.7	258.7	271.0	1782.9	3500.1	273.7	287.5	1837.8	34
36	3407.9	259.2	271.5	1784.7	3503.3	274.2	288.1	1839.7	36
38	3411.1	259.7	272.0	1786.5	3506.5	274.7	288.7	1841.5	38
40	3414.3	260.2	272.6	1788.4	3509.6	275.2	289.2	1843.4	40
42	3417.4	260.7	273.1	1790.2	3512.8	275.7	289.8	1845.2	42
44	3420.6	261.2	273.7	1792.0	3516.0	276.2	290.4	1847.1	44
46	3423.8	261.7	274.2	1793.9	3519.2	276.7	290.9	1848.9	46
48	3427.0	262.2	274.8	1795.7	3522.3	277.2	291.5	1850.7	48
50	3430.2	262.7	275.3	1797.5	3525.5	277.7	292.0	1852.6	50
52	3433.4	263.2	275.9	1799.3	3528.7	278.2	292.6	1854.4	52
54	3436.5	263.7	276.4	1801.2	3531.9	278.7	293.2	1856.3	54
56	3439.7	264.2	277.0	1803.0	3535.0	279.2	293.7	1858.1	56
58	3442.9	264.7	277.5	1804.8	3538.2	279.8	294.3	1859.9	58
60	3446.1	265.2	278.1	1806.7	3541.4	280.4	294.9	1861.8	60

′	36° L. C.	36° M.	36° E.	36° T.	37° L. C.	37° M.	37° E.	37° T.	′
0	3541.4	280.4	294.9	1861.8	3636.3	296.1	312.3	1917.3	0
2	3544.6	280.9	295.4	1863.6	3639.5	296.6	312.8	1919.1	2
4	3547.7	281.4	296.0	1865.5	3642.6	297.1	313.4	1921.0	4
6	3550.9	281.9	296.6	1867.3	3645.8	297.7	314.0	1922.8	6
8	3554.0	282.5	297.2	1869.2	3648.9	298.2	314.6	1924.7	8
10	3557.2	283.0	297.7	1871.0	3652.1	298.7	315.2	1926.5	10
12	3560.4	283.5	298.3	1872.9	3655.2	299.3	315.8	1928.4	12
14	3563.5	284.0	298.9	1874.7	3658.4	299.8	316.4	1930.2	14
16	3566.7	284.6	299.5	1876.5	3661.6	300.3	317.0	1932.1	16
18	3569.9	285.1	300.0	1878.4	3664.7	300.9	317.5	1933.9	18
20	3573.0	285.6	300.6	1880.2	3667.9	301.4	318.1	1935.8	20
22	3576.2	286.1	301.2	1882.1	3671.0	301.9	318.7	1937.6	22
24	3579.4	286.7	301.8	1883.9	3674.2	302.5	319.3	1939.5	24
26	3582.5	287.2	302.3	1885.8	3677.3	303.0	319.9	1941.3	26
28	3585.7	287.7	302.9	1887.6	3680.5	303.5	320.5	1943.2	28
30	3588.8	288.2	303.5	1889.5	3683.6	304.1	321.1	1945.0	30
32	3592.0	288.8	304.1	1891.3	3686.8	304.6	321.7	1946.9	32
34	3595.2	289.3	304.6	1893.2	3690.0	305.1	322.3	1948.8	34
36	3598.3	289.8	305.2	1895.0	3693.1	305.7	322.9	1950.6	36
38	3601.5	290.3	305.8	1896.9	3696.3	306.2	323.5	1952.5	38
40	3604.7	290.9	306.4	1898.7	3699.4	306.7	324.2	1954.4	40
42	3607.8	291.4	307.0	1900.6	3702.6	307.3	324.8	1956.2	42
44	3611.0	291.9	307.5	1902.4	3705.7	307.8	325.4	1958.1	44
46	3614.1	292.4	308.1	1904.3	3708.9	308.3	326.0	1960.0	46
48	3617.3	293.0	308.7	1906.1	3712.1	308.9	326.6	1961.8	48
50	3620.5	293.5	309.3	1908.0	3715.2	309.4	327.2	1963.7	50
52	3623.6	294.0	309.9	1909.8	3718.4	309.9	327.8	1965.5	52
54	3626.8	294.5	310.5	1911.7	3721.5	310.5	328.4	1967.4	54
56	3630.0	295.1	311.1	1913.5	3724.7	311.0	329.0	1969.3	56
58	3633.1	295.6	311.7	1915.4	3727.8	311.6	329.6	1971.1	58
60	3636.3	296.1	312.3	1917.3	3731.0	312.2	330.2	1973.0	60

′	38° L. C.	38° M.	38° E.	38° T.	39° L. C.	39° M	39° E.	39° T.	′
0	3731.0	312.2	330.2	1973.0	3825.5	328.7	348.7	2029.1	0
2	3734.1	312.7	330.8	1974.9	3828.6	329.2	349.3	2031.0	2
4	3737.3	313.3	331.4	1976.7	3831.8	329.8	349.9	2032.9	4
6	3740.4	313.8	332.0	1978.6	3834.9	330.3	350.6	2034.7	6
8	3743.6	314.4	332.6	1980.5	3838.0	330.9	351.2	2036.6	8
10	3746.7	314.9	333.2	1982.3	3841.2	331.5	351.8	2038.5	10
12	3749.9	315.5	333.8	1984.2	3844.3	332.0	352.4	2040.4	12
14	3753.0	316.0	334.5	1986.1	3847.4	332.6	353.1	2042.3	14
16	3756.2	316.6	335.1	1987.9	3850.6	333.2	353.7	2044.1	16
18	3759.3	317.1	335.7	1989.8	3853.7	333.7	354.3	2046.0	18
20	3762.5	317.7	336.3	1991.7	3856.8	334.3	354.9	2047.9	20
22	3765.6	318.2	336.9	1993.6	3860.0	334.9	355.6	2049.8	22
24	3768.8	318.8	337.5	1995.4	3863.1	335.4	356.2	2051.7	24
26	3771.9	319.3	338.1	1997.3	3866.2	336.0	356.9	2053.5	26
28	3775.1	319.9	338.7	1999.2	3869.4	336.6	357.5	2055.4	28
30	3778.2	320.4	339.4	2001.0	3872.5	337.1	358.1	2057.3	30
32	3781.4	321.0	340.0	2002.9	3875.6	337.7	358.8	2059.2	32
34	3784.5	321.5	340.6	2004.8	3878.8	338.3	359.4	2061.1	34
36	3787.7	322.1	341.2	2006.6	3881.9	338.8	360.1	2063.0	36
38	3790.8	322.6	341.8	2008.5	3885.0	339.4	360.7	2064.8	38
40	3794.0	323.2	342.4	2010.4	3888.2	340.0	361.3	2066.7	40
42	3797.1	323.7	343.1	2012.3	3891.3	340.5	362.0	2068.6	42
44	3800.3	324.3	343.7	2014.1	3894.4	341.1	362.6	2070.5	44
46	3803.4	324.8	344.3	2016.0	3897.6	341.7	363.3	2072.4	46
48	3806.6	325.4	344.9	2017.9	3900.7	342.2	363.9	2074.2	48
50	3809.7	325.9	345.6	2019.7	3903.8	342.8	364.5	2076.1	50
52	3812.9	326.5	346.2	2021.6	3907.0	343.4	365.2	2078.0	52
54	3816.0	327.0	346.8	2023.5	3910.1	343.9	365.8	2079.9	54
56	3819.2	327.6	347.4	2025.4	3913.2	344.5	366.5	2081.8	56
68	3822.3	323.1	348.1	2027.2	3916.4	345.1	367.1	2083.7	58
60	3825.5	328.7	348.7	2029.1	3919.5	345.6	367.7	2085.5	60

′	40° L. C.	40° M.	40° E.	40° T.	41° L. C.	41° M.	41° E.	41° T.	′
0	3919.5	345.6	367.7	2085.5	4013.4	362.9	387.4	2142.3	0
2	3922.6	346.1	368.4	2087.4	4016.5	363.4	388.1	2144.2	2
4	3925.8	346.7	369.0	2089.3	4019.6	364.0	388.8	2146.1	4
6	3928.9	347.2	369.7	2091.2	4022.7	364.5	389.4	2148.0	6
8	3932.0	347.8	370.3	2093.1	4025.9	365.1	390.1	2149.9	8
10	3935.1	348.4	371.0	2095.0	4029.0	365.6	390.7	2151.9	10
12	3938.3	348.9	371.6	2096.9	4032.1	366.2	391.4	2153.8	12
14	3941.4	349.5	372.3	2098.8	4035.2	366.8	392.1	2155.7	14
16	3944.5	350.1	372.9	2100.7	4038.3	367.4	392.7	2157.6	16
18	3947.7	350.7	373.6	2102.6	4041.4	368.0	393.4	2159.5	18
20	3950.8	351.3	374.3	2104.5	4044.6	368.6	394.1	2161.4	20
22	3953.9	351.8	374.9	2106.3	4047.7	369.2	394.7	2163.3	22
24	3957.1	352.4	375.6	2108.2	4050.8	369.8	395.4	2165.2	24
26	3960.2	353.0	376.2	2110.1	4053.9	370.4	396.1	2167.1	26
28	3963.3	353.6	376.9	2112.0	4057.0	371.0	396.8	2169.0	28
30	3966.4	354.2	377.5	2113.9	4060.1	371.6	397.5	2170.9	30
32	3969.6	354.7	378.2	2115.8	4063.3	372.2	398.1	2172.8	32
34	3972.7	355.3	378.8	2117.7	4066.4	372.8	398.8	2174.7	34
36	3975.8	355.9	379.5	2119.6	4069.5	373.4	399.5	2176.6	36
38	3979.0	356.5	380.1	2121.5	4072.6	374.0	400.2	2178.5	38
40	3982.1	357.1	380.8	2123.4	4075.7	374.6	400.9	2180.4	40
42	3985.2	357.6	381.4	2125.3	4078.8	375.2	401.5	2182.4	42
44	3988.4	358.2	382.1	2127.2	4082.0	375.8	402.2	2184.3	44
46	3991.5	358.8	382.8	2129.1	4085.1	376.4	402.9	2186.2	46
48	3994.6	359.4	383.4	2131.0	4088.2	377.0	403.6	2188.1	48
50	3997.7	360.0	384.1	2132.9	4091.3	377.6	404.3	2190.0	50
52	4000.9	360.5	384.8	2134.7	4094.4	378.2	404.9	2191.9	52
54	4004.0	361.1	385.4	2136.6	4097.5	378.8	405.6	2193.8	54
56	4007.1	361.7	386.1	2138.5	4100.7	379.4	406.3	2195.7	56
58	4010.3	362.3	386.8	2140.4	4103.8	380.0	407.0	2197.6	58
60	4013.4	362.9	387.4	2142.3	4106.9	380.6	407.7	2199.5	60

′	42°				43°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	4106.9	380.6	407.7	2199.5	4200.1	398.7	428.6	2257.1	0
2	4110.0	381.2	408.3	2201.4	4203.2	399.3	429.3	2259.0	2
4	4113.1	381.8	409.0	2203.3	4206.3	399.9	430.0	2261.0	4
6	4116.2	382.4	409.7	2205.3	4209.4	400.5	430.7	2262.9	6
8	4119.3	383.0	410.4	2207.2	4212.5	401.1	431.4	2264.8	8
10	4122.4	383.6	411.1	2209.1	4215.6	401.7	432.1	2266.7	10
12	4125.5	384.2	411.8	2211.0	4218.7	402.4	432.8	2268.7	12
14	4128.6	384.8	412.5	2212.9	4221.8	403.0	433.5	2270.6	14
16	4131.8	385.4	413.2	2214.9	4224.9	403.6	434.2	2272.5	16
18	4134.9	386.0	413.9	2216.8	4228.0	404.2	434.9	2274.5	18
20	4138.0	386.3	414.6	2218.7	4231.1	404.8	435.6	2276.4	20
22	4141.1	387.2	415.3	2220.6	4234.2	405.4	436.3	2278.3	22
24	4144.2	387.8	416.0	2222.5	4237.3	406.1	437.0	2280.2	24
26	4147.3	388.4	416.6	2224.4	4240.4	406.7	437.8	2282.2	26
28	4150.4	389.0	417.3	2226.4	4243.5	407.3	438.5	2284.1	28
30	4153.5	389.6	418.0	2228.3	4246.5	407.9	439.2	2286.0	30
32	4156.6	390.2	418.7	2230.2	4249.6	408.5	439.9	2288.0	32
34	4159.7	390.8	419.4	2232.1	4252.7	409.1	440.6	2289.9	34
36	4162.8	391.4	420.1	2234.0	4255.8	409.8	441.4	2291.8	36
38	4165.9	392.0	420.8	2236.0	4258.9	410.4	442.1	2293.8	38
40	4169.0	392.6	421.5	2237.9	4262.0	411.0	442.8	2295.7	40
42	4172.1	393.2	422.2	2239.8	4265.1	411.6	443.5	2297.7	42
44	4175.2	393.8	422.9	2241.7	4268.2	412.2	444.2	2299.6	44
46	4178.4	394.4	423.6	2243.6	4271.3	412.8	445.0	2301.5	46
48	4181.5	395.0	424.3	2245.6	4274.4	413.5	445.7	2303.5	48
50	4184.6	395.6	425.0	2247.5	4277.5	414.1	446.4	2305.4	50
52	4187.7	396.2	425.7	2249.4	4280.6	414.7	447.1	2307.3	52
54	4190.8	396.8	426.4	2251.3	4283.7	415.3	447.8	2309.3	54
56	4193.9	397.4	427.1	2253.3	4286.8	415.9	448.6	2311.2	56
58	4197.0	398.0	427.8	2255.2	4289.9	416.5	449.3	2313.1	58
60	4200.1	398.7	428.6	2257.1	4293.0	417.2	450.0	2315.1	60

′	44°				45°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	4293.0	417.2	450.0	2315.1	4385.5	436.2	472.1	2373.4	0
2	4296.1	417.8	450.7	2317.0	4388.6	436.8	472.9	2375.4	2
4	4299.2	418.4	451.5	2319.0	4391.7	437.5	473.6	2377.3	4
6	4302.2	419.1	452.2	2320.9	4394.7	438.1	474.4	2379.3	6
8	4305.3	419.7	452.9	2322.8	4397.8	438.8	475.1	2381.2	8
10	4308.4	420.3	453.7	2324.8	4400.9	439.4	475.9	2383.2	10
12	4311.5	421.0	454.4	2326.7	4404.0	440.0	476.6	2385.2	12
14	4314.6	421.6	455.1	2328.7	4407.0	440.7	477.4	2387.1	14
16	4317.7	422.2	455.9	2330.6	4410.1	441.3	478.1	2389.1	16
18	4320.7	422.9	456.6	2332.6	4413.2	442.0	478.9	2391.0	18
20	4323.8	423.5	457.3	2334.5	4416.3	442.6	479.6	2393.0	20
22	4326.9	424.1	458.1	2336.4	4419.3	443.2	480.4	2394.9	22
24	4330.0	424.8	458.8	2338.4	4422.4	443.9	481.1	2396.9	24
26	4333.1	425.4	459.5	2340.3	4425.5	444.5	481.9	2398.8	26
28	4336.2	426.0	460.3	2342.3	4428.6	445.2	482.6	2400.8	28
30	4339.2	426.7	461.0	2344.2	4431.6	445.8	483.4	2402.8	30
32	4342.3	427.3	461.7	2346.1	4434.7	446.4	484.2	2404.7	32
34	4345.4	427.9	462.5	2348.1	4437.8	447.1	484.9	2406.7	34
36	4348.5	428.6	463.2	2350.0	4440.9	447.7	485.7	2408.6	36
38	4351.6	429.2	463.9	2352.0	4444.0	448.3	486.5	2410.6	38
40	4354.7	429.8	464.7	2353.9	4447.0	448.9	487.2	2412.6	40
42	4357.7	430.5	465.4	2355.9	4450.1	449.5	488.0	2414.5	42
44	4360.8	431.1	466.2	2357.8	4453.2	450.2	488.7	2416.5	44
46	4363.9	431.7	466.9	2359.8	4456.3	450.8	489.5	2418.5	46
48	4367.0	432.4	467.7	2361.7	4459.3	451.5	490.3	2420.4	48
50	4370.1	433.0	468.4	2363.7	4462.4	452.1	491.0	2422.4	50
52	4373.2	433.6	469.1	2365.6	4465.5	452.7	491.8	2424.4	52
54	4376.2	434.3	469.9	2367.6	4468.6	453.4	492.5	2426.3	54
56	4379.3	434.9	470.6	2369.5	4471.6	454.1	493.3	2428.3	56
58	4382.4	435.6	471.4	2371.5	4474.7	454.8	494.1	2430.2	58
60	4385.5	436.2	472.1	2373.4	4477.8	455.5	494.8	2432.2	60

′	46°				47°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	4477.8	455.5	494.8	2432.2	4569.7	475.2	518.3	2491.5	0
2	4480.9	456.1	495.6	2434.2	4572.7	475.9	519.0	2493.4	2
4	4483.9	456.8	496.5	2436.1	4575.8	476.5	519.8	2495.4	4
6	4487.0	457.4	497.2	2438.1	4578.8	477.2	520.6	2497.4	6
8	4490.0	458.1	497.9	2440.1	4581.9	477.8	521.4	2499.4	8
10	4493.1	458.7	498.7	2442.1	4584.9	478.5	522.2	2501.4	10
12	4496.2	459.4	499.5	2444.0	4588.0	479.2	523.0	2503.4	12
14	4499.2	460.0	500.3	2446.0	4591.0	479.8	523.8	2505.4	14
16	4502.3	460.7	501.0	2448.0	4594.1	480.5	524.6	2507.3	16
18	4505.4	461.3	501.8	2449.9	4597.1	481.1	525.4	2509.3	18
20	4508.4	462.0	502.6	2451.9	4600.2	481.7	526.2	2511.3	20
22	4511.5	462.7	503.4	2453.9	4603.2	482.3	527.0	2513.3	22
24	4514.6	463.3	504.1	2455.9	4606.3	483.0	527.8	2515.3	24
26	4517.6	464.0	504.9	2457.8	4609.3	483.7	528.6	2517.3	26
28	4520.7	464.6	505.7	2459.8	4612.4	484.3	529.4	2519.3	28
30	4523.7	465.3	506.5	2461.8	4615.4	485.0	530.2	2521.2	30
32	4526.8	466.0	507.3	2463.8	4618.5	485.7	531.0	2523.2	32
34	4529.9	466.6	508.0	2465.7	4621.5	486.3	531.8	2525.2	34
36	4532.9	467.3	508.8	2467.7	4624.6	487.0	532.6	2527.2	36
38	4536.0	467.9	509.6	2469.7	4627.6	487.7	533.4	2529.2	38
40	4539.1	468.6	510.4	2471.7	4630.7	488.4	534.2	2531.2	40
42	4542.1	469.3	511.1	2473.6	4633.7	489.1	535.0	2533.2	42
44	4545.2	469.9	511.9	2475.6	4636.8	489.8	535.8	2535.2	44
46	4548.2	470.6	512.7	2477.6	4639.8	490.5	536.6	2537.2	46
48	4551.3	471.2	513.5	2479.6	4642.9	491.2	537.4	2539.2	48
50	4554.4	471.9	514.3	2481.6	4645.9	491.9	538.2	2541.2	50
52	4557.4	472.6	515.1	2483.5	4649.0	492.6	539.0	2543.1	52
54	4560.5	473.2	515.9	2485.5	4652.0	493.3	539.8	2545.1	54
56	4563.6	473.9	516.7	2487.5	4655.1	494.0	540.6	2547.1	56
58	4566.6	474.5	517.5	2489.5	4658.1	494.7	541.4	2549.1	58
60	4569.7	475.2	518.3	2491.5	4661.2	495.4	542.3	2551.1	60

′	48°				49°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	4661.2	495.4	542.3	2551.1	4752.3	515.9	567.0	2611.3	0
2	4664.2	496.0	543.1	2553.1	4755.3	516.5	567.8	2613.3	2
4	4667.3	496.7	543.9	2555.1	4758.4	517.2	568.7	2615.3	4
6	4670.3	497.4	544.7	2557.1	4761.4	517.9	569.5	2617.3	6
8	4673.3	498.1	545.5	2559.1	4764.4	518.6	570.3	2619.3	8
10	4676.4	498.8	546.4	2561.1	4767.4	519.3	571.2	2621.4	10
12	4679.4	499.4	547.2	2563.1	4770.5	520.0	572.0	2623.4	12
14	4682.5	500.1	548.0	2565.1	4773.5	520.7	572.8	2625.4	14
16	4685.5	500.8	548.8	2567.1	4776.5	521.4	573.7	2627.4	16
18	4688.5	501.5	549.6	2569.1	4779.6	522.1	574.5	2629.4	18
20	4691.6	502.2	550.5	2571.1	4782.6	522.8	575.3	2631.4	20
22	4694.6	502.8	551.3	2573.1	4785.6	523.5	576.2	2633.5	22
24	4697.6	503.5	552.1	2575.1	4788.7	524.2	577.0	2635.5	24
26	4700.7	504.2	552.9	2577.1	4791.7	524.9	577.9	2637.5	26
28	4703.7	504.9	553.7	2579.1	4794.7	525.6	578.7	2639.5	28
30	4706.7	505.6	554.6	2581.1	4797.7	526.3	579.6	2641.5	30
32	4709.8	506.2	555.4	2583.1	4800.8	527.0	580.4	2643.5	32
34	4712.8	506.9	556.2	2585.1	4803.8	527.7	581.3	2645.6	34
36	4715.9	507.6	557.0	2587.2	4806.8	528.4	582.1	2647.6	36
38	4718.9	508.3	557.8	2589.2	4809.9	529.1	583.0	2649.6	38
40	4721.9	509.0	558.7	2591.2	4812.9	529.8	583.8	2651.6	40
42	4725.0	509.6	559.5	2593.2	4815.9	530.5	584.7	2653.7	42
44	4728.0	510.3	560.3	2595.2	4819.0	531.2	585.5	2655.7	44
46	4731.0	511.0	561.2	2597.2	4822.0	531.9	586.4	2657.7	46
48	4734.1	511.7	562.0	2599.2	4825.0	532.6	587.2	2659.7	48
50	4737.1	512.4	562.8	2601.2	4828.0	533.3	588.1	2661.8	50
52	4740.2	513.1	563.7	2603.2	4831.1	534.0	588.9	2663.8	52
54	4743.2	513.8	564.5	2605.2	4834.1	534.7	589.8	2665.8	54
56	4746.2	514.5	565.3	2607.2	4837.1	535.4	590.6	2667.8	56
58	4749.3	515.2	566.2	2609.3	4840.2	536.1	591.5	2669.9	58
60	4752.3	515.9	567.0	2611.3	4843.2	536.8	592.4	2671.9	60

′	50°				51°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	4843.2	536.8	592.4	2671.9	4933 6	558.2	618.5	2733.0	0
2	4846.2	537.5	593.2	2673 9	4936.6	558.9	619.3	2735.1	2
4	4849.2	538.2	594.1	2676.0	4939.6	559.7	620.2	2737.1	4
6	4852.2	538.9	594.9	2678.0	4942.6	560.4	621.1	2739.2	6
8	4855.2	539.6	595.8	2680.0	4945.6	561.1	622.0	2741.2	8
10	4858.3	540.3	596.7	2682.1	4948.6	561.8	622.9	2743.3	10
12	4861.3	541.0	597.5	2684.1	4951.6	562.5	623.7	2745.3	12
14	4864.3	541.7	598.4	2686.1	4954.6	563.3	624.6	2747.4	14
16	4867.3	542.4	599.3	2688.2	4957.6	564.0	625.5	2749.4	16
18	4870.3	543.1	600.1	2690.2	4960.6	564.7	626.4	2751.5	18
20	4873.3	543.9	601.0	2692.3	4963.6	565.4	627.3	2753.5	20
22	4876.3	544.6	601.9	2694.3	4966.6	566.2	628.2	2755.6	22
24	4879.4	545.3	602.7	2696.3	4969.6	566.9	629.9	2757.7	24
26	4882.4	546.0	603.6	2698.4	4972.6	567.6	630.0	2759.7	26
28	4885.4	546.7	604.5	2700.4	4975.6	568.3	630.9	2761.8	28
30	4888.4	547.4	605.3	2702.4	4978.6	569.1	631.8	2763.8	30
32	4891.4	548.1	606.2	2704.5	4981.6	569.8	632.7	2765.9	32
34	4894.4	548.8	607.0	2706.5	4984.6	570.5	633.6	2767.9	34
36	4897.4	549.5	607.9	2708.6	4987.7	571.2	634.5	2770.0	36
38	4900.4	550.2	608.8	2710.6	4990.7	572.0	635.3	2772.0	38
40	4903.5	551.0	609.7	2712.6	4993.7	572.7	636.2	2774.1	40
42	4906.5	551.7	610.5	2714.7	4996.7	573.4	637.1	2776.2	42
44	4909.5	552.4	611.4	2716.7	4999.7	574.1	638.0	2778.2	44
46	4912.5	553.1	612.3	2718.8	5002.7	574.9	638.9	2780.3	46
48	4915.5	553.8	613.2	2720.8	5005.7	575.6	639.8	2782.3	48
50	4918.5	554.5	614.1	2722.8	5008.7	576.3	640.7	2784.4	50
52	4921.5	555.2	614.9	2724.9	5011.7	577.0	641.6	2786.4	52
54	4924.6	555.9	615.8	2726.9	5014.7	577.8	642.5	2788.5	54
56	4927.6	556.6	616.7	2729.0	5017.7	578.5	643.4	2790.6	56
58	4930.6	557.4	617.6	2731.0	5020.7	579.2	644.3	2792.6	58
60	4933.6	558.2	618.5	2733.0	5023.7	579.9	645.2	2794.7	60

′	52°				53°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	5023.7	579.9	645.2	2794.7	5113.5	602.0	672.7	2856.9	0
2	5026.7	580.6	646.1	2796.8	5116.5	602.8	673.7	2858.9	2
4	5029.7	581.3	647.0	2798.8	5119.4	603.5	674.6	2861.0	4
6	5032.7	582.1	647.9	2800.9	5122.4	604.3	675.5	2863.1	6
8	5035.7	582.8	648.9	2803.0	5125.4	605.0	676.4	2865.2	8
10	5038.7	583.5	649.8	2805.0	5128.4	605.8	677.4	2867.3	10
12	5041.7	584.3	650.7	2807.1	5131.3	606.5	678.3	2869.4	12
14	5044.7	585.0	651.6	2809.2	5134.3	607.3	679.2	2871.5	14
16	5047.7	585.7	652.5	2811.2	5137.3	608.0	680.2	2873.5	16
18	5050.7	586.5	653.4	2813.3	5140.3	608.8	681.1	2875.6	18
20	5053.6	587.2	654.3	2815.4	5143.2	609.5	682.0	2877.7	20
22	5056.6	587.9	655.2	2817.4	5146.2	610.3	683.0	2879.8	22
24	5059.6	588.7	656.2	2819.5	5149.2	611.0	683.9	2881.9	24
26	5062.6	589.4	657.1	2821.6	5152.1	611.8	684.9	2884.0	26
28	5065.6	590.1	658.0	2823.6	5155.1	612.5	685.8	2886.1	28
30	5068.6	590.9	658.9	2825.7	5158.1	613.3	686.7	2888.1	30
32	5071.6	591.6	659.8	2827.8	5161.1	614.0	687.7	2890.2	32
34	5074.6	592.3	660.7	2829.8	5164.0	614.8	688.6	2892.3	34
36	5077.6	593.1	661.6	2831.9	5167.0	615.5	689.6	2894.4	36
38	5080.6	593.8	662.5	2834.0	5170.0	616.3	690.5	2896.5	38
40	5083.6	594.5	663.5	2836.1	5173.0	617.0	691.5	2898.6	40
42	5086.6	595.3	664.4	2838.2	5175.9	617.8	692.4	2900.7	42
44	5089.6	596.0	665.3	2840.2	5178.9	618.5	693.4	2902.8	44
46	5092.6	596.7	666.2	2842.3	5181.9	619.3	694.3	2904.9	46
48	5095.6	597.5	667.2	2844.4	5184.9	620.1	695.3	2907.0	48
50	5098.6	598.2	668.1	2846.5	5187.8	620.8	696.2	2909.1	50
52	5101.6	598.9	669.0	2848.5	5190.8	621.5	697.1	2911.2	52
54	5104.6	599.7	669.9	2850.6	5193.8	622.3	698.1	2913.3	54
56	5107.6	600.4	670.9	2852.7	5196.7	623.0	699.0	2915.4	56
58	5110.6	601.2	671.8	2854.8	5199.7	623.8	700.0	2917.5	58
60	5113.5	602.0	672.7	2856.9	5202.7	624.6	700.9	2919.5	60

′	54°				55°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	5202.7	624.6	700.9	2919.5	5291.7	647.4	729.9	2982.8	0
2	5205.7	625.4	701.9	2921.6	5294.6	648.1	730.9	2984.9	2
4	5208.6	626.1	702.8	2923.8	5297.6	648.9	731.9	2987.1	4
6	5211.6	626.9	703.8	2925.9	5300.5	649.6	732.9	2989.2	6
8	5214.6	627.6	704.8	2928.0	5303.5	650.4	733.8	2991.3	8
10	5217.5	628.4	705.7	2930.1	5306.4	651.2	734.8	2993.4	10
12	5220.5	629.2	706.7	2932.2	5309.4	652.0	735.8	2995.5	12
14	5223.5	629.9	707.7	2934.3	5312.3	652.7	736.8	2997.7	14
16	5226.4	630.7	708.6	2936.4	5315.3	653.5	737.8	2999.8	16
18	5229.4	631.4	709.6	2938.5	5318.2	654.3	738.7	3001.9	18
20	5232.4	632.2	710.5	2940.6	5321.2	655.1	739.7	3004.0	20
22	5235.3	633.0	711.5	2942.7	5324.1	655.8	740.7	3006.2	22
24	5238.3	633.7	712.5	2944.8	5327.1	656.6	741.7	3008.3	24
26	5241.3	634.5	713.4	2946.9	5330.0	657.4	742.7	3010.4	26
28	5244.2	635.2	714.4	2949.0	5333.0	658.2	743.7	3012.5	28
30	5247.2	636.0	715.3	2951.1	5335.9	658.9	744.7	3014.7	30
32	5250.2	636.8	716.3	2953.2	5338.8	659.7	745.7	3016.8	32
34	5253.1	637.5	717.3	2955.3	5341.8	660.5	746.7	3018.9	34
36	5256.1	638.3	718.2	2957.5	5344.7	661.3	747.7	3021.1	36
38	5259.1	639.0	719.2	2959.6	5347.7	662.0	748.7	3023.2	38
40	5262.0	639.8	720.2	2961.7	5350.6	662.8	749.7	3025.3	40
42	5265.0	640.6	721.1	2963.8	5353.6	663.6	750.7	3027.5	42
44	5268.0	641.3	722.1	2965.9	5356.5	664.4	751.7	3029.6	44
46	5270.9	642.1	723.1	2968.0	5359.5	665.1	752.6	3031.7	46
48	5273.9	642.8	724.1	2970.1	5362.4	665.9	753.6	3033.8	48
50	5276.9	643.6	725.0	2972.2	5365.4	666.7	754.6	3036.0	50
52	5279.8	644.4	726.0	2974.4	5368.3	667.5	755.6	3038.1	52
54	5282.8	645.1	727.0	2976.5	5371.3	668.3	756.6	3040.2	54
56	5285.8	645.9	728.0	2978.6	5374.2	669.1	757.6	3042.4	56
58	5288.7	646.6	729.0	2980.7	5377.2	669.9	758.6	3044.5	58
60	5291.7	647.4	729 9	2982.8	5380.1	670.7	759.6	3046.6	60

′	56°				57°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	5380.1	670.7	759.6	3046.6	5468.2	694.4	790.2	3111.1	0
2	5383.0	671.4	760.6	3048.8	5471.1	695.2	791.2	3113.3	2
4	5386.0	672.2	761.6	3050.9	5474.0	696.0	792.2	3115.4	4
6	5388.9	672.9	762.7	3053.1	5477.0	696.8	793.3	3117.6	6
8	5391.8	673.7	763.7	3055.2	5479.9	697.6	794.3	3119.7	8
10	5394.8	674.4	764.7	3057.4	5482.8	698.4	795.3	3121.9	10
12	5397.7	675.2	765.7	3059.5	5485.7	699.2	796.3	3124.1	12
14	5400.7	676.0	766.7	3061.6	5488.7	700.0	797.4	3126.2	14
16	5403.6	676.8	767.7	3063.8	5491.6	700.8	798.4	3128.4	16
18	5406.5	677.6	768.7	3065.9	5494.5	701.6	799.4	3130.6	18
20	5409.5	678.4	769.7	3068.1	5497.4	702.4	800.5	3132.7	20
22	5412.4	679.2	770.8	3070.2	5500.3	703.2	801.5	3134.9	22
24	5415.3	680.0	771.8	3072.4	5503.3	704.0	802.6	3137.0	24
26	5418.3	680.8	772.8	3074.5	5506.2	704.8	803.6	3139.2	26
28	5421.2	681.6	773.8	3076.6	5509.1	705.6	804.7	3141.4	28
30	5424.1	682.4	774.8	3078.8	5512.0	706.4	805.7	3143.5	30
32	5427.1	683.2	775.8	3080.9	5515.0	707.2	806.8	3145.7	32
34	5430.0	684.0	776.8	3083.1	5517.9	708.0	807.8	3147.9	34
36	5433.0	684.8	777.8	3085.2	5520.8	708.8	808.8	3150.0	36
38	5435.9	685.6	778.9	3087.4	5523.7	709.6	809.9	3152.2	38
40	5438.8	686.4	779.9	3089.6	5526.7	710.4	810.9	3154.4	40
42	5441.8	687.2	780.9	3091.7	5529.6	711.2	812.0	3156.6	42
44	5444.7	688.0	781.9	3093.9	5532.5	712.0	813.0	3158.7	44
46	5447.6	688.8	783.0	3096.0	5535.4	712.8	814.1	3160.9	46
48	5450.6	689.6	784.0	3098.2	5538.4	713.6	815.1	3163.1	48
50	5453.5	690.4	785.0	3100.3	5541.3	714.4	816.2	3165.3	50
52	5456.5	691.2	786.0	3102.5	5544.2	715.2	817.2	3167.4	52
54	5459.4	692.0	787.1	3104.6	5547.1	716.0	818.3	3169.6	54
56	5462.3	692.8	788.1	3106.8	5550.0	716.8	819.3	3171.8	56
58	5465.3	693.6	789.1	3108.9	5553.0	717.6	820.4	3174.0	58
60	5468.2	694.4	790.2	3111.1	5555.9	718.4	821.4	3176.1	60

′	58°				59°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	5555.9	718.4	821.4	3176.1	5643.1	742.8	853.5	3241.9	0
2	5558.8	719.2	822.5	3178.3	5646.0	743.6	854.6	3244.1	2
4	5561.7	720.0	823.5	3180.5	5648.9	744.4	855.7	3246.3	4
6	5564.6	720.8	824.6	3182.7	5651.8	745.3	856.8	3248.5	6
8	5567.5	721.6	825.7	3184.9	5654.7	746.1	857.9	3250.7	8
10	5570.4	722.4	826.7	3187.1	5657.6	746.9	859.0	3252.9	10
12	5573.3	723.2	827.8	3189.2	5660.5	747.7	860.0	3255.1	12
14	5576.2	724.0	828.9	3191.4	5663.4	748.6	861.1	3257.3	14
16	5579.2	724.8	829.9	3193.6	5666.3	749.4	862.2	3259.5	16
18	5582.1	725.6	831.0	3195.8	5669.2	750.2	863.3	3261.7	18
20	5585.0	726.5	832.1	3198.0	5672.1	751.1	864.4	3263.9	20
22	5587.9	727.3	833.1	3200.2	5675.0	751.9	865.5	3266.1	22
24	5590.8	728.1	834.2	3202.4	5677.9	752.7	866.6	3268.3	24
26	5593.7	728.9	835.3	3204.5	5680.8	753.5	867.7	3270.5	26
28	5596.6	729.7	836.3	3206.7	5683.7	754.4	868.8	3272.7	28
30	5599.5	730.5	837.4	3208.9	5686.5	755.2	869.9	3274.9	30
32	5602.4	731.3	838.4	3211.1	5689.4	756.0	871.0	3277.1	32
34	5605.3	732.1	839.5	3213.3	5692.3	756.9	872.1	3279.4	34
36	5608.2	732.9	840.6	3215.5	5695.2	757.7	873.2	3281.6	36
38	5611.1	733.7	841.6	3217.7	5698.1	758.5	874.3	3283.8	38
40	5614.0	734.6	842.7	3219.9	5701.0	759.4	875.4	3286.0	40
42	5616.9	735.4	843.8	3222.1	5703.9	760.2	876.5	3288.2	42
44	5619.8	736.2	844.9	3224.3	5706.8	761.0	877.6	3290.5	44
46	5622.8	737.0	846.0	3226.5	5709.7	761.9	878.7	3292.7	46
48	5625.7	737.8	847.0	3228.7	5712.6	762.7	879.8	3294.9	48
50	5628.6	738.6	848.1	3230.9	5715.5	763.5	880.9	3297.1	50
52	5631.5	739.4	849.2	3233.1	5718.4	764.4	882.0	3299.3	52
54	5634.4	740.2	850.3	3235.3	5721.3	765.2	883.1	3301.5	54
56	5637.3	741.0	851.4	3237.5	5724.2	766.0	884.2	3303.8	56
58	5640.2	741.9	852.5	3239.7	5727.1	766.8	885.3	3306.0	58
60	5643.1	742.8	853.5	3241.9	5730.0	767.7	886.4	3308.2	60

′	60°				61°				′
	L. C.	M,	E.	T.	L. C.	M.	E.	T.	
0	5730.0	767.7	886.4	3308.2	5816.4	792.9	920.2	3375.2	0
2	5732.9	768.5	887.5	3310.4	5819.3	793.7	921.4	3377.4	2
4	5735.8	769.4	888.7	3312.7	5822.1	794.6	922.5	3379.7	4
6	5738.6	770.2	889.8	3314.9	5825.0	795.4	923.6	3381.9	6
8	5741.5	771.1	890.9	3317.1	5827.9	796.3	924.8	3384.2	8
10	5744.4	771.9	892.0	3319.3	5830.7	797.1	925.9	3386.4	10
12	5747.3	772.7	893.1	3321.6	5833.6	798.0	927.1	3388.7	12
14	5750.2	773.6	894.3	3323.8	5836.5	798.8	928.2	3390.9	14
16	5753.0	774.4	895.4	3326.0	5839.3	799.7	929.3	3393.2	16
18	5755.9	775.3	896.5	3328.3	5842.2	800.5	930.5	3395.4	18
20	5758.8	776.1	897.6	3330.5	5845.1	801.4	931.6	3397.7	20
22	5761.7	776.9	898.8	3332.7	5847.9	802.2	932.8	3399.9	22
24	5764.6	777.8	899.9	3334.9	5850.8	803.1	933.9	3402.2	24
26	5767.4	778.6	901.0	3337.2	5853.7	803.9	935.1	3404.4	26
28	5770.3	779.5	902.1	3339.4	5856.5	804.8	936.3	3406.7	28
30	5773.2	780.3	903.2	3341.6	5859.4	805.6	937.4	3408.9	30
32	5776.1	781.1	904.4	3343.9	5862.3	806.5	938.6	3411.2	32
34	5779.0	782.0	905.5	3346.1	5865.1	807.3	939.7	3413.5	34
36	5781.8	782.8	906.6	3348.3	5868.0	808.2	940.9	3415.7	36
38	5784.7	783.7	907.7	3350.6	5870.9	809.0	942.1	3418.0	38
40	5787.6	784.5	908.8	3352.8	5873.7	809.9	943.2	3420.3	40
42	5790.5	785.3	910.0	3355.0	5876.6	810.7	944.4	3422.5	42
44	5793.4	786.2	911.1	3357.3	5879.5	811.6	945.5	3424.8	44
46	5796.2	787.0	912.3	3359.5	5882.3	812.4	946.7	3427.1	46
48	5799.1	787.9	913.4	3361.8	5885.2	813.3	947.8	3429.3	48
50	5802.0	788.7	914.5	3364.0	5888.1	814.1	949.0	3431.6	50
52	5804.9	789.5	915.7	3366.2	5890.9	815.0	950.2	3433.9	52
54	5807.8	790.4	916.8	3368.5	5893.8	815.8	951.3	3436.1	54
56	5810.6	791.2	918.0	3370.7	5896.7	816.7	952.5	3438.4	56
58	5813.5	792.1	919.1	3373.0	5899.5	817.5	953.6	3440.7	58
60	5816.4	792.9	920.2	3375.2	5902.4	818.4	954.8	3442.9	60

′	62° L. C.	62° M.	62° E.	62° T.	63° L. C.	63° M.	63° E.	63° T.	′
0	5902.4	818.4	954.8	3442.9	5987.8	844.4	990.3	3511.3	0
2	5905.2	819.3	956.0	3445.2	5990.6	845.3	991.5	3513.6	2
4	5908.1	820.1	957.2	3447.5	5993.5	846.2	992.7	3515.9	4
6	5910.9	821.0	958.3	3449.7	5996.3	847.1	993.9	3518.2	6
8	5913.8	821.8	959.5	3452.0	5999.1	847.9	995.1	3520.5	8
10	5916.6	822.7	960.7	3454.3	6002.0	848.8	996.3	3522.8	10
12	5919.5	823.6	961.9	3456.6	6004.8	849.7	997.5	3525.1	12
14	5922.3	824.4	963.0	3458.8	6007.7	850.6	998.7	3527.4	14
16	5925.2	825.3	964.2	3461.1	6010.5	851.4	999.9	3529.7	16
18	5928.0	826.1	965.4	3463.4	6013.3	852.3	1001.1	3532.0	18
20	5930.9	827.0	966.6	3465.7	6016.2	853.2	1002.3	3534.3	20
22	5933.7	827.9	967.8	3467.9	6019.0	854.1	1003.5	3536.6	22
24	5936.6	828.7	968.9	3470.2	6021.8	854.9	1004.7	3538.9	24
26	5939.4	829.6	970.1	3472.5	6024.7	855.8	1005.9	3541.2	26
28	5942.3	830.4	971.3	3474.7	6027.5	856.7	1007.1	3543.5	28
30	5945.1	831.3	972.5	3477.0	6030.3	857.6	1008.4	3545.8	30
32	5947.9	832.2	973.6	3479.3	6033.2	858.4	1009.6	3548.1	32
34	5950.8	833.0	974.8	3481.6	6036.0	859.3	1010.8	3550.4	34
36	5953.6	833.9	976.0	3483.9	6038.9	860.2	1012.0	3552.7	36
38	5956.5	834.7	977.2	3486.2	6041.7	861.1	1013.2	3555.0	38
40	5959.3	835.6	978.4	3488.5	6044.5	861.9	1014.5	3557.3	40
42	5962.2	836.5	979.6	3490.7	6047.4	862.8	1015.7	3559.6	42
44	5965.0	837.4	980.8	3493.0	6050.2	863.7	1016.9	3562.0	44
46	5967.9	838.3	982.0	3495.3	6053.0	864.6	1018.1	3564.3	46
48	5970.7	839.1	983.2	3497.6	6055.9	865.4	1019.3	3566.6	48
50	5973.6	840.0	984.4	3499.9	6058.7	866.3	1020.6	3568.9	50
52	5976.4	840.9	985.5	3502.2	6061.6	867.2	1021.8	3571.2	52
54	5979.3	841.7	986.7	3504.5	6064.4	868.1	1023.0	3573.5	54
56	5982.1	842.6	987.9	3506.8	6067.2	868.9	1024.2	3575.8	56
58	5985.0	843.5	989.1	3509.0	6070.1	869.8	1025.4	3578.1	58
60	5987.8	844.4	990.3	3511.3	6072.9	870.7	1026.7	3580.4	60

′	64° L. C.	64° M.	64° E.	64° T.	65° L. C.	65° M.	65° E.	65° T.	′
0	6072.9	870.7	1026.7	3580.4	6157.5	897.3	1064.0	3650.4	0
2	6075.7	871.5	1027.9	3582.8	6160.3	898.2	1065.2	3652.8	2
4	6078.5	872.4	1029.2	3585.1	6163.1	899.1	1066.5	3655.1	4
6	6081.4	873.3	1030.4	3587.4	6165.9	900.0	1067.7	3657.5	6
8	6084.2	874.2	1031.7	3589.7	6168.7	900.9	1069.0	3659.8	8
10	6087.0	875.1	1032.9	3592.1	6171.5	901.8	1070.2	3662.2	10
12	6089.8	875.9	1034.1	3594.4	6174.3	902.7	1071.5	3664.5	12
14	6092.6	876.8	1035.4	3596.7	6177.1	903.6	1072.7	3666.9	14
16	6095.5	877.7	1036.6	3599.1	6179.9	904.5	1074.0	3669.2	16
18	6098.3	878.6	1037.9	3601.4	6182.7	905.4	1075.2	3671.6	18
20	6101.1	879.5	1039.1	3603.7	6185.5	906.3	1076.6	3673.9	20
22	6103.9	880.3	1040.3	3606.0	6188.3	907.2	1077.8	3676.2	22
24	6106.7	881.2	1041.6	3608.4	6191.1	908.1	1079.1	3678.6	24
26	6109.6	882.1	1042.8	3610.7	6193.9	909.0	1080.4	3680.9	26
28	6112.4	883.0	1044.1	3613.0	6196.7	909.9	1081.7	3683.3	28
30	6115.2	883.9	1045.3	3615.3	6199.5	910.8	1083.0	3685.6	30
32	6118.0	884.7	1046.5	3617.7	6202.3	911.7	1084.2	3688.0	32
34	6120.8	885.6	1047.8	3620.0	6205.1	912.6	1085.5	3690.4	34
36	6123.7	886.5	1049.0	3622.3	6208.0	913.5	1086.8	3692.7	36
38	6126.5	887.4	1050.3	3624.7	6210.8	914.4	1088.1	3695.1	38
40	6129.3	888.3	1051.5	3627.0	6213.6	915.3	1089.4	3697.4	40
42	6132.1	889.2	1052.7	3629.4	6216.4	916.2	1090.6	3699.8	42
44	6134.9	890.1	1054.0	3631.7	6219.2	917.1	1091.9	3702.2	44
46	6137.8	891.0	1055.2	3634.0	6222.0	918.0	1093.2	3704.5	46
48	6140.6	891.9	1056.5	3636.4	6224.8	918.9	1094.5	3706.9	48
50	6143.4	892.8	1057.7	3638.7	6227.6	919.8	1095.8	3709.3	50
52	6146.2	893.7	1059.0	3641.1	6230.4	920.7	1097.0	3711.6	52
54	6149.0	894.6	1060.2	3643.4	6233.2	921.6	1098.3	3714.0	54
56	6151.9	895.5	1061.5	3645.7	6236.0	922.5	1099.6	3716.3	56
58	6154.7	896.4	1062.7	3648.1	6238.8	923.4	1100.9	3718.7	58
60	6157.5	897.3	1064.0	3650.4	6241.6	924.3	1102.2	3721.1	60

′	66°				67°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	6241.6	924.3	1102.2	3721.1	6325.2	951.8	1141.5	3792.6	0
2	6244.4	925.2	1103.5	3723.4	6328.0	952.7	1142.8	3795.0	2
4	6247.2	926.1	1104.8	3725.8	6330.7	953.6	1144.1	3797.4	4
6	6250.0	927.0	1106.1	3728.2	6333.5	954.5	1145.4	3799.8	6
8	6252.7	927.9	1107.4	3730.6	6336.3	955.5	1146.7	3802.2	8
10	6255.5	928.8	1108.7	3732.9	6339.0	956.4	1148.1	3804.6	10
12	6258.3	929.8	1110.0	3735.3	6341.8	957.3	1149.4	3807.0	12
14	6261.1	930.7	1111.3	3737.7	6344.6	958.2	1150.7	3809.4	14
16	6263.9	931.6	1112.6	3740.1	6347.4	959.2	1152.0	3811.8	16
18	6266.7	932.5	1113.9	3742.4	6350.1	960.1	1153.3	3814.2	18
20	6269.5	933.4	1115.2	3744.8	6352.9	961.0	1154.7	3816.6	20
22	6272.3	934.3	1116.5	3747.2	6355.7	961.9	1156.0	3819.0	22
24	6275.0	935.3	1117.8	3749.6	6358.4	962.9	1157.4	3821.4	24
26	6277.8	936.2	1119.1	3751.9	6361.2	963.8	1158.7	3823.8	26
28	6280.6	937.1	1120.4	3754.3	6364.0	964.7	1160.1	3826.2	28
30	6283.4	938.0	1121.7	3756.7	6366.7	965.6	1161.4	3828.6	30
32	6286.2	938.9	1123.0	3759.1	6369.5	966.6	1162.8	3831.0	32
34	6289.0	939.8	1124.3	3761.5	6372.3	967.5	1164.1	3833.4	34
36	6291.8	940.8	1125.6	3763.9	6375.1	968.4	1165.5	3835.9	36
38	6294.5	941.7	1126.9	3766.3	6377.8	969.3	1166.8	3838.3	38
40	6297.3	942.6	1128.3	3768.7	6380.6	970.3	1168.2	3840.7	40
42	6300.1	943.5	1129.6	3771.0	6383.4	971.2	1169.5	3843.1	42
44	6302.9	944.4	1130.9	3773.4	6386.1	972.1	1170.9	3845.5	44
46	6305.7	945.3	1132.2	3775.8	6388.9	973.0	1172.2	3847.9	46
48	6308.5	946.3	1133.5	3778.2	6391.7	974.0	1173.6	3850.4	48
50	6311.3	947.2	1134.9	3780.6	6394.4	974.9	1174.9	3852.8	50
52	6314.1	948.1	1136.2	3783.0	6397.2	975.8	1176.3	3855.2	52
54	6316.8	949.0	1137.5	3785.4	6400.0	976.8	1177.6	3857.6	54
56	6319.6	949.9	1138.8	3787.8	6402.8	977.7	1179.0	3860.0	56
58	6322.4	950.8	1140.1	3790.2	6405.5	978.6	1180.3	3862.5	58
60	6325.2	951.8	1141.5	3792.6	6408.3	979.6	1181.6	3864.9	60

′	68°				69°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	6408.3	979.6	1181.6	3864.9	6491.1	1007.7	1222.9	3938.1	0
2	6411.1	980.5	1183.0	3867.3	6493.8	1008.7	1224.3	3940.6	2
4	6413.8	981.4	1184.4	3869.7	6496.6	1009.6	1225.7	3943.0	4
6	6416.6	982.4	1185.7	3872.2	6499.3	1010.6	1227.1	3945.5	6
8	6419.3	983.3	1187.1	3874.6	6502.1	1011.5	1228.5	3947.9	8
10	6422.1	984.2	1188.5	3877.0	6504.8	1012.5	1229.9	3950.4	10
12	6424.9	985.2	1189.8	3879.5	6507.5	1013.4	1231.3	3952.9	12
14	6427.6	986.1	1191.2	3881.9	6510.3	1014.4	1232.7	3955.3	14
16	6430.4	987.0	1192.6	3884.3	6513.0	1015.3	1234.1	3957.8	16
18	6433.1	988.0	1193.9	3886.8	6515.8	1016.3	1235.5	3960.2	18
20	6435.9	988.9	1195.3	3889.2	6518.5	1017.2	1236.9	3962.7	20
22	6438.7	989.8	1196.7	3891.6	6521.2	1018.2	1238.3	3965.2	22
24	6441.4	990.8	1198.0	3894.1	6524.0	1019.1	1239.7	3967.6	24
26	6444.2	991.7	1199.4	3896.5	6526.7	1020.1	1241.1	3970.1	26
28	6446.9	992.6	1200.8	3898.9	6529.5	1021.0	1242.5	3972.5	28
30	6449.7	993.6	1202.1	3901.4	6532.2	1022.0	1243.9	3975.0	30
32	6452.5	994.5	1203.5	3903.8	6534.9	1022.9	1245.3	3977.5	32
34	6455.2	995.4	1204.9	3906.3	6537.7	1023.9	1246.7	3980.0	34
36	6458.0	996.4	1206.2	3908.7	6540.4	1024.8	1248.1	3982.4	36
38	6460.7	997.3	1207.6	3911.2	6543.2	1025.8	1249.5	3984.9	38
40	6463.5	998.2	1209.0	3913.6	6545.9	1026.7	1250.9	3987.4	40
42	6466.3	999.2	1210.3	3916.1	6548.6	1027.7	1252.3	3989.9	42
44	6469.0	1000.1	1211.7	3918.5	6551.4	1028.6	1253.7	3992.3	44
46	6471.8	1001.0	1213.1	3921.0	6554.1	1029.6	1255.1	3994.8	46
48	6474.5	1002.0	1214.5	3923.4	6556.9	1030.5	1256.5	3997.3	48
50	6477.3	1002.9	1215.9	3925.9	6559.6	1031.5	1257.9	3999.8	50
52	6480.1	1003.8	1217.3	3928.3	6562.3	1032.4	1259.3	4002.2	52
54	6482.8	1004.8	1218.7	3930.8	6565.1	1033.4	1260.7	4004.7	54
56	6485.6	1005.7	1220.1	3933.2	6567.8	1034.3	1262.1	4007.2	56
58	6488.3	1006.7	1221.5	3935.7	6570.6	1035.3	1263.5	4009.7	58
60	6491.1	1007.7	1222.9	3938.1	6573.3	1036.3	1265.0	4012.1	60

′	70° L. C.	70° M.	70° E.	70° T.	71° L. C.	71° M.	71° E.	71° T.	′
0	6573.3	1036.3	1265.0	4012.1	6654.9	1065.1	1308.4	4087.1	0
2	6576.0	1037.3	1266.4	4014.6	6657.6	1066.1	1309.9	4089.7	2
4	6578.7	1038.2	1267.9	4017.1	6660.3	1067.0	1311.3	4092.2	4
6	6581.5	1039.2	1269.3	4019.6	6663.0	1068.0	1312.8	4094.7	6
8	6584.2	1040.1	1270.8	4022.1	6665.7	1068.9	1314.2	4097.2	8
10	6586.9	1041.1	1272.2	4024.6	6668.4	1069.9	1315.7	4099.8	10
12	6589.6	1042.1	1273.6	4027.1	6671.1	1070.9	1317.2	4102.3	12
14	6592.3	1043.0	1275.1	4029.6	6673.8	1071.9	1318.6	4104.8	14
16	6595.1	1044.0	1276.5	4032.1	6676.6	1072.9	1320.1	4107.3	16
18	6597.8	1044.9	1278.0	4034.6	6679.3	1073.8	1321.5	4109.8	18
20	6600.5	1045.9	1279.4	4037.1	6682.0	1074.8	1323.0	4112.4	20
22	6603.2	1046.9	1280.8	4039.6	6684.7	1075.8	1324.4	4114.9	22
24	6605.9	1047.8	1282.3	4042.1	6687.4	1076.8	1325.9	4117.4	24
26	6608.7	1048.8	1283.7	4044.6	6690.1	1077.7	1327.4	4119.9	26
28	6611.4	1049.7	1285.2	4047.1	6692.8	1078.7	1328.9	4122.4	28
30	6614.1	1050.7	1286.6	4049.6	6695.5	1079.7	1330.4	4125.0	30
32	6616.8	1051.7	1288.0	4052.1	6698.2	1080.7	1331.8	4127.5	32
34	6619.5	1052.6	1289.5	4054.6	6700.9	1081.6	1333.3	4130.1	34
36	6622.3	1053.6	1290.9	4057.1	6703.6	1082.6	1334.8	4132.6	36
38	6625.0	1054.5	1292.4	4059.6	6706.3	1083.6	1336.3	4135.1	38
40	6627.7	1055.5	1293.8	4062.1	6709.0	1084.5	1337.8	4137.7	40
42	6630.4	1056.5	1295.3	4064.6	6711.7	1085.5	1339.2	4140.2	42
44	6633.1	1057.4	1296.7	4067.1	6714.4	1086.5	1340.7	4142.7	44
46	6635.9	1058.4	1298.2	4069.6	6717.2	1087.5	1342.2	4145.3	46
48	6638.6	1059.3	1299.6	4072.1	6719.9	1088.4	1343.7	4147.8	48
50	6641.3	1060.3	1301.1	4074.6	6722.6	1089.4	1345.2	4150.4	50
52	6644.0	1061.3	1302.6	4077.1	6725.3	1090.4	1346.7	4152.9	52
54	6646.7	1062.2	1304.0	4079.6	6728.0	1091.3	1348.2	4155.4	54
56	6649.5	1063.2	1305.5	4082.1	6730.7	1092.3	1349.7	4158.0	56
58	6652.2	1064.1	1306.9	4084.6	6733.4	1093.3	1351.2	4160.5	58
60	6654.9	1065.1	1308.4	4087.1	6736.1	1094.3	1352.7	4163.1	60

′	72° L. C.	72° M.	72° E.	72° T.	73° L. C.	73° M.	73° E.	73° T.	′
0	6736.1	1094.3	1352.7	4163.1	6816.6	1123.9	1398.1	4240.0	0
2	6738.8	1095.2	1354.2	4165.6	6819.3	1124.8	1399.6	4242.6	2
4	6741.5	1096.2	1355.7	4168.2	6821.9	1125.8	1401.2	4245.1	4
6	6744.1	1097.2	1357.2	4170.7	6824.6	1126.8	1402.7	4247.7	6
8	6746.8	1098.2	1358.7	4173.3	6827.3	1127.8	1404.2	4250.3	8
10	6749.5	1099.2	1360.2	4175.8	6830.0	1128.8	1405.8	4252.9	10
12	6752.2	1100.1	1361.7	4178.4	6832.6	1129.8	1407.3	4255.5	12
14	6754.9	1101.1	1363.2	4181.0	6835.3	1130.8	1408.8	4258.1	14
16	6757.6	1102.1	1364.7	4183.5	6838.0	1131.8	1410.4	4260.7	16
18	6760.2	1103.1	1366.2	4186.1	6840.7	1132.8	1411.9	4263.2	18
20	6762.9	1104.1	1367.7	4188.6	6843.3	1133.8	1413.5	4265.8	20
22	6765.6	1105.1	1369.2	4191.2	6846.0	1134.8	1415.1	4268.4	22
24	6768.3	1106.0	1370.7	4193.7	6848.7	1135.8	1416.6	4271.0	24
26	6771.0	1107.0	1372.2	4196.3	6851.3	1136.8	1418.2	4273.6	26
28	6773.7	1108.0	1373.7	4198.8	6854.0	1137.8	1419.7	4276.2	28
30	6776.3	1109.0	1375.2	4201.4	6856.7	1138.8	1421.3	4278.8	30
32	6779.0	1109.9	1376.7	4204.0	6859.4	1139.8	1422.9	4281.4	32
34	6781.7	1110.9	1378.2	4206.5	6862.0	1140.8	1424.4	4284.0	34
36	6784.4	1111.9	1379.7	4209.1	6864.7	1141.8	1426.0	4286.6	36
38	6787.1	1112.9	1381.2	4211.7	6867.4	1142.8	1427.5	4289.2	38
40	6789.8	1113.9	1382.8	4214.3	6870.1	1143.8	1429.1	4291.8	40
42	6792.4	1114.9	1384.3	4216.8	6872.7	1144.8	1430.7	4294.4	42
44	6795.1	1115.9	1385.8	4219.4	6875.4	1145.8	1432.2	4297.0	44
46	6797.8	1116.9	1387.4	4222.0	6878.1	1146.8	1433.8	4299.6	46
48	6800.5	1117.9	1388.9	4224.5	6880.8	1147.8	1435.3	4302.2	48
50	6803.2	1118.9	1390.4	4227.1	6883.4	1148.8	1436.9	4304.8	50
52	6805.9	1119.9	1392.0	4229.7	6886.1	1149.8	1438.5	4307.4	52
54	6808.5	1120.9	1393.5	4232.3	6888.8	1150.8	1440.0	4310.0	54
56	6811.2	1121.9	1395.0	4234.8	6891.4	1151.8	1441.6	4312.6	56
58	6813.9	1122.9	1396.6	4237.4	6894.1	1152.8	1443.1	4315.2	58
60	6816.6	1123.9	1398.1	4240.0	6896.8	1153.8	1444.7	4317.8	60

	74°				75°				
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	6896.8	1153.8	1444.7	4317.8	6976.4	1184.1	1492.5	4396.7	0
2	6899.4	1154.8	1446.2	4320.5	6979.0	1185.1	1494.1	4399.4	2
4	6902.1	1155.8	1447.8	4323.1	6981.7	1186.1	1495.7	4402.1	4
6	6904.8	1156.8	1449.4	4325.7	6984.3	1187.1	1497.3	4404.7	6
8	6907.4	1157.8	1451.0	4328.3	6986.9	1188.1	1499.0	4407.4	8
10	6910.1	1158.8	1452.6	4330.9	6989.6	1189.2	1500.6	4410.0	10
12	6912.7	1159.8	1454.1	4333.6	6992.2	1190.2	1502.2	4412.7	12
14	6915.4	1160.8	1455.7	4336.2	6994.9	1191.2	1503.8	4415.3	14
16	6918.0	1161.8	1457.3	4338.8	6997.5	1192.2	1505.4	4418.0	16
18	6920.7	1162.8	1458.9	4341.4	7000.1	1193.2	1507.0	4420.7	18
20	6923.3	1163.9	1460.5	4344.0	7002.8	1194.3	1508.7	4423.3	20
22	6926.0	1164.9	1462.0	4346.7	7005.4	1195.3	1510.3	4426.0	22
24	6928.6	1165.9	1463.6	4349.3	7008.0	1196.3	1512.0	4428.6	24
26	6931.3	1166.9	1465.2	4351.9	7010.7	1197.3	1513.6	4431.3	26
28	6933.9	1167.9	1466.8	4354.5	7013.3	1198.3	1515.3	4434.0	28
30	6936.6	1168.9	1468.4	4357.1	7015.9	1199.4	1516.9	4436.6	30
32	6939.2	1169.9	1469.9	4359.8	7018.6	1200.4	1518.5	4439.3	32
34	6941.9	1170.9	1471.5	4362.4	7021.2	1201.4	1520.2	4442.0	34
36	6944.6	1171.9	1473.1	4365.1	7023.9	1202.4	1521.8	4444.6	36
38	6947.2	1172.9	1474.7	4367.7	7026.5	1203.4	1523.5	4447.3	38
40	6949.9	1174.0	1476.4	4370.3	7029.1	1204.5	1525.1	4450.0	40
42	6952.5	1175.0	1478.0	4373.0	7031.8	1205.5	1526.7	4452.7	42
44	6955.2	1176.0	1479.6	4375.6	7034.4	1206.5	1528.4	4455.3	44
46	6957.8	1177.0	1481.2	4378.3	7037.0	1207.5	1530.0	4458.0	46
48	6960.5	1178.0	1482.8	4380.9	7039.7	1208.5	1531.7	4460.7	48
50	6963.1	1179.0	1484.4	4383.5	7042.3	1209.6	1533.3	4463.4	50
52	6965.8	1180.0	1486.0	4386.2	7045.0	1210.6	1534.9	4466.0	52
54	6968.4	1181.0	1487.7	4388.8	7047.6	1211.6	1536.6	4468.7	54
56	6971.1	1182.0	1489.3	4391.5	7050.2	1212.6	1538.2	4471.4	56
58	6973.7	1183.0	1490.9	4394.1	7052.9	1213.6	1539.9	4474.1	58
60	6976.4	1184.1	1492.5	4396.7	7055.5	1214.7	1541.5	4476.7	60

′	76°				77°				′
	L. C.	M.	E.	T.	L. C.	M	E.	T.	
0	7055.5	1214.7	1541.5	4476.7	7134.0	1245.6	1591.7	4557.8	0
2	7058.1	1215.7	1543.2	4479.4	7136.6	1246.6	1593.4	4560.5	2
4	7060.7	1216.7	1544.9	4482.1	7139.2	1247.7	1595.1	4563.3	4
6	7063.3	1217.8	1546.5	4484.8	7141.8	1248.7	1596.8	4566.0	6
8	7066.0	1218.8	1548.2	4487.5	7144.4	1249.8	1598.5	4568.7	8
10	7068.6	1219.8	1549.9	4490.2	7147.0	1250.8	1600.2	4571.5	10
12	7071.2	1220.9	1551.5	4492.9	7149.6	1251.8	1601.9	4574.2	12
14	7073.8	1221.9	1553.2	4495.6	7152.2	1252.9	1603.6	4576.9	14
16	7076.4	1222.9	1554.9	4498.3	7154.8	1253.9	1605.3	4579.7	16
18	7079.0	1224.0	1556.5	4501.0	7157.4	1255.0	1607.0	4582.4	18
20	7081.7	1225.0	1558.2	4503.7	7160.0	1256.0	1608.7	4585.1	20
22	7084.3	1226.0	1559.9	4506.3	7162.6	1257.0	1610.4	4587.9	22
24	7086.9	1227.1	1561.5	4509.0	7165.2	1258.1	1612.1	4590.6	24
26	7089.5	1228.1	1563.2	4511.7	7167.8	1259.1	1613.8	4593.3	26
28	7092.1	1229.1	1564.9	4514.4	7170.4	1260.2	1615.5	4596.0	28
30	7094.7	1230.2	1566.5	4517.1	7173.0	1261.2	1617.3	4598.8	30
32	7097.4	1231.2	1568.2	4519.8	7175.6	1262.2	1619.0	4601.5	32
34	7100.0	1232.2	1569.9	4522.5	7178.2	1263.3	1620.7	4604.3	34
36	7102.6	1233.3	1571.5	4525.3	7180.8	1264.3	1622.4	4607.0	36
38	7105.2	1234.3	1573.2	4528.0	7183.4	1265.4	1624.1	4609.8	38
40	7107.8	1235.3	1574.8	4530.7	7186.0	1266.4	1625.9	4612.5	40
42	7110.4	1236.4	1576.4	4533.4	7188.6	1267.4	1627.6	4615.3	42
44	7113.1	1237.4	1578.1	4536.1	7191.2	1268.5	1629.3	4618.0	44
46	7115.7	1238.4	1579.8	4538.8	7193.8	1269.5	1631.0	4620.8	46
48	7118.3	1239.5	1581.5	4541.5	7196.4	1270.6	1632.7	4623.5	48
50	7120.9	1240.5	1583.2	4544.2	7199.0	1271.6	1634.5	4626.3	50
52	7123.5	1241.5	1584.9	4547.0	7201.6	1272.7	1636.2	4629.0	52
54	7126.1	1242.6	1586.6	4549.7	7204.2	1273.7	1637.9	4631.8	54
56	7128.8	1243.6	1588.3	4552.4	7206.8	1274.8	1639.6	4634.5	56
58	7131.4	1244.6	1590.0	4555.1	7209.4	1275.8	1641.3	4637.3	58
60	7134.0	1245.6	1591.7	4557.8	7212.0	1276.9	1643.1	4640.0	60

′	78° L. C.	78° M.	78° E.	78° T.	79° L. C.	79° M.	79° E.	79° T.	′
0	7212.0	1276.9	1643.1	4640.0	7289.5	1308.5	1696.0	4723.4	0
2	7214.6	1278.0	1644.8	4642.8	7292.1	1309.5	1697.7	4726.2	2
4	7217.2	1279.0	1646.6	4645.6	7294.6	1310.6	1699.5	4729.0	4
6	7219.7	1280.1	1648.3	4648.3	7297.2	1311.7	1701.3	4731.8	6
8	7222.3	1281.1	1650.1	4651.1	7299.7	1312.7	1703.1	4734.7	8
10	7224.9	1282.2	1651.8	4653.9	7302.3	1313.8	1704.9	4737.5	10
12	7227.5	1283.2	1653.6	4656.7	7304.9	1314.9	1706.6	4740.3	12
14	7230.1	1284.3	1655.3	4659.4	7307.4	1315.9	1708.4	4743.1	14
16	7232.7	1285.3	1657.1	4662.2	7310.0	1317.0	1710.2	4745.9	16
18	7235.2	1286.4	1658.8	4665.0	7312.6	1318.1	1712.0	4748.7	18
20	7237.8	1287.4	1660.6	4667.7	7315.1	1319.1	1713.8	4751.5	20
22	7240.4	1288.5	1662.3	4670.5	7317.7	1320.2	1715.6	4754.3	22
24	7243.0	1289.5	1664.1	4673.3	7320.3	1321.3	1717.4	4757.1	24
26	7245.6	1290.6	1665.8	4676.0	7322.8	1322.3	1719.2	4760.0	26
28	7248.2	1291.6	1667.6	4678.8	7325.4	1323.4	1721.0	4762.8	28
30	7250.7	1292.7	1669.3	4681.6	7327.9	1324.5	1722.8	4765.6	30
32	7253.3	1293.7	1671.1	4684.4	7330.5	1325.5	1724.6	4768.4	32
34	7255.9	1294.8	1672.8	4687.2	7333.1	1326.6	1726.4	4771.2	34
36	7258.5	1295.8	1674.6	4689.9	7335.6	1327.7	1728.2	4774.1	36
38	7261.1	1296.9	1676.3	4692.7	7338.2	1328.7	1730.0	4776.9	38
40	7263.7	1297.9	1678.2	4695.5	7340.8	1329.8	1731.9	4779.7	40
42	7266.2	1299.0	1679.9	4698.3	7343.3	1330.8	1733.7	4782.6	42
44	7268.8	1300.0	1681.7	4701.1	7345.9	1331.9	1735.5	4785.4	44
46	7271.4	1301.1	1683.5	4703.9	7348.4	1333.0	1737.3	4788.2	46
48	7274.0	1302.1	1685.3	4706.7	7351.0	1334.1	1739.1	4791.0	48
50	7276.6	1303.2	1687.1	4709.5	7353.6	1335.2	1740.9	4793.9	50
52	7279.2	1304.2	1688.8	4712.2	7356.1	1336.2	1742.7	4796.7	52
54	7281.7	1305.3	1690.6	4715.0	7358.7	1337.3	1744.5	4799.5	54
56	7284.3	1306.3	1692.4	4717.8	7361.3	1338.4	1746.3	4802.4	56
58	7286.9	1307.4	1694.2	4720.6	7363.8	1339.5	1748.1	4805.2	58
60	7289.5	1308.5	1696.0	4723.4	7366.4	1340.6	1750.0	4808.0	60

′	80° L. C.	80° M.	80° E.	80° T.	81° L. C.	81° M.	81° E.	81° T.	′
0	7366.4	1340.6	1750.0	4808.0	7442.7	1372.8	1805.5	4893.9	0
2	7368.9	1341.7	1751.8	4810.9	7445.2	1373.9	1807.3	4896.8	2
4	7371.5	1342.7	1753.7	4813.7	7447.7	1375.0	1809.2	4899.7	4
6	7374.0	1343.8	1755.5	4816.6	7450.3	1376.1	1811.1	4902.6	6
8	7376.6	1344.9	1757.4	4819.4	7452.8	1377.1	1813.0	4905.4	8
10	7379.1	1346.0	1759.2	4822.3	7455.3	1378.2	1814.9	4908.3	10
12	7381.7	1347.0	1761.0	4825.1	7457.8	1379.3	1816.8	4911.2	12
14	7384.2	1348.1	1762.9	4828.0	7460.4	1380.4	1818.6	4914.1	14
16	7386.7	1349.2	1764.7	4830.8	7462.9	1381.4	1820.5	4917.0	16
18	7389.3	1350.3	1766.6	4833.7	7465.4	1382.5	1822.4	4919.9	18
20	7391.8	1351.3	1768.4	4836.5	7467.9	1383.6	1824.2	4922.8	20
22	7394.4	1352.4	1770.2	4839.4	7470.4	1384.7	1826.1	4925.7	22
24	7396.9	1353.5	1772.1	4842.2	7473.0	1385.7	1828.0	4928.6	24
26	7399.5	1354.6	1773.9	4845.1	7475.5	1386.8	1829.9	4931.5	26
28	7402.0	1355.6	1775.8	4847.9	7478.0	1387.9	1831.8	4934.4	28
30	7404.5	1356.7	1777.6	4850.8	7480.5	1389.0	1833.7	4937.2	30
32	7407.1	1357.8	1779.4	4853.7	7483.1	1390.1	1835.6	4940.2	32
34	7409.6	1358.9	1781.3	4856.5	7485.6	1391.2	1837.5	4943.1	34
36	7412.2	1359.9	1783.1	4859.4	7488.1	1392.3	1839.4	4946.0	36
38	7414.7	1361.0	1785.0	4862.3	7490.6	1393.4	1841.3	4948.9	38
40	7417.3	1362.1	1786.8	4865.1	7493.2	1394.5	1843.2	4951.8	40
42	7419.8	1363.2	1788.6	4868.0	7495.7	1395.6	1845.1	4954.7	42
44	7422.3	1364.2	1790.5	4870.9	7498.2	1396.7	1847.0	4957.6	44
46	7424.9	1365.3	1792.4	4873.8	7500.7	1397.8	1848.9	4960.6	46
48	7427.4	1366.4	1794.3	4876.6	7503.3	1398.9	1850.8	4963.5	48
50	7430.0	1367.5	1796.2	4879.5	7505.8	1400.0	1852.7	4966.4	50
52	7432.5	1368.5	1798.0	4882.4	7508.3	1401.1	1854.6	4969.3	52
54	7435.1	1369.6	1799.9	4885.3	7510.8	1402.2	1856.5	4972.2	54
56	7437.6	1370.7	1801.8	4888.1	7513.3	1403.3	1858.4	4975.1	56
58	7440.1	1371.8	1803.7	4891.0	7515.9	1404.4	1860.3	4978.0	58
60	7442.7	1372.8	1805.5	4893.9	7518.4	1405.5	1862.3	4981.0	60

′	82°				83°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	7518.4	1405.5	1862.3	4981.0	7593.6	1438.5	1920.6	5069.4	0
2	7520.9	1406.6	1864.2	4983.9	7596.1	1439.6	1922.6	5072.4	2
4	7523.4	1407.7	1866.1	4986.8	7598.6	1440.7	1924.6	5075.4	4
6	7525.9	1408.8	1868.1	4989.8	7601.1	1441.8	1926.5	5078.4	6
8	7528.4	1409.9	1870.0	4992.7	7603.6	1442.9	1928.5	5081.4	8
10	7530.9	1411.0	1871.9	4995,7	7606.0	1444.0	1930.5	5084.4	10
12	7533.4	1412.1	1873 9	4998.6	7608.5	1445.1	1932.4	5087.3	12
14	7535.9	1413.2	1875.8	5001.5	7611.0	1446.2	1934.4	5090.3	14
16	7538.5	1414.3	1877.7	5004.5	7613.5	1447.3	1936.4	5093.3	16
18	7541.0	1415.4	1879.7	5007.4	7616.0	1448.4	1938.4	5096.3	18
20	7543.5	1416.5	1881.6	5010.3	7618.5	1449.6	1940.4	5099.3	20
22	7546.0	1417.6	1883.5	5013.3	7621.0	1450.7	1942.4	5102.3	22
24	7548.5	1418.7	1885.5	5016.2	7623.5	1451.8	1944.4	5105.2	24
26	7551.0	1419.8	1887.4	5019.2	7626.0	1452.9	1946.4	5108.2	26
28	7553.5	1420.9	1889.3	5022.1	7628.5	1454.0	1948.4	5111.2	28
30	7556.0	1422.0	1891.3	5025.0	7630.9	1455.1	1950.4	5114.2	30
32	7558.5	1423.1	1893.2	5028.0	7633.4	1456.2	1952.4	5117.2	32
34	7561.0	1424.2	1895.1	5031.0	7635.9	1457.3	1954.4	5120.2	34
36	7563.5	1425.3	1897.1	5033.9	7638.4	1458.4	1956.4	5123.2	36
38	7566.0	1426.4	1899.0	5036.9	7640.9	1459.5	1958.4	5126.2	38
40	7568.5	1427.5	1901.0	5039.8	7643.4	1460.7	1960.4	5129.2	40
42	7571.0	1428.6	1902.9	5042.8	7645.9	1461.8	1962.4	5132.2	42
44	7573.5	1429.7	1904.9	5045.8	7648.4	1462.9	1964.4	5135.2	44
46	7576.1	1430.8	1906.9	5048.7	7650.9	1464.0	1966.4	5138.2	46
48	7578.6	1431.9	1908.8	5051.7	7653.4	1465.1	1968.4	5141.2	48
50	7581.1	1433.0	1910.8	5054.6	7655.8	1466.2	1970.4	5144.3	50
52	7583.6	1434.1	1912.8	5057.6	7658.3	1467.3	1972.4	5147.3	52
54	7586.1	1435.2	1914.7	5060.6	7660.8	1468.4	1974.4	5150.3	54
56	7588.6	1436.3	1916.7	5063.5	7663.3	1469.5	1976.4	5153.3	56
58	7591.1	1437.4	1918.7	5066.5	7665.8	1470.6	1978.4	5156.3	58
60	7593.6	1438.5	1920.6	5069.4	7668.3	1471.8	1980.5	5159.3	60

′	84°				85°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	7668.3	1471.8	1980.5	5159.3	7742.4	1505.4	2041.8	5250.6	0
2	7670.8	1472.9	1982.5	5162.3	7744.8	1506.5	2043.9	5253.6	2
4	7673.2	1474.0	1984.5	5165.3	7747.3	1507.6	2046.0	5256.7	4
6	7675.7	1475.1	1986.6	5168.4	7749.7	1508.8	2048.0	5259.8	6
8	7678.2	1476.2	1988.6	5171.4	7752.2	1509.9	2050.1	5262.9	8
10	7680.6	1477.4	1990.6	5174.4	7754.6	1511.0	2052.2	5266 0	10
12	7683.1	1478.5	1992.7	5177.5	7757.1	1512.2	2054.2	5269.0	12
14	7685.6	1479.6	1994.7	5180.5	7759.5	1513.3	2056.3	5272.1	14
16	7688.1	1480.7	1996.7	5183.5	7762.0	1514.4	2058.4	5275.2	16
18	7690.5	1481.8	1998.8	5186.6	7764.4	1515.6	2060.5	5278.3	18
20	7693.0	1483.0	2000.8	5189.6	7766.9	1516.7	2062.6	5281.4	20
22	7695.5	1484.1	2002.8	5192.6	7769.3	1517.8	2064.7	5284.4	22
24	7697.9	1485.2	2004.9	5195.6	7771.8	1519.0	2066.8	5287.5	24
26	7700.4	1486.3	2006.9	5198.7	7774.2	1520.1	2068.9	5290.6	26
28	7702.9	1487.4	2008.9	5201.7	7776.7	1521.2	2071.0	5293.7	28
30	7705.3	1488.6	2011.0	5204.7	7779.1	1522.4	2073.1	5296.7	30
32	7707.8	1489.7	2013.0	5207.8	7781.5	1523.5	2075.2	5299.8	32
34	7710.3	1490.8	2015.0	5210.8	7784.0	1524.6	2077 3	5302.9	34
36	7712.8	1491.9	2017.0	5213.9	7786.4	1525.8	2079.4	5306.1	36
38	7715.2	1493.0	2019.1	5216.9	7788.9	1526.9	2081.5	5309.2	38
40	7717.7	1494.2	2021.2	5220.0	7791.3	1528.0	2083.7	5312.3	40
42	7720.2	1495.3	2023.2	5223.1	7793.8	1529.2	2085.8	5315.4	42
44	7722.6	1496.4	2025.3	5226.1	7796.2	1530.3	2087.9	5318.5	44
46	7725.1	1497.5	2027.4	5229.2	7798.7	1531.4	2090.0	5321.6	46
48	7727.6	1498.6	2029.4	5232.2	7801.1	1532.6	2092.1	5324.7	48
50	7730.0	1499.8	2031.5	5235.3	7803.6	1533.7	2094.2	5327.8	50
52	7732.5	1500.9	2033.6	5238.3	7806.0	1534.8	2096.3	5330 9	52
54	7735.0	1502.0	2035.6	5241.4	7808.5	1536.0	2098.4	5334.0	54
56	7737.5	1503.1	2037.7	5244.5	7810.9	1537.1	2100.6	5337.1	56
58	7739 9	1504.2	2039.8	5247.5	7813 4	1538.2	2102.7	5340.2	58
60	7742.4	1505.4	2041.8	5250.6	7815.8	1539.3	2104.8	5343.3	60

′	86°				87°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	7815.8	1539.3	2104.8	5343.3	7888.5	1573.6	2169.5	5437.5	0
2	7818.2	1540.4	2106.9	5346.4	7890.9	1574.8	2171.6	5440.7	2
4	7820.6	1541.6	2109.1	5349.5	7893.3	1575.9	2173.8	5443.9	4
6	7823.1	1542.7	2111.2	5352.7	7895.7	1577.1	2176.0	5447.1	6
8	7825.5	1543.9	2113.4	5355.8	7898.1	1578.2	2178.2	5450.3	8
10	7827.9	1545.0	2115.5	5358.9	7900.5	1579.4	2180.4	5453.4	10
12	7830.3	1546.1	2117.6	5362.0	7903.0	1580.5	2182.5	5456.6	12
14	7832.8	1547.3	2119.8	5365.2	7905.4	1581.7	2184.7	5459.8	14
16	7835.2	1548.4	2121.9	5368.3	7907.8	1582.9	2186.9	5463.0	16
18	7837.6	1549.6	2124.1	5371.4	7910.2	1584.0	2189.1	5466.2	18
20	7840.0	1550.7	2126.2	5374.6	7912.6	1585.1	2191.3	5469.4	20
22	7842.4	1551.8	2128.3	5377.7	7915.0	1586.3	2193.5	5472.5	22
24	7844.9	1553.0	2130.5	5380.8	7917.4	1587.4	2195.7	5475.7	24
26	7847.3	1554.1	2132.6	5383.9	7919.8	1588.6	2197.9	5478.9	26
28	7849.7	1555.3	2134.8	5387.1	7922.2	1589.7	2200.1	5482.1	28
30	7852.1	1556.4	2136.9	5390.2	7924.6	1590.9	2202.3	5485.3	30
32	7854.6	1557.5	2139.0	5393.4	7927.1	1592.0	2204.5	5488.5	32
34	7857.0	1558.7	2141.2	5396.5	7929.5	1593.2	2206.8	5491.7	34
36	7859.4	1559.8	2143.3	5399.7	7931.9	1594.3	2209.0	5494.9	36
38	7861.8	1561.0	2145.5	5402.8	7934.3	1595.5	2211.2	5498.1	38
40	7864.3	1562.1	2147.7	5406.0	7936.7	1596.6	2213.4	5501.3	40
42	7866.7	1563.2	2149.8	5409.1	7939.1	1597.8	2215.6	5504.5	42
44	7869.1	1564.4	2152.0	5412.3	7941.5	1598.9	2217.8	5507.7	44
46	7871.5	1565.5	2154.2	5415.4	7943.9	1600.1	2220.0	5510.9	46
48	7874.0	1566.7	2156.4	5418.6	7946.3	1601.2	2222.3	5514.1	48
50	7876.4	1567.8	2158.6	5421.8	7948.7	1602.4	2224.5	5517.3	50
52	7878.8	1568.9	2160.7	5424.9	7951.2	1603.5	2226.7	5520.5	52
54	7881.2	1570.1	2162.9	5428.1	7953.6	1604.7	2228.9	5523.7	54
56	7883.6	1571.2	2165.1	5431.2	7956.0	1605.8	2231.1	5526.9	56
58	7886.1	1572.4	2167.3	5434.4	7958.4	1607.0	2233.3	5530.1	58
60	7888.5	1573.6	2169.5	5437.5	7960.8	1608.2	2235.6	5533.3	60

′	88°				89°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	7960.8	1608.2	2235.6	5533.3	8032.4	1643.0	2303.6	5630.8	0
2	7963.2	1609.4	2237.8	5536.6	8034.8	1644.1	2305.9	5634.1	2
4	7965.6	1610.5	2240.1	5539.8	8037.1	1645.3	2308.2	5637.4	4
6	7968.0	1611.7	2242.3	5543.1	8039.5	1646.5	2310.5	5640.7	6
8	7970.3	1612.8	2244.6	5546.3	8041.9	1647.7	2312.8	5644.0	8
10	7972.7	1614.0	2246.8	5549.5	8044.2	1648.9	2315.1	5647.3	10
12	7975.1	1615.2	2249.1	5552.8	8046.6	1650.0	2317.4	5650.6	12
14	7977.5	1616.3	2251.3	5556.0	8049.0	1651.2	2319.7	5653.9	14
16	7979.9	1617.5	2253.6	5559.2	8051.4	1652.4	2322.0	5657.1	16
18	7982.3	1618.6	2255.8	5562.5	8053.7	1653.6	2324.3	5660.4	18
20	7984.7	1619.8	2258.1	5565.7	8056.1	1654.8	2326.7	5663.7	20
22	7987.1	1621.0	2260.4	5568.9	8058.5	1655.9	2329.0	5667.0	22
24	7989.4	1622.1	2262.7	5572.2	8060.8	1657.1	2331.3	5670.3	24
26	7991.8	1623.3	2264.9	5575.4	8063.2	1658.3	2333.7	5673.6	26
28	7994.2	1624.4	2267.2	5578.6	8065.6	1659.5	2336.0	5676.9	28
30	7996.6	1625.6	2269.5	5581.9	8067.9	1660.7	2338.3	5680.2	30
32	7999.0	1626.8	2271.7	5585.1	8070.3	1661.8	2340.7	5683.5	32
34	8001.4	1627.9	2273.9	5588.4	8073.7	1663.0	2343.0	5686.8	34
36	8003.8	1629.1	2276.2	5591.7	8075.1	1664.2	2345.3	5690.2	36
38	8006.1	1630.2	2278.5	5594.9	8077.4	1665.4	2347.7	5693.5	38
40	8008.5	1631.4	2280.8	5598.2	8079.8	1666.6	2350.0	5696.8	40
42	8010.9	1632.6	2283.0	5601.4	8082.2	1667.7	2352.3	5700.1	42
44	8013.3	1633.7	2285.3	5604.7	8084.5	1668.8	2354.7	5703.4	44
46	8015.7	1634.9	2287.6	5608.0	8086.9	1670.0	2357.0	5706.8	46
48	8018.1	1636.0	2289.9	5611.2	8089.3	1671.2	2359.3	5710.1	48
50	8020.5	1637.2	2292.2	5614.5	8091.6	1672.4	2361.7	5713.4	50
52	8022.9	1638.4	2294.4	5617.8	8094.0	1673.5	2364.0	5716.7	52
54	8025.2	1639.5	2296.7	5621.0	8096.4	1674.7	2366.3	5720.0	54
56	8027.6	1640.7	2299.0	5624.3	8098.8	1675.9	2368.7	5723.4	56
58	8030.0	1641.8	2301.3	5627.5	8101.1	1677.1	2371.0	5726.7	58
60	8032.4	1643.0	2303.6	5630.8	8103.5	1678.3	2373.4	5730.0	60

′	90°				91°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	8103.5	1678.3	2373.4	5730.0	8173.9	1713.8	2445.1	5830.9	0
2	8105.8	1679.5	2375.8	5733.3	8176.2	1715.0	2447.5	5834.3	2
4	8108.2	1680.6	2378.2	5736.7	8178.5	1716.2	2450.0	5837.7	4
6	8110.5	1681.8	2380.5	5740.0	8180.9	1717.4	2452.4	5841.1	6
8	8112.9	1683.0	2382.9	5743.4	8183.2	1718.6	2454.8	5844.5	8
10	8115.2	1684.2	2385.3	5746.7	8185.5	1719.7	2457.2	5847.9	10
12	8117.6	1685.4	2387.6	5750.0	8187.9	1720.9	2459.7	5851.3	12
14	8119.9	1686.5	2390.0	5753.4	8190.2	1722.1	2462.1	5854.7	14
16	8122.3	1687.7	2392.4	5756.7	8192.5	1723.3	2464.5	5858.1	16
18	8124.6	1688.9	2394.7	5760.1	8194.8	1724.5	2467.0	5861.5	18
20	8127.0	1690.1	2397.1	5763.4	8197.2	1725.7	2469.4	5864.9	20
22	8129.3	1691.3	2399.5	5766.8	8199.5	1726.9	2471.9	5868.3	22
24	8131.7	1692.5	2401.9	5770.1	8201.8	1728.1	2474.3	5871.8	24
26	8134.0	1693.6	2404.3	5773.5	8204.2	1729.3	2476.7	5875.2	26
28	8136.4	1694.8	2406.6	5776.9	8206.5	1730.5	2479.2	5878.6	28
30	8138.7	1696.0	2409.0	5780.2	8208.8	1731.7	2481.6	5882.0	30
32	8141.1	1697.2	2411.4	5783.6	8211.1	1732.9	2484.1	5885.4	32
34	8143.4	1698.4	2413.8	5787.0	8213.5	1734.1	2486.5	5888.9	34
36	8145.8	1699.6	2416.2	5790.3	8215.8	1735.3	2489.0	5892.3	36
38	8148.1	1700.7	2418.6	5793.7	8218.1	1736.4	2491.5	5895.7	38
40	8150.4	1701.9	2421.0	5797.1	8220.4	1737.6	2493.9	5899.2	40
42	8152.8	1703.1	2423.4	5800.4	8222.8	1738.8	2496.4	5902.6	42
44	8155.1	1704.3	2425.8	5803.8	8225.1	1740.0	2498.9	5906.0	44
46	8157.5	1705.5	2428.2	5807.2	8227.4	1741.2	2501.3	5909.4	46
48	8159.8	1706.7	2430.6	5810.6	8229.7	1742.4	2503.8	5912.9	48
50	8162.2	1707.9	2433.0	5814.0	8232.0	1743.6	2506.3	5916.3	50
52	8164.5	1709.0	2435.4	5817.3	8234.3	1744.8	2508.7	5919.8	52
54	8166.8	1710.2	2437.9	5820.7	8236.7	1746.0	2511.2	5923.2	54
56	8169.2	1711.4	2440.3	5824.1	8239.0	1747.2	2513.7	5926.7	56
58	8171.5	1712.6	2442.7	5827.5	8241.3	1748.4	2516.2	5930.1	58
60	8173.9	1713.8	2445.1	5830.9	8243.6	1749.6	2518.7	5933.6	60

′	92°				93°				′
	L. C	M.	E.	T.	L. C.	M.	E.	T.	
0	8243.6	1749.6	2518.7	5933.6	8312.8	1785.7	2594.2	6038.2	0
2	8245.9	1750.8	2521.2	5937.0	8315.1	1786.9	2596.8	6041.7	2
4	8248.2	1752.0	2523.6	5940.5	8317.4	1788.2	2599.3	6045.2	4
6	8250.6	1753.2	2526.1	5944.0	8319.7	1789.4	2601.9	6048.7	6
8	8252.9	1754.4	2528.6	5947.4	8322.0	1790.6	2604.4	6052.2	8
10	8255.2	1755.6	2531.1	5950.9	8324.3	1791.8	2607.0	6055.8	10
12	8257.5	1756.8	2533.6	5954.4	8326.6	1793.0	2609.6	6059.3	12
14	8259.8	1758.0	2536.1	5957.8	8328.8	1794.2	2612.1	6062.8	14
16	8262.2	1759.2	2538.6	5961.3	8331.1	1795.4	2614.7	6066.4	16
18	8264.5	1760.4	2541.1	5964.8	8333.3	1796.6	2617.3	6069.9	18
20	8266.8	1761.6	2543.6	5968.2	8335.6	1797.8	2619.8	6073.4	20
22	8269.1	1762.8	2546.1	5971.7	8337.9	1799.1	2622.4	6077.0	22
24	8271.4	1764.0	2548.6	5975.2	8340.2	1800.3	2625.0	6080.5	24
26	8273.7	1765.2	2551.2	5978.7	8342.5	1801.5	2627.6	6084.1	26
28	8276.0	1766.4	2553.7	5982.2	8344.8	1802.7	2630.2	6087.6	28
30	8278.3	1767.6	2556.2	5985.6	8347.1	1803.9	2632.7	6091.2	30
32	8280.6	1768.8	2558.7	5989.1	8349.4	1805.1	2635.3	6094.7	32
34	8282.9	1770.0	2561.2	5992.6	8351.7	1806.3	2637.9	6098.3	34
36	8285.2	1771.2	2563.8	5996.1	8354.0	1807.6	2640.5	6101.8	36
38	8287.5	1772.5	2566.3	5999.6	8356.3	1808.8	2643.1	6105.4	38
40	8289.8	1773.7	2568.8	6003.1	8358.5	1810.0	2645.7	6109.0	40
42	8292.1	1774.9	2571.3	6006.6	8360.8	1811.2	2648.3	6112.5	42
44	8294.4	1776.1	2573.9	6010.1	8363.1	1812.4	2650.9	6116.1	44
46	8296.7	1777.3	2576.4	6013.6	8365.4	1813.6	2653.5	6119.7	46
48	8299.0	1778.5	2578.9	6017.1	8367.7	1814.9	2656.1	6123.2	48
50	8301.3	1779.7	2581.5	6020.6	8369.9	1816.1	2658.7	6126.8	50
52	8303.6	1780.9	2584.0	6024.1	8372.2	1817.3	2661.3	6130.4	52
54	8305.9	1782.1	2586.6	6027.6	8374.5	1818.5	2663.9	6133.9	54
56	8308.2	1783.3	2589.1	6031.1	8376.8	1819.7	2666.6	6137.5	56
58	8310.5	1784.5	2591.7	6034.6	8379.1	1820.9	2669.2	6141.1	58
60	8312.8	1785.7	2594.2	6038.2	8381.3	1822.2	2671.8	6144.7	60

′	94°				95°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	8381.3	1822.2	2671.8	6144.7	8449.2	1858.9	2751.5	6253.2	0
2	8383.6	1823.4	2674.4	6148.3	8451.5	1860.1	2754.2	6256.9	2
4	8385.9	1824.6	2677.0	6151.9	8453.7	1861.3	2756.9	6260.5	4
6	8388.1	1825.8	2679.7	6155.4	8456.0	1862.6	2759.6	6264.2	6
8	8390.4	1827.0	2682.3	6159.0	8458.2	1863.8	2762.3	6267.8	8
10	8392.7	1828.3	2684.9	6162.6	8460.4	1865.0	2765 0	6271.5	10
12	8395.0	1829.5	2687.6	6166.2	8462.7	1866.3	2767.7	6275.2	12
14	8397.2	1830.7	2690.2	6169.8	8464.9	1867.5	2770.4	6278.8	14
16	8399.5	1831.9	2692.8	6173.4	8467.2	1868.7	2773.1	6282.5	16
18	8401.7	1833.1	2695.6	6177.0	8469.4	1869.9	2775.8	6286.2	18
20	8404.0	1834.4	2698.1	6180.6	8471.7	1871.2	2778.5	6289.8	20
22	8406.3	1835.6	2700.8	6184.2	8473.9	1872.4	2781.2	6293.5	22
24	8408.5	1836.8	2703.4	6187.8	8476.2	1873.6	2784.0	6297.2	24
26	8410.8	1838.0	2706.1	6191.5	8478.4	1874.9	2786.7	6300.9	26
28	8413.1	1839.3	2708.7	6195.1	8480.7	1876.1	2789.4	6304.6	28
30	8415.3	1840.5	2711.4	6198.7	8482.9	1877.3	2792.1	6308.2	30
32	8417.6	1841.7	2714.0	6202.3	8485.1	1878.6	2794.9	6311.9	32
34	8419.9	1842.9	2716.7	6205.9	8487.4	1879.8	2797.6	6315.6	34
36	8422.1	1844.2	2719.3	6209.5	8489.6	1881.0	2800.3	6319.3	36
38	8424.4	1845.4	2722.0	6213.2	8491.9	1882.3	2803.1	6323.0	38
40	8426.6	1846.6	2724.7	6216.8	8494.1	1883.5	2805.8	6326.7	40
42	8428.9	1847.8	2727.3	6220.4	8496.3	1884.8	2808.6	6330.4	42
44	8431.2	1849.1	2730.0	6224.1	8498.6	1886.0	2811.3	6334.1	44
46	8433.4	1850.3	2732.7	6227.7	8500.8	1887.2	2814.1	6337.8	46
48	8435.7	1851.5	2735.4	6231.3	8503.0	1888.5	2816.8	6341.5	48
50	8437.9	1852.7	2738.0	6235.0	8505.3	1889.7	2819.6	6345.2	50
52	8440.2	1854.0	2740.7	6238.6	8507.5	1890.9	2822.3	6349.0	52
54	8442.4	1855.2	2743.4	6242.3	8509.8	1892.2	2825.1	6352.7	54
56	8444.7	1856.4	2746.1	6245.9	8512.0	1893.4	2827.8	6356.4	56
58	8447.0	1857.6	2748.8	6249.6	8514.2	1894.6	2830.6	6360.1	58
60	8449.2	1858.9	2751.5	6253.2	8516.4	1895.9	2833.4	6363.8	60

′	96°				97°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	8516.4	1895.9	2833.4	6363.8	8583.0	1933.2	2917.5	6476.6	0
2	8518.7	1897.1	2836.1	6367.5	8585.2	1934.4	2920.3	6480.4	2
4	8520.9	1898.4	2838.9	6371.3	8587.5	1935.7	2923.2	6484.2	4
6	8523.1	1899.6	2841.7	6375.0	8589.7	1936.9	2926.0	6488.0	6
8	8525.4	1900.8	2844.5	6378.7	8591.9	1938.2	2928.9	6491.8	8
10	8527.6	1902.1	2847.2	6382.5	8594.1	1939.4	2931.7	6495.6	10
12	8529.8	1903.3	2850.0	6386.2	8596.3	1940.7	2934.6	6499.4	12
14	8532.0	1904 6	2852.8	6389.9	8598.5	1941.9	2937.5	6503.2	14
16	8534.3	1905.8	2855.6	6393.7	8600.7	1943.2	2940.3	6507.1	16
18	8536.5	1907.0	2858.4	6397.4	8602.9	1944.4	2943.2	6510.9	18
20	8538.7	1908.3	2861.2	6401.2	8605.1	1945.7	2946.1	6514.7	20
22	8540.9	1909.5	2864.0	6404.9	8607.3	1946.9	2948.9	6518.5	22
24	8543.2	1910.8	2866.7	6408.7	8609.5	1948.2	2951.8	6522.3	24
26	8545.4	1912.0	2869.5	6412.4	8611.7	1949.4	2954.7	6526.2	26
28	8547.6	1913.3	2872.3	6416.2	8613.9	1950.7	2957.6	6530.0	28
30	8549.8	1914.5	2875.1	6419.9	8616.1	1952.0	2960.4	6533.8	30
32	8552.0	1915.7	2877.9	6423.7	8618.3	1953.2	2963.3	6537.7	32
34	8554.3	1917.0	2880.8	6427.5	8620.5	1954.5	2966.2	6541.5	34
36	8556.5	1918.2	2883.6	6431.2	8622.7	1955.7	2969.1	6545.3	36
38	8558.7	1919.5	2886.4	6435.0	8624.9	1957.0	2972.0	6549.2	38
40	8560.9	1920.7	2889.2	6438.8	8627.1	1958.2	2974.9	6553.0	40
42	8563.1	1922.0	2892.0	6442 5	8629.3	1959 5	2977.8	6556.9	42
44	8565.3	1923.2	2894.8	6446.3	8631.5	1960.7	2980.7	6560.7	44
46	8567 6	1924 5	2897.7	6450.1	8633.7	1962.0	2983.6	6564.6	46
48	8569 8	1925.7	2900.5	6453.9	8635.8	1963.2	2986.5	6568 4	48
50	8572.0	1927.0	2903.3	6457.6	8638.0	1964.5	2989.4	6572.3	50
52	8574.2	1928.2	2906.1	6461.4	8640.2	1965.8	2992.3	6576.2	52
54	8576.4	1929 4	2909.0	6465.2	8642.4	1967.0	2995.2	6580.0	54
56	8578.6	1930.7	2911.8	6469.0	8644.6	1968.3	2998.1	6583.9	56
58	8580.8	1931.9	2914.7	6472.8	8646.8	1969.5	3001.1	6587.7	58
60	8583.0	1933.2	2917.5	6476.6	8649 0	1970.8	3004 0	6591.6	60

′	98°				99°				′
	L. C.	M.	E.	T.	L. C.	M.	E.	T.	
0	8649.0	1970.8	3004.0	6591.6	8714.3	2008.7	3092.9	6709.0	0
2	8651.2	1972.0	3006.9	6595.5	8716.4	2009.9	3095.9	6712.9	2
4	8653.3	1973.3	3009.8	6599.4	8718.6	2011.2	3098.9	6716.9	4
6	8655.5	1974.6	3012.8	6603.2	8720.7	2012.5	3101.9	6720.8	6
8	8657.7	1975.8	3015.7	6607.1	8722.9	2013.7	3104.9	6724.8	8
10	8659.9	1977.1	3018.6	6611.0	8725.1	2015.0	3107.9	6728.8	10
12	8662.1	1978.3	3021.6	6614.9	8727.2	2016.3	3111.0	6732.7	12
14	8664.3	1979.6	3024.5	6618.8	8729.4	2017.5	3114.0	6736.7	14
16	8666.4	1980.9	3027.5	6622.7	8731.5	2018.8	3117.0	6740.7	16
18	8668.6	1982.1	3030.4	6626.6	8733.7	2020.1	3120.0	6744.6	18
20	8670.8	1983.4	3033.3	6630.5	8735.9	2021.4	3123.1	6748.6	20
22	8673.0	1984.6	3036.3	6634.4	8738.0	2022.6	3126.1	6752.6	22
24	8675.2	1985.9	3039.3	6638.3	8740.2	2023.9	3129.1	6756.6	24
26	8677.3	1987.2	3042.2	6642.2	8742.3	2025.2	3132.2	6760.6	26
28	8679.5	1988.4	3045.2	6646.1	8744.5	2026.4	3135.2	6764.6	28
30	8681.7	1989.7	3048.1	6650.0	8746.6	2027.7	3138.3	6768.6	30
32	8683.9	1991.0	3051.1	6653.9	8748.8	2029.0	3141.3	6772.6	32
34	8686.0	1992.2	3054.1	6657.8	8750.9	2030.3	3144.4	6776.6	34
36	8688.2	1993.5	3057.0	6661.7	8753.1	2031.5	3147.4	6780.6	36
38	8690.4	1994.7	3060.0	6665.7	8755.3	2032.8	3150.5	6784.6	38
40	8692.6	1996.0	3063.0	6669.6	8757.4	2034.1	3153.5	6788.6	40
42	8694.7	1997.3	3066.0	6673.5	8759.5	2035.4	3156.6	6792.6	42
44	8696.9	1998.5	3068.9	6677.4	8761.7	2036.6	3159.7	6796.6	44
46	8699.1	1999.8	3071.9	6681.4	8763.8	2037.9	3162.7	6800.6	46
48	8701.2	2001.1	3074.9	6685.3	8766.0	2039.2	3165.8	6804.6	48
50	8703.4	2002.3	3077.9	6689.2	8768.1	2040.5	3168.9	6808.6	50
52	8705.6	2003.6	3080.9	6693.2	8770.3	2041.7	3172.0	6812.6	52
54	8707.8	2004.9	3083.9	6697.1	8772.4	2043.0	3175.1	6816.7	54
56	8709.9	2006.1	3086.9	6701.1	8774.6	2044.3	3178.1	6820.7	56
58	8712.1	2007.4	3089.9	6705.2	8776.7	2045.6	3181.2	6824.7	58
60	8714.3	2008.7	3092.9	6709.0	8778.9	2046.8	3184.3	6828.8	60

′	100°				101°				′
	L C.	M.	E.	T.	L. C.	M.	E.	T.	
0	8778.9	2046.8	3184.3	6828.8	8842.8	2085.3	3278.3	6951.0	0
2	8781.0	2048.1	3187.4	6832.8	8844.9	2086.6	3281.5	6955.2	2
4	8783.1	2049.4	3190.5	6836.8	8847.0	2087.8	3284.7	6959.3	4
6	8785.3	2050.7	3193.6	6840.9	8849.2	2089.1	3287.9	6963.4	6
8	8787.4	2051.9	3196.7	6844.9	8851.3	2090.4	3291.1	6967.6	8
10	8789.6	2053.2	3199.8	6849.0	8853.4	2091.7	3294.3	6971.7	10
12	8791.7	2054.5	3202.9	6853.0	8855.5	2093.0	3297.5	6975.8	12
14	8793.9	2055.8	3206.0	6857.1	8857.6	2094.3	3300.7	6980.0	14
16	8796.0	2057.1	3209.1	6861.1	8859.8	2095.6	3303.9	6984.1	16
18	8798.9	2058.3	3212.2	6865.2	8861.9	2096.9	3307.1	6988.2	18
20	8800.3	2059.6	3215.4	6869.2	8864.0	2098.2	3310.3	6992.4	20
22	8802.4	2060.9	3218.5	6873.3	8866.1	2099.4	3313.5	6996.6	22
24	8804.5	2062.2	3221.6	6877.4	8868.2	2100.7	3316.7	7000.7	24
26	8806.7	2063.5	3224.7	6881.4	8870.3	2102.0	3319.9	7004.9	26
28	8808.8	2064.7	3227.9	6885.5	8872.4	2103.3	3323.1	7009.0	28
30	8810.9	2066.0	3231.0	6889.6	8874.5	2104.6	3326.4	7013.2	30
32	8813.1	2067.3	3234.1	6893.7	8876.7	2105.9	3329.6	7017.3	32
34	8815.2	2068.6	3237.3	6897.8	8878.8	2107.2	3332.8	7021.5	34
36	8817.3	2069.9	3240.4	6901.8	8880.9	2108.5	3336.0	7025.7	36
38	8819.5	2071.1	3243.5	6905.9	8883.0	2109.8	3339.3	7029.9	38
40	8821.6	2072.4	3246.7	6910.0	8885.1	2111.1	3342.5	7034.0	40
42	8823.7	2073.7	3249.8	6914.1	8887.2	2112.4	3345.8	7038.2	42
44	8825.8	2075.0	3253.0	6918.2	8889.3	2113.6	3349.0	7042.4	44
46	8828.0	2076.3	3256.2	6922.3	8891.4	2114.9	3352.3	7046.6	46
48	8830.1	2077.6	3259.3	6926.4	8893.5	2116.2	3355.5	7050.8	48
50	8832.2	2078.9	3262.5	6930.5	8895.6	2117.5	3358.8	7055.0	50
52	8834.3	2080.1	3265.7	6934.6	8897.7	2118.8	3362.0	7059.2	52
54	8836.4	2081.4	3268.8	6938.7	8899.8	2120.1	3365.5	7063.4	54
56	8838.6	2082.7	3272.0	6942.8	8901.9	2121.4	3368.7	7067.6	56
58	8340.7	2084.0	3275.2	6946.9	8904.0	2122.7	3372.0	7071.8	58
60	8842.8	2085.3	3278.3	6951.0	8906.1	2124.0	3375.1	7076.0	60

′	102° L. C.	102° M.	102° E.	102° T.	103° L. C.	103° M.	103° E.	103° T.	′
0	8906.1	2124.0	3375.1	7076.0	8968.7	2163.0	3474.6	7203.6	0
2	8908.2	2125.3	3378.3	7080.2	8970.8	2164.3	3478.0	7207.9	2
4	8910.3	2126.6	3381.6	7084.4	8972.9	2165.6	3481.4	7212.2	4
6	8912.4	2127.9	3384.9	7088.6	8974.9	2166.9	3484.7	7216.5	6
8	8914.5	2129.2	3388.2	7092.8	8977.0	2168.2	3488.1	7220.8	8
10	8916.6	2130.5	3391.5	7097.1	8979.1	2169.5	3491.5	7225.1	10
12	8918.7	2131.8	3394.7	7101.3	8981.1	2170.8	3494.9	7229.5	12
14	8920.8	2133.1	3398.0	7105.5	8983.2	2172.1	3498.3	7233.8	14
16	8922.9	2134.4	3401.3	7109.7	8985.3	2173.4	3501.6	7238.1	16
18	8925.0	2135.7	3404.6	7114.0	8987.3	2174.7	3505.3	7242.4	18
20	8927.0	2137.0	3407.9	7118.2	8989.4	2176.1	3508.4	7246.8	20
22	8929.1	2138.3	3411.2	7122.4	8991.5	2177.4	3511.8	7251.1	22
24	8931.2	2139.6	3414.5	7126.7	8993.5	2178.7	3515.2	7255.4	24
26	8933.3	2140.9	3417.9	7130.9	8995.6	2180.0	3518.7	7259.8	26
28	8935.4	2142.2	3421.2	7135.2	8997.7	2181.3	3522.1	7264.1	28
30	8937.5	2143.5	3424.5	7139.4	8999.7	2182.6	3525.5	7268.5	30
32	8939.6	2144.8	3427.8	7143.7	9001.8	2183.9	3528.9	7272.8	32
34	8941.6	2146.1	3431.1	7148.0	9003.9	2185.2	3532.3	7277.2	34
36	8943.7	2147.4	3434.5	7152.2	9005.9	2186.5	3535.7	7281.5	36
38	8945.8	2148.7	3437.8	7156.5	9008.0	2187.8	3539.2	7285.9	38
40	8947.9	2150.0	3441.1	7160.7	9010.0	2189.1	3542.6	7290.3	40
42	8950.0	2151.3	3444.4	7165.0	9012.1	2190.5	3546.0	7294.6	42
44	8952.1	2152.6	3447.8	7169.3	9014.2	2191.8	3549.5	7299.0	44
46	8954.1	2153.9	3451.1	7173.6	9016.2	2193.1	3552.9	7303.4	46
48	8956.2	2155.2	3454.5	7177.9	9018.3	2194.4	3556.3	7307.7	48
50	8958.3	2156.5	3457.8	7182.1	9020.3	2195.7	3559.8	7312.1	50
52	8960.4	2157.8	3461.2	7186.4	9022.4	2197.0	3563.2	7316.5	52
54	8962.5	2159.1	3464.5	7190.7	9024.5	2198.3	3566.7	7320.9	54
56	8964.5	2160.4	3467.9	7195.0	9026.5	2199.6	3570.2	7325.3	56
58	8966.6	2161.7	3471.2	7199.3	9028.6	2200.9	3573.6	7329.7	58
60	8968.7	2163.0	3474.6	7203.6	9030.6	2202.3	3577.1	7334.1	60

′	104° L. C.	104° M.	104° E.	104° T.	105° L. C.	105° M.	105° E.	105° T.	′
0	9030.6	2202.3	3577.1	7334.1	9091.8	2241.8	3682.6	7467.5	0
2	9032.7	2203.6	3580.5	7338.5	9093.9	2243.1	3686.1	7472.0	2
4	9034.7	2204.9	3584.0	7342.9	9095.9	2244.4	3689.7	7476.5	4
6	9036.8	2206.2	3587.5	7347.3	9097.9	2245.8	3693.3	7481.0	6
8	9038.8	2207.5	3591.0	7351.7	9099.9	2247.1	3696.9	7485.5	8
10	9040.9	2208.8	3594.4	7356.1	9102.0	2248.4	3700.4	7490.0	10
12	9042.9	2210.2	3597.9	7360.5	9104.0	2249.7	3704.0	7494.5	12
14	9045.0	2211.5	3601.4	7364.9	9106.0	2251.1	3707.6	7499.1	14
16	9047.0	2212.8	3604.9	7369.4	9108.0	2252.4	3711.2	7503.6	16
18	9049.1	2214.1	3608.4	7373.8	9110.1	2253.7	3714.8	7508.1	18
20	9051.1	2215.4	3611.9	7378.2	9112.1	2255.0	3718.4	7512.6	20
22	9053.1	2216.7	3615.4	7382.6	9114.1	2256.4	3722.0	7517.2	22
24	9055.2	2218.0	3618.9	7387.1	9116.1	2257.7	3725.6	7521.7	24
26	9057.2	2219.4	3622.4	7391.5	9118.1	2259.0	3729.3	7526.3	26
28	9059.3	2220.7	3625.9	7396.0	9120.2	2260.3	3732.9	7530.8	28
30	9061.3	2222.0	3629.4	7400.4	9122.2	2261.7	3736.5	7535.3	30
32	9063.3	2223.3	3633.0	7404.8	9124.2	2263.0	3740.1	7539.9	32
34	9065.4	2224.6	3636.5	7409.3	9126.2	2264.3	3743.7	7544.4	34
36	9067.4	2226.0	3640.0	7413.8	9128.2	2265.7	3747.4	7549.0	36
38	9069.5	2227.3	3643.5	7418.2	9130.2	2267.0	3751.0	7553.6	38
40	9071.5	2228.6	3647.1	7422.7	9132.3	2268.3	3754.6	7558.1	40
42	9073.5	2229.9	3650.6	7427.1	9134.3	2269.6	3758.3	7562.7	42
44	9075.6	2231.2	3654.1	7431.6	9136.3	2271.0	3761.9	7567.3	44
46	9077.6	2232.6	3657.7	7436.1	9138.3	2272.3	3765.6	7571.8	46
48	9079.6	2233.9	3661.2	7440.6	9140.3	2273.6	3769.2	7576.4	48
50	9081.7	2235.2	3664.8	7445.0	9142.3	2275.0	3772.9	7581.0	50
52	9083.7	2236.5	3668.3	7449.5	9144.3	2276.3	3776.5	7585.6	52
54	9085.7	2237.8	3671.9	7454.0	9146.3	2277.6	3780.2	7590.2	54
56	9087.8	2239.2	3675.4	7458.5	9148.3	2278.9	3783.9	7594.8	56
58	9089.8	2240.5	3679.0	7463.0	9150.4	2280.3	3787.5	7599.4	58
60	9091.8	2241.8	3682.6	7467.5	9152.4	2281.6	3791.2	7604.0	60

N	0	1	2	3	4	5	6	7	8	9
100	00000	00043	00087	00130	00173	00217	00260	00303	00346	00389
1	0432	0475	0518	0561	0604	0647	0689	0732	0775	0817
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5	1116	1121	1126	1132	1137	1142	1148	1153	1158	1164
6	1169	1174	1180	1185	1190	1196	1201	1206	1212	1217
7	1222	1228	1233	1238	1243	1249	1254	1259	1265	1270
8	1275	1281	1286	1291	1297	1302	1307	1312	1318	1323
9	1328	1334	1339	1344	1350	1355	1360	1365	1371	1376
820	91381	91387	91392	91397	91403	91408	91413	91418	91424	91429
1	1434	1440	1445	1450	1455	1461	1466	1471	1477	1482
2	1487	1492	1498	1503	1508	1514	1519	1524	1529	1535
3	1540	1545	1551	1556	1561	1566	1572	1577	1582	1587
4	1593	1598	1603	1609	1614	1619	1624	1630	1635	1640
5	1645	1651	1656	1661	1666	1672	1677	1682	1687	1693
6	1698	1703	1709	1714	1719	1724	1730	1735	1740	1745
7	1751	1756	1761	1766	1772	1777	1782	1787	1793	1798
8	1803	1808	1814	1819	1824	1829	1834	1840	1845	1850
9	1855	1861	1866	1871	1876	1882	1887	1892	1897	1903
830	91908	91913	91918	91924	91929	91934	91939	91944	91950	91955
1	1960	1965	1971	1976	1981	1986	1991	1997	2002	2007
2	2012	2018	2023	2028	2033	2038	2044	2049	2054	2059
3	2065	2070	2075	2080	2085	2091	2096	2101	2106	2111
4	2117	2122	2127	2132	2137	2143	2148	2153	2158	2163
5	2169	2174	2179	2184	2189	2195	2200	2205	2210	2215
6	2221	2226	2231	2236	2241	2247	2252	2257	2262	2267
7	2273	2278	2283	2288	2293	2298	2304	2309	2314	2319
8	2324	2330	2335	2340	2345	2350	2355	2361	2366	2371
9	2376	2381	2387	2392	2397	2402	2407	2412	2418	2423
840	92428	92433	92438	92443	92449	92454	92459	92464	92469	92474
1	2480	2485	2490	2495	2500	2505	2511	2516	2521	2526
2	2531	2536	2542	2547	2552	2557	2562	2567	2572	2578
3	2583	2588	2593	2598	2603	2609	2614	2619	2624	2629
4	2634	2639	2645	2650	2655	2660	2665	2670	2675	2681
5	2686	2691	2696	2701	2706	2711	2716	2722	2727	2732
6	2737	2742	2747	2752	2758	2763	2768	2773	2778	2783
7	2788	2793	2799	2804	2809	2814	2819	2824	2829	2834
8	2840	2845	2850	2855	2860	2865	2870	2875	2881	2886
9	2891	2896	2901	2906	2911	2916	2921	2927	2932	2937
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850	92942	92947	92952	92957	92962	92967	92973	92978	92983	92988
1	2993	2998	3003	3008	3013	3018	3024	3029	3034	3039
2	3044	3049	3054	3059	3064	3069	3075	3080	3085	3090
3	3095	3100	3105	3110	3115	3120	3125	3131	3136	3141
4	3146	3151	3156	3161	3166	3171	3176	3181	3186	3192
5	3197	3202	3207	3212	3217	3222	3227	3232	3237	3242
6	3247	3252	3258	3263	3268	3273	3278	3283	3288	3293
7	3298	3303	3308	3313	3318	3323	3328	3334	3339	3344
8	3349	3354	3359	3364	3369	3374	3379	3384	3389	3394
9	3399	3404	3409	3414	3420	3425	3430	3435	3440	3445
860	93450	93455	93460	93465	93470	93475	93480	93485	93490	93495
1	3500	3505	3510	3515	3520	3526	3531	3536	3541	3546
2	3551	3556	3561	3566	3571	3576	3581	3586	3591	3596
3	3601	3606	3611	3616	3621	3626	3631	3636	3641	3646
4	3651	3656	3661	3666	3671	3676	3682	3687	3692	3697
5	3702	3707	3712	3717	3722	3727	3732	3737	3742	3747
6	3752	3757	3762	3767	3772	3777	3782	3787	3792	3797
7	3802	3807	3812	3817	3822	3827	3832	3837	3842	3847
8	3852	3857	3862	3867	3872	3877	3882	3887	3892	3897
9	3902	3907	3912	3917	3922	3927	3932	3937	3942	3947
870	93952	93957	93962	93967	93972	93977	93982	93987	93992	93997
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2	4052	4057	4062	4067	4072	4077	4082	4086	4091	4096
3	4101	4106	4111	4116	4121	4126	4131	4136	4141	4146
4	4151	4156	4161	4166	4171	4176	4181	4186	4191	4196
5	4201	4206	4211	4216	4221	4226	4231	4236	4240	4245
6	4250	4255	4260	4265	4270	4275	4280	4285	4290	4295
7	4300	4305	4310	4315	4320	4325	4330	4335	4340	4345
8	4349	4354	4359	4364	4369	4374	4379	4384	4389	4394
9	4399	4404	4409	4414	4419	4424	4429	4433	4438	4443
880	94448	94453	94458	94463	94468	94473	94478	94483	94488	94493
1	4498	4503	4507	4512	4517	4522	4527	4532	4537	4542
2	4547	4552	4557	4562	4567	4571	4576	4581	4586	4591
3	4596	4601	4606	4611	4616	4621	4626	4630	4635	4640
4	4645	4650	4655	4660	4665	4670	4675	4680	4685	4689
5	4694	4699	4704	4709	4714	4719	4724	4729	4734	4738
6	4743	4748	4753	4758	4763	4768	4773	4778	4783	4787
7	4792	4797	4802	4807	4812	4817	4822	4827	4832	4836
8	4841	4846	4851	4856	4861	4866	4871	4876	4880	4885
9	4890	4895	4900	4905	4910	4915	4919	4924	4929	4934
890	94939	94944	94949	94954	94959	94963	94968	94973	94978	94983
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2	5036	5041	5046	5051	5056	5061	5066	5071	5075	5080
3	5085	5090	5095	5100	5105	5109	5114	5119	5124	5129
4	5134	5139	5143	5148	5153	5158	5163	5168	5173	5177
5	5182	5187	5192	5197	5202	5207	5211	5216	5221	5226
6	5231	5236	5240	5245	5250	5255	5260	5265	5270	5274
7	5279	5284	5289	5294	5299	5303	5308	5313	5318	5323
8	5328	5332	5337	5342	5347	5352	5357	5361	5366	5371
9	5376	5381	5386	5390	5395	5400	5405	5410	5415	5419
900	95424	95429	95434	95439	95444	95448	95453	95458	95463	95468

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900	95424	95429	95434	95439	95444	95448	95453	95458	95463	95468
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2	5521	5525	5530	5535	5540	5545	5550	5554	5559	5564
3	5569	5574	5578	5583	5588	5593	5598	5602	5607	5612
4	5617	5622	5626	5631	5636	5641	5646	5650	5655	5660
5	5665	5670	5674	5679	5684	5689	5694	5698	5703	5708
6	5713	5718	5722	5727	5732	5737	5742	5746	5751	5756
7	5761	5766	5770	5775	5780	5785	5789	5794	5799	5804
8	5809	5813	5818	5823	5828	5832	5837	5842	5847	5852
9	5856	5861	5866	5871	5875	5880	5885	5890	5895	5899
910	95904	95909	95914	95918	95923	95928	95933	95938	95942	95947
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2	5999	6004	6009	6014	6019	6023	6028	6033	6038	6042
3	6047	6052	6057	6061	6066	6071	6076	6080	6085	6090
4	6095	6099	6104	6109	6114	6118	6123	6128	6133	6137
5	6142	6147	6152	6156	6161	6166	6171	6175	6180	6185
6	6190	6194	6199	6204	6209	6213	6218	6223	6227	6232
7	6237	6242	6246	6251	6256	6261	6265	6270	6275	6280
8	6284	6289	6294	6298	6303	6308	6313	6317	6322	6327
9	6332	6336	6341	6346	6350	6355	6360	6365	6369	6374
920	96379	96384	96388	96393	96398	96402	96407	96412	96417	96421
1	6426	6431	6435	6440	6445	6450	6454	6459	6464	6468
2	6473	6478	6483	6487	6492	6497	6501	6506	6511	6515
3	6520	6525	6530	6534	6539	6544	6548	6553	6558	6562
4	6567	6572	6577	6581	6586	6591	6595	6600	6605	6609
5	6614	6619	6624	6628	6633	6638	6642	6647	6652	6656
6	6661	6666	6670	6675	6680	6685	6689	6694	6699	6703
7	6708	6713	6717	6722	6727	6731	6736	6741	6745	6750
8	6755	6759	6764	6769	6774	6778	6783	6788	6792	6797
9	6802	6806	6811	6816	6820	6825	6830	6834	6839	6844
930	96848	96853	96858	96862	96867	96872	96876	96881	96886	96890
1	6895	6900	6904	6909	6914	6918	6923	6928	6932	6937
2	6942	6946	6951	6956	6960	6965	6970	6974	6979	6984
3	6988	6993	6997	7002	7007	7011	7016	7021	7025	7030
4	7035	7039	7044	7049	7053	7058	7063	7067	7072	7077
5	7081	7086	7090	7095	7100	7104	7109	7114	7118	7123
6	7128	7132	7137	7142	7146	7151	7155	7160	7165	7169
7	7174	7179	7183	7188	7192	7197	7202	7206	7211	7216
8	7220	7225	7230	7234	7239	7243	7248	7253	7257	7262
9	7267	7271	7276	7280	7285	7290	7294	7299	7304	7308
940	97313	97317	97322	97327	97331	97336	97340	97345	97350	97354
1	7359	7364	7368	7373	7377	7382	7387	7391	7396	7400
2	7405	7410	7414	7419	7424	7428	7433	7437	7442	7447
3	7451	7456	7460	7465	7470	7474	7479	7483	7488	7493
4	7497	7502	7506	7511	7516	7520	7525	7529	7534	7539
5	7543	7548	7552	7557	7562	7566	7571	7575	7580	7585
6	7589	7594	7598	7603	7607	7612	7617	7621	7626	7630
7	7635	7640	7644	7649	7653	7658	7663	7667	7672	7676
8	7681	7685	7690	7695	7699	7704	7708	7713	7717	7722
9	7727	7731	7736	7740	7745	7749	7754	7759	7763	7768
950	97772	97777	97782	97786	97791	97795	97800	97804	97809	97813

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950	97772	97777	97782	97786	97791	97795	97800	97804	97809	97813
1	7818	7823	7827	7832	7836	7841	7845	7850	7855	7859
2	7864	7868	7873	7877	7882	7886	7891	7896	7900	7905
3	7909	7914	7918	7923	7928	7932	7937	7941	7946	7950
4	7955	7959	7964	7968	7973	7978	7982	7987	7991	7996
5	8000	8005	8009	8014	8019	8023	8028	8032	8037	8041
6	8046	8050	8055	8059	8064	8068	8073	8078	8082	8087
7	8091	8096	8100	8105	8109	8114	8118	8123	8127	8132
8	8137	8141	8146	8150	8155	8159	8164	8168	8173	8177
9	8182	8186	8191	8195	8200	8204	8209	8214	8218	8223
960	98227	98232	98236	98241	98245	98250	98254	98259	98263	98268
1	8272	8277	8281	8286	8290	8295	8299	8304	8308	8313
2	8318	8322	8327	8331	8336	8340	8345	8349	8354	8358
3	8363	8367	8372	8376	8381	8385	8390	8394	8399	8403
4	8408	8412	8417	8421	8426	8430	8435	8439	8444	8448
5	8453	8457	8462	8466	8471	8475	8480	8484	8489	8493
6	8498	8502	8507	8511	8516	8520	8525	8529	8534	8538
7	8543	8547	8552	8556	8561	8565	8570	8574	8579	8583
8	8588	8592	8597	8601	8605	8610	8614	8619	8623	8628
9	8632	8637	8641	8646	8650	8655	8659	8664	8668	8673
970	98677	98682	98686	98691	98695	98700	98704	98709	98713	98717
1	8722	8726	8731	8735	8740	8744	8749	8753	8758	8762
2	8767	8771	8776	8780	8784	8789	8793	8798	8802	8807
3	8811	8816	8820	8825	8829	8834	8838	8843	8847	8851
4	8856	8860	8865	8869	8874	8878	8883	8887	8892	8896
5	8900	8905	8909	8914	8918	8923	8927	8932	8936	8941
6	8945	8949	8954	8958	8963	8967	8972	8976	8981	8985
7	8989	8994	8998	9003	9007	9012	9016	9021	9025	9029
8	9034	9038	9043	9047	9052	9056	9061	9065	9069	9074
9	9078	9083	9087	9092	9096	9100	9105	9109	9114	9118
980	99123	99127	99131	99136	99140	99145	99149	99154	99158	99162
1	9167	9171	9176	9180	9185	9189	9193	9198	9202	9207
2	9211	9216	9220	9224	9229	9233	9238	9242	9247	9251
3	9255	9260	9264	9269	9273	9277	9282	9286	9291	9295
4	9300	9304	9308	9313	9317	9322	9326	9330	9335	9339
5	9344	9348	9352	9357	9361	9366	9370	9374	9379	9383
6	9388	9392	9396	9401	9405	9410	9414	9419	9423	9427
7	9432	9436	9441	9445	9449	9454	9458	9463	9467	9471
8	9476	9480	9484	9489	9493	9498	9502	9506	9511	9515
9	9520	9524	9528	9533	9537	9542	9546	9550	9555	9559
990	99564	99568	99572	99577	99581	99585	99590	99594	99599	99603
1	9607	9612	9616	9621	9625	9629	9634	9638	9642	9647
2	9651	9656	9660	9664	9669	9673	9677	9682	9686	9691
3	9695	9699	9704	9708	9712	9717	9721	9726	9730	9734
4	9739	9743	9747	9752	9756	9760	9765	9769	9774	9778
5	9782	9787	9791	9795	9800	9804	9808	9813	9817	9822
6	9826	9830	9835	9839	9843	9848	9852	9856	9861	9865
7	9870	9874	9878	9883	9887	9891	9896	9900	9904	9909
8	9913	9917	9922	9926	9930	9935	9939	9944	9948	9952
9	9957	9961	9965	9970	9974	9978	9983	9987	9991	9996
1000	00000	00004	00009	00013	00017	00022	00026	00030	00035	00039

′	0°		1°		2°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
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1	6.46373	00000	24903	99993	54642	99973	59
2	76476	00000	25609	99993	54999	99973	58
3	94085	00000	26304	99993	55354	99972	57
4	7.06579	00000	26988	99992	55705	99972	56
5	16270	00000	27661	99992	56054	69971	55
6	24188	00000	28324	99992	56400	99971	54
7	30882	00000	28977	99992	56743	99970	53
8	36682	00000	29621	99992	57084	99970	52
9	41797	00000	30255	99991	57421	99969	51
10	7.46373	10.00000	8.30879	9.99991	8.57757	9.99969	50
11	50512	00000	31495	99991	58089	99968	49
12	54291	00000	32103	99990	58419	99968	48
13	57767	00000	32702	99990	58747	99967	47
14	60985	00000	33292	99990	59072	99967	46
15	63982	00000	33875	99990	59395	99967	45
16	66784	00000	34450	99989	59715	99966	44
17	69417	9.99999	35018	99989	60033	99966	43
18	71900	99999	35578	99989	60349	99965	42
19	74248	99999	36131	99989	60662	99964	41
20	7.76475	9.99999	8.36678	9.99988	8.60973	9.99964	40
21	78594	99999	37217	99988	61282	99963	39
22	80615	99999	37750	99988	61589	99963	38
23	82545	99999	38276	99987	61894	99962	37
24	84393	99999	38796	99987	62196	99962	36
25	86166	99999	39310	99987	62497	99961	35
26	87870	99999	39818	99986	62795	99961	34
27	89509	99999	40320	99986	63091	99960	33
28	91088	99999	40816	99986	63385	99960	32
29	92612	99998	41307	99985	63678	99959	31
30	7.94084	9.99998	8.41792	9.99985	8.63968	9.99959	30
31	95508	99998	42272	99985	64256	99958	29
32	96887	99998	42746	99984	64543	99958	28
33	98223	99998	43216	99984	64827	99957	27
34	99520	99998	43680	99984	65110	99956	26
35	8.00779	99998	44139	99983	65391	99956	25
36	02002	99998	44594	99983	65670	99955	24
37	03192	99997	45044	99983	65947	99955	23
38	04350	99997	45489	99982	66223	99954	22
39	05478	99997	45930	99982	66497	99954	21
40	8.06578	9.99997	8.46366	9.99982	8.66769	9.99953	20
41	07650	99997	46799	99981	67039	99952	19
42	08696	99997	47226	99981	67308	99952	18
43	09718	99997	47650	99981	67575	99951	17
44	10717	99996	48069	99980	67841	99951	16
45	11693	99996	48485	99980	68104	99950	15
46	12647	99996	48896	99979	68367	99949	14
47	13581	99996	49304	99979	68627	99949	13
48	14495	99996	49708	99979	68886	99948	12
49	15391	99996	50108	99978	69144	99948	11
50	8.16268	9.99995	8.50504	9.99978	8.69400	9.99947	10
51	17128	99995	50897	99977	69654	99946	9
52	17971	99995	51287	99977	69907	99946	8
53	18798	99995	51673	99977	70159	99945	7
54	19610	99995	52055	99976	70409	99944	6
55	20407	99994	52434	99976	70658	99944	5
56	21189	99994	52810	99975	70905	99943	4
57	21958	99994	53183	99975	71151	99942	3
58	22713	99994	53552	99974	71395	99942	2
59	23456	99994	53919	99974	71638	99941	1
60	24186	99993	54282	99974	71880	99940	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	89°		88°		87°		

′	3° Sine	3° Cosine	4° Sine	4° Cosine	5° Sine	5° Cosine	′
0	8.71880	9.99940	8.84358	9.99894	8.94030	9.99834	60
1	72120	99940	84539	99893	94174	99833	59
2	72359	99939	84718	99892	94317	99832	58
3	72597	99938	84897	99891	94461	99831	57
4	72834	99938	85075	99891	94603	99830	56
5	73069	99937	85252	99890	94746	99829	55
6	73303	99936	85429	99889	94887	99828	54
7	73535	99936	85605	99888	95029	99827	53
8	73767	99935	85780	99887	95170	99825	52
9	73997	99934	85955	99886	95310	99824	51
10	8.74226	9.99934	8.86128	9.99885	8.95450	9.99823	50
11	74454	99933	86301	99884	95589	99822	49
12	74680	99932	86474	99883	95728	99821	48
13	74906	99932	86645	99882	95867	99820	47
14	75130	99931	86816	99881	96005	99819	46
15	75353	99930	86987	99880	96143	99817	45
16	75575	99929	87156	99879	96280	99816	44
17	75795	99929	87325	99879	96417	99815	43
18	76015	99928	87494	99878	96553	99814	42
19	76234	99927	87661	99877	96689	99813	41
20	8.76451	9.99926	8.87829	9.99876	8.96825	9.99812	40
21	76667	99926	87995	99875	96960	99810	39
22	76883	99925	88161	99874	97095	99809	38
23	77097	99924	88326	99873	97229	99808	37
24	77310	99923	88490	99872	97363	99807	36
25	77522	99923	88654	99871	97496	99806	35
26	77733	99922	88817	99870	97629	99804	34
27	77943	99921	88980	99869	97762	99803	33
28	78152	99920	89142	99868	97894	99802	32
29	78360	99920	89304	99867	98026	99801	31
30	8.78568	9.99919	8.89464	9.99866	8.98157	9.99800	30
31	78774	99918	89625	99865	98288	99798	29
32	78979	99917	89784	99864	98419	99797	28
33	79183	99917	89943	99863	98549	99796	27
34	79386	99916	90102	99862	98679	99795	26
35	79588	99915	90260	99861	98808	99793	25
36	79789	99914	90417	99860	98937	99792	24
37	79990	99913	90574	99859	99066	99791	23
38	80189	99913	90730	99858	99194	99790	22
39	80388	99912	90885	99857	99322	99788	21
40	8.80585	9.99911	8.91040	9.99856	8.99450	9.99787	20
41	80782	99910	91195	99855	99577	99786	19
42	80978	99909	91349	99854	99704	99785	18
43	81173	99909	91502	99853	99830	99783	17
44	81367	99908	91655	99852	99956	99782	16
45	81560	99907	91807	99851	9.00082	99781	15
46	81752	99906	91959	99850	00207	99780	14
47	81944	99905	92110	99848	00332	99778	13
48	82134	99904	92261	99847	00456	99777	12
49	82324	99904	92411	99846	00581	99776	11
50	8.82513	9.99903	8.92561	9.99845	9.00704	9.99775	10
51	82701	99902	92710	99844	00828	99773	9
52	82888	99901	92859	99843	00951	99772	8
53	83075	99900	93007	99842	01074	99771	7
54	83261	99899	93154	99841	01196	99769	6
55	83446	99898	93301	99840	01318	99768	5
56	83630	99898	93448	99839	01440	99767	4
57	83813	99897	93594	99838	01561	99765	3
58	83996	99896	93740	99837	01682	99764	2
59	84177	99895	93885	99836	01803	99763	1
60	84358	99894	94030	99834	01923	99761	0
′	86° Cosine	86° Sine	85° Cosine	85° Sine	84° Cosine	84° Sine	′

′	6°		7°		8°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.01923	9.99761	9.08589	9.99675	9.14356	9.99575	60
1	02043	99760	08692	99674	14445	99574	59
2	02163	99759	08795	99672	14535	99572	58
3	02283	99757	08897	99670	14624	99570	57
4	02402	99756	08999	99669	14714	99568	56
5	02520	99755	09101	99667	14803	99566	55
6	02639	99753	09202	99666	14891	99565	54
7	02757	99752	09304	99664	14980	99563	53
8	02874	99751	09405	99663	15069	99561	52
9	02992	99749	09506	99661	15157	99559	51
10	9.03109	9.99748	9.09606	9.99659	9.15245	9.99557	50
11	03226	99747	09707	99658	15333	99556	49
12	03342	99745	09807	99656	15421	99554	48
13	03458	99744	09907	99655	15508	99552	47
14	03574	99742	10006	99653	15596	99550	46
15	03690	99741	10106	99651	15683	99548	45
16	03805	99740	10205	99650	15770	99546	44
17	03920	99738	10304	99648	15857	99545	43
18	04034	99737	10402	99647	15944	99543	42
19	04149	99736	10501	99645	16030	99541	41
20	9.04262	9.99734	9.10599	9.99643	9.16116	9.99539	40
21	04376	99733	10697	99642	16203	99537	39
22	04490	99731	10795	99640	16289	99535	38
23	04603	99730	10893	99638	16374	99533	37
24	04715	99728	10990	99637	16460	99532	36
25	04828	99727	11087	99635	16545	99530	35
26	04940	99726	11184	99633	16631	99528	34
27	05052	99724	11281	99632	16716	99526	33
28	05164	99723	11377	99630	16801	99524	32
29	05275	99721	11474	99629	16886	99522	31
30	9.05386	9.99720	9.11570	9.99627	9.16970	9.99520	30
31	05497	99718	11666	99625	17055	99518	29
32	05607	99717	11761	99624	17139	99517	28
33	05717	99716	11857	99622	17223	99515	27
34	05827	99714	11952	99620	17307	99513	26
35	05937	99713	12047	99618	17391	99511	25
36	06046	99711	12142	99617	17474	99509	24
37	06155	99710	12236	99615	17558	99507	23
38	06264	99708	12331	99613	17641	99505	22
39	06372	99707	12425	99612	17724	99503	21
40	9.06481	9.99705	9.12519	9.99610	9.17807	9.99501	20
41	06589	99704	12612	99608	17890	99499	19
42	06696	99702	12706	99607	17973	99497	18
43	06804	99701	12799	99605	18055	99495	17
44	06911	99699	12892	99603	18137	99494	16
45	07018	99698	12985	99601	18220	99492	15
46	07124	99696	13078	99600	18302	99490	14
47	07231	99695	13171	99598	18383	99488	13
48	07337	99693	13263	99596	18465	99486	12
49	07442	99692	13355	99595	18547	99484	11
50	9.07548	9.99690	9.13447	9.99593	9.18628	9.99482	10
51	07653	99689	13539	99591	18709	99480	9
52	07758	99687	13630	99589	18790	99478	8
53	07863	99686	13722	99588	18871	99476	7
54	07968	99684	13813	99586	18952	99474	6
55	08072	99683	13904	99584	19033	99472	5
56	08176	99681	13994	99582	19113	99470	4
57	08280	99680	14085	99581	19193	99468	3
58	08383	99678	14175	99579	19273	99466	2
59	08486	99677	14266	99577	19353	99464	1
60	08589	99675	14356	99575	19433	99462	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	83°		82°		81°		

′	9°		10°		11°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.19433	9.99462	9.23967	9.99335	9.28060	9.99195	60
1	19513	99460	24039	99333	28125	99192	59
2	19592	99458	24110	99331	28190	99190	58
3	19672	99456	24181	99328	28254	99187	57
4	19751	99454	24253	99326	28319	99185	56
5	19830	99452	24324	99324	28384	99182	55
6	19909	99450	24395	99322	28448	99180	54
7	19988	99448	24466	99319	28512	99177	53
8	20067	99446	24536	99317	28577	99175	52
9	20145	99444	24607	99315	28641	99172	51
10	9.20223	9.99442	9.24677	9.99313	9.28705	9.99170	50
11	20302	99440	24748	99310	28769	99167	49
12	20380	99438	24818	99308	28833	99165	48
13	20458	99436	24888	99306	28896	99162	47
14	20535	99434	24958	99304	28960	99160	46
15	20613	99432	25028	99301	29024	99157	45
16	20691	99429	25098	99299	29087	99155	44
17	20768	99427	25168	99297	29150	99152	43
18	20845	99425	25237	99294	29214	99150	42
19	20922	99423	25307	99292	29277	99147	41
20	9.20999	9.99421	9.25376	9.99290	9.29340	9.99145	40
21	21076	99419	25445	99288	29403	99142	39
22	21153	99417	25514	99285	29466	99140	38
23	21229	99415	25583	99283	29529	99137	37
24	21306	99413	25652	99281	29591	99135	36
25	21382	99411	25721	99278	29654	99132	35
26	21458	99409	25790	99276	29716	99130	34
27	21534	99407	25858	99274	29779	99127	33
28	21610	99404	25927	99271	29841	99124	32
29	21685	99402	25995	99269	29903	99122	31
30	9.21761	9.99400	9.26063	9.99267	9.29966	9.99119	30
31	21836	99398	26131	99264	30028	99117	29
32	21912	99396	26199	99262	30090	99114	28
33	21987	99394	26267	99260	30151	99112	27
34	22062	99392	26335	99257	30213	99109	26
35	22137	99390	26403	99255	30275	99106	25
36	22211	99388	26470	99252	30336	99104	24
37	22286	99385	26538	99250	30398	99001	23
38	22361	99383	26605	99248	30459	99099	22
39	22435	99381	26672	99245	30521	99096	21
40	9.22509	9.99379	9.26739	9.99243	9.30582	9.99093	20
41	22583	99377	26806	99241	30643	99091	19
42	22657	99375	26873	99238	30704	99088	18
43	22731	99372	26940	99236	30765	99086	17
44	22805	99370	27007	99233	30826	99083	16
45	22878	99368	27073	99231	30887	99080	15
46	22952	99366	27140	99229	30947	99078	14
47	23025	99364	27206	99226	31008	99075	13
48	23098	99362	27273	99224	31068	99072	12
49	23171	99359	27339	99221	31129	99070	11
50	9.23244	9.99357	9.27405	9.99219	9.31189	9.99067	10
51	23317	99255	27471	99217	31250	99064	9
52	23390	99353	27537	99214	31310	99062	8
53	23462	99351	27602	99212	31370	99059	7
54	23535	99348	27668	99209	31430	99056	6
55	23607	99346	27734	99207	31490	99054	5
56	23679	99344	27799	99204	31549	99051	4
57	23752	99342	27864	99202	31609	99048	3
58	23823	99340	27930	99200	31669	99046	2
59	23895	99337	27995	99197	31728	99043	1
60	23967	99335	28060	99195	31788	99040	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	80°		79°		78°		

′	12° Sine	12° Cosine	13° Sine	13° Cosine	14° Sine	14° Cosine	′
0	9.31788	9.99040	9.35209	9.98872	9.38368	9.98690	60
1	31847	99038	35263	98869	38418	98687	59
2	31907	99035	35318	98867	38469	98684	58
3	31966	99032	35373	98864	38519	98681	57
4	32025	99030	35427	98861	38570	98678	56
5	32084	99027	35481	98858	38620	98675	55
6	32143	99024	35536	98855	38670	98671	54
7	32202	99022	35590	98852	38721	98668	53
8	32261	99019	35644	98849	38771	98665	52
9	32319	99016	35698	98846	38821	98662	51
10	9.32378	9.99013	9.35752	9.98843	9.38871	9.98659	50
11	32437	99011	35806	98840	38921	98656	49
12	32495	99008	35860	98837	38971	98652	48
13	32553	99005	35914	98834	39021	98649	47
14	32612	99002	35968	98831	39071	98646	46
15	32670	99000	36022	98828	39121	98643	45
16	32728	98997	36075	98825	39170	98640	44
17	32786	98994	36129	98822	39220	98636	43
18	32844	98991	36182	98819	39270	98633	42
19	32902	98989	36236	98816	39319	98630	41
20	9.32960	9.98986	9.36289	9.98813	9.39369	9.98627	40
21	33018	98983	36342	98810	39418	98623	39
22	33075	98980	36395	98807	39467	98620	38
23	33133	98978	36449	98804	39517	98617	37
24	33190	98975	36502	98801	39566	98614	36
25	33248	98972	36555	98798	39615	98610	35
26	33305	98969	36608	98795	39664	98607	34
27	33362	98967	36660	98792	39713	98604	33
28	33420	98964	36713	98789	39762	98601	32
29	33477	98961	36766	98786	39811	98597	31
30	9.33534	9.98958	9.36819	9.98783	9.39860	9.98594	30
31	33591	98955	36871	98780	39909	98591	29
32	33647	98953	36924	98777	39958	98588	28
33	33704	98950	36976	98774	40006	98584	27
34	33761	98947	37028	98771	40055	98581	26
35	33818	98944	37081	98768	40103	98578	25
36	33874	98941	37133	98765	40152	98574	24
37	33931	98938	37185	98762	40200	98571	23
38	33987	98936	37237	98759	40249	98568	22
39	34043	98933	37289	98756	40297	98565	21
40	9.34100	9.98930	9.37341	9.98753	9.40346	9.98561	20
41	34156	98927	37393	98750	40394	98558	19
42	34212	98924	37445	98746	40442	98555	18
43	34268	98921	37497	98743	40490	98551	17
44	34324	98919	37549	98740	40538	98548	16
45	34380	98916	37600	98737	40586	98545	15
46	34436	98913	37652	98734	40634	98541	14
47	34491	98910	37703	98731	40682	98538	13
48	34547	98907	37755	98728	40730	98535	12
49	34602	98904	37806	98725	40778	98531	11
50	9.34658	9.98901	9.37858	9.98722	9.40825	9.98528	10
51	34713	98898	37909	98719	40873	98525	9
52	34769	98896	37960	98715	40921	98521	8
53	34824	98893	38011	98712	40968	98518	7
54	34879	98890	38062	98709	41016	98515	6
55	34934	98887	38113	98706	41063	98511	5
56	34989	98884	38164	98703	41111	98508	4
57	35044	98881	38215	98700	41158	98505	3
58	35099	98878	38266	98697	41205	98501	2
59	35154	98875	38317	98694	41252	98498	1
60	35209	98872	38368	98690	41300	98494	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	77°		76°		75°		

′	15°		16°		17°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.41300	9.98494	9.44034	9.98284	9.46594	9.98060	60
1	41347	98491	44078	98281	46635	98056	59
2	41394	98488	44122	98277	46676	98052	58
3	41441	98484	44166	98273	46717	98048	57
4	41488	98481	44210	98270	46758	98044	56
5	41535	98477	44253	98266	46800	98040	55
6	41582	98474	44297	98262	46841	98036	54
7	41628	98471	44341	98259	46882	98032	53
8	41675	98467	44385	98255	46923	98029	52
9	41722	98464	44428	98251	46964	98025	51
10	9.41768	9.98460	9.44472	9.98248	9.47005	9.98021	50
11	41815	98457	44516	98244	47045	98017	49
12	41861	98453	44559	98240	47086	98013	48
13	41908	98450	44602	98237	47127	98009	47
14	41954	98447	44646	98233	47168	98005	46
15	42001	98443	44689	98229	47209	98001	45
16	42047	98440	44733	98226	47249	97997	44
17	42093	98436	44776	98222	47290	97993	43
18	42140	98433	44819	98218	47330	97989	42
19	42186	98429	44862	98215	47371	97986	41
20	9.42232	9.98426	9.44905	9.98211	9.47411	9.97982	40
21	42278	98422	44948	98207	47452	97978	39
22	42324	98419	44992	98204	47492	97974	38
23	42370	98415	45035	98200	47533	97970	37
24	42416	98412	45077	98196	47573	97966	36
25	42461	98409	45120	98192	47613	97962	35
26	42507	98405	45163	98189	47654	97958	34
27	42553	98402	45206	98185	47694	97954	33
28	42599	98398	45249	98181	47734	97950	32
29	42644	98395	45292	98177	47774	97946	31
30	9.42690	9.98391	9.45334	9.98174	9.47814	9.97942	30
31	42735	98388	45377	98170	47854	97938	29
32	42781	98384	45419	98166	47894	97934	28
33	42826	98381	45462	98162	47934	97930	27
34	42872	98377	45504	98159	47974	97926	26
35	42917	98373	45547	98155	48014	97922	25
36	42962	98370	45589	98151	48054	97918	24
37	43008	98366	45632	98147	48094	97914	23
38	43053	98363	45674	98144	48133	97910	22
39	43098	98359	45716	98140	48173	97906	21
40	9.43143	9.98356	9.45758	9.98136	9.48213	9.97902	20
41	43188	98352	45801	98132	48252	97898	19
42	43233	98349	45843	98129	48292	97894	18
43	43278	98345	45885	98125	48332	97890	17
44	43323	98342	45927	98121	48371	97886	16
45	43367	98338	45969	98117	48411	97882	15
46	43412	98334	46011	98113	48450	97878	14
47	43457	98331	46053	98110	48490	97874	13
48	43502	98327	46095	98106	48529	97870	12
49	43546	98324	46136	98102	48568	97866	11
50	9.43591	9.98320	9.46178	9.98098	9.48607	9.97861	10
51	43635	98317	46220	98094	48647	97857	9
52	43680	98313	46262	98090	48686	97853	8
53	43724	98309	46303	98087	48725	97849	7
54	43769	98306	46345	98083	48764	97845	6
55	43813	98302	46386	98079	48803	97841	5
56	43857	98299	46428	98075	48842	97837	4
57	43901	98295	46469	98071	48881	97833	3
58	43946	98291	46511	98067	48920	97829	2
59	43990	98288	46552	98063	48959	97825	1
60	44034	98284	46594	98060	48998	97821	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	74°		73°		72°		

′	18°		19°		20°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.48998	9.97821	9.51264	9.97567	9.53405	9.97299	60
1	49037	97817	51301	97563	53440	97294	59
2	49076	97812	51338	97558	53475	97289	58
3	49115	97808	51374	97554	53509	97285	57
4	49153	97804	51411	97550	53544	97280	56
5	49192	97800	51447	97545	53578	97276	55
6	49231	97796	51484	97541	53613	97271	54
7	49269	97792	51520	97536	53647	97266	53
8	49308	97788	51557	97532	53682	97262	52
9	49347	97784	51593	97528	53716	97257	51
10	9.49385	9.97779	9.51629	9.97523	9.53751	9.97252	50
11	49424	97775	51666	97519	53785	97248	49
12	49462	97771	51702	97515	53819	97243	48
13	49500	97767	51738	97510	53854	97238	47
14	49539	97763	51774	97506	53888	97234	46
15	49577	97759	51811	97501	53922	97229	45
16	49615	97754	51847	97497	53957	97224	44
17	49654	97750	51883	97492	53991	97220	43
18	49692	97746	51919	97488	54025	97215	42
19	49730	97742	51955	97484	54059	97210	41
20	9.49768	9.97738	9.51991	9.97479	9.54093	9.97206	40
21	49806	97734	52027	97475	54127	97201	39
22	49844	97729	52063	97470	54161	97196	38
23	49882	97725	52099	97466	54195	97192	37
24	49920	97721	52135	97461	54229	97187	36
25	49958	97717	52171	97457	54263	97182	35
26	49996	97713	52207	97453	54297	97178	34
27	50034	97708	52242	97448	54331	97173	33
28	50072	97704	52278	97444	54365	97168	32
29	50110	97700	52314	97439	54399	97163	31
30	9.50148	9.97696	9.52350	9.97435	9.54433	9.97159	30
31	50185	97691	52385	97430	54466	97154	29
32	50223	97687	52421	97426	54500	97149	28
33	50261	97683	52456	97421	54534	97145	27
34	50298	97679	52492	97417	54567	97140	26
35	50336	97674	52527	97412	54601	97135	25
36	50374	97670	52563	97408	54635	97130	24
37	50411	97666	52598	97403	54668	97126	23
38	50449	97662	52634	97399	54702	97121	22
39	50486	97657	52669	97394	54735	97116	21
40	9.50523	9.97653	9.52705	9.97390	9.54769	9.97111	20
41	50561	97649	52740	97385	54802	97107	19
42	50598	97645	52775	97381	54836	97102	18
43	50635	97640	52811	97376	54869	97097	17
44	50673	97636	52846	97372	54903	97092	16
45	50710	97632	52881	97367	54936	97087	15
46	50747	97628	52916	97363	54969	97083	14
47	50784	97623	52951	97358	55003	97078	13
48	50821	97619	52986	97353	55036	97073	12
49	50858	97615	53021	97349	55069	97068	11
50	9.50896	9.97610	9.53056	9.97344	9.55102	9.97063	10
51	50933	97606	53092	97340	55136	97059	9
52	50970	97602	53126	97335	55169	97054	8
53	51007	97597	53161	97331	55202	97049	7
54	51043	97593	53196	97326	55235	97044	6
55	51080	97589	53231	97322	55268	97039	5
56	51117	97584	53266	97317	55301	97035	4
57	51154	97580	53301	97312	55334	97030	3
58	51191	97576	53336	97308	55367	97025	2
59	51227	97571	53370	97303	55400	97020	1
60	51264	97567	53405	97299	55433	97015	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	71°		70°		69°		

′	21° Sine	21° Cosine	22° Sine	22° Cosine	23° Sine	23° Cosine	′
0	9.55433	9.97015	9.57358	9.96717	9.59188	9.96403	60
1	55466	97010	57389	96711	59218	96397	59
2	55499	97005	57420	96706	59247	96392	58
3	55532	97001	57451	96701	59277	96387	57
4	55564	96996	57482	96696	59307	96381	56
5	55597	96991	57514	96691	59336	96376	55
6	55630	96986	57545	96686	59366	96370	54
7	55663	96981	57576	96681	59396	96365	53
8	55695	96976	57607	96676	59425	96360	52
9	55728	96971	57638	96670	59455	96354	51
10	9.55761	9.96966	9.57669	9.96665	9.59484	9.96349	50
11	55793	96962	57700	96660	59514	96343	49
12	55826	96957	57731	96655	59543	96338	48
13	55858	96952	57762	96650	59573	96333	47
14	55891	96947	57793	96645	59602	96327	46
15	55923	96942	57824	96640	59632	96322	45
16	55956	96937	57855	96634	59661	96316	44
17	55988	96932	57885	96629	59690	96311	43
18	56021	96927	57916	96624	59720	96305	42
19	56053	96922	57947	96619	59749	96300	41
20	9.56085	9.96917	9.57978	9.96614	9.59778	9.96294	40
21	56118	96912	58008	96608	59808	96289	39
22	56150	96907	58039	96603	59837	96284	38
23	56182	96903	58070	96598	59866	96278	37
24	56215	96898	58101	96593	59895	96273	36
25	56247	96893	58131	96588	59924	96267	35
26	56279	96888	58162	96582	59954	96262	34
27	56311	96883	58192	96577	59983	96256	33
28	56343	96878	58223	96572	60012	96251	32
29	56375	96873	58253	96567	60041	96245	31
30	9.56408	9.96868	9.58284	9.96562	9.60070	9.96240	30
31	56440	96863	58314	96556	60099	96234	29
32	56472	96858	58345	96551	60128	96229	28
33	56504	96853	58375	96546	60157	96223	27
34	56536	96848	58406	96541	60186	96218	26
35	56568	96843	58436	96535	60215	96212	25
36	56599	96838	58467	96530	60244	96207	24
37	56631	96833	58497	96525	60273	96201	23
38	56663	96828	58527	96520	60302	96196	22
39	56695	96823	58557	96514	60331	96190	21
40	9.56727	9.96818	9.58588	9.96509	9.60359	9.96185	20
41	56759	96813	58618	96504	60388	96179	19
42	56790	96808	58648	96498	60417	96174	18
43	56822	96803	58678	96493	60446	96168	17
44	56854	96798	58709	96488	60474	96162	16
45	56886	96793	58739	96483	60503	96157	15
46	56917	96788	58769	96477	60532	96151	14
47	56949	96783	58799	96472	60561	96146	13
48	56980	96778	58829	96467	60589	96140	12
49	57012	96772	58859	96461	60618	96135	11
50	9.57044	9.96767	9.58889	9.96456	9.60646	9.96129	10
51	57075	96762	58919	96451	60675	96123	9
52	57107	96757	58949	96445	60704	96118	8
53	57138	96752	58979	96440	60732	96112	7
54	57169	96747	59009	96435	60761	96107	6
55	57201	96742	59039	96429	60789	96101	5
56	57232	96737	59069	96424	60818	96095	4
57	57264	96732	59098	96419	60846	96090	3
58	57295	96727	59128	96413	60875	96084	2
59	57326	96722	59158	96408	60903	96079	1
60	57358	96717	59188	96403	60931	96073	0
′	Cosine 68°	Sine 68°	Cosine 67°	Sine 67°	Cosine 66°	Sine 66°	′

′	24°		25°		26°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.60931	9.96073	9.62595	9.95728	9.64184	9.95366	60
1	60960	96067	62622	95722	64210	95360	59
2	60988	96062	62649	95716	64236	95354	58
3	61016	96056	62676	95710	64262	95348	57
4	61045	96050	62703	95704	64288	95341	56
5	61073	96045	62730	95698	64313	95335	55
6	61101	96039	62757	95692	64339	95329	54
7	61129	96034	62784	95686	64365	95323	53
8	61158	96028	62811	95680	64391	95317	52
9	61186	96022	62838	95674	64417	95310	51
10	9.61214	9.96017	9.62865	9.95668	9.64442	9.95304	50
11	61242	96011	62892	95663	64468	95298	49
12	61270	96005	62918	95657	64494	95292	48
13	61298	96000	62945	95651	64519	95286	47
14	61326	95994	62972	95645	64545	95279	46
15	61354	95988	62999	95639	64571	95273	45
16	61382	95982	63026	95633	64596	95267	44
17	61411	95977	63052	95627	64622	95261	43
18	61438	95971	63079	95621	64647	95254	42
19	61466	95965	63106	95615	64673	95248	41
20	9.61494	9.95960	9.63133	9.95609	9.64698	9.95242	40
21	61522	95954	63159	95603	64724	95236	39
22	61550	95948	63186	95597	64749	95229	38
23	61578	95942	63213	95591	64775	95223	37
24	61606	95937	63239	95585	64800	95217	36
25	61634	95931	63266	95579	64826	95211	35
26	61662	95925	63292	95573	64851	95204	34
27	61689	95920	63319	95567	64877	95198	33
28	61717	95914	63345	95561	64902	95192	32
29	61745	95908	63372	95555	64927	95185	31
30	9.61773	9.95902	9.63398	9.95549	9.64953	9.95179	30
31	61800	95897	63425	95543	64978	95173	29
32	61828	95891	63451	95537	65003	95167	28
33	61856	95885	63478	95531	65029	95160	27
34	61883	95879	63504	95525	65054	95154	26
35	61911	95873	63531	95519	65079	95148	25
36	61939	95868	63557	95513	65104	95141	24
37	61966	95862	63583	95507	65130	95135	23
38	61994	95856	63610	95500	65155	95129	22
39	62021	95850	63636	95494	65180	95122	21
40	9.62049	9.95844	9.63662	9.95488	9.65205	9.95116	20
41	62076	95839	63689	95482	65230	95110	19
42	62104	95833	63715	95476	65255	95103	18
43	62131	95827	63741	95470	65281	95097	17
44	62159	95821	63767	95464	65306	95090	16
45	62186	95815	63794	95458	65331	95084	15
46	62214	95810	63820	95452	65356	95078	14
47	62241	95804	63846	95446	65381	95071	13
48	62268	95798	63872	95440	65406	95065	12
49	62296	95792	63898	95434	65431	95059	11
50	9.62323	9.95786	9.63924	9.95427	9.65456	9.95052	10
51	62350	95780	63950	95421	65481	95046	9
52	62377	95775	63976	95415	65506	95039	8
53	62405	95769	64002	95409	65531	95033	7
54	62432	95763	64028	95403	65565	95027	6
55	62459	95757	64054	95397	65580	95020	5
56	62486	95751	64080	95391	65605	95014	4
57	62513	95745	64106	95384	65630	95007	3
58	62541	95739	64132	95378	65655	95001	2
59	62568	95733	64158	95372	65680	94995	1
60	62595	95728	64184	95366	65705	94988	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	65°		64°		63°		

′	27°		28°		29°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.65705	9.94988	9.67161	9.94593	9.68557	9.94182	60
1	65729	94982	67185	94587	68580	94175	59
2	65754	94975	67208	94580	68603	94168	58
3	65779	94969	67232	94573	68625	94161	57
4	65804	94962	67256	94567	68648	94154	56
5	65828	94956	67280	94560	68671	94147	55
6	65853	94949	67303	94553	68694	94140	54
7	65878	94943	67327	94546	68716	94133	53
8	65902	94936	67350	94540	68739	94126	52
9	65927	94930	67374	94533	68762	94119	51
10	9.65952	9.94923	9.67398	9.94526	9.68784	9.94112	50
11	65976	94917	67421	94519	68807	94105	49
12	66001	94911	67445	94513	68829	94098	48
13	66025	94904	67468	94506	68852	94090	47
14	66050	94898	67492	94499	68875	94083	46
15	66075	94891	67515	94492	68897	94076	45
16	66099	94885	67539	94485	68920	94069	44
17	66124	94878	67562	94479	68942	94062	43
18	66148	94871	67586	94472	68965	94055	42
19	66173	94865	67609	94465	68987	94048	41
20	9.66197	9.94858	9.67633	9.94458	9.69010	9.94041	40
21	66221	94852	67656	94451	69032	94034	39
22	66246	94845	67680	94445	69055	94027	38
23	66270	94839	67703	94438	69077	94020	37
24	66295	94832	67726	94431	69100	94012	36
25	66319	94826	67750	94424	69122	94005	35
26	66343	94819	67773	94417	69144	93998	34
27	66368	94813	67796	94410	69167	93991	33
28	66392	94806	67820	94404	69189	93984	32
29	66416	94799	67843	94397	69212	93977	31
30	9.66441	9.94793	9.67866	9.94390	9.69234	9.93970	30
31	66465	94786	67890	94383	69256	93963	29
32	66489	94780	67913	94376	69279	93955	28
33	66513	94773	67936	94369	69301	93948	27
34	66537	94767	67959	94362	69323	93941	26
35	66562	94760	67982	94355	69345	93934	25
36	66586	94753	68006	94349	69368	93927	24
37	66610	94747	68029	94342	69390	93920	23
38	66634	94740	68052	94335	69412	93912	22
39	66658	94734	68075	94328	69434	93905	21
40	9.66682	9.94727	9.68098	9.94321	9.69456	9.93898	20
41	66706	94720	68121	94314	69479	93891	19
42	66731	94714	68144	94307	69501	93884	18
43	66755	94707	68167	94300	69523	93876	17
44	66779	94700	68190	94293	69545	93869	16
45	66803	94694	68213	94286	69567	93862	15
46	66827	94687	68237	94279	69589	93855	14
47	66851	94680	68260	94273	69611	93847	13
48	66875	94674	68283	94266	69633	93840	12
49	66899	94667	68305	94259	69655	93833	11
50	9.66922	9.94660	9.68328	9.94252	9.69677	9.93826	10
51	66946	94654	68351	94245	69699	93819	9
52	66970	94647	68374	94238	69721	93811	8
53	66994	94640	68397	94231	69743	93804	7
54	67018	94634	68420	94224	69765	93797	6
55	67042	94627	68443	94217	69787	93789	5
56	67066	94620	68466	94210	69809	93782	4
57	67090	94614	68489	94203	69831	93775	3
58	67113	94607	68512	94196	69853	93768	2
59	67137	94600	68534	94189	69875	93760	1
60	67161	94593	68557	94182	69897	93753	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	62°		61°		60°		

′	30°		31°		32°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.69897	9.93753	9.71184	9.93307	9.72421	9.92842	60
1	69919	93746	71205	93299	72441	92834	59
2	69941	93738	71226	93291	72461	92826	58
3	69963	93731	71247	93284	72482	92818	57
4	69984	93724	71268	93276	72502	92810	56
5	70006	93717	71289	93269	72522	92803	55
6	70028	93709	71310	93261	72542	92795	54
7	70050	93702	71331	93253	72562	92787	53
8	70072	93695	71352	93246	72582	92779	52
9	70093	93687	71373	93238	72602	92771	51
10	9.70115	9.93680	9.71393	9.93230	9.72622	9.92763	50
11	70137	93673	71414	93223	72643	92755	49
12	70159	93665	71435	93215	72663	92747	48
13	70180	93658	71456	93207	72683	92739	47
14	70202	93650	71477	93200	72703	92731	46
15	70224	93643	71498	93192	72723	92723	45
16	70245	93636	71519	93184	72743	92715	44
17	70267	93628	71539	93177	72763	92707	43
18	70288	93621	71560	93169	72783	92699	42
19	70310	93614	71581	93161	72803	92691	41
20	9.70332	9.93606	9.71602	9.93154	9.72823	9.92683	40
21	70353	93599	71622	93146	72843	92675	39
22	70375	93591	71643	93138	72863	92667	38
23	70396	93584	71664	93131	72883	92659	37
24	70418	93577	71685	93123	72902	92651	36
25	70439	93569	71705	93115	72922	92643	35
26	70461	93562	71726	93108	72942	92635	34
27	70482	93554	71747	93100	72962	92627	33
28	70504	93547	71767	93092	72982	92619	32
29	70525	93539	71788	93084	73002	92611	31
30	9.70547	9.93532	9.71809	9.93077	9.73022	9.92603	30
31	70568	93525	71829	93069	73041	92595	29
32	70590	93517	71850	93061	73061	92587	28
33	70611	93510	71870	93053	73081	92579	27
34	70633	93502	71891	93046	73101	92571	26
35	70654	93495	71911	93038	73121	92563	25
36	70675	93487	71932	93030	73140	92555	24
37	70697	93480	71952	93022	73160	92546	23
38	70718	93472	71973	93014	73180	92538	22
39	70739	93465	71994	93007	73200	92530	21
40	9.70761	9.93457	9.72014	9.92999	9.73219	9.92522	20
41	70782	93450	72034	92991	73239	92514	19
42	70803	93442	72055	92983	73259	92506	18
43	70824	93435	72075	92976	73278	92498	17
44	70846	93427	72096	92968	73298	92490	16
45	70867	93420	72116	92960	73318	92482	15
46	70888	93412	72137	92952	73337	92473	14
47	70909	93405	72157	92944	73357	92465	13
48	70931	93397	72177	92936	73377	92457	12
49	70952	93390	72198	92929	73396	92449	11
50	9.70973	9.93382	9.72218	9.92921	9.73416	9.92441	10
51	70994	93375	72238	92913	73435	92433	9
52	71015	93367	72259	92905	73455	92425	8
53	71036	93360	72279	92897	73474	92416	7
54	71058	93352	72299	92889	73494	92408	6
55	71079	93344	72320	92881	73513	92400	5
56	71100	93337	72340	92874	73533	92392	4
57	71121	93329	72360	92866	73552	92384	3
58	71142	93322	72381	92858	73572	92376	2
59	71163	93314	72401	92850	73591	92367	1
60	71184	93307	72421	92842	73611	92359	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	59°		58°		57°		

′	33°		34°		35°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.73611	9.92359	9.74756	9.91857	9.75859	9.91336	60
1	73630	92351	74775	91849	75877	91328	59
2	73650	92343	74794	91840	75895	91319	58
3	73669	92335	74812	91832	75913	91310	57
4	73689	92326	74831	91823	75931	91301	56
5	73708	92318	74850	91815	75949	91292	55
6	73727	92310	74868	91806	75967	91283	54
7	73747	92302	74887	91798	75985	91274	53
8	73766	92293	74906	91789	76003	91266	52
9	73785	92285	74924	91781	76021	91257	51
10	9.73805	9.92277	9.74943	9.91772	9.76039	9.91248	50
11	73824	92269	74961	91763	76057	91239	49
12	73843	92260	74980	91755	76075	91230	48
13	73863	92252	74999	91746	76093	91221	47
14	73882	92244	75017	91738	76111	91212	46
15	73901	92235	75036	91729	76129	91203	45
16	73921	92227	75054	91720	76146	91194	44
17	73940	92219	75073	91712	76164	91185	43
18	73959	92211	75091	91703	76182	91176	42
19	73978	92202	75110	91695	76200	91167	41
20	9.73997	9.92194	9.75128	9.91686	9.76218	9.91158	40
21	74017	92186	75147	91677	76236	91149	39
22	74036	92177	75165	91669	76253	91141	38
23	74055	92169	75184	91660	76271	91132	37
24	74074	92161	75202	91651	76289	91123	36
25	74093	92152	75221	91643	76307	91114	35
26	74113	92144	75239	91634	76324	91105	34
27	74132	92136	75258	91625	76342	91096	33
28	74151	92127	75276	91617	76360	91087	32
29	74170	92119	75294	91608	76378	91078	31
30	9.74189	9.92111	9.75313	9.91599	9.76395	9.91069	30
31	74208	92102	75331	91591	76413	91060	29
32	74227	92094	75350	91582	76431	91051	28
33	74246	92086	75368	91573	76448	91042	27
34	74265	92077	75386	91565	76466	91033	26
35	74284	92069	75405	91556	76484	91023	25
36	74303	92060	75423	91547	76501	91014	24
37	74322	92052	75441	91538	76519	91005	23
38	74341	92044	75459	91530	76537	90996	22
39	74360	92035	75478	91521	76554	90987	21
40	9.74379	9.92027	9.75496	9.91512	9.76572	9.90978	20
41	74398	92018	75514	91504	76590	90969	19
42	74417	92010	75533	91495	76607	90960	18
43	74436	92002	75551	91486	76625	90951	17
44	74455	91993	75569	91477	76642	90942	16
45	74474	91985	75587	91469	76660	90933	15
46	74493	91976	75605	91460	76677	90924	14
47	74512	91968	75624	91451	76695	90915	13
48	74531	91959	75642	91442	76712	90906	12
49	74549	91951	75660	91433	76730	90896	11
50	9.74568	9.91942	9.75678	9.91425	9.76747	9.90887	10
51	74587	91934	75696	91416	76765	90878	9
52	74606	91925	75714	91407	76782	90869	8
53	74625	91917	75733	91398	76800	90860	7
54	74644	91908	75751	91389	76817	90851	6
55	74662	91900	75769	91381	76835	90842	5
56	74681	91891	75787	91372	76852	90832	4
57	74700	91883	75805	91363	76870	90823	3
58	74719	91874	75823	91354	76887	90814	2
59	74737	91866	75841	91345	76904	90805	1
60	74756	91857	75859	91336	76922	90796	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	56°		55°		54°		

′	36°		37°		38°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.76922	9.90796	9.77946	9.90235	9.78934	9.89653	60
1	76939	90787	77963	90225	78950	89643	59
2	76957	90777	77980	90216	78967	89633	58
3	76974	90768	77997	90206	78983	89624	57
4	76991	90759	78013	90197	78999	89614	56
5	77009	90750	78030	90187	79015	89604	55
6	77026	90741	78047	90178	79031	89594	54
7	77043	90731	78063	90168	79047	89584	53
8	77061	90722	78080	90159	79063	89574	52
9	77078	90713	78097	90149	79079	89564	51
10	9.77095	9.90704	9.78113	9.90139	9.79095	9.89554	50
11	77112	90694	78130	90130	79111	89544	49
12	77130	90685	78147	90120	79128	89534	48
13	77147	90676	78163	90111	79144	89524	47
14	77164	90667	78180	90101	79160	89514	46
15	77181	90657	78197	90091	79176	89504	45
16	77199	90648	78213	90082	79192	89495	44
17	77216	90639	78230	90072	79208	89485	43
18	77233	90630	78246	90063	79224	89475	42
19	77250	90620	78263	90053	79240	89465	41
20	9.77268	9.90611	9.78280	9.90043	9.79256	9.89455	40
21	77285	90602	78296	90034	79272	89445	39
22	77302	90592	78313	90024	79288	89435	38
23	77319	90583	78329	90014	79304	89425	37
24	77336	90574	78346	90005	79319	89415	36
25	77353	90565	78362	89995	79335	89405	35
26	77370	90555	78379	89985	79351	89395	34
27	77387	90546	78395	89976	79367	89385	33
28	77405	90537	78412	89966	79383	89375	32
29	77422	90527	78428	89956	79399	89364	31
30	9.77439	9.90518	9.78445	9.89947	9.79415	9.89354	30
31	77456	90509	78461	89937	79431	89344	29
32	77473	90499	78478	89927	79447	89334	28
33	77490	90490	78494	89918	79463	89324	27
34	77507	90480	78510	89908	79478	89314	26
35	77524	90471	78527	89898	79494	89304	25
36	77541	90462	78543	89888	79510	89294	24
37	77558	90452	78560	89879	79526	89284	23
38	77575	90443	78576	89869	79542	89274	22
39	77592	90434	78592	89859	79558	89264	21
40	9.77609	9.90424	9.78609	9.89849	9.79573	9.89254	20
41	77626	90415	78625	89840	79589	89244	19
42	77643	90405	78642	89830	79605	89233	18
43	77660	90396	78658	89820	78621	89223	17
44	77677	90386	78674	89810	79636	89213	16
45	77694	90377	78691	89801	79652	89203	15
46	77711	90368	78707	89791	79668	89193	14
47	77728	90358	78723	89781	79684	89183	13
48	77744	90349	78739	89771	79699	89173	12
49	77761	90339	78756	89761	79715	89162	11
50	9.77778	9.90330	9.78772	9.89752	9.79731	9.89152	10
51	77795	90320	78788	89742	79746	89142	9
52	77812	90311	78805	89732	79762	89132	8
53	77829	90301	78821	89722	79778	89122	7
54	77846	90292	78837	89712	79793	89112	6
55	77862	90282	78853	89702	79809	89101	5
56	77879	90273	78869	89693	79825	89091	4
57	77896	90263	78886	89683	79840	89081	3
58	77913	90254	78902	89673	79856	89071	2
59	77930	90244	78918	89663	79872	89060	1
60	77946	90235	78934	89653	79887	89050	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	53°		52°		51°		

′	39°		40°		41°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.79887	9.89050	9.80807	9.88425	9.81694	9.87778	60
1	79903	89040	80822	88415	81709	87767	59
2	79918	89030	80837	88404	81723	87756	58
3	79934	89020	80852	88394	81738	87745	57
4	79950	89009	80867	88383	81752	87734	56
5	79965	88999	80882	88372	81767	87723	55
6	79981	88989	80897	88362	81781	87712	54
7	79996	88978	80912	88351	81796	87701	53
8	80012	88968	80927	88340	81810	87690	52
9	80027	88958	80942	88330	81825	87679	51
10	9.80043	9.88948	9.80957	9.88319	9.81839	9.87668	50
11	80058	88937	80972	88308	81854	87657	49
12	80074	88927	80987	88298	81868	87646	48
13	80089	88917	81002	88287	81882	87635	47
14	80105	88906	81017	88276	81897	87624	46
15	80120	88896	81032	88266	81911	87613	45
16	80136	88886	81047	88255	81926	87601	44
17	80151	88875	81061	88244	81940	87590	43
18	80166	88865	81076	88234	81955	87579	42
19	80182	88855	81091	88223	81969	87568	41
20	9.80197	9.88844	9.81106	9.88212	9.81983	9.87557	40
21	80213	88834	81121	88201	81998	87546	39
22	80228	88824	81136	88191	82012	87535	38
23	80244	88813	81151	88180	82026	87524	37
24	80259	88803	81166	88169	82041	87513	36
25	80274	88793	81180	88158	82055	87501	35
26	80290	88782	81195	88148	82069	87490	34
27	80305	88772	81210	88137	82084	87479	33
28	80320	88761	81225	88126	82098	87468	32
29	80336	88751	81240	88115	82112	87457	31
30	9.80351	9.88741	9.81254	9.88105	9.82126	9.87446	30
31	80366	88730	81269	88094	82141	87434	29
32	80382	88720	81284	88083	82155	87423	28
33	80397	88709	81299	88072	82169	87412	27
34	80412	88699	81314	88061	82184	87401	26
35	80428	88688	81328	88051	82198	87390	25
36	80443	88678	81343	88040	82212	87378	24
37	80458	88668	81358	88029	82226	87367	23
38	80473	88657	81372	88018	82240	87356	22
39	80489	88647	81387	88007	82255	87345	21
40	9.80504	9.88636	9.81402	9.87996	9.82269	9.87334	20
41	80519	88626	81417	87985	82283	87322	19
42	80534	88615	81431	87975	82297	87311	18
43	80550	88605	81446	87964	82311	87300	17
44	80565	88594	81461	87953	82326	87288	16
45	80580	88584	81475	87942	82340	87277	15
46	80595	88573	81490	87931	82354	87266	14
47	80610	88563	81505	87920	82368	87255	13
48	80625	88552	81519	87909	82382	87243	12
49	80641	88542	81534	87898	82396	87232	11
50	9.80656	9.88531	9.81549	9.87887	9.82410	9.87221	10
51	80671	88521	81563	87877	82424	87209	9
52	80686	88510	81578	87866	82439	87198	8
53	80701	88499	81592	87855	82453	87187	7
54	80716	88489	81607	87844	82467	87175	6
55	80731	88478	81622	87833	82481	87164	5
56	80746	88468	81636	87822	82495	87153	4
57	80762	88457	81651	87811	82509	87141	3
58	80777	88447	81665	87800	82523	87130	2
59	80792	88436	81680	87789	82537	87119	1
60	80807	88425	81694	87778	82551	87107	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	50°		49°		48°		

′	42° Sine	42° Cosine	43° Sine	43° Cosine	44° Sine	44° Cosine	′
0	9.82551	9.87107	9.83378	9.86413	9.84177	9.85693	60
1	82565	87096	83392	86401	84190	85681	59
2	82579	87085	83405	86389	84203	85669	58
3	82593	87073	83419	86377	84216	85657	57
4	82607	87062	83432	86366	84229	85645	56
5	82621	87050	83446	86354	84242	85632	55
6	82635	87039	83459	86342	84255	85620	54
7	82649	87028	83473	86330	84269	85608	53
8	82663	87016	83486	86318	84282	85596	52
9	82677	87005	83500	86306	84295	85583	51
10	9.82691	9.86993	9.83513	9.86295	9.84308	9.85571	50
11	82705	86982	83527	86283	84321	85559	49
12	82719	86970	83540	86271	84334	85547	48
13	82733	86959	83554	86259	84347	85534	47
14	82747	86947	83567	86247	84360	85522	46
15	82761	86936	83581	86235	84373	85510	45
16	82775	86924	83594	86223	84385	85497	44
17	82788	86913	83608	86211	84398	85485	43
18	82802	86902	83621	86200	84411	85473	42
19	82816	86890	83634	86188	84424	85460	41
20	9.82830	9.86879	9.83648	9.86176	9.84437	9.85448	40
21	82844	86867	83661	86164	84450	85436	39
22	82858	86855	83674	86152	84463	85423	38
23	82872	86844	83688	86140	84476	85411	37
24	82885	86832	83701	86128	84489	85399	36
25	82899	86821	83715	86116	84502	85386	35
26	82913	86809	83728	86104	84515	85374	34
27	82927	86798	83741	86092	84528	85361	33
28	82941	86786	83755	86080	84540	85349	32
29	82955	86775	83768	86068	84553	85337	31
30	9.82968	9.86763	9.83781	9.86056	9.84566	9.85324	30
31	82982	86752	83795	86044	84579	85312	29
32	82996	86740	83808	86032	84592	85299	28
33	83010	86728	83821	86020	84605	85287	27
34	83023	86717	83834	86008	84618	85274	26
35	83037	86705	83848	85996	84630	85262	25
36	83051	86694	83861	85984	84643	85250	24
37	83065	86682	83874	85972	84656	85237	23
38	83078	86670	83887	85960	84669	85225	22
39	83092	86659	83901	85948	84682	85212	21
40	9.83106	9.86647	9.83914	9.85936	9.84694	9.85200	20
41	83120	86635	83927	85924	84707	85187	19
42	83133	86624	83940	85912	84720	85175	18
43	83147	86612	83954	85900	84733	85162	17
44	83161	86600	83967	85888	84745	85150	16
45	83174	86589	83980	85876	84758	85137	15
46	83188	86577	83993	85864	84771	85125	14
47	83202	86565	84006	85851	84784	85112	13
48	83215	86554	84020	85839	84796	85100	12
49	83229	86542	84033	85827	84809	85087	11
50	9.83242	9.86530	9.84046	9.85815	9.84822	9.85074	10
51	83256	86518	84059	85803	84835	85062	9
52	83270	86507	84072	85791	84847	85049	8
53	83283	86495	84085	85779	84860	85037	7
54	83297	86483	84098	85766	84873	85024	6
55	83310	86472	84112	85754	84885	85012	5
56	83324	86460	84125	85742	84898	84999	4
57	83338	86448	84138	85730	84911	84986	3
58	83351	86436	84151	85718	84923	84974	2
59	83365	86425	84164	85706	84936	84961	1
60	83378	86413	84177	85693	84949	84949	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	47°		46°		45°		

′	0° Tan	0° Cotan	1° Tan	1° Cotan	2° Tan	2° Cotan	′
0	−∞	∞	8.24192	11.75808	8.54308	11.45692	60
1	6.46373	13.53627	24910	75090	54669	45331	59
2	76476	23524	25616	74384	55027	44973	58
3	94085	05915	26312	73688	55382	44618	57
4	7.06579	12.93421	26996	73004	55734	44266	56
5	16270	83730	27669	72331	56083	43917	55
6	24188	75812	28332	71668	56429	43571	54
7	30882	69118	28986	71014	56773	43227	53
8	36682	63318	29629	70371	57114	42886	52
9	41797	58203	30263	69737	57452	42548	51
10	7.46373	12.53627	8.30888	11.69112	8.57788	11.42212	50
11	50512	49488	31505	68495	58121	41879	49
12	54291	45709	32112	67888	58451	41549	48
13	57767	42233	32711	67289	58779	41221	47
14	60986	39014	33302	66698	59105	40895	46
15	63982	36018	33886	66114	59428	40572	45
16	66785	33215	34461	65539	59749	40251	44
17	69418	30582	35029	64971	60068	39932	43
18	71900	28100	35590	64410	60384	39616	42
19	74248	25752	36143	63857	60698	39302	41
20	7.76476	12.23524	8.36689	11.63311	8.61009	11.38991	40
21	78595	21405	37229	62771	61319	38681	39
22	80615	19385	37762	62238	61626	38374	38
23	82546	17454	38289	61711	61931	38069	37
24	84394	15606	38809	61191	62234	37766	36
25	86167	13833	39323	60677	62535	37465	35
26	87871	12129	39832	60168	62834	37166	34
27	89510	10490	40334	59666	63131	36869	33
28	91089	08911	40830	59170	63426	36574	32
29	92613	07387	41321	58679	63718	36282	31
30	7.94086	12.05914	8.41807	11.58193	8.64009	11.35991	30
31	95510	04490	42287	57713	64298	35702	29
32	96889	03111	42762	57238	64585	35415	28
33	98225	01775	43232	56768	64870	35130	27
34	99522	00478	43696	56304	65154	34846	26
35	8.00781	11.99219	44156	55844	65435	34565	25
36	02004	97996	44611	55389	65715	34285	24
37	03194	96806	45061	54939	65993	34007	23
38	04353	95647	45507	54493	66269	33731	22
39	05481	94519	45948	54052	66543	33457	21
40	8.06581	11.93419	8.46385	11.53615	8.66816	11.33184	20
41	07653	92347	46817	53183	67087	32913	19
42	08700	91300	47245	52755	67356	32644	18
43	09722	90278	47669	52331	67624	32376	17
44	10720	89280	48089	51911	67890	32110	16
45	11696	88304	48505	51495	68154	31846	15
46	12651	87349	48917	51083	68417	31583	14
47	13585	86415	49325	50675	68678	31322	13
48	14500	85500	49729	50271	68938	31062	12
49	15395	84605	50130	49870	69196	30804	11
50	8.16273	11.83727	8.50527	11.49473	8.69453	11.30547	10
51	17133	82867	50920	49080	69708	20292	9
52	17976	82024	51310	48690	69962	30038	8
53	18804	81196	51696	48304	70214	29786	7
54	19616	80384	52079	47921	70465	29535	6
55	20413	79587	52459	47541	70714	29286	5
56	21195	78805	52835	47165	70962	29038	4
57	21964	78036	53208	46792	71208	28792	3
58	22720	77280	53578	46422	71453	28547	2
59	23462	76538	53945	46055	71697	28303	1
60	24192	75808	54308	45692	71940	28060	0
′	89° Cotan	89° Tan	88° Cotan	88° Tan	87° Cotan	87° Tan	′

′	3°		4°		5°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	8.71940	11.28060	8.84464	11.15536	8.94195	11.05805	60
1	72181	27819	84646	15354	94340	05660	59
2	72420	27580	84826	15174	94485	05515	58
3	72659	27341	85006	14994	94630	05370	57
4	72896	27104	85185	14815	94773	05227	56
5	73132	26868	85363	14637	94917	05083	55
6	73366	26634	85540	14460	95060	04940	54
7	73600	26400	85717	14283	95202	04798	53
8	73832	26168	85893	14107	95344	04656	52
9	74063	25937	86069	13931	95486	04514	51
10	8.74292	11.25708	8.86243	11.13757	8.95627	11.04373	50
11	74521	25479	86417	13583	95767	04233	49
12	74748	25252	86591	13409	95908	04092	48
13	74974	25026	86763	13237	96047	03953	47
14	75199	24801	86935	13065	96187	03813	46
15	75423	24577	87106	12894	96325	03675	45
16	75645	24355	87277	12723	96464	03536	44
17	75867	24133	87447	12553	96602	03398	43
18	76087	23913	87616	12384	96739	03261	42
19	76306	23694	87785	12215	96877	02123	41
20	8.76525	11.23475	8.87953	11.12047	8.97013	11.02987	40
21	76742	23258	88120	11880	97150	02850	39
22	76958	23042	88287	11713	97285	02715	38
23	77173	22827	88453	11547	97421	02579	37
24	77387	22613	88618	11382	97556	02444	36
25	77600	22400	88783	11217	97691	02309	35
26	77811	22189	88948	11052	97825	02175	34
27	78022	21978	89111	10889	97959	02041	33
28	78232	21768	89274	10726	98092	01908	32
29	78441	21559	89437	10563	98225	01775	31
30	8.78649	11.21351	8.89598	11.10402	8.98358	11.01642	30
31	78855	21145	89760	10240	98490	01510	29
32	79061	20939	89920	10080	98622	01378	28
33	79266	20734	90080	09920	98753	01247	27
34	79470	20530	90240	09760	98884	01116	26
35	79673	20327	90399	09601	99015	00985	25
36	79875	20125	90557	09443	99145	00855	24
37	80076	19924	90715	09285	99275	00725	23
38	80277	19723	90872	09128	99405	00595	22
39	80476	19524	91029	08971	99534	00466	21
40	8.80674	11.19326	8.91185	11.08815	8.99662	11.00338	20
41	80872	19128	91340	08660	99791	00209	19
42	81068	18932	91495	08505	99919	00081	18
43	81264	18736	91650	08350	9.00046	10.99954	17
44	81459	18541	91803	08197	00174	99826	16
45	81653	18347	91957	08043	00301	99699	15
46	81846	18154	92110	07890	00427	99573	14
47	82038	17962	92262	07738	00553	99447	13
48	82230	17770	92414	07586	00679	99321	12
49	82420	17580	92565	07435	00805	99195	11
50	8.82610	11.17390	8.92716	11.07284	9.00930	10.99070	10
51	82799	17201	92866	07134	01055	98945	9
52	82987	17013	93016	06984	01179	98821	8
53	83175	16825	93165	06835	01303	98697	7
54	83361	16639	93313	06687	01427	98573	6
55	83547	16453	93462	06538	01550	98450	5
56	83732	16268	93609	06391	01673	98327	4
57	83916	16084	93756	06244	01796	98204	3
58	84100	15900	93903	06097	01918	98082	2
59	84282	15718	94049	05951	02040	97960	1
60	84464	15536	94195	05805	02162	97838	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	86°		85°		84°		

′	6°		7°		8°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.02162	10.97838	9.08914	10.91086	9.14780	10.85220	60
1	02283	97717	09019	90981	14872	85128	59
2	02404	97596	09123	90877	14963	85037	58
3	02525	97475	09227	90773	15054	84946	57
4	02645	97355	09330	90670	15145	84855	56
5	02766	97234	09434	90566	15236	84764	55
6	02885	97115	09537	90463	15327	84673	54
7	03005	96995	09640	90360	15417	84583	53
8	03124	96876	09742	90258	15508	84492	52
9	03242	96758	09845	90155	15598	84402	51
10	9.03361	10.96639	9.09947	10.90053	9.15688	10.84312	50
11	03479	96521	10049	89951	15777	84223	49
12	03597	96403	10150	89850	15867	84133	48
13	03714	96286	10252	89748	15956	84044	47
14	03832	96168	10353	89647	16046	83954	46
15	03948	96052	10454	89546	16135	83865	45
16	04065	95935	10555	89445	16224	83776	44
17	04181	95819	10656	89344	16312	83688	43
18	04297	95703	10756	89244	16401	83599	42
19	04413	95587	10856	89144	16489	83511	41
20	9.04528	10.95472	9.10956	10.89044	9.16577	10.83423	40
21	04643	95357	11056	88944	16665	83335	39
22	04758	95242	11155	88845	16753	83247	38
23	04873	95127	11254	88746	16841	83159	37
24	04987	95013	11353	88647	16928	83072	36
25	05101	94899	11452	88548	17016	82984	35
26	05214	94786	11551	88449	17103	82897	34
27	05328	94672	11649	88351	17190	82810	33
28	05441	94559	11747	88253	17277	82723	32
29	05553	94447	11845	88155	17363	82637	31
30	9.05666	10.94334	9.11943	10.88057	9.17450	10.82550	30
31	05778	94222	12040	87960	17536	82464	29
32	05890	94110	12138	87862	17622	82378	28
33	06002	93998	12235	87765	17708	82292	27
34	06113	93887	12332	87668	17794	82206	26
35	06224	93776	12428	87572	17880	82120	25
36	06335	93665	12525	87475	17965	82035	24
37	06445	93555	12621	87379	18051	81949	23
38	06556	93444	12717	87283	18136	81864	22
39	06666	93334	12813	87187	18221	81779	21
40	9.06775	10.93225	9.12909	10.87091	9.18306	10.81694	20
41	06885	93115	13004	86996	18391	81609	19
42	06994	93006	13099	86901	18475	81525	18
43	07103	92897	13194	86806	18560	81440	17
44	07211	92789	13289	86711	18644	81356	16
45	07320	92680	13384	86616	18728	81272	15
46	07428	92572	13478	86522	18812	81188	14
47	07536	92464	13573	86427	18896	81104	13
48	07643	92357	13667	86333	18979	81021	12
49	07751	92249	13761	86239	19063	80937	11
50	9.07858	10.92142	9.13854	10.86146	9.19146	10.80854	10
51	07964	92036	13948	86052	19229	80771	9
52	08071	91929	14041	85959	19312	80688	8
53	08177	91823	14134	85866	19395	80605	7
54	08283	91717	14227	85773	19478	80522	6
55	08389	91611	14320	85680	19561	80439	5
56	08495	91505	14412	85588	19643	80357	4
57	08600	91400	14504	85496	19725	80275	3
58	08705	91295	14597	85403	19807	80193	2
59	08810	91190	14688	85312	19889	80111	1
60	08914	91086	14780	85220	19971	80029	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	83°		82°		81°		

′	9°		10°		11°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.19971	10.80029	9.24632	10.75368	9.28865	10.71135	60
1	20053	79947	24706	75294	28933	71067	59
2	20134	79866	24779	75221	29000	71000	58
3	20216	79784	24853	75147	29067	70933	57
4	20297	79703	24926	75074	29134	70866	56
5	20378	79622	25000	75000	29201	70799	55
6	20459	79541	25073	74927	29268	70732	54
7	20540	79460	25146	74854	29335	70665	53
8	20621	79379	25219	74781	29402	70598	52
9	20701	79299	25292	74708	29468	70532	51
10	9.20782	10.79218	9.25365	10.74635	9.29535	10.70465	50
11	20862	79138	25437	74563	29601	70399	49
12	20942	79058	25510	74490	29668	70332	48
13	21022	78978	25582	74418	29734	70266	47
14	21102	78898	25655	74345	29800	70200	46
15	21182	78818	25727	74273	29866	70134	45
16	21261	78739	25799	74201	29932	70068	44
17	21341	78659	25871	74129	29998	70002	43
18	21420	78580	25943	74057	30064	69936	42
19	21499	78501	26015	73985	30130	69870	41
20	9.21578	10.78422	9.26086	10.73914	9.30195	10.69805	40
21	21657	78343	26158	73842	30261	69739	39
22	21736	78264	26229	73771	30326	69674	38
23	21814	78186	26301	73699	30391	69609	37
24	21893	78107	26372	73628	30457	69543	36
25	21971	78029	26443	73557	30522	69478	35
26	22049	77951	26514	73486	30587	69413	34
27	22127	77873	26585	73415	30652	69348	33
28	22205	77795	26655	73345	30717	69283	32
29	22283	77717	26726	73274	30782	69218	31
30	9.22361	10.77639	9.26797	10.73203	9.30846	10.69154	30
31	22438	77562	26867	73133	30911	69089	29
32	22516	77484	26937	73063	30975	69025	28
33	22598	77407	27008	72992	31040	68960	27
34	22670	77330	27078	72922	31104	68896	26
35	22747	77253	27148	72852	31168	68832	25
36	22824	77176	27218	72782	31233	68767	24
37	22901	77099	27288	72712	31297	68703	23
38	22977	77023	27357	72643	31361	68639	22
39	23054	76946	27427	72573	31425	68575	21
40	9.23130	10.76870	9.27496	10.72504	9.31489	10.68511	20
41	23206	76794	27566	72434	31552	68448	19
42	23283	76717	27635	72365	31616	68384	18
43	23359	76641	27704	72296	31679	68321	17
44	23435	76565	27773	72227	31743	68257	16
45	23510	76490	27842	72158	31806	68194	15
46	23586	76414	27911	72089	31870	68130	14
47	23661	76339	27980	72020	31933	68067	13
48	23737	76263	28049	71951	31996	68004	12
49	23812	76188	28117	71883	32059	67941	11
50	9.23887	10.76113	9.28186	10.71814	9.32122	10.67878	10
51	23962	76038	28254	71746	32185	67815	9
52	24037	75963	28323	71677	32248	67752	8
53	24112	75888	28391	71609	32311	67689	7
54	24186	75814	28459	71541	32373	67627	6
55	24261	75739	28527	71473	32436	67564	5
56	24335	75665	28595	71405	32498	67502	4
57	24410	75590	28662	71338	32561	67439	3
58	24484	75516	28730	71270	32623	67377	2
59	24558	75442	28798	71202	32685	67315	1
60	24632	75368	28865	71135	32747	67253	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	
	80°		79°		78°		

′	12°		13°		14°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.32747	10.67253	9.36336	10.63664	9.39677	10.60323	60
1	32810	67190	36394	63606	39731	60269	59
2	32872	67128	36452	63548	39785	60215	58
3	32933	67067	36509	63491	39838	60162	57
4	32995	67005	36566	63434	39892	60108	56
5	33057	66943	36624	63376	39945	60055	55
6	33119	66881	36681	63319	39999	60001	54
7	33180	66820	36738	63262	40052	59948	53
8	33242	66758	36795	63205	40106	59894	52
9	33303	66697	36852	63148	40159	59841	51
10	9.33365	10.66635	9.36909	10.63091	9.40212	10.59788	50
11	33426	66574	36966	63034	40266	59734	49
12	33487	66513	37023	62977	40319	59681	48
13	33548	66452	37080	62920	40372	59628	47
14	33609	66391	37137	62863	40425	59575	46
15	33670	66330	37193	62807	40478	59522	45
16	33731	66269	37250	62750	40531	59469	44
17	33792	66208	37306	62694	40584	59416	43
18	33853	66147	37363	62637	40636	59364	42
19	33913	66087	37419	62581	40689	59311	41
20	9.33974	10.66026	9.37476	10.62524	9.40742	10.59258	40
21	34034	65966	37532	62468	40795	59205	39
22	34095	65905	37588	62412	40847	59153	38
23	34155	65845	37644	62356	40900	59100	37
24	34215	65785	37700	62300	40952	59048	36
25	34276	65724	37756	62244	41005	58995	35
26	34336	65664	37812	62188	41057	58943	34
27	34396	65604	37868	62132	41109	58891	33
28	34456	65544	37924	62076	41161	58839	32
29	34516	65484	37980	62020	41214	58786	31
30	9.34576	10.65424	9.38035	10.61965	9.41266	10.58734	30
31	34635	65365	38091	61909	41318	58682	29
32	34695	65305	38147	61853	41370	58630	28
33	34755	65245	38202	61798	41422	58578	27
34	34814	65186	38257	61743	41474	58526	26
35	34874	65126	38313	61687	41526	58474	25
36	34933	65067	38368	61632	41578	58422	24
37	34992	65008	38423	61577	41629	58371	23
38	35051	64949	38479	61521	41681	58319	22
39	35111	64889	38534	61466	41733	58267	21
40	9.35170	10.64830	9.38589	10.61411	9.41784	10.58216	20
41	35229	64771	38644	61356	41836	58164	19
42	35288	64712	38699	61301	41887	58113	18
43	35347	64653	38754	61246	41939	58061	17
44	35405	64595	38808	61192	41990	58010	16
45	35464	64536	38863	61137	42041	57959	15
46	35523	64477	38918	61082	42093	57907	14
47	35581	64419	38972	61028	42144	57856	13
48	35640	64360	39027	60973	42195	57805	12
49	35698	64302	39082	60918	42246	57754	11
50	9.35757	10.64243	9.39136	10.60864	9.42297	10.57703	10
51	35815	64185	39190	60810	42348	57652	9
52	35873	64127	39245	60755	42399	57601	8
53	35931	64069	39299	60701	42450	57550	7
54	35989	64011	39353	60647	42501	57499	6
55	36047	63953	39407	60593	42552	57448	5
56	36105	63895	39461	60539	42603	57397	4
57	36163	63837	39515	60485	42653	57347	3
58	36221	63779	39569	60431	42704	57296	2
59	36279	63721	39623	60377	42755	57245	1
60	36336	63664	39677	60323	42805	57195	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	77°		76°		75°		

′	15°		16°		17°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.42805	10.57195	9.45750	10.54250	9.48534	10.51466	60
1	42856	57144	45797	54203	48579	51421	59
2	42906	57094	45845	54155	48624	51376	58
3	42957	57043	45892	54108	48669	51331	57
4	43007	56993	45940	54060	48714	51286	56
5	43057	56943	45987	54013	48759	51241	55
6	43108	56892	46035	53965	48804	51196	54
7	43158	56842	46082	53918	48849	51151	53
8	43208	56792	46130	53870	48894	51106	52
9	43258	56742	46177	53823	48939	51061	51
10	9.43308	10.56692	9.46224	10.53776	9.48984	10.51016	50
11	43358	56642	46271	53729	49029	50971	49
12	43408	56592	46319	53681	49073	50927	48
13	43458	56542	46366	53634	49118	50882	47
14	43508	56492	46413	53587	49163	50837	46
15	43558	56442	46460	53540	49207	50793	45
16	43607	56393	46507	53493	49252	50748	44
17	43657	56343	46554	53446	49296	50704	43
18	43707	56293	46601	53399	49341	50659	42
19	43756	56244	46648	53352	49385	50615	41
20	9.43806	10.56194	9.46694	10.53306	9.49430	10.50570	40
21	43855	56145	46741	53259	49474	50526	39
22	43905	56095	46788	53212	49519	50481	38
23	43954	56046	46835	53165	49563	50437	37
24	44004	55996	46881	53119	49607	50393	36
25	44053	55947	46928	53072	49652	50348	35
26	44102	55898	46975	53025	49696	50304	34
27	44151	55849	47021	52979	49740	50260	33
28	44201	55799	47068	52932	49784	50216	32
29	44250	55750	47114	52886	49828	50172	31
30	9.44299	10.55701	9.47160	10.52840	9.49872	10.50128	30
31	44348	55652	47207	52793	49916	50084	29
32	44397	55603	47253	52747	49960	50040	28
33	44446	55554	47299	52701	50004	49996	27
34	44495	55505	47346	52654	50048	49952	26
35	44544	55456	47392	52608	50092	49908	25
36	44592	55408	47438	52562	50136	49864	24
37	44641	55359	47484	52516	50180	49820	23
38	44690	55310	47530	52470	50223	49777	22
39	44738	55262	47576	52424	50267	49733	21
40	9.44787	10.55213	9.47622	10.52378	9.50311	10.49689	20
41	44836	55164	47668	52332	50355	49645	19
42	44884	55116	47714	52286	50398	49602	18
43	44933	55067	47760	52240	50442	49558	17
44	44981	55019	47806	52194	50485	49515	16
45	45029	54971	47852	52148	50529	49471	15
46	45078	54922	47897	52103	50572	49428	14
47	45126	54874	47943	52057	50616	49384	13
48	45174	54826	47989	52011	50659	49341	12
49	45222	54778	48035	51965	50703	49297	11
50	9.45271	10.54729	9.48080	10.51920	9.50746	10.49254	10
51	45319	54681	48126	51874	50789	49211	9
52	45367	54633	48171	51829	50833	49167	8
53	45415	54585	48217	51783	50876	49124	7
54	45463	54537	48262	51738	50919	49081	6
55	45511	54489	48307	51693	50962	49038	5
56	45559	54441	48353	51647	51005	48995	4
57	45606	54394	48398	51602	51048	48952	3
58	45654	54346	48443	51557	51092	48908	2
59	45702	54298	48489	51511	51135	48865	1
60	45750	54250	48534	51466	51178	48822	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	74°		73°		72°		

′	18°		19°		20°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.51178	10.48822	9.53697	10.46303	9.56107	10.43893	60
1	51221	48779	53738	46262	56146	43854	59
2	51264	48736	53779	46221	56185	43815	58
3	51306	48694	53820	46180	56224	43776	57
4	51349	48651	53861	46139	56264	43736	56
5	51392	48608	53902	46098	56303	43697	55
6	51435	48565	53943	46057	56342	43658	54
7	51478	48522	53984	46016	56381	43619	53
8	51520	48480	54025	45975	56420	43580	52
9	51563	48437	54065	45935	56459	43541	51
10	9.51606	10.48394	9.54106	10.45894	9.56498	10.43502	50
11	51648	48352	54147	45853	56537	43463	49
12	51691	48309	54187	45813	56576	43424	48
13	51734	48266	54228	45772	56615	43385	47
14	51776	48224	54269	45731	56654	43346	46
15	51819	48181	54309	45691	56693	43307	45
16	51861	48139	54350	45650	56732	43268	44
17	51903	48097	54390	45610	56771	43229	43
18	51946	48054	54431	45569	56810	43190	42
19	51988	48012	54471	45529	56849	43151	41
20	9.52031	10.47969	9.54512	10.45488	9.56887	10.43113	40
21	52073	47927	54552	45448	56926	43074	39
22	52115	47885	54593	45407	56965	43035	38
23	52157	47843	54633	45367	57004	42996	37
24	52200	47800	54673	45327	57042	42958	36
25	52242	47758	54714	45286	57081	42919	35
26	52284	47716	54754	45246	57120	42880	34
27	52326	47674	54794	45206	57158	42842	33
28	52368	47632	54835	45165	57197	42803	32
29	52410	47590	54875	45125	57235	42765	31
30	9.52452	10.47548	9.54915	10.45085	9.57274	10.42726	30
31	52494	47506	54955	45045	57312	42688	29
32	52536	47464	54995	45005	57351	42649	28
33	52578	47422	55035	44965	57389	42611	27
34	52620	47380	55075	44925	57428	42572	26
35	52661	47339	55115	44885	57466	42534	25
36	52703	47297	55155	44845	57504	42496	24
37	52745	47255	55195	44805	57543	42457	23
38	52787	47213	55235	44765	57581	42419	22
39	52829	47171	55275	44725	57619	42381	21
40	9.52870	10.47130	9.55315	10.44685	9.57658	10.42342	20
41	52912	47088	55355	44645	57696	42304	19
42	52953	47047	55395	44605	57734	42266	18
43	52995	47005	55434	44566	57772	42228	17
44	53037	46963	55474	44526	57810	42190	16
45	53078	46922	55514	44486	57849	42151	15
46	53120	46880	55554	44446	57887	42113	14
47	53161	46839	55593	44407	57925	42075	13
48	53202	46798	55633	44367	57963	42037	12
49	53244	46756	55673	44327	58001	41999	11
50	9.53285	10.46715	9.55712	10.44288	9.58039	10.41961	10
51	53327	46673	55752	44248	58077	41923	9
52	53368	46632	55791	44209	58115	41885	8
53	53409	46591	55831	44169	58153	41847	7
54	53450	46550	55870	44130	58191	41809	6
55	53492	46508	55910	44090	58229	41771	5
56	53533	46467	55949	44051	58267	41733	4
57	53574	46426	55989	44011	58304	41696	3
58	53615	46385	56028	43972	58342	41658	2
59	53656	46344	56067	43933	58380	41620	1
60	53697	46303	56107	43893	58418	41582	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	71°		70°		69°		

′	21°		22°		23°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.58418	10.41582	9.60641	10.39359	9.62785	10.37215	60
1	58455	41545	60677	39323	62820	37180	59
2	58493	41507	60714	39286	62855	37145	58
3	58531	41469	60750	39250	62890	37110	57
4	58569	41431	60786	39214	62926	37074	56
5	58606	41394	60823	39177	62961	37039	55
6	58644	41356	60859	39141	62996	37004	54
7	58681	41319	60895	39105	63031	36969	53
8	58719	41281	60931	39069	63066	36934	52
9	58757	41243	60967	39033	63101	36899	51
10	9.58794	10.41206	9.61004	10.38996	9.63135	10.36865	50
11	58832	41168	61040	38960	63170	36830	49
12	58869	41131	61076	38924	63205	36795	48
13	58907	41093	61112	38888	63240	36760	47
14	58944	41056	61148	38852	63275	36725	46
15	58981	41019	61184	38816	63310	36690	45
16	59019	40981	61220	38780	63345	36655	44
17	59056	40944	61256	38744	63379	36621	43
18	59094	40906	61292	38708	63414	36586	42
19	59131	40869	61328	38672	63449	36551	41
20	9.59168	10.40832	9.61364	10.38636	9.63484	10.36516	40
21	59205	40795	61400	38600	63519	36481	39
22	59243	40757	61436	38564	63553	36447	38
23	59280	40720	61472	38528	63588	36412	37
24	59317	40683	61508	38492	63623	36377	36
25	59354	40646	61544	38456	63657	36343	35
26	59391	40609	61579	38421	63692	36308	34
27	59429	40571	61615	38385	63726	36274	33
28	59466	40534	61651	38349	63761	36239	32
29	59503	40497	61687	38313	63796	36204	31
30	9.59540	10.40460	9.61722	10.38278	9.63830	10.36170	30
31	59577	40423	61758	38242	63865	36135	29
32	59614	40386	61794	38206	63899	36101	28
33	59651	40349	61830	38170	63934	36066	27
34	59688	40312	61865	38135	63968	36032	26
35	59725	40275	61901	38099	64003	35997	25
36	59762	40238	61936	38064	64037	35963	24
37	59799	40201	61972	38028	64072	35928	23
38	59835	40165	62008	37992	64106	35894	22
39	59872	40128	62043	37957	64140	35860	21
40	9.59909	10.40091	9.62079	10.37921	9.64175	10.35825	20
41	59946	40054	62114	37886	64209	35791	19
42	59983	40017	62150	37850	64243	35757	18
43	60019	39981	62185	37815	64278	35722	17
44	60056	39944	62221	37779	64312	35688	16
45	60093	39907	62256	37744	64346	35654	15
46	60130	39870	62292	37708	64381	35619	14
47	60166	39834	62327	37673	64415	35585	13
48	60203	39797	62362	37638	64449	35551	12
49	60240	39760	62398	37602	64483	35517	11
50	9.60276	10.39724	9.62433	10.37567	9.64517	10.35483	10
51	60313	39687	62468	37532	64552	35448	9
52	60349	39651	62504	37496	64586	35414	8
53	60386	39614	62539	37461	64620	35380	7
54	60422	39578	62574	37426	64654	35346	6
55	60459	39541	62609	37391	64688	35312	5
56	60495	39505	62645	37355	64722	35278	4
57	60532	39468	62680	37320	64756	35244	3
58	60568	39432	62715	37285	64790	35210	2
59	60605	39395	62750	37250	64824	35176	1
60	60641	39359	62785	37215	64858	35142	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	68°		67°		66°		

′	24° Tan	24° Cotan	25° Tan	25° Cotan	26° Tan	26° Cotan	′
0	9.64858	10.35142	9.66867	10.33133	9.68818	10.31182	60
1	64892	35108	66900	33100	68850	31150	59
2	64926	35074	66933	33067	68882	31118	58
3	64960	35040	66966	33034	68914	31086	57
4	64994	35006	66999	33001	68946	31054	56
5	65028	34972	67032	32968	68978	31022	55
6	65062	34938	67065	32935	69010	30990	54
7	65096	34904	67098	32902	69042	30958	53
8	65130	34870	67131	32869	69074	30926	52
9	65164	34836	67163	32837	69106	30894	51
10	9.65197	10.34803	9.67196	10.32804	9.69138	10.30862	50
11	65231	34769	67229	32771	69170	30830	49
12	65265	34735	67262	32738	69202	30798	48
13	65299	34701	67295	32705	69234	30766	47
14	65333	34667	67327	32673	69266	30734	46
15	65366	34634	67360	32640	69298	30702	45
16	65400	34600	67393	32607	69329	30671	44
17	65434	34566	67426	32574	69361	30639	43
18	65467	34533	67458	32542	69393	30607	42
19	65501	34499	67491	32509	69425	30575	41
20	9.65535	10.34465	9.67524	10.32476	9.69457	10.30543	40
21	65568	34432	67556	32444	69488	30512	39
22	65602	34398	67589	32411	69520	30480	38
23	65636	34364	67622	32378	69552	30448	37
24	65669	34331	67654	32346	69584	30416	36
25	65703	34297	67687	32313	69615	30385	35
26	65736	34264	67719	32281	69647	30353	34
27	65770	34230	67752	32248	69679	30321	33
28	65803	34197	67785	32215	69710	30290	32
29	65837	34163	67817	32183	69742	30258	31
30	9.65870	10.34130	9.67850	10.32150	9.69774	10.30226	30
31	65904	34096	67882	32118	69805	30195	29
32	65937	34063	67915	32085	69837	30163	28
33	65971	34029	67947	32053	69868	30132	27
34	66004	33996	67980	32020	69900	30100	26
35	66038	33962	68012	31988	69932	30068	25
36	66071	33929	68044	31956	69963	30037	24
37	66104	33896	68077	31923	69995	30005	23
38	66138	33862	68109	31891	70026	29974	22
39	66171	33829	68142	31858	70058	29942	21
40	9.66204	10.33796	9.68174	10.31826	9.70089	10.29911	20
41	66238	33762	68206	31794	70121	29879	19
42	66271	33729	68239	31761	70152	29848	18
43	66304	33696	68271	31729	70184	29816	17
44	66337	33663	68303	31697	70215	29785	16
45	66371	33629	68336	31664	70247	29753	15
46	66404	33596	68368	31632	70278	29722	14
47	66437	33563	68400	31600	70309	29691	13
48	66470	33530	68432	31568	70341	29659	12
49	66503	33497	68465	31535	70372	29628	11
50	9.66537	10.33463	9.68497	10.31503	9.70404	10.29596	10
51	66570	33430	68529	31471	70435	29565	9
52	66603	33397	68561	31439	70466	29534	8
53	66636	33364	68593	31407	70498	29502	7
54	66669	33331	68626	31374	70529	29471	6
55	66702	33298	68658	31342	70560	29440	5
56	66735	33265	68690	31310	70592	29408	4
57	66768	33232	68722	31278	70623	29377	3
58	66801	33199	68754	31246	70654	29346	2
59	66834	33166	68786	31214	70685	29315	1
60	66867	33133	68818	31182	70717	29283	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	65°		64°		63°		

′	27° Tan	27° Cotan	28° Tan	28° Cotan	29° Tan	29° Cotan	′
0	9.70717	10.29283	9.72567	10.27433	9.74375	10.25625	60
1	70748	29252	72598	27402	74405	25595	59
2	70779	29221	72628	27372	74435	25565	58
3	70810	29190	72659	27341	74465	25535	57
4	70841	29159	72689	27311	74494	25506	56
5	70873	29127	72720	27280	74524	25476	55
6	70904	29096	72750	27250	74554	25446	54
7	70935	29065	72780	27220	74583	25417	53
8	70966	29034	72811	27189	74613	25387	52
9	70997	29003	72841	27159	74643	25357	51
10	9.71028	10.28972	9.72872	10.27128	9.74673	10.25327	50
11	71059	28941	72902	27098	74702	25298	49
12	71090	28910	72932	27068	74732	25268	48
13	71121	28879	72963	27037	74762	25238	47
14	71153	28847	72993	27007	74791	25209	46
15	71184	28816	73023	26977	74821	25179	45
16	71215	28785	73054	26946	74851	25149	44
17	71246	28754	73084	26916	74880	25120	43
18	71277	28723	73114	26886	74910	25090	42
19	71308	28692	73144	26856	74939	25061	41
20	9.71339	10.28661	9.73175	10.26825	9.74969	10.25031	40
21	71370	28630	73205	26795	74998	25002	39
22	71401	28599	73235	26765	75028	24972	38
23	71431	28569	73265	26735	75058	24942	37
24	71462	28538	73295	26705	75087	24913	36
25	71493	28507	73326	26674	75117	24883	35
26	71524	28476	73356	26644	75146	24854	34
27	71555	28445	73386	26614	75176	24824	33
28	71586	28414	73416	26584	75205	24795	32
29	71617	28383	73446	26554	75235	24765	31
30	9.71648	10.28352	9.73476	10.26524	9.75264	10.24736	30
31	71679	28321	73507	26493	75294	24706	29
32	71709	28291	73537	26463	75323	24677	28
33	71740	28260	73567	26433	75353	24647	27
34	71771	28229	73597	26403	75382	24618	26
35	71802	28198	73627	26373	75411	24589	25
36	71833	28167	73657	26343	75441	24559	24
37	71863	28137	73687	26313	75470	24530	23
38	71894	28106	73717	26283	75500	24500	22
39	71925	28075	73747	26253	75529	24471	21
40	9.71955	10.28045	9.73777	10.26223	9.75558	10.24442	20
41	71986	28014	73807	26193	75588	24412	19
42	72017	27983	73837	26163	75617	24383	18
43	72048	27952	73867	26133	75647	24353	17
44	72078	27922	73897	26103	75676	24324	16
45	72109	27891	73927	26073	75705	24295	15
46	72140	27860	73957	26043	75735	24265	14
47	72170	27830	73987	26013	75764	24236	13
48	72201	27799	74017	25983	75793	24207	12
49	72231	27769	74047	25953	75822	24178	11
50	9.72262	10.27738	9.74077	10.25923	9.75852	10.24148	10
51	72293	27707	74107	25893	75881	24119	9
52	72323	27677	74137	25863	75910	24090	8
53	72354	27646	74166	25834	75939	24061	7
54	72384	27616	74196	25804	75969	24031	6
55	72415	27585	74226	25774	75998	24002	5
56	72445	27555	74256	25744	76027	23973	4
57	72476	27524	74286	25714	76056	23944	3
58	72506	27494	74316	25684	76086	23914	2
59	72537	27463	74345	25655	76115	23885	1
60	72567	27433	74375	25625	76144	23856	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	62°		61°		60°		

′	30°		31°		32°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.76144	10.23856	9.77877	10.22123	9.79579	10.20421	60
1	76173	23827	77906	22094	79607	20393	59
2	76202	23798	77935	22065	79635	20365	58
3	76231	23769	77963	22037	79663	20337	57
4	76261	23739	77992	22008	79691	20309	56
5	76290	23710	78020	21980	79719	20281	55
6	76319	23681	78049	21951	79747	20253	54
7	76348	23652	78077	21923	79776	20224	53
8	76377	23623	78106	21894	79804	20196	52
9	76406	23594	78135	21865	79832	20168	51
10	9.76435	10.23565	9.78163	10.21837	9.79860	10.20140	50
11	76464	23536	78192	21808	79888	20112	49
12	76493	23507	78220	21780	79916	20084	48
13	76522	23478	78249	21751	79944	20056	47
14	76551	23449	78277	21723	79972	20028	46
15	76580	23420	78306	21694	80000	20000	45
16	76609	23391	78334	21666	80028	19972	44
17	76639	23361	78363	21637	80056	19944	43
18	76668	23332	78391	21609	80084	19916	42
19	76697	23303	78419	21581	80112	19888	41
20	9.76725	10.23275	9.78448	10.21552	9.80140	10.19860	40
21	76754	23246	78476	21524	80168	19832	39
22	76783	23217	78505	21495	80195	19805	38
23	76812	23188	78533	21467	80223	19777	37
24	76841	23159	78562	21438	80251	19749	36
25	76870	23130	78590	21410	80279	19721	35
26	76899	23101	78618	21382	80307	19693	34
27	76928	23072	78647	21353	80335	19665	33
28	76957	23043	78675	21325	80363	19637	32
29	76986	23014	78704	21296	80391	19609	31
30	9.77015	10.22985	9.78732	10.21268	9.80419	10.19581	30
31	77044	22956	78760	21240	80447	19553	29
32	77073	22927	78789	21211	80474	19526	28
33	77101	22899	78817	21183	80502	19498	27
34	77130	22870	78845	21155	80530	19470	26
35	77159	22841	78874	21126	80558	19442	25
36	77188	22812	78902	21098	80586	19414	24
37	77217	22783	78930	21070	80614	19386	23
38	77246	22754	78959	21041	80642	19358	22
39	77274	22726	78987	21013	80669	19331	21
40	9.77303	10.22697	9.79015	10.20985	9.80697	10.19303	20
41	77332	22668	79043	20957	80725	19275	19
42	77361	22639	79072	20928	80753	19247	18
43	77390	22610	79100	20900	80781	19219	17
44	77418	22582	79128	20872	80808	19192	16
45	77447	22553	79156	20844	80836	19164	15
46	77476	22524	79185	20815	80864	19136	14
47	77505	22495	79213	20787	80892	19108	13
48	77533	22467	79241	20759	80919	19081	12
49	77562	22438	79269	20731	80947	19053	11
50	9.77591	10.22409	9.79297	10.20703	9.80975	10.19025	10
51	77619	22381	79326	20674	81003	18997	9
52	77648	22352	79354	20646	81030	18970	8
53	77677	22323	79382	20618	81058	18942	7
54	77706	22294	79410	20590	81086	18914	6
55	77734	22266	79438	20562	81113	18887	5
56	77763	22237	79466	20534	81141	18859	4
57	77791	22209	79495	20505	81169	18831	3
58	77820	22180	79523	20477	81196	18804	2
59	77849	22151	79551	20449	81224	18776	1
60	77877	22123	79579	20421	81252	18748	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	59°		58°		57°		

′	33°		34°		35°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.81252	10.18748	9.82899	10.17101	9.84523	10.15477	60
1	81279	18721	82926	17074	84550	15450	59
2	81307	18693	82953	17047	84576	15424	58
3	81335	18665	82980	17020	84603	15397	57
4	81362	18638	83008	16992	84630	15370	56
5	81390	18610	83035	16965	84657	15343	55
6	81418	18582	83062	16938	84684	15316	54
7	81445	18555	83089	16911	84711	15289	53
8	81473	18527	83117	16883	84738	15262	52
9	81500	18500	83144	16856	84764	15236	51
10	9.81528	10.18472	9.83171	10.16829	9.84791	10.15209	50
11	81556	18444	83198	16802	84818	15182	49
12	81583	18417	83225	16775	84845	15155	48
13	81611	18389	83252	16748	84872	15128	47
14	81638	18362	83280	16720	84899	15101	46
15	81666	18334	83307	16693	84925	15075	45
16	81693	18307	83334	16666	84952	15048	44
17	81721	18279	83361	16639	84979	15021	43
18	81748	18252	83388	16612	85006	14994	42
19	81776	18224	83415	16585	85033	14967	41
20	9.81803	10.18197	9.83442	10.16558	9.85059	10.14941	40
21	81831	18169	83470	16530	85086	14914	39
22	81858	18142	83497	16503	85113	14887	38
23	81886	18114	83524	16476	85140	14860	37
24	81913	18087	83551	16449	85166	14834	36
25	81941	18059	83578	16422	85193	14807	35
26	81968	18032	83605	16395	85220	14780	34
27	81996	18004	83632	16368	85247	14753	33
28	82023	17977	83659	16341	85273	14727	32
29	82051	17949	83686	16314	85300	14700	31
30	9.82078	10.17922	9.83713	10.16287	9.85327	10.14673	30
31	82106	17894	83740	16260	85354	14646	29
32	82133	17867	83768	16232	85380	14620	28
33	82161	17839	83795	16205	85407	14593	27
34	82188	17812	83822	16178	85434	14566	26
35	82215	17785	83849	16151	85460	14540	25
36	82243	17757	83876	16124	85487	14513	24
37	82270	17730	83903	16097	85514	14486	23
38	82298	17702	83930	16070	85540	14460	22
39	82325	17675	83957	16043	85567	14433	21
40	9.82352	10.17648	9.83984	10.16016	9.85594	10.14406	20
41	82380	17620	84011	15989	85620	14380	19
42	82407	17593	84038	15962	85647	14353	18
43	82435	17565	84065	15935	85674	14326	17
44	82462	17538	84092	15908	85700	14300	16
45	82489	17511	84119	15881	85727	14273	15
46	82517	17483	84146	15854	85754	14246	14
47	82544	17456	84173	15827	85780	14220	13
48	82571	17429	84200	15800	85807	14193	12
49	82599	17401	84227	15773	85834	14166	11
50	9.82626	10.17374	9.84254	10.15746	9.85860	10.14140	10
51	82653	17347	84280	15720	85887	14113	9
52	82681	17319	84307	15693	85913	14087	8
53	82708	17292	84334	15666	85940	14060	7
54	82735	17265	84361	15639	85967	14033	6
55	82762	17238	84388	15612	85993	14007	5
56	82790	17210	84415	15585	86020	13980	4
57	82817	17183	84442	15558	86046	13954	3
58	82844	17156	84469	15531	86073	13927	2
59	82871	17129	84496	15504	86100	13900	1
60	82899	17101	84523	15477	86126	13874	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	56°		55°		54°		

′	36°		37°		38°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.86126	10.13874	9.87711	10.12289	9.89281	10.10719	60
1	86153	13847	87738	12262	89307	10693	59
2	86179	13821	87764	12236	89333	10667	58
3	86206	13794	87790	12210	89359	10641	57
4	86232	13768	87817	12183	89385	10615	56
5	86259	13741	87843	12157	89411	10589	55
6	86285	13715	87869	12131	89437	10563	54
7	86312	13688	87895	12105	89463	10537	53
8	86338	13662	87922	12078	89489	10511	52
9	86365	13635	87948	12052	89515	10485	51
10	9.86392	10.13608	9.87974	10.12026	9.89541	10.10459	50
11	86418	13582	88000	12000	89567	10433	49
12	86445	13555	88027	11973	89593	10407	48
13	86471	13529	88053	11947	89619	10381	47
14	86498	13502	88079	11921	89645	10355	46
15	86524	13476	88105	11895	89671	10329	45
16	86551	13449	88131	11869	89697	10303	44
17	86577	13423	88158	11842	89723	10277	43
18	86603	13397	88184	11816	89749	10251	42
19	86630	13370	88210	11790	89775	10225	41
20	9.86656	10.13344	9.88236	10.11764	9.89801	10.10199	40
21	86683	13317	88262	11738	89827	10173	39
22	86709	13291	88289	11711	89853	10147	38
23	86736	13264	88315	11685	89879	10121	37
24	86762	13238	88341	11659	89905	10095	36
25	86789	13211	88367	11633	89931	10069	35
26	86815	13185	88393	11607	89957	10043	34
27	86842	13158	88420	11580	89983	10017	33
28	86868	13132	88446	11554	90009	09991	32
29	86894	13106	88472	11528	90035	09965	31
30	9.86921	10.13079	9.88498	10.11502	9.90061	10.09939	30
31	86947	13053	88524	11476	90086	09914	29
32	86974	13026	88550	11450	90112	09888	28
33	87000	13000	88577	11423	90138	09862	27
34	87027	12973	88603	11397	90164	09836	26
35	87053	12947	88629	11371	90190	09810	25
36	87079	12921	88655	11345	90216	09784	24
37	87106	12894	88681	11319	90242	09758	23
38	87132	12868	88707	11293	90268	09732	22
39	87158	12842	88733	11267	90294	09706	21
40	9.87185	10.12815	9.88759	10.11241	9.90320	10.09680	20
41	87211	12789	88786	11214	90346	09654	19
42	87238	12762	88812	11188	90371	09629	18
43	87264	12736	88838	11162	90397	09603	17
44	87290	12710	88864	11136	90423	09577	16
45	87317	12683	88890	11110	90449	09551	15
46	87343	12657	88916	11084	90475	09525	14
47	87369	12631	88942	11058	90501	09499	13
48	87396	12604	88968	11032	90527	09473	12
49	87422	12578	88994	11006	90553	09447	11
50	9.87448	10.12552	9.89020	10.10980	9.90578	10.09422	10
51	87475	12525	89046	10954	90604	09396	9
52	87501	12499	89073	10927	90630	09370	8
53	87527	12473	89099	10901	90656	09344	7
54	87554	12446	89125	10875	90682	09318	6
55	87580	12420	89151	10849	90708	09292	5
56	87606	12394	89177	10823	90734	09266	4
57	87633	12367	89203	10797	90759	09241	3
58	87659	12341	89229	10771	90785	09215	2
59	87685	12315	89255	10745	90811	09189	1
60	87711	12289	89281	10719	90837	09163	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	53°		52°		51°		

′	39°		40°		41°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.90837	10.09163	9.92381	10.07619	9.93916	10.06084	60
1	90863	09137	92407	07593	93942	06058	59
2	90889	09111	92433	07567	93967	06033	58
3	90914	09086	92458	07542	93993	06007	57
4	90940	09060	92484	07516	94018	05982	56
5	90966	09034	92510	07490	94044	05956	55
6	90992	09008	92535	07465	94069	05931	54
7	91018	08982	92561	07439	94095	05905	53
8	91043	08957	92587	07413	94120	05880	52
9	91069	08931	92612	07388	94146	05854	51
10	9.91095	10.08905	9.92638	10.07362	9.94171	10.05829	50
11	91121	08879	92663	07337	94197	05803	49
12	91147	08853	92689	07311	94222	05778	48
13	91172	08828	92715	07285	94248	05752	47
14	91198	08802	92740	07260	94273	05727	46
15	91224	08776	92766	07234	94299	05701	45
16	91250	08750	92792	07208	94324	05676	44
17	91276	08724	92817	07183	94350	05650	43
18	91301	08699	92843	07157	94375	05625	42
19	91327	08673	92868	07132	94401	05599	41
20	9.91353	10.08647	9.92894	10.07106	9.94426	10.05574	40
21	91379	08621	92920	07080	94452	05548	39
22	91404	08596	92945	07055	94477	05523	38
23	91430	08570	92971	07029	94503	05497	37
24	91456	08544	92996	07004	94528	05472	36
25	91482	08518	93022	06978	94554	05446	35
26	91507	08493	93048	06952	94579	05421	34
27	91533	08467	93073	06927	94604	05396	33
28	91559	08441	93099	06901	94630	05370	32
29	91585	08415	93124	06876	94655	05345	31
30	9.91610	10.08390	9.93150	10.06850	9.94681	10.05319	30
31	91636	08364	93175	06825	94706	05294	29
32	91662	08338	93201	06799	94732	05268	28
33	91688	08312	93227	06773	94757	05243	27
34	91713	08287	93252	06748	94783	05217	26
35	91739	08261	93278	06722	94808	05192	25
36	91765	08235	93303	06697	94834	05166	24
37	91791	08209	93329	06671	94859	05141	23
38	91816	08184	93354	06646	94884	05116	22
39	91842	08158	93380	06620	94910	05090	21
40	9.91868	10.08132	9.93406	10.06594	9.94935	10.05065	20
41	91893	08107	93431	06569	94961	05039	19
42	91919	08081	93457	06543	94986	05014	18
43	91945	08055	93482	06518	95012	04988	17
44	91971	08029	93508	06492	95037	04963	16
45	91996	08004	93533	06467	95062	04938	15
46	92022	07978	93559	06441	95088	04912	14
47	92048	07952	93584	06416	95113	04887	13
48	92073	07927	93610	06390	95139	04861	12
49	92099	07901	93636	06364	95164	04836	11
50	9.92125	10.07875	9.93661	10.06339	9.95190	10.04810	10
51	92150	07850	93687	06313	95215	04785	9
52	92176	07824	93712	06288	95240	04760	8
53	92202	07798	93738	06262	95266	04734	7
54	92227	07773	93763	06237	95291	04709	6
55	92253	07747	93789	06211	95317	04683	5
56	92279	07721	93814	06186	95342	04658	4
57	92304	07696	93840	06160	95368	04632	3
58	92330	07670	93865	06135	95393	04607	2
59	92356	07644	93891	06109	95418	04582	1
60	92381	07619	93916	06084	95444	04556	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	50°		49°		48°		

′	42°		43°		44°		′
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.95444	10.04556	9.96966	10.03034	9.98484	10.01516	60
1	95469	04531	96991	03009	98509	01491	59
2	95495	04505	97016	02984	98534	01466	58
3	95520	04480	97042	02958	98560	01440	57
4	95545	04455	97067	02933	98585	01415	56
5	95571	04429	97092	02908	98610	01390	55
6	95596	04404	97118	02882	98635	01365	54
7	95622	04378	97143	02857	98661	01339	53
8	95647	04353	97168	02832	98686	01314	52
9	95672	04328	97193	02807	98711	01289	51
10	9.95698	10.04302	9.97219	10.02781	9.98737	10.01263	50
11	95723	04277	97244	02756	98762	01238	49
12	95748	04252	97269	02731	98787	01213	48
13	95774	04226	97295	02705	98812	01188	47
14	95799	04201	97320	02680	98838	01162	46
15	95825	04175	97345	02655	98863	01137	45
16	95850	04150	97371	02629	98888	01112	44
17	95875	04125	97396	02604	98913	01087	43
18	95901	04099	97421	02579	98939	01061	42
19	95926	04074	97447	02553	98964	01086	41
20	9.95952	10.04048	9.97472	10.02528	9.98989	10.01011	40
21	95977	04023	97497	02503	99015	00985	39
22	96002	03998	97523	02477	99040	00960	38
23	96028	03972	97548	02452	99065	00935	37
24	96053	03947	97573	02427	99090	00910	36
25	96078	03922	97598	02402	99116	00884	35
26	96104	03896	97624	02376	99141	00859	34
27	96129	03871	97649	02351	99166	00834	33
28	96155	03845	97674	02326	99191	00809	32
29	96180	03820	97700	02300	99217	00783	31
30	9.96205	10.03795	9.97725	10.02275	9.99242	10.00758	30
31	96231	03769	97750	02250	99267	00733	29
32	96256	03744	97776	02224	99293	00707	28
33	96281	03719	97801	02199	99318	00682	27
34	96307	03693	97826	02174	99343	00657	26
35	96332	03668	97851	02149	99368	00632	25
36	96357	03643	97877	02123	99394	00606	24
37	96383	03617	97902	02098	99419	00581	23
38	96408	03592	97927	02073	99444	00556	22
39	96433	03567	97953	02047	99469	00531	21
40	9.96459	10.03541	9.97978	10.02022	9.99495	10.00505	20
41	96484	03516	98003	01997	99520	00480	19
42	96510	03490	98029	01971	99545	00455	18
43	96535	03465	98054	01946	99570	00430	17
44	96560	03440	98079	01921	99596	00404	16
45	96586	03414	98104	01896	99621	00379	15
46	96611	03389	98130	01870	99646	00354	14
47	96636	03364	98155	01845	99672	00328	13
48	96662	03338	98180	01820	99697	00303	12
49	96687	03313	98206	01794	99722	00278	11
50	9.96712	10.03288	9.98231	10.01769	9.99747	10.00253	10
51	96738	03262	98256	01744	99773	00227	9
52	96763	03237	98281	01719	99798	00202	8
53	96788	03212	98307	01693	99823	00177	7
54	96814	03186	98332	01668	99848	00152	6
55	96839	03161	98357	01643	99874	00126	5
56	96864	03136	98383	01617	99899	00101	4
57	96890	03110	98408	01592	99924	00076	3
58	96915	03085	98433	01567	99949	00051	2
59	96940	03060	98458	01542	99975	00025	1
60	96966	03034	98484	01516	10.00000	00000	0
′	Cotan	Tan	Cotan	Tan	Cotan	Tan	′
	47°		46°		45°		

TABLE 10.—NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

	0°				1°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.00000	One	.00000	Infinite	.01745	.99985	.01746	57.2900	60
1	.00029	One	.00029	3437.75	.01774	.99984	.01775	56.3506	59
2	.00058	One	.00058	1718.87	.01803	.99984	.01804	55.4415	58
3	.00087	One	.00087	1145.92	.01832	.99983	.01833	54.5613	57
4	.00116	One	.00116	859.436	.01862	.99983	.01862	53.7086	56
5	.00145	One	.00145	687.549	.01891	.99982	.01891	52.8821	55
6	.00175	One	.00175	572.957	.01920	.99982	.01920	52.0807	54
7	.00204	One	.00204	491.106	.01949	.99981	.01949	51.3032	53
8	.00233	One	.00233	429.718	.01978	.99980	.01978	50.5485	52
9	.00262	One	.00262	381.971	.02007	.99980	.02007	49.8157	51
10	.00291	One	.00291	343.774	.02036	.99979	.02036	49.1039	50
11	.00320	.99999	.00320	312.521	.02065	.99979	.02066	48.4121	49
12	.00349	.99999	.00349	286.478	.02094	.99978	.02095	47.7395	48
13	.00378	.99999	.00378	264.441	.02123	.99977	.02124	47.0853	47
14	.00407	.99999	.00407	245.552	.02152	.99977	.02153	46.4489	46
15	.00436	.99999	.00436	229.182	.02181	.99976	.02182	45.8294	45
16	.00465	.99999	.00465	214.858	.02211	.99976	.02211	45.2261	44
17	.00495	.99999	.00495	202.219	.02240	.99975	.02240	44.6386	43
18	.00524	.99999	.00524	190.984	.02269	.99974	.02269	44.0661	42
19	.00553	.99998	.00553	180.932	.02298	.99974	.02298	43.5081	41
20	.00582	.99998	.00582	171.885	.02327	.99973	.02328	42.9641	40
21	.00611	.99998	.00611	163.700	.02356	.99972	.02357	42.4335	39
22	.00640	.99998	.00640	156.259	.02385	.99972	.02386	41.9158	38
23	.00669	.99998	.00669	149.465	.02414	.99971	.02415	41.4106	37
24	.00698	.99998	.00698	143.237	.02443	.99970	.02444	40.9174	36
25	.00727	.99997	.00727	137.507	.02472	.99969	.02473	40.4358	35
26	.00756	.99997	.00756	132.219	.02501	.99969	.02502	39.9655	34
27	.00785	.99997	.00785	127.321	.02530	.99968	.02531	39.5059	33
28	.00814	.99997	.00815	122.774	.02560	.99967	.02560	39.0568	32
29	.00844	.99996	.00844	118.540	.02589	.99966	.02589	38.6177	31
30	.00873	.99996	.00873	114.589	.02618	.99966	.02619	38.1885	30
31	.00902	.99996	.00902	110.892	.02647	.99965	.02648	37.7686	29
32	.00931	.99996	.00931	107.426	.02676	.99964	.02677	37.3579	28
33	.00960	.99995	.00960	104.171	.02705	.99963	.02706	36.9560	27
34	.00989	.99995	.00989	101.107	.02734	.99963	.02735	36.5627	26
35	.01018	.99995	.01018	98.2179	.02763	.99962	.02764	36.1776	25
36	.01047	.99995	.01047	95.4895	.02792	.99961	.02793	35.8006	24
37	.01076	.99994	.01076	92.9085	.02821	.99960	.02822	35.4313	23
38	.01105	.99994	.01105	90.4633	.02850	.99959	.02851	35.0695	22
39	.01134	.99994	.01135	88.1436	.02879	.99959	.02881	34.7151	21
40	.01164	.99993	.01164	85.9398	.02908	.99958	.02910	34.3678	20
41	.01193	.99993	.01193	83.8435	.02938	.99957	.02939	34.0273	19
42	.01222	.99993	.01222	81.8470	.02967	.99956	.02968	33.6935	18
43	.01251	.99992	.01251	79.9434	.02996	.99955	.02997	33.3662	17
44	.01280	.99992	.01280	78.1263	.03025	.99954	.03026	33.0452	16
45	.01309	.99991	.01309	76.3900	.03054	.99953	.03055	32.7303	15
46	.01338	.99991	.01338	74.7292	.03083	.99952	.03084	32.4213	14
47	.01367	.99991	.01367	73.1390	.03112	.99952	.03114	32.1181	13
48	.01396	.99990	.01396	71.6151	.03141	.99951	.03143	31.8205	12
49	.01425	.99990	.01425	70.1533	.03170	.99950	.03172	31.5284	11
50	.01454	.99989	.01455	68.7501	.03199	.99949	.03201	31.2416	10
51	.01483	.99989	.01484	67.4019	.03228	.99948	.03230	30.9599	9
52	.01513	.99989	.01513	66.1055	.03257	.99947	.03259	30.6833	8
53	.01542	.99988	.01542	64.8580	.03286	.99946	.03288	30.4116	7
54	.01571	.99988	.01571	63.6567	.03316	.99945	.03317	30.1446	6
55	.01600	.99987	.01600	62.4992	.03345	.99944	.03346	29.8823	5
56	.01629	.99987	.01629	61.3829	.03374	.99943	.03376	29.6245	4
57	.01658	.99986	.01658	60.3058	.03403	.99942	.03405	29.3711	3
58	.01687	.99986	.01687	59.2659	.03432	.99941	.03434	29.1220	2
59	.01716	.99985	.01716	58.2612	.03461	.99940	.03463	28.8771	1
60	.01745	.99985	.01746	57.2900	.03490	.99939	.03492	28.6363	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	89°				88°				

Inserted by permission from Webb's Railroad Construction.

TABLE 10.—NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

′	2° Sin.	Cos.	Tan.	Cot.	3° Sin.	Cos.	Tan.	Cot.	′
0	.03490	.99939	.03492	28.6363	.05234	.99863	.05241	19.0811	60
1	.03519	.99938	.03521	28.3994	.05263	.99861	.05270	18.9755	59
2	.03548	.99937	.03550	28.1664	.05292	.99860	.05299	18.8711	58
3	.03577	.99936	.03579	27.9372	.05321	.99858	.05328	18.7678	57
4	.03606	.99935	.03609	27.7117	.05350	.99857	.05357	18.6656	56
5	.03635	.99934	.03638	27.4899	.05379	.99855	.05387	18.5645	55
6	.03664	.99933	.03667	27.2715	.05408	.99854	.05416	18.4645	54
7	.03693	.99932	.03696	27.0566	.05437	.99852	.05445	18.3655	53
8	.03723	.99931	.03725	26.8450	.05466	.99851	.05474	18.2677	52
9	.03752	.99930	.03754	26.6367	.05495	.99849	.05503	18.1708	51
10	.03781	.99929	.03783	26.4316	.05524	.99847	.05533	18.0750	50
11	.03810	.99927	.03812	26.2296	.05553	.99846	.05562	17.9802	49
12	.03839	.99926	.03842	26.0307	.05582	.99844	.05591	17.8863	48
13	.03868	.99925	.03871	25.8348	.05611	.99842	.05620	17.7934	47
14	.03897	.99924	.03900	25.6418	.05640	.99841	.05649	17.7015	46
15	.03926	.99923	.03929	25.4517	.05669	.99839	.05678	17.6106	45
16	.03955	.99922	.03958	25.2644	.05698	.99838	.05708	17.5205	44
17	.03984	.99921	.03987	25.0798	.05727	.99836	.05737	17.4314	43
18	.04013	.99919	.04016	24.8978	.05756	.99834	.05766	17.3432	42
19	.04042	.99918	.04046	24.7185	.05785	.99833	.05795	17.2558	41
20	.04071	.99917	.04075	24.5418	.05814	.99831	.05824	17.1693	40
21	.04100	.99916	.04104	24.3675	.05844	.99829	.05854	17.0837	39
22	.04129	.99915	.04133	24.1957	.05873	.99827	.05883	16.9990	38
23	.04159	.99913	.04162	24.0263	.05902	.99826	.05912	16.9150	37
24	.04188	.99912	.04191	23.8593	.05931	.99824	.05941	16.8319	36
25	.04217	.99911	.04220	23.6945	.05960	.99822	.05970	16.7496	35
26	.04246	.99910	.04250	23.5321	.05989	.99821	.05999	16.6681	34
27	.04275	.99909	.04279	23.3718	.06018	.99819	.06029	16.5874	33
28	.04304	.99907	.04308	23.2137	.06047	.99817	.06058	16.5075	32
29	.04333	.99906	.04337	23.0577	.06076	.99815	.06087	16.4283	31
30	.04362	.99905	.04366	22.9038	.06105	.99813	.06116	16.3499	30
31	.04391	.99904	.04395	22.7519	.06134	.99812	.06145	16.2722	29
32	.04420	.99902	.04424	22.6020	.06163	.99810	.06175	16.1952	28
33	.04449	.99901	.04454	22.4541	.06192	.99808	.06204	16.1190	27
34	.04478	.99900	.04483	22.3081	.06221	.99806	.06233	16.0435	26
35	.04507	.99898	.04512	22.1640	.06250	.99804	.06262	15.9687	25
36	.04536	.99897	.04541	22.0217	.06279	.99803	.06291	15.8945	24
37	.04565	.99896	.04570	21.8813	.06308	.99801	.06321	15.8211	23
38	.04594	.99894	.04599	21.7426	.06337	.99799	.06350	15.7483	22
39	.04623	.99893	.04628	21.6056	.06366	.99797	.06379	15.6762	21
40	.04653	.99892	.04658	21.4704	.06395	.99795	.06408	15.6048	20
41	.04682	.99890	.04687	21.3369	.06424	.99793	.06437	15.5340	19
42	.04711	.99889	.04716	21.2049	.06453	.99792	.06467	15.4638	18
43	.04740	.99888	.04745	21.0747	.06482	.99790	.06496	15.3943	17
44	.04769	.99886	.04774	20.9460	.06511	.99788	.06525	15.3254	16
45	.04798	.99885	.04803	20.8188	.06540	.99786	.06554	15.2571	15
46	.04827	.99883	.04833	20.6932	.06569	.99784	.06584	15.1893	14
47	.04856	.99882	.04862	20.5691	.06598	.99782	.06613	15.1222	13
48	.04885	.99881	.04891	20.4465	.06627	.99780	.06642	15.0557	12
49	.04914	.99879	.04920	20.3253	.06656	.99778	.06671	14.9898	11
50	.04943	.99878	.04949	20.2056	.06685	.99776	.06700	14.9244	10
51	.04972	.99876	.04978	20.0872	.06714	.99774	.06730	14.8596	9
52	.05001	.99875	.05007	19.9702	.06743	.99772	.06759	14.7954	8
53	.05030	.99873	.05037	19.8546	.06773	.99770	.06788	14.7317	7
54	.05059	.99872	.05066	19.7403	.06802	.99768	.06817	14.6685	6
55	.05088	.99870	.05095	19.6273	.06831	.99766	.06847	14.6059	5
56	.05117	.99869	.05124	19.5156	.06860	.99764	.06876	14.5438	4
57	.05146	.99867	.05153	19.4051	.06889	.99762	.06905	14.4823	3
58	.05175	.99866	.05182	19.2959	.06918	.99760	.06934	14.4212	2
59	.05205	.99864	.05212	19.1879	.06947	.99758	.06963	14.3607	1
60	.05234	.99863	.05241	19.0811	.06976	.99756	.06993	14.3007	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	87°				86°				

TABLE 10.—NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

	4°				5°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.06976	.99756	.06993	14.3007	.08716	.99619	.08749	11.4301	60
1	.07005	.99754	.07022	14.2411	.08745	.99617	.08778	11.3919	59
2	.07034	.99752	.07051	14.1821	.08774	.99614	.08807	11.3540	58
3	.07063	.99750	.07080	14.1235	.08803	.99612	.08837	11.3163	57
4	.07092	.99748	.07110	14.0655	.08831	.99609	.08866	11.2789	56
5	.07121	.99746	.07139	14.0079	.08860	.99607	.08895	11.2417	55
6	.07150	.99744	.07168	13.9507	.08889	.99604	.08925	11.2048	54
7	.07179	.99742	.07197	13.8940	.08918	.99602	.08954	11.1681	53
8	.07208	.99740	.07227	13.8378	.08947	.99599	.08983	11.1316	52
9	.07237	.99738	.07256	13.7821	.08976	.99596	.09013	11.0954	51
10	.07266	.99736	.07285	13.7267	.09005	.99594	.09042	11.0594	50
11	.07295	.99734	.07314	13.6719	.09034	.99591	.09071	11.0237	49
12	.07324	.99731	.07344	13.6174	.09063	.99588	.09101	10.9882	48
13	.07353	.99729	.07373	13.5634	.09092	.99586	.09130	10.9529	47
14	.07382	.99727	.07402	13.5098	.09121	.99583	.09159	10.9178	46
15	.07411	.99725	.07431	13.4566	.09150	.99580	.09189	10.8829	45
16	.07440	.99723	.07461	13.4039	.09179	.99578	.09218	10.8483	44
17	.07469	.99721	.07490	13.3515	.09208	.99575	.09247	10.8139	43
18	.07498	.99719	.07519	13.2996	.09237	.99572	.09277	10.7797	42
19	.07527	.99716	.07548	13.2480	.09266	.99570	.09306	10.7457	41
20	.07556	.99714	.07578	13.1969	.09295	.99567	.09335	10.7119	40
21	.07585	.99712	.07607	13.1461	.09324	.99564	.09365	10.6783	39
22	.07614	.99710	.07636	13.0958	.09353	.99562	.09394	10.6450	38
23	.07643	.99708	.07665	13.0458	.09382	.99559	.09423	10.6118	37
24	.07672	.99705	.07695	12.9962	.09411	.99556	.09453	10.5789	36
25	.07701	.99703	.07724	12.9469	.09440	.99553	.09482	10.5462	35
26	.07730	.99701	.07753	12.8981	.09469	.99551	.09511	10.5136	34
27	.07759	.99699	.07782	12.8496	.09498	.99548	.09541	10.4813	33
28	.07788	.99696	.07812	12.8014	.09527	.99545	.09570	10.4491	32
29	.07817	.99694	.07841	12.7536	.09556	.99542	.09600	10.4172	31
30	.07846	.99692	.07870	12.7062	.09585	.99540	.09629	10.3854	30
31	.07875	.99689	.07899	12.6591	.09614	.99537	.09658	10.3538	29
32	.07904	.99687	.07929	12.6124	.09642	.99534	.09688	10.3224	28
33	.07933	.99685	.07958	12.5660	.09671	.99531	.09717	10.2913	27
34	.07962	.99683	.07987	12.5199	.09700	.99528	.09746	10.2602	26
35	.07991	.99680	.08017	12.4742	.09729	.99526	.09776	10.2294	25
36	.08020	.99678	.08046	12.4288	.09758	.99523	.09805	10.1988	24
37	.08049	.99676	.08075	12.3838	.09787	.99520	.09834	10.1683	23
38	.08078	.99673	.08104	12.3390	.09816	.99517	.09864	10.1381	22
39	.08107	.99671	.08134	12.2946	.09845	.99514	.09893	10.1080	21
40	.08136	.99668	.08163	12.2505	.09874	.99511	.09923	10.0780	20
41	.08165	.99666	.08192	12.2067	.09903	.99508	.09952	10.0483	19
42	.08194	.99664	.08221	12.1632	.09932	.99506	.09981	10.0187	18
43	.08223	.99661	.08251	12.1201	.09961	.99503	.10011	9.98931	17
44	.08252	.99659	.08280	12.0772	.09990	.99500	.10040	9.96007	16
45	.08281	.99657	.08309	12.0346	.10019	.99497	.10069	9.93101	15
46	.08310	.99654	.08339	11.9923	.10048	.99494	.10099	9.90211	14
47	.08339	.99652	.08368	11.9504	.10077	.99491	.10128	9.87338	13
48	.08368	.99649	.08397	11.9087	.10106	.99488	.10158	9.84482	12
49	.08397	.99647	.08427	11.8673	.10135	.99485	.10187	9.81641	11
50	.08426	.99644	.08456	11.8262	.10164	.99482	.10216	9.78817	10
51	.08455	.99642	.08485	11.7853	.10192	.99479	.10246	9.76009	9
52	.08484	.99639	.08514	11.7448	.10221	.99476	.10275	9.73217	8
53	.08513	.99637	.08544	11.7045	.10250	.99473	.10305	9.70441	7
54	.08542	.99635	.08573	11.6645	.10279	.99470	.10334	9.67680	6
55	.08571	.99632	.08602	11.6248	.10308	.99467	.10363	9.64935	5
56	.08600	.99630	.08632	11.5853	.10337	.99464	.10393	9.62205	4
57	.08629	.99627	.08661	11.5461	.10366	.99461	.10422	9.59490	3
58	.08658	.99625	.08690	11.5072	.10395	.99458	.10452	9.56791	2
59	.08687	.99622	.08720	11.4685	.10424	.99455	.10481	9.54106	1
60	.08716	.99619	.08749	11.4301	.10453	.99452	.10510	9.51436	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	85°				84°				

	6°				7°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.10453	.99452	.10510	9.51436	.12187	.99255	.12278	8.14435	60
1	.10482	.99449	.10540	9.48781	.12216	.99251	.12308	8.12481	59
2	.10511	.99446	.10569	9.46141	.12245	.99248	.12338	8.10536	58
3	.10540	.99443	.10599	9.43515	.12274	.99244	.12367	8.08600	57
4	.10569	.99440	.10628	9.40904	.12302	.99240	.12397	8.06674	56
5	.10597	.99437	.10657	9.38307	.12331	.99237	.12426	8.04756	55
6	.10626	.99434	.10687	9.35724	.12360	.99233	.12456	8.02848	54
7	.10655	.99431	.10716	9.33155	.12389	.99230	.12485	8.00948	53
8	.10684	.99428	.10746	9.30599	.12418	.99226	.12515	7.99058	52
9	.10713	.99424	.10775	9.28058	.12447	.99222	.12544	7.97176	51
10	.10742	.99421	.10805	9.25530	.12476	.99219	.12574	7.95302	50
11	.10771	.99418	.10834	9.23016	.12504	.99215	.12603	7.93438	49
12	.10800	.99415	.10863	9.20516	.12533	.99211	.12633	7.91582	48
13	.10829	.99412	.10893	9.18028	.12562	.99208	.12662	7.89734	47
14	.10858	.99409	.10922	9.15554	.12591	.99204	.12692	7.87895	46
15	.10887	.99406	.10952	9.13093	.12620	.99200	.12722	7.86064	45
16	.10916	.99402	.10981	9.10646	.12649	.99197	.12751	7.84242	44
17	.10945	.99399	.11011	9.08211	.12678	.99193	.12781	7.82428	43
18	.10973	.99396	.11040	9.05789	.12706	.99189	.12810	7.80622	42
19	.11002	.99393	.11070	9.03379	.12735	.99186	.12840	7.78825	41
20	.11031	.99390	.11099	9.00983	.12764	.99182	.12869	7.77035	40
21	.11060	.99386	.11128	8.98598	.12793	.99178	.12899	7.75254	39
22	.11089	.99383	.11158	8.96227	.12822	.99175	.12929	7.73480	38
23	.11118	.99380	.11187	8.93867	.12851	.99171	.12958	7.71715	37
24	.11147	.99377	.11217	8.91520	.12880	.99167	.12988	7.69957	36
25	.11176	.99374	.11246	8.89185	.12908	.99163	.13017	7.68208	35
26	.11205	.99370	.11276	8.86862	.12937	.99160	.13047	7.66466	34
27	.11234	.99367	.11305	8.84551	.12966	.99156	.13076	7.64732	33
28	.11263	.99364	.11335	8.82252	.12995	.99152	.13106	7.63005	32
29	.11291	.99360	.11364	8.79964	.13024	.99148	.13136	7.61287	31
30	.11320	.99357	.11394	8.77689	.13053	.99144	.13165	7.59575	30
31	.11349	.99354	.11423	8.75425	.13081	.99141	.13195	7.57872	29
32	.11378	.99351	.11452	8.73172	.13110	.99137	.13224	7.56176	28
33	.11407	.99347	.11482	8.70931	.13139	.99133	.13254	7.54487	27
34	.11436	.99344	.11511	8.68701	.13168	.99129	.13284	7.52806	26
35	.11465	.99341	.11541	8.66482	.13197	.99125	.13313	7.51132	25
36	.11494	.99337	.11570	8.64275	.13226	.99122	.13343	7.49465	24
37	.11523	.99334	.11600	8.62078	.13254	.99118	.13372	7.47806	23
38	.11552	.99331	.11629	8.59893	.13283	.99114	.13402	7.46154	22
39	.11580	.99327	.11659	8.57718	.13312	.99110	.13432	7.44509	21
40	.11609	.99324	.11688	8.55555	.13341	.99106	.13461	7.42871	20
41	.11638	.99320	.11718	8.53402	.13370	.99102	.13491	7.41240	19
42	.11667	.99317	.11747	8.51259	.13399	.99098	.13521	7.39616	18
43	.11696	.99314	.11777	8.49128	.13427	.99094	.13550	7.37999	17
44	.11725	.99310	.11806	8.47007	.13456	.99091	.13580	7.36389	16
45	.11754	.99307	.11836	8.44896	.13485	.99087	.13609	7.34786	15
46	.11783	.99303	.11865	8.42795	.13514	.99083	.13639	7.33190	14
47	.11812	.99300	.11895	8.40705	.13543	.99079	.13669	7.31600	13
48	.11840	.99297	.11924	8.38625	.13572	.99075	.13698	7.30018	12
49	.11869	.99293	.11954	8.36555	.13600	.99071	.13728	7.28442	11
50	.11898	.99290	.11983	8.34496	.13629	.99067	.13758	7.26873	10
51	.11927	.99286	.12013	8.32446	.13658	.99063	.13787	7.25310	9
52	.11956	.99283	.12042	8.30406	.13687	.99059	.13817	7.23754	8
53	.11985	.99279	.12072	8.28376	.13716	.99055	.13846	7.22204	7
54	.12014	.99276	.12101	8.26355	.13744	.99051	.13876	7.20661	6
55	.12043	.99272	.12131	8.24345	.13773	.99047	.13906	7.19125	5
56	.12071	.99269	.12160	8.22344	.13802	.99043	.13935	7.17594	4
57	.12100	.99265	.12190	8.20352	.13831	.99039	.13965	7.16071	3
58	.12129	.99262	.12219	8.18370	.13860	.99035	.13995	7.14553	2
59	.12158	.99258	.12249	8.16398	.13889	.99031	.14024	7.13042	1
60	.12187	.99255	.12278	8.14435	.13917	.99027	.14054	7.11537	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	83°				82°				

	8°				9°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.13917	.99027	.14054	7.11537	.15643	.98769	.15838	6.31375	60
1	.13946	.99023	.14084	7.10038	.15672	.98764	.15868	6.30189	59
2	.13975	.99019	.14113	7.08546	.15701	.98760	.15898	6.29007	58
3	.14004	.99015	.14143	7.07059	.15730	.98755	.15928	6.27829	57
4	.14033	.99011	.14173	7.05579	.15758	.98751	.15958	6.26655	56
5	.14061	.99006	.14202	7.04105	.15787	.98746	.15988	6.25486	55
6	.14090	.99002	.14232	7.02637	.15816	.98741	.16017	6.24321	54
7	.14119	.98998	.14262	7.01174	.15845	.98737	.16047	6.23160	53
8	.14148	.98994	.14291	6.99718	.15873	.98732	.16077	6.22003	52
9	.14177	.98990	.14321	6.98268	.15902	.98728	.16107	6.20851	51
10	.14205	.98986	.14351	6.96823	.15931	.98723	.16137	6.19703	50
11	.14234	.98982	.14381	6.95385	.15959	.98718	.16167	6.18559	49
12	.14263	.98978	.14410	6.93952	.15988	.98714	.16196	6.17419	48
13	.14292	.98973	.14440	6.92525	.16017	.98709	.16226	6.16283	47
14	.14320	.98969	.14470	6.91104	.16046	.98704	.16256	6.15151	46
15	.14349	.98965	.14499	6.89688	.16074	.98700	.16286	6.14023	45
16	.14378	.98961	.14529	6.88278	.16103	.98695	.16316	6.12899	44
17	.14407	.98957	.14559	6.86874	.16132	.98690	.16346	6.11779	43
18	.14436	.98953	.14588	6.85475	.16160	.98686	.16376	6.10664	42
19	.14464	.98948	.14618	6.84082	.16189	.98681	.16405	6.09552	41
20	.14493	.98944	.14648	6.82694	.16218	.98676	.16435	6.08444	40
21	.14522	.98940	.14678	6.81312	.16246	.98671	.16465	6.07340	39
22	.14551	.98936	.14707	6.79936	.16275	.98667	.16495	6.06240	38
23	.14580	.98931	.14737	6.78564	.16304	.98662	.16525	6.05143	37
24	.14608	.98927	.14767	6.77199	.16333	.98657	.16555	6.04051	36
25	.14637	.98923	.14796	6.75838	.16361	.98652	.16585	6.02962	35
26	.14666	.98919	.14826	6.74483	.16390	.98648	.16615	6.01878	34
27	.14695	.98914	.14856	6.73133	.16419	.98643	.16645	6.00797	33
28	.14723	.98910	.14886	6.71789	.16447	.98638	.16674	5.99720	32
29	.14752	.98906	.14915	6.70450	.16476	.98633	.16704	5.98646	31
30	.14781	.98902	.14945	6.69116	.16505	.98629	.16734	5.97576	30
31	.14810	.98897	.14975	6.67787	.16533	.98624	.16764	5.96510	29
32	.14838	.98893	.15005	6.66463	.16562	.98619	.16794	5.95448	28
33	.14867	.98889	.15034	6.65144	.16591	.98614	.16824	5.94390	27
34	.14896	.98884	.15064	6.63831	.16620	.98609	.16854	5.93335	26
35	.14925	.98880	.15094	6.62523	.16648	.98604	.16884	5.92283	25
36	.14954	.98876	.15124	6.61219	.16677	.98600	.16914	5.91236	24
37	.14982	.98871	.15153	6.59921	.16706	.98595	.16944	5.90191	23
38	.15011	.98867	.15183	6.58627	.16734	.98590	.16974	5.89151	22
39	.15040	.98863	.15213	6.57339	.16763	.98585	.17004	5.88114	21
40	.15069	.98858	.15243	6.56055	.16792	.98580	.17033	5.87080	20
41	.15097	.98854	.15272	6.54777	.16820	.98575	.17063	5.86051	19
42	.15126	.98849	.15302	6.53503	.16849	.98570	.17093	5.85024	18
43	.15155	.98845	.15332	6.52234	.16878	.98565	.17123	5.84001	17
44	.15184	.98841	.15362	6.50970	.16906	.98561	.17153	5.82982	16
45	.15212	.98836	.15391	6.49710	.16935	.98556	.17183	5.81966	15
46	.15241	.98832	.15421	6.48456	.16964	.98551	.17213	5.80953	14
47	.15270	.98827	.15451	6.47206	.16992	.98546	.17243	5.79944	13
48	.15299	.98823	.15481	6.45961	.17021	.98541	.17273	5.78938	12
49	.15327	.98818	.15511	6.44720	.17050	.98536	.17303	5.77936	11
50	.15356	.98814	.15540	6.43484	.17078	.98531	.17333	5.76937	10
51	.15385	.98809	.15570	6.42253	.17107	.98526	.17363	5.75941	9
52	.15414	.98805	.15600	6.41026	.17136	.98521	.17393	5.74949	8
53	.15442	.98800	.15630	6.39804	.17164	.98516	.17423	5.73960	7
54	.15471	.98796	.15660	6.38587	.17193	.98511	.17453	5.72974	6
55	.15500	.98791	.15689	6.37374	.17222	.98506	.17483	5.71992	5
56	.15529	.98787	.15719	6.36165	.17250	.98501	.17513	5.71013	4
57	.15557	.98782	.15749	6.34961	.17279	.98496	.17543	5.70037	3
58	.15586	.98778	.15779	6.33761	.17308	.98491	.17573	5.69064	2
59	.15615	.98773	.15809	6.32566	.17336	.98486	.17603	5.68094	1
60	.15643	.98769	.15838	6.31375	.17365	.98481	.17633	5.67128	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	81°				80°				

	10°				11°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.17365	.98481	.17633	5.67128	.19081	.98163	.19438	5.14455	60
1	.17393	.98476	.17663	5.66165	.19109	.98157	.19468	5.13658	59
2	.17422	.98471	.17693	5.65205	.19138	.98152	.19498	5.12862	58
3	.17451	.98466	.17723	5.64248	.19167	.98146	.19529	5.12069	57
4	.17479	.98461	.17753	5.63295	.19195	.98140	.19559	5.11279	56
5	.17508	.98455	.17783	5.62344	.19224	.98135	.19589	5.10490	55
6	.17537	.98450	.17813	5.61397	.19252	.98129	.19619	5.09704	54
7	.17565	.98445	.17843	5.60452	.19281	.98124	.19649	5.08921	53
8	.17594	.98440	.17873	5.59511	.19309	.98118	.19680	5.08139	52
9	.17623	.98435	.17903	5.58573	.19338	.98112	.19710	5.07360	51
10	.17651	.98430	17933	5.57638	.19366	.98107	.19740	5.06584	50
11	.17680	.98425	.17963	5.56706	.19395	.98101	.19770	5.05809	49
12	.17708	.98420	.17993	5.55777	.19423	.98096	.19801	5.05037	48
13	.17737	.98414	.18023	5.54851	.19452	.98090	.19831	5.04267	47
14	.17766	.98409	.18053	5.53927	.19481	.98084	.19861	5.03499	46
15	.17794	.98404	.18083	5.53007	.19509	.98079	.19891	5.02734	45
16	.17823	.98399	.18113	5.52090	.19538	.98073	.19921	5.01971	44
17	.17852	.98394	.18143	5.51176	.19566	.98067	.19952	5.01210	43
18	.17880	.98389	.18173	5.50264	.19595	.98061	.19982	5.00451	42
19	.17909	.98383	.18203	5.49356	.19623	.98056	.20012	4.99695	41
20	17937	.98378	.18233	5.48451	.19652	.98050	.20042	4.98940	40
21	.17966	.98373	.18263	5.47548	.19680	.98044	.20073	4.98188	39
22	.17995	.98368	.18293	5.46648	.19709	.98039	.20103	4.97438	38
23	.18023	.98362	.18323	5.45751	.19737	.98033	.20133	4.96690	37
24	.18052	.98357	.18353	5.44857	.19766	.98027	.20164	4.95945	36
25	.18081	.98352	.18384	5.43966	.19794	.98021	.20194	4.95201	35
26	.18109	.98347	.18414	5.43077	.19823	.98016	.20224	4.94460	34
27	.18138	.98341	.18444	5.42192	.19851	.98010	.20254	4.93721	33
28	.18166	.98336	.18474	5.41309	.19880	.98004	.20285	4.92984	32
29	.18195	.98331	.18504	5.40429	.19908	.97998	.20315	4.92249	31
30	.18224	.98325	.18534	5.39552	.19937	.97992	.20345	4.91516	30
31	.18252	.98320	.18564	5.38677	.19965	.97987	.20376	4.90785	29
32	.18281	.98315	.18594	5.37805	.19994	.97981	.20406	4.90056	28
33	.18309	.98310	.18624	5.36936	.20022	.97975	.20436	4.89330	27
34	.18338	.98304	.18654	5.36070	.20051	.97969	.20466	4.88605	26
35	.18367	.98299	.18684	5.35206	.20079	.97963	.20497	4.87882	25
36	.18395	.98294	.18714	5.34345	.20108	.97958	.20527	4.87162	24
37	.18424	.98288	.18745	5.33487	.20136	.97952	.20557	4.86444	23
38	.18452	.98283	.18775	5.32631	.20165	.97946	.20588	4.85727	22
39	.18481	.98277	.18805	5.31778	.20193	.97940	.20618	4.85013	21
40	.18509	.98272	.18835	5.30928	.20222	.97934	.20648	4.84300	20
41	.18538	.98267	.18865	5.30080	.20250	.97928	.20679	4.83590	19
42	.18567	.98261	.18895	5.29235	.20279	.97922	.20709	4.82882	18
43	.18595	.98256	.18925	5.28393	.20307	.97916	.20739	4.82175	17
44	.18624	.98250	.18955	5.27553	.20336	.97910	.20770	4.81471	16
45	.18652	.98245	.18986	5.26715	.20364	.97905	.20800	4.80769	15
46	.18681	.98240	.19016	5.25880	.20393	.97899	.20830	4.80068	14
47	.18710	.98234	.19046	5.25048	.20421	.97893	.20861	4.79370	13
48	.18738	.98229	.19076	5.24218	.20450	.97887	.20891	4.78673	12
49	.18767	.98223	.19106	5.23391	.20478	.97881	.20921	4.77978	11
50	.18795	.98218	.19136	5.22566	.20507	.97875	.20952	4.77286	10
51	.18824	.98212	.19166	5.21744	.20535	.97869	.20982	4.76595	9
52	.18852	.98207	.19197	5.20925	.20563	.97863	.21013	4.75906	8
53	.18881	.98201	.19227	5.20107	.20592	.97857	.21043	4.75219	7
54	.18910	.98196	.19257	5.19293	.20620	.97851	.21073	4.74534	6
55	.18938	.98190	.19287	5.18480	.20649	.97845	.21104	4.73851	5
56	.18967	.98185	.19317	5.17671	.20677	.97839	.21134	4.73170	4
57	.18995	.98179	.19347	5.16863	.20706	.97833	.21164	4.72490	3
58	.19024	.98174	.19378	5.16058	.20734	.97827	.21195	4.71813	2
59	.19052	.98168	.19408	5.15256	.20763	.97821	.21225	4.71137	1
60	.19081	.98163	.19438	5.14455	.20791	.97815	.21256	4.70463	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	79°				78°				

′	12°				13°				′
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.20791	.97815	.21256	4.70463	.22495	.97437	.23087	4.33148	60
1	.20820	.97809	.21286	4.69791	.22523	.97430	.23117	4.32573	59
2	.20848	.97803	.21316	4.69121	.22552	.97424	.23148	4.32001	58
3	.20877	.97797	.21347	4.68452	.22580	.97417	.23179	4.31430	57
4	.20905	.97791	.21377	4.67786	.22608	.97411	.23209	4.30860	56
5	.20933	.97784	.21408	4.67121	.22637	.97404	.23240	4.30291	55
6	.20962	.97778	.21438	4.66458	.22665	.97398	.23271	4.29724	54
7	.20990	.97772	.21469	4.65797	.22693	.97391	.23301	4.29159	53
8	.21019	.97766	.21499	4.65138	.22722	.97384	.23332	4.28595	52
9	.21047	.97760	.21529	4.64480	.22750	.97378	.23363	4.28032	51
10	.21076	.97754	.21560	4.63825	.22778	.97371	.23393	4.27471	50
11	.21104	.97748	.21590	4.63171	.22807	.97365	.23424	4.26911	49
12	.21132	.97742	.21621	4.62518	.22835	.97358	.23455	4.26352	48
13	.21161	.97735	.21651	4.61868	.22863	.97351	.23485	4.25795	47
14	.21189	.97729	.21682	4.61219	.22892	.97345	.23516	4.25239	46
15	.21218	.97723	.21712	4.60572	.22920	.97338	.23547	4.24685	45
16	.21246	.97717	.21743	4.59927	.22948	.97331	.23578	4.24132	44
17	.21275	.97711	.21773	4.59283	.22977	.97325	.23608	4.23580	43
18	.21303	.97705	.21804	4.58641	.23005	.97318	.23639	4.23030	42
19	.21331	.97698	.21834	4.58001	.23033	.97311	.23670	4.22481	41
20	.21360	.97692	.21864	4.57363	.23062	.97304	.23700	4.21933	40
21	.21388	.97686	.21895	4.56726	.23090	.97298	.23731	4.21387	39
22	.21417	.97680	.21925	4.56091	.23118	.97291	.23762	4.20842	38
23	.21445	.97673	.21956	4.55458	.23146	.97284	.23793	4.20298	37
24	.21474	.97667	.21986	4.54826	.23175	.97278	.23823	4.19756	36
25	.21502	.97661	.22017	4.54196	.23203	.97271	.23854	4.19215	35
26	.21530	.97655	.22047	4.53568	.23231	.97264	.23885	4.18675	34
27	.21559	.97648	.22078	4.52941	.23260	.97257	.23916	4.18137	33
28	.21587	.97642	.22108	4.52316	.23288	.97251	.23946	4.17600	32
29	.21616	.97636	.22139	4.51693	.23316	.97244	.23977	4.17064	31
30	.21644	.97630	.22169	4.51071	.23345	.97237	.24008	4.16530	30
31	.21672	.97623	.22200	4.50451	.23373	.97230	.24039	4.15997	29
32	.21701	.97617	.22231	4.49832	.23401	.97223	.24069	4.15465	28
33	.21729	.97611	.22261	4.49215	.23429	.97217	.24100	4.14934	27
34	.21758	.97604	.22292	4.48600	.23458	.97210	.24131	4.14405	26
35	.21786	.97598	.22322	4.47986	23486	.97203	.24162	4.13877	25
36	.21814	.97592	.22353	4.47374	.23514	.97196	.24193	4.13350	24
37	.21843	.97585	.22383	4.46764	.23542	.97189	.24223	4.12825	23
38	.21871	.97579	.22414	4.46155	.23571	.97182	.24254	4.12301	22
39	.21899	.97573	.22444	4.45548	.23599	.97176	.24285	4.11778	21
40	.21928	.97566	.22475	4.44942	.23627	.97169	.24316	4.11256	20
41	.21956	.97560	.22505	4.44338	.23656	.97162	.24347	4.10736	19
42	.21985	.97553	.22536	4.43735	.23684	.97155	.24377	4.10216	18
43	.22013	.97547	.22567	4.43134	.23712	.97148	.24408	4.09699	17
44	.22041	.97541	.22597	4.42534	.23740	.97141	.24439	4.09182	16
45	.22070	.97534	.22628	4.41936	.23769	.97134	.24470	4.08666	15
46	.22098	.97528	.22658	4.41340	.23797	.97127	.24501	4.08152	14
47	.22126	.97521	.22689	4.40745	.23825	.97120	.24532	4.07639	13
48	.22155	.97515	.22719	4.40152	.23853	.97113	.24562	4.07127	12
49	.22183	.97508	.22750	4.39560	.23882	.97106	.24593	4.06616	11
50	.22212	.97502	.22781	4.38969	.23910	.97100	.24624	4.06107	10
51	.22240	.97496	.22811	4.38381	.23938	.97093	.24655	4.05599	9
52	.22268	.97489	.22842	4.37793	.23966	.97086	.24686	4.05092	8
53	.22297	.97483	.22872	4.37207	.23995	.97079	.24717	4.04586	7
54	.22325	.97476	.22903	4.36623	.24023	.97072	.24747	4.04081	6
55	.22353	.97470	.22934	4.36040	.24051	.97065	.24778	4.03578	5
56	.22382	.97463	.22964	4.35459	.24079	.97058	.24809	4.03076	4
57	.22410	.97457	.22995	4.34879	.24108	.97051	.24840	4.02574	3
58	.22438	.97450	.23026	4.34300	.24136	.97044	.24871	4.02074	2
59	.22467	.97444	.23056	4.33723	.24164	.97037	.24902	4.01576	1
60	.22495	.97437	.23087	4.33148	.24192	.97030	.24933	4.01078	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	77°				76°				

	14°				15°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.24192	.97030	.24933	4.01078	.25882	.96593	.26795	3.73205	60
1	.24220	.97023	.24964	4.00582	.25910	.96585	.26826	3.72771	59
2	.24249	.97015	.24995	4.00086	.25938	.96578	.26857	3.72338	58
3	.24277	.97008	.25026	3.99592	.25966	.96570	.26888	3.71907	57
4	.24305	.97001	.25056	3.99099	.25994	.96562	.26920	3.71476	56
5	.24333	.96994	.25087	3.98607	.26022	.96555	.26951	3.71046	55
6	.24362	.96987	.25118	3.98117	.26050	.96547	.26982	3.70616	54
7	.24390	.96980	.25149	3.97627	.26079	.96540	.27013	3.70188	53
8	.24418	.96973	.25180	3.97139	.26107	.96532	.27044	3.69761	52
9	.24446	.96966	.25211	3.96651	.26135	.96524	.27076	3.69335	51
10	.24474	.96959	.25242	3.96165	.26163	.96517	.27107	3.68909	50
11	.24503	.96952	.25273	3.95680	.26191	.96509	.27138	3.68485	49
12	.24531	.96945	.25304	3.95196	.26219	.96502	.27169	3.68061	48
13	.24559	.96937	.25335	3.94713	.26247	.96494	.27201	3.67638	47
14	.24587	.96930	.25366	3.94232	.26275	.96486	.27232	3.67217	46
15	.24615	.96923	.25397	3.93751	.26303	.96479	.27263	3.66796	45
16	.24644	.96916	.25428	3.93271	.26331	.96471	.27294	3.66376	44
17	.24672	.96909	.25459	3.92793	.26359	.96463	.27326	3.65957	43
18	.24700	.96902	.25490	3.92316	.26387	.96456	.27357	3.65538	42
19	.24728	.96894	.25521	3.91839	.26415	.96448	.27388	3.65121	41
20	.24756	.96887	.25552	3.91364	.26443	.96440	.27419	3.64705	40
21	.24784	.96880	.25583	3.90890	.26471	.96433	.27451	3.64289	39
22	.24813	.96873	.25614	3.90417	.26500	.96425	.27482	3.63874	38
23	.24841	.96866	.25645	3.89945	.26528	.96417	.27513	3.63461	37
24	.24869	.96858	.25676	3.89474	.26556	.96410	.27545	3.63048	36
25	.24897	.96851	.25707	3.89004	.26584	.96402	.27576	3.62636	35
26	.24925	.96844	.25738	3.88536	.26612	.96394	.27607	3.62224	34
27	.24954	.96837	.25769	3.88068	.26640	.96386	.27638	3.61814	33
28	.24982	.96829	.25800	3.87601	.26668	.96379	.27670	3.61405	32
29	.25010	.96822	.25831	3.87136	.26696	.96371	.27701	3.60996	31
30	.25038	.96815	.25862	3.86671	.26724	.96363	.27732	3.60588	30
31	.25066	.96807	.25893	3.86208	.26752	.96355	.27764	3.60181	29
32	.25094	.96800	.25924	3.85745	.26780	.96347	.27795	3.59775	28
33	.25122	.96793	.25955	3.85284	.26808	.96340	.27826	3.59370	27
34	.25151	.96786	.25986	3.84824	.26836	.96332	.27858	3.58966	26
35	.25179	.96778	.26017	3.84364	.26864	.96324	.27889	3.58562	25
36	.25207	.96771	.26048	3.83906	.26892	.96316	.27921	3.58160	24
37	.25235	.96764	.26079	3.83449	.26920	.96308	.27952	3.57758	23
38	.25263	.96756	.26110	3.82992	.26948	.96301	.27983	3.57357	22
39	.25291	.96749	.26141	3.82537	.26976	.96293	.28015	3.56957	21
40	.25320	.96742	.26172	3.82083	.27004	.96285	.28046	3.56557	20
41	.25348	.96734	.26203	3.81630	.27032	.96277	.28077	3.56159	19
42	.25376	.96727	.26235	3.81177	.27060	.96269	.28109	3.55761	18
43	.25404	.96719	.26266	3.80726	.27088	.96261	.28140	3.55364	17
44	.25432	.96712	.26297	3.80276	.27116	.96253	.28172	3.54968	16
45	.25460	.96705	.26328	3.79827	.27144	.96246	.28203	3.54573	15
46	.25488	.96697	.26359	3.79378	.27172	.96238	.28234	3.54179	14
47	.25516	.96690	.26390	3.78931	.27200	.96230	.28266	3.53785	13
48	.25545	.96682	.26421	3.78485	.27228	.96222	.28297	3.53393	12
49	.25573	.96675	.26452	3.78040	.27256	.96214	.28329	3.53001	11
50	.25601	.96667	.26483	3.77595	.27284	.96206	.28360	3.52609	10
51	.25629	.96660	.26515	3.77152	.27312	.96198	.28391	3.52219	9
52	.25657	.96653	.26546	3.76709	.27340	.96190	.28423	3.51829	8
53	.25685	.96645	.26577	3.76268	.27368	.96182	.28454	3.51441	7
54	.25713	.96638	.26608	3.75828	.27396	.96174	.28486	3.51053	6
55	.25741	.96630	.26639	3.75388	.27424	.96166	.28517	3.50666	5
56	.25769	.96623	.26670	3.74950	.27452	.96158	.28549	3.50279	4
57	.25798	.96615	.26701	3.74512	.27480	.96150	.28580	3.49894	3
58	.25826	.96608	.26733	3.74075	.27508	.96142	.28612	3.49509	2
59	.25854	.96600	.26764	3.73640	.27536	.96134	.28643	3.49125	1
60	.25882	.96593	.26795	3.73205	.27564	.96126	.28675	3.48741	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	75°				74°				

	16°				17°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.27564	.96126	.28675	3.48741	.29237	.95630	.30573	3.27085	60
1	.27592	.96118	.28706	3.48359	.29265	.95622	.30605	3.26745	59
2	.27620	.96110	.28738	3.47977	.29293	.95613	.30637	3.26406	58
3	.27648	.96102	.28769	3.47596	.29321	.95605	.30669	3.26067	57
4	.27676	.96094	.28800	3.47216	.29348	.95596	.30700	3.25729	56
5	.27704	.96086	.28832	3.46837	.29376	.95588	.30732	3.25392	55
6	.27731	.96078	.28864	3.46458	.29404	.95579	.30764	3.25055	54
7	.27759	.96070	.28895	3.46080	.29432	.95571	.30796	3.24719	53
8	.27787	.96062	.28927	3.45703	.29460	.95562	.30828	3.24383	52
9	.27815	.96054	.28958	3.45327	.29487	.95554	.30860	3.24049	51
10	.27843	.96046	.28990	3.44951	.29515	.95545	.30891	3.23714	50
11	.27871	.96037	.29021	3.44576	.29543	.95536	.30923	3.23381	49
12	.27899	.96029	.29053	3.44202	.29571	.95528	.30955	3.23048	48
13	.27927	.96021	.29084	3.43829	.29599	.95519	.30987	3.22715	47
14	.27955	.96013	.29116	3.43456	.29626	.95511	.31019	3.22384	46
15	.27983	.96005	.29147	3.43084	.29654	.95502	.31051	3.22053	45
16	.28011	.95997	.29179	3.42713	.29682	.95493	.31083	3.21722	44
17	.28039	.95989	.29210	3.42343	.29710	.95485	.31115	3.21392	43
18	.28067	.95981	.29242	3.41973	.29737	.95476	.31147	3.21063	42
19	.28095	.95972	.29274	3.41604	.29765	.95467	.31178	3.20734	41
20	.28123	.95964	.29305	3.41236	.29793	.95459	.31210	3.20406	40
21	.28150	.95956	.29337	3.40869	.29821	.95450	.31242	3.20079	39
22	.28178	.95948	.29368	3.40502	.29849	.95441	.31274	3.19752	38
23	.28206	.95940	.29400	3.40136	.29876	.95433	.31306	3.19426	37
24	.28234	.95931	.29432	3.39771	.29904	.95424	.31338	3.19100	36
25	.28262	.95923	.29463	3.39406	.29932	.95415	.31370	3.18775	35
26	.28290	.95915	.29495	3.39042	.29960	.95407	.31402	3.18451	34
27	.28318	.95907	.29526	3.38679	.29987	.95398	.31434	3.18127	33
28	.28346	.95898	.29558	3.38317	.30015	.95389	.31466	3.17804	32
29	.28374	.95890	.29590	3.37955	.30043	.95380	.31498	3.17481	31
30	.28402	.95882	.29621	3.37594	.30071	.95372	.31530	3.17159	30
31	.28429	.95874	.29653	3.37234	.30098	.95363	.31562	3.16838	29
32	.28457	.95865	.29685	3.36875	.30126	.95354	.31594	3.16517	28
33	.28485	.95857	.29716	3.36516	.30154	.95345	.31626	3.16197	27
34	.28513	.95849	.29748	3.36158	.30182	.95337	.31658	3.15877	26
35	.28541	.95841	.29780	3.35800	.30209	.95328	.31690	3.15558	25
36	.28569	.95832	.29811	3.35443	.30237	.95319	.31722	3.15240	24
37	.28597	.95824	.29843	3.35087	.30265	.95310	.31754	3.14922	23
38	.28625	.95816	.29875	3.34732	.30292	.95301	.31786	3.14605	22
39	.28652	.95807	.29906	3.34377	.30320	.95293	.31818	3.14288	21
40	.28680	.95799	.29938	3.34023	.30348	.95284	.31850	3.13972	20
41	.28708	.95791	.29970	3.33670	.30376	.95275	.31882	3.13656	19
42	.28736	.95782	.30001	3.33317	.30403	.95266	.31914	3.13341	18
43	.28764	.95774	.30033	3.32965	.30431	.95257	.31946	3.13027	17
44	.28792	.95766	.30065	3.32614	.30459	.95248	.31978	3.12713	16
45	.28820	.95757	.30097	3.32264	.30486	.95240	.32010	3.12400	15
46	.28847	.95749	.30128	3.31914	.30514	.95231	.32042	3.12087	14
47	.28875	.95740	.30160	3.31565	.30542	.95222	.32074	3.11775	13
48	.28903	.95732	.30192	3.31216	.30570	.95213	.32106	3.11464	12
49	.28931	.95724	.30224	3.30868	.30597	.95204	.32139	3.11153	11
50	.28959	.95715	.30255	3.30521	.30625	.95195	.32171	3.10842	10
51	.28987	.95707	.30287	3.30174	.30653	.95186	.32203	3.10532	9
52	.29015	.95698	.30319	3.29829	.30680	.95177	.32235	3.10223	8
53	.29042	.95690	.30351	3.29483	.30708	.95168	.32267	3.09914	7
54	.29070	.95681	.30382	3.29139	.30736	.95159	.32299	3.09606	6
55	.29098	.95673	.30414	3.28795	.30763	.95150	.32331	3.09298	5
56	.29126	.95664	.30446	3.28452	.30791	.95142	.32363	3.08991	4
57	.29154	.95656	.30478	3.28109	.30819	.95133	.32396	3.08685	3
58	.29182	.95647	.30509	3.27767	.30846	.95124	.32428	3.08379	2
59	.29209	.95639	.30541	3.27426	.30874	.95115	.32460	3.08073	1
60	.29237	.95630	.30573	3.27085	.30902	.95106	.32492	3.07768	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	73°				72°				

TABLE 10.—NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

	18°				19°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.30902	.95106	.32492	3.07768	.32557	.94552	.34433	2.90421	60
1	.30929	.95097	.32524	3.07464	.32584	.94542	.34465	2.90147	59
2	.30957	.95088	.32556	3.07160	.32612	.94533	.34498	2.89873	58
3	.30985	.95079	.32588	3.06857	.32639	.94523	.34530	2.89600	57
4	.31012	.95070	.32621	3.06554	.32667	.94514	.34563	2.89327	56
5	.31040	.95061	.32653	3.06252	.32694	.94504	.34596	2.89055	55
6	.31068	.95052	.32685	3.05950	.32722	.94495	.34628	2.88783	54
7	.31095	.95043	.32717	3.05649	.32749	.94485	.34661	2.88511	53
8	.31123	.95033	.32749	3.05349	.32777	.94476	.34693	2.88240	52
9	.31151	.95024	.32782	3.05049	.32804	.94466	.34726	2.87970	51
10	.31178	.95015	.32814	3.04749	.32832	.94457	.34758	2.87700	50
11	.31206	.95006	.32846	3.04450	.32859	.94447	.34791	2.87430	49
12	.31233	.94997	.32878	3.04152	.32887	.94438	.34824	2.87161	48
13	.31261	.94988	.32911	3.03854	.32914	.94428	.34856	2.86892	47
14	.31289	.94979	.32943	3.03556	.32942	.94418	.34889	2.86624	46
15	.31316	.94970	.32975	3.03260	.32969	.94409	.34922	2.86356	45
16	.31344	.94961	.33007	3.02963	.32997	.94399	.34954	2.86089	44
17	.31372	.94952	.33040	3.02667	.33024	.94390	.34987	2.85822	43
18	.31399	.94943	.33072	3.02372	.33051	.94380	.35020	2.85555	42
19	.31427	.94933	.33104	3.02077	.33079	.94370	.35052	2.85289	41
20	.31454	.94924	.33136	3.01783	.33106	.94361	.35085	2.85023	40
21	.31482	.94915	.33169	3.01489	.33134	.94351	.35118	2.84758	39
22	.31510	.94906	.33201	3.01196	.33161	.94342	.35150	2.84494	38
23	.31537	.94897	.33233	3.00903	.33189	.94332	.35183	2.84229	37
24	.31565	.94888	.33266	3.00611	.33216	.94322	.35216	2.83965	36
25	.31593	.94878	.33298	3.00319	.33244	.94313	.35248	2.83702	35
26	.31620	.94869	.33330	3.00028	.33271	.94303	.35281	2.83439	34
27	.31648	.94860	.33363	2.99738	.33298	.94293	.35314	2.83176	33
28	.31675	.94851	.33395	2.99447	.33326	.94284	.35346	2.82914	32
29	.31703	.94842	.33427	2.99158	.33353	.94274	.35379	2.82653	31
30	.31730	.94832	.33460	2.98868	.33381	.94264	.35412	2.82391	30
31	.31758	.94823	.33492	2.98580	.33408	.94254	.35445	2.82130	29
32	.31786	.94814	.33524	2.98292	.33436	.94245	.35477	2.81870	28
33	.31813	.94805	.33557	2.98004	.33463	.94235	.35510	2.81610	27
34	.31841	.94795	.33589	2.97717	.33490	.94225	.35543	2.81350	26
35	.31868	.94786	.33621	2.97430	.33518	.94215	.35576	2.81091	25
36	.31896	.94777	.33654	2.97144	.33545	.94206	.35608	2.80833	24
37	.31923	.94768	.33686	2.96858	.33573	.94196	.35641	2.80574	23
38	.31951	.94758	.33718	2.96573	.33600	.94186	.35674	2.80316	22
39	.31979	.94749	.33751	2.96288	.33627	.94176	.35707	2.80059	21
40	.32006	.94740	.33783	2.96004	.33655	.94167	.35740	2.79802	20
41	.32034	.94730	.33816	2.95721	.33682	.94157	.35772	2.79545	19
42	.32061	.94721	.33848	2.95437	.33710	.94147	.35805	2.79289	18
43	.32089	.94712	.33881	2.95155	.33737	.94137	.35838	2.79033	17
44	.32116	.94702	.33913	2.94872	.33764	.94127	.35871	2.78778	16
45	.32144	.94693	.33945	2.94591	.33792	.94118	.35904	2.78523	15
46	.32171	.94684	.33978	2.94309	.33819	.94108	.35937	2.78269	14
47	.32199	.94674	.34010	2.94028	.33846	.94098	.35969	2.78014	13
48	.32227	.94665	.34043	2.93748	.33874	.94088	.36002	2.77761	12
49	.32254	.94656	.34075	2.93468	.33901	.94078	.36035	2.77507	11
50	.32282	.94646	.34108	2.93189	.33929	.94068	.36068	2.77254	10
51	.32309	.94637	.34140	2.92910	.33956	.94058	.36101	2.77002	9
52	.32337	.94627	.34173	2.92632	.33983	.94049	.36134	2.76750	8
53	.32364	.94618	.34205	2.92354	.34011	.94039	.36167	2.76498	7
54	.32392	.94609	.34238	2.92076	.34038	.94029	.36199	2.76247	6
55	.32419	.94599	.34270	2.91799	.34065	.94019	.36232	2.75996	5
56	.32447	.94590	.34303	2.91523	.34093	.94009	.36265	2.75746	4
57	.32474	.94580	.34335	2.91246	.34120	.93999	.36298	2.75496	3
58	.32502	.94571	.34368	2.90971	.34147	.93989	.36331	2.75246	2
59	.32529	.94561	.34400	2.90696	.34175	.93979	.36364	2.74997	1
60	.32557	.94552	.34433	2.90421	.34202	.93969	.36397	2.74748	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	71°				70°				

′	20° Sin.	20° Cos.	20° Tan.	20° Cot.	21° Sin.	21° Cos.	21° Tan.	21° Cot.	′
0	.34202	.93969	.36397	2.74748	.35837	.93358	.38386	2.60509	60
1	.34229	.93959	.36430	2.74499	.35864	.93348	.38420	2.60283	59
2	.34257	.93949	.36463	2.74251	.35891	.93337	.38453	2.60057	58
3	.34284	.93939	.36496	2.74004	.35918	.93327	.38487	2.59831	57
4	.34311	.93929	.36529	2.73756	.35945	.93316	.38520	2.59606	56
5	.34339	.93919	.36562	2.73509	.35973	.93306	.38553	2.59381	55
6	.34366	.93909	.36595	2.73263	.36000	.93295	.38587	2.59156	54
7	.34393	.93899	.36628	2.73017	.36027	.93285	.38620	2.58932	53
8	.34421	.93889	.36661	2.72771	.36054	.93274	.38654	2.58708	52
9	.34448	.93879	.36694	2.72526	.36081	.93264	.38687	2.58484	51
10	.34475	.93869	.36727	2.72281	.36108	.93253	.38721	2.58261	50
11	.34503	.93859	.36760	2.72036	.36135	.93243	.38754	2.58038	49
12	.34530	.93849	.36793	2.71792	.36162	.93232	.38787	2.57815	48
13	.34557	.93839	.36826	2.71548	.36190	.93222	.38821	2.57593	47
14	.34584	.93829	.36859	2.71305	.36217	.93211	.38854	2.57371	46
15	.34612	.93819	.36892	2.71062	.36244	.93201	.38888	2.57150	45
16	.34639	.93809	.36925	2.70819	.36271	.93190	.38921	2.56928	44
17	.34666	.93799	.36958	2.70577	.36298	.93180	.38955	2.56707	43
18	.34694	.93789	.36991	2.70335	.36325	.93169	.38988	2.56487	42
19	.34721	.93779	.37024	2.70094	.36352	.93159	.39022	2.56266	41
20	.34748	.93769	.37057	2.69853	.36379	.93148	.39055	2.56046	40
21	.34775	.93759	.37090	2.69612	.36406	.93137	.39089	2.55827	39
22	.34803	.93748	.37123	2.69371	.36434	.93127	.39122	2.55608	38
23	.34830	.93738	.37157	2.69131	.36461	.93116	.39156	2.55389	37
24	.34857	.93728	.37190	2.68892	.36488	.93106	.39190	2.55170	36
25	.34884	.93718	.37223	2.68653	.36515	.93095	.39223	2.54952	35
26	.34912	.93708	.37256	2.68414	.36542	.93084	39257	2.54734	34
27	.34939	.93698	.37289	2.68175	.36569	.93074	.39290	2.54516	33
28	.34966	.93688	.37322	2.67937	.36596	.93063	.39324	2.54299	32
29	.34993	.93677	.37355	2.67700	.36623	.93052	.39357	2.54082	31
30	.35021	.93667	.37388	2.67462	.36650	.93042	.39391	2.53865	30
31	.35048	.93657	.37422	2.67225	.36677	.93031	.39425	2.53648	29
32	.35075	.93647	.37455	2.66989	.36704	.93020	.39458	2.53432	28
33	.35102	.93637	.37488	2.66752	.36731	.93010	.39492	2.53217	27
34	.35130	.93626	.37521	2.66516	.36758	.92999	.39526	2.53001	26
35	.35157	.93616	.37554	2.66281	.36785	.92988	.39559	2.52786	25
36	.35184	.93606	.37588	2.66046	.36812	.92978	.39593	2.52571	24
37	.35211	.93596	.37621	2.65811	.36839	.92967	.39626	2.52357	23
38	.35239	.93585	.37654	2.65576	.36867	.92956	.39660	2.52142	22
39	.35266	.93575	.37687	2.65342	.36894	.92945	.39694	2.51929	21
40	.35293	.93565	.37720	2.65109	.36921	.92935	.39727	2.51715	20
41	.35320	.93555	.37754	2.64875	.36948	.92924	.39761	2.51502	19
42	.35347	.93544	.37787	2.64642	.36975	.92913	.39795	2.51289	18
43	.35375	.93534	.37820	2.64410	.37002	.92902	.39829	2.51076	17
44	.35402	.93524	.37853	2.64177	.37029	.92892	.39862	2.50864	16
45	.35429	.93514	.37887	2.63945	.37056	.92881	.39896	2.50652	15
46	.35456	.93503	.37920	2.63714	.37083	.92870	.39930	2.50440	14
47	.35484	.93493	.37953	2.63483	.37110	.92859	.39963	2.50229	13
48	.35511	.93483	.37986	2.63252	.37137	.92849	.39997	2.50018	12
49	.35538	.93472	.38020	2.63021	.37164	.92838	.40031	2.49807	11
50	.35565	.93462	.38053	2.62791	.37191	.92827	.40065	2.49597	10
51	.35592	.93452	.38086	2.62561	.37218	.92816	.40098	2.49386	9
52	.35619	.93441	.38120	2.62332	.37245	.92805	.40132	2.49177	8
53	.35647	.93431	.38153	2.62103	.37272	.92794	.40166	2.48967	7
54	.35674	.93420	.38186	2.61874	.37299	.92784	.40200	2.48758	6
55	.35701	.93410	.38220	2.61646	.37326	.92773	.40234	2.48549	5
56	.35728	.93400	.38253	2.61418	.37353	.92762	.40267	2.48340	4
57	.35755	.93389	.38286	2.61190	.37380	.92751	.40301	2.48132	3
58	.35782	.93379	.38320	2.60963	.37407	.92740	.40335	2.47924	2
59	.35810	.93368	.38353	2.60736	.37434	.92729	.40369	2.47716	1
60	.35837	.93358	.38386	2.60509	.37461	.92718	.40403	2.47509	0
′	69° Cos.	69° Sin.	69° Cot.	69° Tan.	68° Cos.	68° Sin.	68° Cot.	68° Tan.	′

	22°				23°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.37461	.92718	.40403	2.47509	.39073	.92050	.42447	2.35585	60
1	.37488	.92707	.40436	2.47302	.39100	.92039	.42482	2.35395	59
2	.37515	.92697	.40470	2.47095	.39127	.92028	.42516	2.35205	58
3	.37542	.92686	.40504	2.46888	.39153	.92016	.42551	2.35015	57
4	.37569	.92675	.40538	2.46682	.39180	.92005	.42585	2.34825	56
5	.37595	.92664	.40572	2.46476	.39207	.91994	.42619	2.34636	55
6	.37622	.92653	.40606	2.46270	.39234	.91982	.42654	2.34447	54
7	.37649	.92642	.40640	2.46065	.39260	.91971	.42688	2.34258	53
8	.37676	.92631	.40674	2.45860	.39287	.91959	.42722	2.34069	52
9	.37703	92620	.40707	2.45655	.39314	.91948	.42757	2.33881	51
10	.37730	.92609	.40741	2.45451	.39341	.91936	.42791	2.33693	50
11	.37757	.92598	.40775	2.45246	.39367	.91925	.42826	2.33505	49
12	.37784	.92587	.40809	2.45043	.39394	.91914	.42860	2.33317	48
13	.37811	.92576	.40843	2.44839	.39421	.91902	.42894	2.33130	47
14	.37838	.92565	.40877	2.44636	.39448	.91891	.42929	2.32943	46
15	.37865	.92554	.40911	2.44433	.39474	.91879	.42963	2.32756	45
16	.37892	.92543	.40945	2.44230	.39501	.91868	.42998	2.32570	44
17	.37919	.92532	.40979	2.44027	.39528	.91856	.43032	2.32383	43
18	.37946	.92521	.41013	2.43825	.39555	.91845	.43067	2.32197	42
19	.37973	.92510	.41047	2.43623	.39581	.91833	.43101	2.32012	41
20	.37999	.92499	.41081	2.43422	.39608	.91822	.43136	2.31826	40
21	.38026	.92488	.41115	2.43220	.39635	.91810	.43170	2.31641	39
22	.38053	.92477	.41149	2.43019	.39661	.91799	.43205	2.31456	38
23	.38080	.92466	.41183	2.42819	.39688	.91787	.43239	2.31271	37
24	.38107	.92455	.41217	2.42618	.39715	.91775	.43274	2.31086	36
25	.38134	.92444	.41251	2.42418	.39741	.91764	.43308	2.30902	35
26	.38161	.92432	.41285	2.42218	.39768	.91752	.43343	2.30718	34
27	.38188	.92421	.41319	2.42019	.39795	.91741	.43378	2.30534	33
28	.38215	.92410	.41353	2.41819	.39822	.91729	.43412	2.30351	32
29	.38241	.92399	.41387	2.41620	.39848	.91718	.43447	2.30167	31
30	.38268	.92388	.41421	2.41421	.39875	.91706	.43481	2.29984	30
31	.38295	.92377	.41455	2.41223	.39902	.91694	.43516	2.29801	29
32	.38322	.92366	.41490	2.41025	.39928	.91683	.43550	2.29619	28
33	.38349	.92355	.41524	2.40827	.39955	.91671	.43585	2.29437	27
34	.38376	.92343	.41558	2.40629	.39982	.91660	.43620	2.29254	26
35	.38403	.92332	.41592	2.40432	.40008	.91648	.43654	2.29073	25
36	.38430	.92321	.41626	2.40235	.40035	.91636	.43689	2.28891	24
37	.38456	.92310	.41660	2.40038	.40062	.91625	.43724	2.28710	23
38	.38483	.92299	.41694	2.39841	.40088	.91613	.43758	2.28528	22
39	.38510	.92287	.41728	2.39645	.40115	.91601	.43793	2.28348	21
40	.38537	.92276	.41763	2.39449	.40141	.91590	.43828	2.28167	20
41	.38564	.92265	.41797	2.39253	.40168	.91578	.43862	2.27987	19
42	.38591	.92254	.41831	2.39058	.40195	.91566	.43897	2.27806	18
43	.38617	.92243	.41865	2.38863	.40221	.91555	.43932	2.27626	17
44	.38644	.92231	.41899	2.38668	.40248	.91543	.43966	2.27447	16
45	.38671	.92220	.41933	2.38473	.40275	.91531	.44001	2.27267	15
46	.38698	.92209	.41968	2.38279	40301	.91519	.44036	2.27088	14
47	.38725	.92198	.42002	2.38084	.40328	.91508	.44071	2.26909	13
48	.38752	.92186	.42036	2.37891	.40355	.91496	.44105	2.26730	12
49	.38778	.92175	.42070	2.37697	.40381	.91484	.44140	2.26552	11
50	.38805	.92164	.42105	2.37504	.40408	.91472	.44175	2.26374	10
51	.38832	.92152	.42139	2.37311	.40434	.91461	.44210	2.26196	9
52	.38859	.92141	.42173	2.37118	.40461	.91449	.44244	2.26018	8
53	.38886	.92130	.42207	2.36925	.40488	.91437	.44279	2.25840	7
54	.38912	.92119	.42242	2.36733	.40514	.91425	.44314	2.25663	6
55	.38939	.92107	.42276	2.36541	.40541	.91414	.44349	2.25486	5
56	.38966	.92096	.42310	2.36349	.40567	.91402	.44384	2.25309	4
57	.38993	.92085	.42345	2.36158	.40594	.91390	.44418	2.25132	3
58	.39020	.92073	.42379	2.35967	.40621	.91378	.44453	2.24956	2
59	.39046	.92062	.42413	2.35776	.40647	.91366	.44488	2.24780	1
60	.39073	.92050	.42447	2.35585	.40674	.91355	.44523	2.24604	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	67°				66°				

TABLE 10.—NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

	24°				25°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.40674	.91355	.44523	2.24604	.42262	.90631	.46631	2.14451	60
1	.40700	.91343	.44558	2.24428	.42288	.90618	.46666	2.14288	59
2	.40727	.91331	.44593	2.24252	.42315	.90606	.46702	2.14125	58
3	.40753	.91319	.44627	2.24077	.42341	.90594	.46737	2.13963	57
4	.40780	.91307	.44662	2.23902	.42367	.90582	.46772	2.13801	56
5	.40806	.91295	.44697	2.23727	.42394	.90569	.46808	2.13639	55
6	.40833	.91283	.44732	2.23553	.42420	.90557	.46843	2.13477	54
7	.40860	.91272	.44767	2.23378	.42446	.90545	.46879	2.13316	53
8	.40886	.91260	.44802	2.23204	.42473	.90532	.46914	2.13154	52
9	.40913	.91248	.44837	2.23030	.42499	.90520	.46950	2.12993	51
10	.40939	.91236	.44872	2.22857	.42525	.90507	.46985	2.12832	50
11	.40966	.91224	.44907	2.22683	.42552	.90495	.47021	2.12671	49
12	.40992	.91212	.44942	2.22510	.42578	.90483	.47056	2.12511	48
13	.41019	.91200	.44977	2.22337	.42604	.90470	.47092	2.12350	47
14	.41045	.91188	.45012	2.22164	.42631	.90458	.47128	2.12190	46
15	.41072	.91176	.45047	2.21992	.42657	.90446	.47163	2.12030	45
16	.41098	.91164	.45082	2.21819	.42683	.90433	.47199	2.11871	44
17	.41125	.91152	.45117	2.21647	.42709	.90421	.47234	2.11711	43
18	.41151	.91140	.45152	2.21475	.42736	.90408	.47270	2.11552	42
19	.41178	.91128	.45187	2.21304	.42762	.90396	.47305	2.11392	41
20	.41204	.91116	.45222	2.21132	.42788	.90383	.47341	2.11233	40
21	.41231	.91104	.45257	2.20961	.42815	.90371	.47377	2.11075	39
22	.41257	.91092	.45292	2.20790	.42841	.90358	.47412	2.10916	38
23	.41284	.91080	.45327	2.20619	.42867	.90346	.47448	2.10758	37
24	.41310	.91068	.45362	2.20449	.42894	.90334	.47483	2.10600	36
25	.41337	.91056	.45397	2.20278	.42920	.90321	.47519	2.10442	35
26	.41363	.91044	.45432	2.20108	.42946	.90309	.47555	2.10284	34
27	.41390	.91032	.45467	2.19938	.42972	.90296	.47590	2.10126	33
28	.41416	.91020	.45502	2.19769	.42999	.90284	.47626	2.09969	32
29	.41443	.91008	.45538	2.19599	.43025	.90271	.47662	2.09811	31
30	.41469	.90996	.45573	2.19430	.43051	.90259	.47698	2.09654	30
31	.41496	.90984	.45608	2.19261	.43077	.90246	.47733	2.09498	29
32	.41522	.90972	.45643	2.19092	.43104	.90233	.47769	2.09341	28
33	.41549	.90960	.45678	2.18923	.43130	.90221	.47805	2.09184	27
34	.41575	.90948	.45713	2.18755	.43156	.90208	.47840	2.09028	26
35	.41602	.90936	.45748	2.18587	.43182	.90196	.47876	2.08872	25
36	.41628	.90924	.45784	2.18419	.43209	.90183	.47912	2.08716	24
37	.41655	.90911	.45819	2.18251	.43235	.90171	.47948	2.08560	23
38	.41681	.90899	.45854	2.18084	.43261	.90158	.47984	2.08405	22
39	.41707	.90887	.45889	2.17916	.43287	.90146	.48019	2.08250	21
40	.41734	.90875	.45924	2.17749	.43313	.90133	.48055	2.08094	20
41	.41760	.90863	.45960	2.17582	.43340	.90120	.48091	2.07939	19
42	.41787	.90851	.45995	2.17416	.43366	.90108	.48127	2.07785	18
43	.41813	.90839	.46030	2.17249	.43392	.90095	.48163	2.07630	17
44	.41840	.90826	.46065	2.17083	.43418	.90082	.48198	2.07476	16
45	.41866	.90814	.46101	2.16917	.43445	.90070	.48234	2.07321	15
46	.41892	.90802	.46136	2.16751	.43471	.90057	.48270	2.07167	14
47	.41919	.90790	.46171	2.16585	.43497	.90045	.48306	2.07014	13
48	.41945	.90778	.46206	2.16420	.43523	.90032	.48342	2.06860	12
49	.41972	.90766	.46242	2.16255	.43549	.90019	.48378	2.06706	11
50	.41998	.90753	.46277	2.16090	.43575	.90007	.48414	2.06553	10
51	.42024	.90741	.46312	2.15925	.43602	.89994	.48450	2.06400	9
52	.42051	.90729	.46348	2.15760	.43628	.89981	.48486	2.06247	8
53	.42077	.90717	.46383	2.15596	.43654	.89968	.48521	2.06094	7
54	.42104	.90704	.46418	2.15432	.43680	.89956	.48557	2.05942	6
55	.42130	.90692	.46454	2.15268	.43706	.89943	.48593	2.05790	5
56	.42156	.90680	.46489	2.15104	.43733	.89930	.48629	2.05637	4
57	.42183	.90668	.46525	2.14940	.43759	.89918	.48665	2.05485	3
58	.42209	.90655	.46560	2.14777	.43785	.89905	.48701	2.05333	2
59	.42235	.90643	.46595	2.14614	.43811	.89892	.48737	2.05182	1
60	.42262	.90631	.46631	2.14451	.43837	.89879	.48773	2.05030	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	65°				64°				

TABLE 10.—NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

	26°				27°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.43837	.89879	.48773	2.05030	.45399	.89101	.50953	1.96261	60
1	.43863	.89867	.48809	2.04879	.45425	.89087	.50989	1.96120	59
2	.43889	.89854	.48845	2.04728	.45451	.89074	.51026	1.95979	58
3	.43916	.89841	.48881	2.04577	.45477	.89061	.51063	1.95838	57
4	.43942	.89828	.48917	2.04426	.45503	.89048	.51099	1.95698	56
5	.43968	.89816	.48953	2.04276	.45529	.89035	.51136	1.95557	55
6	.43994	.89803	.48989	2.04125	.45554	.89021	.51173	1.95417	54
7	.44020	.89790	.49026	2.03975	.45580	.89008	.51209	1.95277	53
8	.44046	.89777	.49062	2.03825	.45606	.88995	.51246	1.95137	52
9	.44072	.89764	.49098	2.03675	.45632	.88981	.51283	1.94997	51
10	.44098	.89752	.49134	2.03526	.45658	.88968	.51319	1.94858	50
11	.44124	.89739	.49170	2.03376	.45684	.88955	.51356	1.94718	49
12	.44151	.89726	.49206	2.03227	.45710	.88942	.51393	1.94579	48
13	.44177	.89713	.49242	2.03078	.45736	.88928	.51430	1.94440	47
14	.44203	.89700	.49278	2.02929	.45762	.88915	.51467	1.94301	46
15	.44229	.89687	.49315	2.02780	.45787	.88902	.51503	1.94162	45
16	.44255	.89674	.49351	2.02631	.45813	.88888	.51540	1.94023	44
17	.44281	.89662	.49387	2.02483	.45839	.88875	.51577	1.93885	43
18	.44307	.89649	.49423	2.02335	.45865	.88862	.51614	1.93746	42
19	.44333	.89636	.49459	2.02187	.45891	.88848	.51651	1.93608	41
20	.44359	.89623	.49495	2.02039	.45917	.88835	.51688	1.93470	40
21	.44385	.89610	.49532	2.01891	.45942	.88822	.51724	1.93332	39
22	.44411	.89597	.49568	2.01743	.45968	.88808	.51761	1.93195	38
23	.44437	.89584	.49604	2.01596	.45994	.88795	.51798	1.93057	37
24	.44464	.89571	.49640	2.01449	.46020	.88782	.51835	1.92920	36
25	.44490	.89558	.49677	2.01302	.46046	.88768	.51872	1.92782	35
26	.44516	.89545	.49713	2.01155	.46072	.88755	.51909	1.92645	34
27	.44542	.89532	.49749	2.01008	.46097	.88741	.51946	1.92508	33
28	.44568	.89519	.49786	2.00862	.46123	.88728	.51983	1.92371	32
29	.44594	.89506	.49822	2.00715	.46149	.88715	.52020	1.92235	31
30	.44620	.89493	.49858	2.00569	.46175	.88701	.52057	1.92098	30
31	.44646	.89480	.49894	2.00423	.46201	.88688	.52094	1.91962	29
32	.44672	.89467	.49931	2.00277	.46226	.88674	.52131	1.91826	28
33	.44698	.89454	.49967	2.00131	.46252	.88661	.52168	1.91690	27
34	.44724	.89441	.50004	1.99986	.46278	.88647	.52205	1.91554	26
35	.44750	.89428	.50040	1.99841	.46304	.88634	.52242	1.91418	25
36	.44776	.89415	.50076	1.99695	.46330	.88620	.52279	1.91282	24
37	.44802	.89402	.50113	1.99550	.46355	.88607	.52316	1.91147	23
38	.44828	.89389	.50149	1.99406	.46381	.88593	.52353	1.91012	22
39	.44854	.89376	.50185	1.99261	.46407	.88580	.52390	1.90876	21
40	.44880	.89363	.50222	1.99116	.46433	.88566	.52427	1.90741	20
41	.44906	.89350	.50258	1.98972	.46458	.88553	.52464	1.90607	19
42	.44932	.89337	.50295	1.98828	.46484	.88539	.52501	1.90472	18
43	.44958	.89324	.50331	1.98684	.46510	.88526	.52538	1.90337	17
44	.44984	.89311	.50368	1.98540	.46536	.88512	.52575	1.90203	16
45	.45010	.89298	.50404	1.98396	.46561	.88499	.52613	1.90069	15
46	.45036	.89285	.50441	1.98253	.46587	.88485	.52650	1.89935	14
47	.45062	.89272	.50477	1.98110	.46613	.88472	.52687	1.89801	13
48	.45088	.89259	.50514	1.97966	.46639	.88458	.52724	1.89667	12
49	.45114	.89245	.50550	1.97823	.46664	.88445	.52761	1.89533	11
50	.45140	.89232	.50587	1.97681	.46690	.88431	.52798	1.89400	10
51	.45166	.89219	.50623	1.97538	.46716	.88417	.52836	1.89266	9
52	.45192	.89206	.50660	1.97395	.46742	.88404	.52873	1.89133	8
53	.45218	.89193	.50696	1.97253	.46767	.88390	.52910	1.89000	7
54	.45243	.89180	.50733	1.97111	.46793	.88377	.52947	1.88867	6
55	.45269	.89167	.50769	1.96969	.46819	.88363	.52985	1.88734	5
56	.45295	.89153	.50806	1.96827	.46844	.88349	.53022	1.88602	4
57	.45321	.89140	.50843	1.96685	.46870	.88336	.53059	1.88469	3
58	.45347	.89127	.50879	1.96544	.46896	.88322	.53096	1.88337	2
59	.45373	.89114	.50916	1.96402	.46921	.88308	.53134	1.88205	1
60	.45399	.89101	.50953	1.96261	.46947	.88295	.53171	1.88073	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	63°				62°				

	28°				29°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.46947	.88295	.53171	1.88073	.48481	87462	.55431	1.80405	60
1	.46973	.88281	.53208	1.87941	.48506	.87448	.55469	1.80281	59
2	.46999	.88267	53246	1.87809	.48532	.87434	.55507	1.80158	58
3	.47024	.88254	.53283	1.87677	.48557	87420	.55545	1.80034	57
4	.47050	.88240	.53320	1.87546	.48583	.87406	.55583	1.79911	56
5	.47076	.88226	.53358	1.87415	.48608	.87391	.55621	1.79788	55
6	.47101	88213	.53395	1.87283	.48634	.87377	.55659	1.79665	54
7	.47127	.88199	.53432	1.87152	.48659	.87363	.55697	1.79542	53
8	.47153	.88185	53470	1.87021	.48684	.87349	.55736	1.79419	52
9	.47178	.88172	.53507	1.86891	.48710	.87335	.55774	1.79296	51
10	.47204	.88158	.53545	1.86760	.48735	.87321	.55812	1.79174	50
11	.47229	.88144	.53582	1.86630	.48761	.87306	.55850	1.79051	49
12	.47255	.88130	.53620	1.86499	.48786	.87292	.55888	1.78929	48
13	.47281	.88117	.53657	1.86369	.48811	.87278	.55926	1.78807	47
14	.47306	.88103	.53694	1.86239	.48837	.87264	.55964	1.78685	46
15	.47332	.88089	.53732	1.86109	.48862	.87250	.56003	1.78563	45
16	.47358	.88075	.53769	1.85979	.48888	.87235	.56041	1.78441	44
17	.47383	.88062	.53807	1.85850	.48913	.87221	.56079	1.78319	43
18	.47409	.88048	.53844	1.85720	.48938	.87207	.56117	1.78198	42
19	.47434	.88034	.53882	1.85591	.48964	.87193	.56156	1.78077	41
20	.47460	.88020	.53920	1.85462	.48989	.87178	.56194	1.77955	40
21	.47486	.88006	.53957	1.85333	.49014	.87164	.56232	1.77834	39
22	.47511	.87993	.53995	1.85204	.49040	.87150	.56270	1.77713	38
23	.47537	.87979	.54032	1.85075	.49065	.87136	.56309	1.77592	37
24	.47562	.87965	.54070	1.84946	.49090	.87121	.56347	1.77471	36
25	.47588	.87951	.54107	1.84818	.49116	.87107	.56385	1.77351	35
26	.47614	.87937	.54145	1.84689	.49141	87093	.56424	1.77230	34
27	.47639	.87923	.54183	1.84561	.49166	.87079	.56462	1.77110	33
28	.47665	.87909	.54220	1.84433	.49192	.87064	.56501	1.76990	32
29	.47690	.87896	.54258	1.84305	.49217	.87050	.56539	1.76869	31
30	.47716	.87882	.54296	1.84177	.49242	.87036	.56577	1.76749	30
31	.47741	.87868	.54333	1.84049	.49268	.87021	.56616	1.76629	29
32	.47767	.87854	.54371	1.83922	.49293	.87007	.56654	1.76510	28
33	.47793	.87840	.54409	1.83794	.49318	.86993	.56693	1.76390	27
34	.47818	.87826	.54446	1.83667	.49344	.86978	.56731	1.76271	26
35	.47844	.87812	.54484	1.83540	.49369	.86964	.56769	1.76151	25
36	.47869	.87798	.54522	1.83413	.49394	.86949	.56808	1.76032	24
37	.47895	.87784	.54560	1.83286	.49419	.86935	.56846	1.75913	23
38	.47920	.87770	.54597	1.83159	.49445	.86921	.56885	1.75794	22
39	.47946	.87756	.54635	1.83033	.49470	.86906	.56923	1.75675	21
40	.47971	.87743	.54673	1.82906	.49495	.86892	.56962	1.75556	20
41	.47997	.87729	.54711	1.82780	.49521	.86878	.57000	1.75437	19
42	.48022	.87715	.54748	1.82654	.49546	.86863	.57039	1.75319	18
43	.48048	.87701	.54786	1.82528	.49571	.86849	.57078	1.75200	17
44	.48073	.87687	.54824	1.82402	.49596	.86834	.57116	1.75082	16
45	.48099	.87673	.54862	1.82276	.49622	.86820	.57155	1.74964	15
46	.48124	.87659	.54900	1.82150	.49647	.86805	.57193	1.74846	14
47	.48150	.87645	.54938	1.82025	.49672	.86791	.57232	1.74728	13
48	.48175	.87631	.54975	1.81899	.49697	.86777	.57271	1.74610	12
49	.48201	.87617	.55013	1.81774	.49723	.86762	.57309	1.74492	11
50	.48226	.87603	.55051	1.81649	.49748	.86748	.57348	1.74375	10
51	.48252	.87589	.55089	1.81524	.49773	.86733	.57386	1.74257	9
52	.48277	.87575	.55127	1.81399	.49798	.86719	.57425	1.74140	8
53	.48303	.87561	.55165	1.81274	.49824	.86704	.57464	1.74022	7
54	.48328	.87546	.55203	1.81150	.49849	.86690	.57503	1.73905	6
55	.48354	.87532	.55241	1.81025	.49874	.86675	.57541	1.73788	5
56	.48379	.87518	.55279	1.80901	.49899	.86661	.57580	1.73671	4
57	.48405	.87504	.55317	1.80777	.49924	.86646	.57619	1.73555	3
58	.48430	.87490	.55355	1.80653	.49950	.86632	.57657	1.73438	2
59	.48456	.87476	.55393	1.80529	.49975	.86617	.57696	1.73321	1
60	.48481	.87462	.55431	1.80405	.50000	.86603	.57735	1.73205	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	61°				60°				

TABLE 10.—NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

	30°				31°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.50000	.86603	.57735	1.73205	.51504	.85717	.60086	1.66428	60
1	.50025	.86588	.57774	1.73089	.51529	.85702	.60126	1.66318	59
2	.50050	.86573	.57813	1.72973	.51554	.85687	.60165	1.66209	58
3	.50076	.86559	.57851	1.72857	.51579	.85672	.60205	1.66099	57
4	.50101	.86544	.57890	1.72741	.51604	.85657	.60245	1.65990	56
5	.50126	.86530	.57929	1.72625	.51628	.85642	.60284	1.65881	55
6	.50151	.86515	.57968	1.72509	.51653	.85627	.60324	1.65772	54
7	.50176	.86501	.58007	1.72393	.51678	.85612	.60364	1.65663	53
8	.50201	.86486	.58046	1.72278	.51703	.85597	.60403	1.65554	52
9	.50227	.86471	.58085	1.72163	.51728	.85582	.60443	1.65445	51
10	.50252	.86457	.58124	1.72047	.51753	.85567	.60483	1.65337	50
11	.50277	.86442	.58162	1.71932	.51778	.85551	.60522	1.65228	49
12	.50302	.86427	.58201	1.71817	.51803	.85536	.60562	1.65120	48
13	.50327	.86413	.58240	1.71702	.51828	.85521	.60602	1.65011	47
14	.50352	.86398	.58279	1.71588	.51852	.85506	.60642	1.64903	46
15	.50377	.86384	.58318	1.71473	.51877	.85491	.60681	1.64795	45
16	.50403	.86369	.58357	1.71358	.51902	.85476	.60721	1.64687	44
17	.50428	.86354	.58396	1.71244	.51927	.85461	.60761	1.64579	43
18	.50453	.86340	.58435	1.71129	.51952	.85446	.60801	1.64471	42
19	.50478	.86325	.58474	1.71015	.51977	.85431	.60841	1.64363	41
20	.50503	.86310	.58513	1.70901	.52002	.85416	.60881	1.64256	40
21	.50528	.86295	.58552	1.70787	.52026	.85401	.60921	1.64148	39
22	.50553	.86281	.58591	1.70673	.52051	.85385	.60960	1.64041	38
23	.50578	.86266	.58631	1.70560	.52076	.85370	.61000	1.63934	37
24	.50603	.86251	.58670	1.70446	.52101	.85355	.61040	1.63826	36
25	.50628	.86237	58709	1.70332	.52126	.85340	.61080	1.63719	35
26	.50654	.86222	.58748	1.70219	.52151	.85325	.61120	1.63612	34
27	.50679	.86207	.58787	1.70106	.52175	.85310	.61160	1.63505	33
28	.50704	.86192	.58826	1.69992	.52200	.85294	.61200	1.63398	32
29	.50729	.86178	.58865	1.69879	.52225	.85279	.61240	1.63292	31
30	.50754	.86163	.58905	1.69766	.52250	.85264	.61280	1.63185	30
31	.50779	.86148	.58944	1.69653	.52275	.85249	.61320	1.63079	29
32	.50804	.86133	.58983	1.69541	.52299	.85234	.61360	1.62972	28
33	.50829	.86119	.59022	1.69428	.52324	.85218	.61400	1.62866	27
34	.50854	.86104	.59061	1.69316	.52349	.85203	.61440	1.62760	26
35	.50879	.86089	.59101	1.69203	.52374	.85188	.61480	1.62654	25
36	.50904	.86074	.59140	1.69091	.52399	.85173	.61520	1.62548	24
37	.50929	.86059	.59179	1.68979	.52423	.85157	.61561	1.62442	23
38	.50954	.86045	59218	1.68866	.52448	.85142	.61601	1.62336	22
39	.50979	.86030	.59258	1.68754	.52473	.85127	.61641	1.62230	21
40	.51004	.86015	.59297	1.68643	.52498	.85112	.61681	1.62125	20
41	.51029	.86000	.59336	1.68531	.52522	.85096	.61721	1.62019	19
42	.51054	.85985	.59376	1.68419	.52547	.85081	.61761	1.61914	18
43	.51079	.85970	.59415	1.68308	.52572	.85066	.61801	1.61808	17
44	.51104	.85956	.59454	1.68196	.52597	.85051	.61842	1.61703	16
45	.51129	.85941	.59494	1.68085	.52621	.85035	.61882	1.61598	15
46	.51154	.85926	.59533	1.67974	.52646	.85020	.61922	1.61493	14
47	.51179	.85911	.59573	1.67863	.52671	.85005	.61962	1.61388	13
48	.51204	.85896	.59612	1.67752	.52696	.84989	.62003	1.61283	12
49	.51229	.85881	.59651	1.67641	.52720	.84974	.62043	1.61179	11
50	.51254	.85866	.59691	1.67530	.52745	.84959	.62083	1.61074	10
51	.51279	.85851	.59730	1.67419	.52770	.84943	.62124	1.60970	9
52	.51304	.85836	.59770	1.67309	.52794	.84928	.62164	1.60865	8
53	.51329	.85821	.59809	1.67198	.52819	.84913	.62204	1.60761	7
54	.51354	.85806	.59849	1.67088	.52844	.84897	.62245	1.60657	6
55	.51379	.85792	.59888	1.66978	.52869	.84882	.62285	1.60553	5
56	.51404	.85777	.59928	1.66867	.52893	.84866	.62325	1.60449	4
57	.51429	.85762	.59967	1.66757	.52918	.84851	.62366	1.60345	3
58	.51454	.85747	.60007	1.66647	.52943	.84836	.62406	1.60241	2
59	.51479	.85732	.60046	1.66538	.52967	.84820	.62446	1.60137	1
60	.51504	.85717	.60086	1.66428	.52992	.84805	.62487	1.60033	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	59°				58°				

	32°				33°				
′	Sin.	Cos	Tan.	Cot	Sin.	Cos.	Tan.	Cot.	′
0	.52992	.84805	.62487	1.60033	.54464	.83867	.64941	1.53986	60
1	.53017	.84789	.62527	1.59930	.54488	.83851	.64982	1.53888	59
2	.53041	.84774	.62568	1.59826	.54513	.83835	.65024	1.53791	58
3	.53066	.84759	.62608	1.59723	.54537	.83819	.65065	1.53693	57
4	.53091	.84743	.62649	1.59620	.54561	.83804	.65106	1.53595	56
5	.53115	.84728	.62689	1.59517	.54586	.83788	.65148	1.53497	55
6	.53140	.84712	.62730	1.59414	.54610	.83772	.65189	1.53400	54
7	.53164	.84697	.62770	1.59311	.54635	.83756	.65231	1.53302	53
8	.53189	.84681	.62811	1.59208	.54659	.83740	.65272	1.53205	52
9	.53214	.84666	.62852	1.59105	.54683	.83724	.65314	1.53107	51
10	.53238	.84650	.62892	1.59002	.54708	.83708	.65355	1.53010	50
11	53263	.84635	.62933	1.58900	.54732	.83692	.65397	1.52913	49
12	53288	.84619	.62973	1.58797	.54756	.83676	.65438	1.52816	48
13	.53312	.84604	.63014	1.58695	.54781	.83660	.65480	1.52719	47
14	.53337	.84588	.63055	1.58593	.54805	.83645	.65521	1.52622	46
15	.53361	.84573	.63095	1.58490	.54829	.83629	.65563	1.52525	45
16	.53386	.84557	.63136	1.58388	.54854	.83613	.65604	1.52429	44
17	.53411	.84542	.63177	1.58286	.54878	.83597	.65646	1.52332	43
18	.53435	.84526	.63217	1.58184	.54902	.83581	.65688	1.52235	42
19	.53460	.84511	.63258	1.58083	.54927	.83565	.65729	1.52139	41
20	.53484	.84495	.63299	1.57981	.54951	.83549	.65771	1.52043	40
21	.53509	.84480	.63340	1.57879	.54975	.83533	.65813	1.51946	39
22	.53534	.84464	.63380	1.57778	.54999	.83517	.65854	1.51850	38
23	.53558	.84448	.63421	1.57676	.55024	.83501	.65896	1.51754	37
24	.53583	.84433	.63462	1.57575	.55048	.83485	.65938	1.51658	36
25	.53607	.84417	.63503	1.57474	.55072	.83469	.65980	1.51562	35
26	.53632	.84402	.63544	1.57372	.55097	.83453	.66021	1.51466	34
27	.53656	.84386	.63584	1.57271	.55121	.83437	.66063	1.51370	33
28	.53681	.84370	.63625	1.57170	.55145	.83421	.66105	1.51275	32
29	.53705	.84355	.63666	1.57069	.55169	.83405	.66147	1.51179	31
30	.53730	.84339	.63707	1.56969	.55194	.83389	.66189	1.51084	30
31	.53754	.84324	.63748	1.56868	.55218	.83373	.66230	1.50988	29
32	.53779	.84308	.63789	1.56767	.55242	.83356	.66272	1.50893	28
33	.53804	.84292	.63830	1.56667	.55266	.83340	.66314	1.50797	27
34	.53828	.84277	.63871	1.56566	.55291	.83324	.66356	1.50702	26
35	.53853	.84261	.63912	1.56466	.55315	.83308	.66398	1.50607	25
36	.53877	.84245	.63953	1.56366	.55339	.83292	.66440	1.50512	24
37	.53902	.84230	.63994	1.56265	.55363	.83276	.66482	1.50417	23
38	.53926	.84214	.64035	1.56165	.55388	.83260	.66524	1.50322	22
39	.53951	.84198	.64076	1.56065	.55412	.83244	.66566	1.50228	21
40	.53975	.84182	.64117	1.55966	.55436	.83228	.66608	1.50133	20
41	.54000	.84167	.64158	1.55866	.55460	.83212	.66650	1.50038	19
42	.54024	.84151	.64199	1.55766	.55484	.83195	.66692	1.49944	18
43	.54049	.84135	.64240	1.55666	.55509	.83179	.66734	1.49849	17
44	.54073	.84120	.64281	1.55567	.55533	.83163	.66776	1.49755	16
45	.54097	.84104	.64322	1.55467	.55557	.83147	.66818	1.49661	15
46	.54122	.84088	.64363	1.55368	.55581	.83131	.66860	1.49566	14
47	.54146	.84072	.64404	1.55269	.55605	.83115	.66902	1.49472	13
48	.54171	.84057	.64446	1.55170	.55630	.83098	.66944	1.49378	12
49	.54195	.84041	.64487	1.55071	.55654	.83082	.66986	1.49284	11
50	.54220	.84025	.64528	1.54972	.55678	.83066	.67028	1.49190	10
51	.54244	.84009	.64569	1.54873	.55702	.83050	.67071	1.49097	9
52	.54269	.83994	.64610	1.54774	.55726	.83034	.67113	1.49003	8
53	.54293	.83978	.64652	1.54675	.55750	.83017	.67155	1.48909	7
54	.54317	.83962	.64693	1.54576	.55775	.83001	.67197	1.48816	6
55	.54342	.83946	.64734	1.54478	.55799	.82985	.67239	1.48722	5
56	.54366	.83930	.64775	1.54379	.55823	.82969	.67282	1.48629	4
57	.54391	.83915	.64817	1.54281	.55847	.82953	.67324	1.48536	3
58	.54415	.83899	.64858	1.54183	.55871	.82936	.67366	1.48442	2
59	.54440	.83883	.64899	1.54085	.55895	.82920	.67409	1.48349	1
60	.54464	.83867	.64941	1.53986	.55919	.82904	.67451	1.48256	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	57°				56°				

	34°				35°				
	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.55919	.82904	.67451	1.48256	.57358	.81915	.70021	1.42815	60
1	.55943	.82887	.67493	1.48163	.57381	.81899	.70064	1.42726	59
2	.55968	.82871	.67536	1.48070	.57405	.81882	.70107	1.42638	58
3	.55992	.82855	.67578	1.47977	.57429	.81865	.70151	1.42550	57
4	.56016	.82839	.67620	1.47885	.57453	.81848	.70194	1.42462	56
5	.56040	.82822	.67663	1.47792	.57477	.81832	.70238	1.42374	55
6	.56064	.82806	.67705	1.47699	.57501	.81815	.70281	1.42286	54
7	.56088	.82790	.67748	1.47607	.57524	.81798	.70325	1.42198	53
8	.56112	.82773	.67790	1.47514	.57548	.81782	.70368	1.42110	52
9	.56136	.82757	.67832	1.47422	.57572	.81765	.70412	1.42022	51
10	.56160	.82741	.67875	1.47330	.57596	.81748	.70455	1.41934	50
11	.56184	.82724	.67917	1.47238	.57619	.81731	.70499	1.41847	49
12	.56208	.82708	.67960	1.47146	.57643	.81714	.70542	1.41759	48
13	.56232	.82692	.68002	1.47053	.57667	.81698	.70586	1.41672	47
14	.56256	.82675	.68045	1.46962	.57691	.81681	.70629	1.41584	46
15	.56280	.82659	.68088	1.46870	.57715	.81664	.70673	1.41497	45
16	.56305	.82643	.68130	1.46778	.57738	.81647	.70717	1.41409	44
17	.56329	.82626	.68173	1.46686	.57762	.81631	.70760	1.41322	43
18	.56353	.82610	.68215	1.46595	.57786	.81614	.70804	1.41235	42
19	.56377	.82593	.68258	1.46503	.57810	.81597	.70848	1.41148	41
20	.56401	.82577	.68301	1.46411	.57833	.81580	.70891	1.41061	40
21	.56425	.82561	.68343	1.46320	.57857	.81563	.70935	1.40974	39
22	.56449	.82544	.68386	1.46229	.57881	.81546	.70979	1.40887	38
23	.56473	.82528	.68429	1.46137	.57904	.81530	.71023	1.40800	37
24	.56497	.82511	.68471	1.46046	.57928	.81513	.71066	1.40714	36
25	.56521	.82495	.68514	1.45955	.57952	.81496	.71110	1.40627	35
26	.56545	.82478	.68557	1.45864	.57976	.81479	.71154	1.40540	34
27	.56569	.82462	.68600	1.45773	.57999	.81462	.71198	1.40454	33
28	.56593	.82446	.68642	1.45682	.58023	.81445	.71242	1.40367	32
29	.56617	.82429	.68685	1.45592	.58047	.81428	.71285	1.40281	31
30	.56641	.82413	.68728	1.45501	.58070	.81412	.71329	1.40195	30
31	.56665	.82396	.68771	1.45410	.58094	.81395	.71373	1.40109	29
32	.56689	.82380	.68814	1.45320	.58118	.81378	.71417	1.40022	28
33	.56713	.82363	.68857	1.45229	.58141	.81361	.71461	1.39936	27
34	.56736	.82347	.68900	1.45139	.58165	.81344	.71505	1.39850	26
35	.56760	.82330	.68942	1.45049	.58189	.81327	.71549	1.39764	25
36	.56784	.82314	.68985	1.44958	.58212	.81310	.71593	1.39679	24
37	.56803	.82297	.69028	1.44868	.58236	.81293	.71637	1.39593	23
38	.56832	.82281	.69071	1.44778	.58260	.81276	.71681	1.39507	22
39	.56856	.82264	.69114	1.44688	.58283	.81259	.71725	1.39421	21
40	.56880	.82248	.69157	1.44598	.58307	.81242	.71769	1.39336	20
41	.56904	.82231	.69200	1.44508	.58330	.81225	.71813	1.39250	19
42	.56928	.82214	.69243	1.44418	.58354	.81208	.71857	1.39165	18
43	.56952	.82198	.69286	1.44329	.58378	.81191	.71901	1.39079	17
44	.56976	.82181	.69329	1.44239	.58401	.81174	.71946	1.38994	16
45	.57000	.82165	.69372	1.44149	.58425	.81157	.71990	1.38909	15
46	.57024	.82148	.69416	1.44060	.58449	.81140	.72034	1.38824	14
47	.57047	.82132	.69459	1.43970	.58472	.81123	.72078	1.38738	13
48	.57071	.82115	.69502	1.43881	.58496	.81106	.72122	1.38653	12
49	.57095	.82098	.69545	1.43792	.58519	.81089	.72167	1.38568	11
50	.57119	.82082	.69588	1.43703	.58543	.81072	.72211	1.38484	10
51	.57143	.82065	.69631	1.43614	.58567	.81055	.72255	1.38399	9
52	.57167	.82048	.69675	1.43525	.58590	.81038	.72299	1.38314	8
53	.57191	.82032	.69718	1.43436	.58614	.81021	.72344	1.38229	7
54	.57215	.82015	.69761	1.43347	.58637	.81004	.72388	1.38145	6
55	.57238	.81999	.69804	1.43258	.58661	.80987	.72432	1.38060	5
56	.57262	.81982	.69847	1.43169	.58684	.80970	.72477	1.37976	4
57	.57286	.81965	.69891	1.43080	.58708	.80953	.72521	1.37891	3
58	.57310	.81949	.69934	1.42992	.58731	.80936	.72565	1.37807	2
59	.57334	.81932	.69977	1.42903	.58755	.80919	.72610	1.37722	1
60	.57358	.81915	.70021	1.42815	.58779	.80902	.72654	1.37638	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	55°				54°				

TABLE 10.—NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS

′	36° Sin.	Cos.	Tan.	Cot.	37° Sin.	Cos.	Tan.	Cot.	′
0	.58779	.80902	.72654	1.37638	.60182	.79864	.75355	1.32704	60
1	.58802	.80885	.72699	1.37554	.60205	.79846	.75401	1.32624	59
2	.58826	.80867	.72743	1.37470	.60228	.79829	.75447	1.32544	58
3	.58849	.80850	.72788	1.37386	.60251	.79811	.75492	1.32464	57
4	.58873	.80833	.72832	1.37302	.60274	.79793	.75538	1.32384	56
5	58896	.80816	.72877	1.37218	.60298	.79776	.75584	1.32304	55
6	.58920	.80799	.72921	1.37134	.60321	.79758	.75629	1.32224	54
7	.58943	.80782	.72966	1.37050	.60344	.79741	.75675	1.32144	53
8	.58967	.80765	.73010	1.36967	.60367	.79723	.75721	1.32064	52
9	58990	.80748	.73055	1.36883	.60390	.79706	.75767	1.31984	51
10	.59014	.80730	.73100	1.36800	.60414	.79688	.75812	1.31904	50
11	.59037	.80713	.73144	1.36716	.60437	.79671	.75858	1.31825	49
12	.59061	.80696	.73189	1.36633	.60460	.79653	.75904	1.31745	48
13	.59084	.80679	.73234	1.36549	.60483	.79635	.75950	1.31666	47
14	.59108	.80662	.73278	1.36466	.60506	.79618	.75996	1.31586	46
15	.59131	.80644	.73323	1.36383	.60529	.79600	.76042	1.31507	45
16	.59154	.80627	.73368	1.36300	.60553	.79583	.76088	1.31427	44
17	.59178	.80610	.73413	1.36217	.60576	.79565	.76134	1.31348	43
18	.59201	.80593	.73457	1.36134	.60599	.79547	.76180	1.31269	42
19	.59225	.80576	.73502	1.36051	.60622	.79530	76226	1.31190	41
20	.59248	.80558	.73547	1.35968	.60645	.79512	.76272	1.31110	40
21	.59272	.80541	.73592	1.35885	.60668	.79494	.76318	1.31031	39
22	.59295	.80524	.73637	1.35802	.60691	.79477	.76364	1.30952	38
23	.59318	.80507	.73681	1.35719	.60714	.79459	.76410	1.30873	37
24	.59342	.80489	.73726	1.35637	.60738	.79441	.76456	1.30795	36
25	.59365	.80472	.73771	1.35554	.60761	.79424	.76502	1.30716	35
26	.59389	.80455	.73816	1.35472	.60784	.79406	.76548	1.30637	34
27	.59412	.80438	.73861	1.35389	.60807	.79388	.76594	1.30558	33
28	.59436	.80420	.73906	1.35307	.60830	.79371	.76640	1.30480	32
29	.59459	.80403	.73951	1.35224	.60853	.79353	.76686	1.30401	31
30	.59482	.80386	.73996	1.35142	.60876	.79335	.76733	1.30323	30
31	.59506	.80368	.74041	1.35060	.60899	.79318	.76779	1.30244	29
32	.59529	.80351	.74086	1.34978	.60922	.79300	.76825	1.30166	28
33	.59552	.80334	.74131	1.34896	.60945	.79282	.76871	1.30087	27
34	.59576	.80316	.74176	1.34814	.60968	.79264	.76918	1.30009	26
35	.59599	.80299	.74221	1.34732	.60991	79247	.76964	1.29931	25
36	.59622	.80282	.74267	1.34650	.61015	.79229	.77010	1.29853	24
37	.59646	.80264	.74312	1.34568	.61038	.79211	.77057	1.29775	23
38	.59669	.80247	.74357	1.34487	.61061	.79193	.77103	1.29696	22
39	.59693	.80230	.74402	1.34405	.61084	.79176	.77149	1.29618	21
40	.59716	.80212	.74447	1.34323	.61107	.79158	.77196	1.29541	20
41	.59739	.80195	.74492	1.34242	.61130	.79140	.77242	1.29463	19
42	.59763	.80178	.74538	1.34160	.61153	.79122	.77289	1.29385	18
43	.59786	.80160	.74583	1.34079	.61176	.79105	.77335	1.29307	17
44	.59809	.80143	.74628	1.33998	.61199	.79087	.77382	1.29229	16
45	.59832	.80125	.74674	1.33916	.61222	.79069	.77428	1.29152	15
46	.59856	.80108	.74719	1.33835	.61245	.79051	.77475	1.29074	14
47	.59879	.80091	.74764	1.33754	.61268	.79033	.77521	1.28997	13
48	.59902	.80073	.74810	1.33673	.61291	.79016	.77568	1.28919	12
40	.59926	.80056	.74855	1.33592	.61314	.78998	.77615	1.28842	11
50	.59949	.80038	.74900	1.33511	.61337	.78980	.77661	1.28764	10
51	.59972	.80021	.74946	1.33430	.61360	.78962	.77708	1.28687	9
52	.59995	.80003	.74991	1.33349	.61383	.78944	.77754	1.28610	8
53	.60019	.79986	.75037	1.33268	.61406	.78926	.77801	1.28533	7
54	.60042	.79968	.75082	1.33187	.61429	.78908	.77848	1.28456	6
55	.60065	.79951	.75128	1.33107	.61451	.78891	.77895	1.28379	5
56	.60089	.79934	.75173	1.33026	.61474	.78873	.77941	1.28302	4
57	.60112	.79916	.75219	1.32946	.61497	.78855	.77988	1.28225	3
58	.60135	.79899	.75264	1.32865	.61520	.78837	.78035	1.28148	2
59	.60158	.79881	.75310	1.32785	.61543	78819	.78082	1.28071	1
60	.60182	.79864	.75355	1.32704	.61566	.78801	.78129	1.27994	0
′	Cos. 53°	Sin.	Cot.	Tan.	Cos. 52°	Sin.	Cot.	Tan.	′

TABLE 10.—NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

	38°				39°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.61566	.78801	.78129	1.27994	.62932	.77715	.80978	1.23490	60
1	.61589	.78783	.78175	1.27917	.62955	.77696	.81027	1.23416	59
2	.61612	.78765	.78222	1.27841	.62977	.77678	.81075	1.23343	58
3	.61635	.78747	.78269	1.27764	.63000	.77660	.81123	1.23270	57
4	.61658	.78729	.78316	1.27688	.63022	.77641	.81171	1.23196	56
5	.61681	.78711	.78363	1.27611	.63045	.77623	.81220	1.23123	55
6	.61704	.78694	.78410	1.27535	.63068	.77605	.81268	1.23050	54
7	.61726	.78676	.78457	1.27458	.63090	77586	.81316	1.22977	53
8	.61749	.78658	.78504	1.27382	.63113	.77568	.81364	1.22904	52
9	.61772	.78640	.78551	1.27306	.63135	.77550	.81413	1.22831	51
10	.61795	.78622	.78598	1.27230	.63158	.77531	.81461	1.22758	50
11	.61818	.78604	.78645	1.27153	.63180	.77513	.81510	1.22685	49
12	.61841	.78586	.78692	1.27077	.63203	.77494	.81558	1.22612	48
13	.61864	.78568	.78739	1.27001	.63225	.77476	.81606	1.22539	47
14	.61887	.78550	.78786	1.26925	.63248	.77458	.81655	1.22467	46
15	.61909	.78532	.78834	1.26849	.63271	.77439	.81703	1.22394	45
16	.61932	.78514	.78881	1.26774	.63293	.77421	.81752	1.22321	44
17	.61955	.78496	.78928	1.26698	.63316	.77402	.81800	1.22249	43
18	.61978	.78478	.78975	1.26622	.63338	.77384	.81849	1.22176	42
19	.62001	.78460	.79022	1.26546	.63361	.77366	.81898	1.22104	41
20	.62024	.78442	.79070	1.26471	.63383	.77347	.81946	1.22031	40
21	.62046	.78424	.79117	1.26395	.63406	.77329	.81995	1.21959	39
22	.62069	.78405	.79164	1.26319	.63428	.77310	.82044	1.21886	38
23	.62092	.78387	.79212	1.26244	.63451	.77292	.82092	1.21814	37
24	.62115	.78369	.79259	1.26169	.63473	.77273	.82141	1.21742	36
25	.62138	.78351	.79306	1.26093	.63496	.77255	.82190	1.21670	35
26	.62160	.78333	.79354	1.26018	.63518	.77236	.82238	1.21598	34
27	.62183	.78315	.79401	1.25943	.63540	.77218	.82287	1.21526	33
28	.62206	.78297	.79449	1.25867	.63563	.77199	.82336	1.21454	32
29	.62229	.78279	.79496	1.25792	.63585	.77181	.82385	1.21382	31
30	.62251	.78261	.79544	1.25717	.63608	.77162	.82434	1.21310	30
31	.62274	.78243	.79591	1.25642	.63630	.77144	.82483	1.21238	29
32	.62297	.78225	.79639	1.25567	.63653	.77125	.82531	1.21166	28
33	.62320	.78206	.79686	1.25492	.63675	.77107	.82580	1.21094	27
34	.62342	.78188	.79734	1.25417	.63698	.77088	.82629	1.21023	26
35	.62365	.78170	.79781	1.25343	.63720	.77070	.82678	1.20951	25
36	.62388	.78152	.79829	1.25268	.63742	.77051	.82727	1.20879	24
37	.62411	.78134	.79877	1.25193	.63765	.77033	.82776	1.20808	23
38	.62433	.78116	.79924	1.25118	.63787	.77014	.82825	1.20736	22
39	.62456	.78098	.79972	1.25044	.63810	.76996	.82874	1.20665	21
40	.62479	.78079	.80020	1.24969	.63832	.76977	.82923	1.20593	20
41	.62502	.78061	.80067	1.24895	.63854	.76959	.82972	1.20522	19
42	.62524	.78043	.80115	1.24820	.63877	.76940	.83022	1.20451	18
43	.62547	.78025	.80163	1.24746	.63899	.76921	.83071	1.20379	17
44	.62570	.78007	.80211	1.24672	.63922	.76903	.83120	1.20308	16
45	.62592	.77988	.80258	1.24597	.63944	.76884	.83169	1.20237	15
46	.62615	.77970	.80306	1.24523	.63966	.76866	.83218	1.20166	14
47	.62638	.77952	.80354	1.24449	.63989	.76847	.83268	1.20095	13
48	.62660	.77934	.80402	1.24375	.64011	.76828	.83317	1.20024	12
49	.62683	.77916	.80450	1.24301	.64033	.76810	.83366	1.19953	11
50	.62706	.77897	.80498	1.24227	.64056	.76791	.83415	1.19882	10
51	.62728	.77879	.80546	1.24153	.64078	.76772	.83465	1.19811	9
52	.62751	.77861	.80594	1.24079	.64100	.76754	.83514	1.19740	8
53	.62774	.77843	.80642	1.24005	.64123	.76735	.83564	1.19669	7
54	.62796	.77824	.80690	1.23931	.64145	.76717	.83613	1.19599	6
55	.62819	.77806	.80738	1.23858	.64167	.76698	.83662	1.19528	5
56	.62842	.77788	.80786	1.23784	.64190	.76679	.83712	1.19457	4
57	.62864	.77769	.80834	1.23710	.64212	.76661	.83761	1.19387	3
58	.62887	.77751	.80882	1.23637	.64234	.76642	.83811	1.19316	2
59	.62909	.77733	.80930	1.23563	.64256	.76623	.83860	1.19246	1
60	.62932	.77715	80978	1.23490	.64279	.76604	.83910	1.19175	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	51°				50°				

TABLE 10.—NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

	40°				41°				
′	Sin.	Cos.	Tan.	Cot.	Sin.	Cos.	Tan.	Cot.	′
0	.64279	.76604	.83910	1.19175	.65606	.75471	.86929	1.15037	60
1	.64301	.76586	.83960	1.19105	.65628	.75452	.86980	1.14969	59
2	.64323	.76567	.84009	1.19035	.65650	.75433	.87031	1.14902	58
3	.64346	.76548	.84059	1.18964	.65672	.75414	.87082	1.14834	57
4	.64368	.76530	.84108	1.18894	.65694	.75395	.87133	1.14767	56
5	.64390	.76511	.84158	1.18824	.65716	.75375	.87184	1.14699	55
6	.64412	.76492	.84208	1.18754	.65738	.75356	.87236	1.14632	54
7	.64435	.76473	.84258	1.18684	.65759	.75337	.87287	1.14565	53
8	.64457	.76455	.84307	1.18614	.65781	.75318	.87338	1.14498	52
9	.64479	.76436	.84357	1.18544	.65803	.75299	.87389	1.14430	51
10	.64501	.76417	.84407	1.18474	.65825	.75280	.87441	1.14363	50
11	.64524	.76398	.84457	1.18404	.65847	.75261	.87492	1.14296	49
12	.64546	.76380	.84507	1.18334	.65869	.75241	.87543	1.14229	48
13	.64568	.76361	.84556	1.18264	.65891	.75222	.87595	1.14162	47
14	.64590	.76342	.84606	1.18194	.65913	.75203	.87646	1.14095	46
15	.64612	.76323	.84656	1.18125	.65935	.75184	.87698	1.14028	45
16	.64635	.76304	.84706	1.18055	.65956	.75165	.87749	1.13961	44
17	.64657	.76286	.84756	1.17986	.65978	.75146	.87801	1.13894	43
18	.64679	.76267	.84806	1.17916	.66000	.75126	.87852	1.13828	42
19	.64701	.76248	.84856	1.17846	.66022	.75107	.87904	1.13761	41
20	.64723	.76229	.84906	1.17777	.66044	.75088	.87955	1.13694	40
21	.64746	.76210	.84956	1.17708	.66066	.75069	.88007	1.13627	39
22	.64768	.76192	.85006	1.17638	.66088	.75050	.88059	1.13561	38
23	.64790	.76173	.85057	1.17569	.66109	.75030	.88110	1.13494	37
24	.64812	.76154	.85107	1.17500	.66131	.75011	.88162	1.13428	36
25	.64834	.76135	.85157	1.17430	.66053	.74992	.88204	1.13361	35
26	.64856	.76116	.85207	1.17361	.66175	.74973	.88265	1.13295	34
27	.64878	.76097	.85257	1.17292	.66197	.74953	.88317	1.13228	33
28	.64901	.76078	.85308	1.17223	.66218	.74934	.88369	1.13162	32
29	.64923	.76059	.85358	1.17154	.66240	.74915	.88421	1.13096	31
30	.64945	.76041	.85408	1.17085	.66262	.74896	.88473	1.13029	30
31	.64967	.76022	.85458	1.17016	.66284	.74876	.88524	1.12963	29
32	.64989	.76003	.85509	1.16947	.66306	.74857	.88576	1.12897	28
33	.65011	.75984	.85559	1.16878	.66327	.74838	.88628	1.12831	27
34	.65033	.75965	.85609	1.16809	.66349	.74818	.88680	1.12765	26
35	.65055	.75946	.85660	1.16741	.66371	.74799	.88732	1.12699	25
36	.65077	.75927	.85710	1.16672	.66393	.74780	.88784	1.12633	24
37	.65100	.75908	.85761	1.16603	.66414	.74760	.88836	1.12567	23
38	.65122	.75889	.85811	1.16535	.66436	.74741	.88888	1.12501	22
39	.65144	.75870	.85862	1.16466	.66458	.74722	.88940	1.12435	21
40	.65166	.75851	.85912	1.16398	.66480	.74703	.88992	1.12369	20
41	.65188	.75832	.85963	1.16329	.66501	.74683	.89045	1.12303	19
42	.65210	.75813	.86014	1.16261	.66523	.74664	.89097	1.12238	18
43	.65232	.75794	.86064	1.16192	.66545	.74644	.89149	1.12172	17
44	.65254	.75775	.86115	1.16124	.66566	.74625	.89201	1.12106	16
45	.65276	.75756	.86166	1.16056	.66588	.74606	.89253	1.12041	15
46	.65298	.75738	86216	1.15987	.66610	.74586	.89306	1.11975	14
47	.65320	.75719	.86267	1.15919	.66632	.74567	.89358	1.11909	13
48	.65342	.75700	.86318	1.15851	.66653	.74548	.89410	1.11844	12
49	.65364	.75680	.86368	1.15783	.66675	.74528	.89463	1.11778	11
50	.65386	.75661	.86419	1.15715	.66697	.74509	.89515	1.11713	10
51	.65408	.75642	.86470	1.15647	.66718	.74489	.89567	1.11648	9
52	.65430	.75623	.86521	1.15579	.66740	.74470	.89620	1.11582	8
53	.65452	.75604	.86572	1.15511	.66762	.74451	.89672	1.11517	7
54	.65474	.75585	.86623	1.15443	.66783	.74431	.89725	1.11452	6
55	.65496	.75566	.86674	1.15375	.66805	.74412	.89777	1.11387	5
56	.65518	.75547	.86725	1.15308	.66827	.74392	.89830	1.11321	4
57	.65540	.75528	.86776	1.15240	.66848	.74373	.89883	1.11256	3
58	.65562	.75509	.86827	1.15172	.66870	.74353	.89935	1.11191	2
59	.65584	.75490	.86878	1.15104	.66891	.74334	.89988	1.11126	1
60	.65606	.75471	.86929	1.15037	.66913	.74314	.90040	1.11061	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	49°				48°				

TABLE 10.—NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

′	42° Sin.	Cos.	Tan.	Cot.	43° Sin.	Cos.	Tan.	Cot.	′
0	.66913	.74314	.90040	1.11061	.68200	.73135	.93252	1.07237	60
1	.66935	.74295	.90093	1 10996	.68221	.73116	.93306	1.07174	59
2	.66956	.74276	.90146	1.10931	.68242	.73096	.93360	1.07112	58
3	.66978	.74256	.90199	1.10867	.68264	.73076	.93415	1.07049	57
4	.66999	.74237	.90251	1.10802	.68285	.73056	.93469	1.06987	56
5	.67021	.74217	.90304	1.10737	68306	.73036	.93524	1.06925	55
6	67043	.74198	.90357	1.10672	.68327	.73016	.93578	1.06862	54
7	.67064	.74178	.90410	1.10607	.68349	.72996	.93633	1.06800	53
8	.67086	.74159	.90463	1.10543	.68370	.72976	.93688	1.06738	52
9	.67107	.74139	.90516	1.10478	.68391	.72957	.93742	1.06676	51
10	.67129	.74120	.90569	1.10414	.68412	.72937	.93797	1.06613	50
11	.67151	.74100	.90621	1.10349	.68434	.72917	.93852	1.06551	49
12	.67172	.74080	.90674	1.10285	.68455	.72897	.93906	1.06489	48
13	.67194	.74061	90727	1.10220	.68476	.72877	.93961	1.06427	47
14	.67215	.74041	.90781	1.10156	.68497	.72857	.94016	1.06365	46
15	.67237	.74022	.90834	1.10091	.68518	.72837	.94071	1.06303	45
16	.67258	.74002	.90887	1.10027	.68539	.72817	.94125	1.06241	44
17	.67280	.73983	.90940	1.09963	.68561	.72797	.94180	1.06179	43
18	.67301	.73963	.90993	1.09899	.68582	.72777	.94235	1.06117	42
19	.67323	.73944	.91046	1.09834	.68603	.72757	.94290	1.06056	41
20	.67344	.73924	.91099	1.09770	.68624	.72737	.94345	1.05994	40
21	.67366	.73904	.91153	1.09706	.68645	.72717	.94400	1.05932	39
22	.67387	.73885	.91206	1.09642	.68666	.72697	.94455	1.05870	38
23	.67409	.73865	.91259	1.09578	.68688	.72677	.94510	1.05809	37
24	.67430	.73846	.91313	1.09514	.68709	.72657	.94565	1.05747	36
25	67452	.73826	.91366	1.09450	.68730	.72637	.94620	1.05685	35
26	.67473	.73806	.91419	1.09386	.68751	.72617	.94676	1.05624	34
27	.67495	.73787	.91473	1.09322	.68772	.72597	.94731	1.05562	33
28	.67516	.73767	.91526	1.09258	.68793	.72577	.94786	1.05501	32
29	.67538	.73747	.91580	1.09195	.68814	.72557	.94841	1.05439	31
30	.67559	.73728	.91633	1.09131	.68835	.72537	.94896	1.05378	30
31	.67580	.73708	.91687	1.09067	.68857	.72517	.94952	1.05317	29
32	.67602	.73688	.91740	1.09003	.68878	.72497	.95007	1.05255	28
33	.67623	.73669	.91794	1.08940	.68899	.72477	.95062	1.05194	27
34	.67645	.73649	.91847	1.08876	.68920	.72457	.95118	1.05133	26
35	.67666	.73629	.91901	1.08813	.68941	.72437	.95173	1.05072	25
36	.67688	.73610	.91955	1.08749	.68962	.72417	.95229	1.05010	24
37	.67709	.73590	.92008	1.08686	.68983	.72397	.95284	1.04949	23
38	.67730	73570	.92062	1.08622	.69004	.72377	.95340	1.04888	22
39	.67752	.73551	.92116	1.08559	.69025	.72357	.95395	1.04827	21
40	.67773	.73531	.92170	1.08496	.69046	.72337	.95451	1.04766	20
41	.67795	.73511	.92224	1.08432	.69067	.72317	.95506	1.04705	19
42	.67816	.73491	.92277	1.08369	.69088	.72297	.95562	1.04644	18
43	.67837	.73472	.92331	1.08306	.69109	.72277	.95618	1.04583	17
44	.67859	.73452	.92385	1.08243	.69130	.72257	.95673	1.04522	16
45	.67880	.73432	.92439	1.08179	.69151	.72236	.95729	1.04461	15
46	.67901	.73413	.92493	1.08116	.69172	.72216	.95785	1.04401	14
47	.67923	.73393	.92547	1.08053	.69193	.72196	.95841	1.04340	13
48	.67944	.73373	.92601	1.07990	.69214	.72176	.95897	1.04279	12
49	.67965	.73353	.92655	1.07927	.69235	.72156	.95952	1.04218	11
50	.67987	.73333	.92709	1.07864	.69256	.72136	.96008	1.04158	10
51	.68008	.73314	.92763	1.07801	.69277	.72116	.96064	1.04097	9
52	.68029	.73294	.92817	1.07738	.69298	.72095	.96120	1.04036	8
53	.68051	.73274	.92872	1.07676	.69319	.72075	.96176	1.03976	7
54	.68072	.73254	.92926	1.07613	.69340	.72055	.96232	1.03915	6
55	.68093	.73234	.92980	1.07550	.69361	.72035	.96288	1.03855	5
56	.68115	.73215	.93034	1.07487	.69382	.72015	.96344	1.03794	4
57	.68136	.73195	.93088	1.07425	.69403	.71995	.96400	1.03734	3
58	.68157	.73175	.93143	1.07362	.69424	.71974	96457	1.03674	2
59	.68179	.73155	.93197	1.07299	.69445	.71954	.96513	1.03613	1
60	.68200	.73135	.93252	1.07237	69466	71934	.96569	1.03553	0
′	Cos.	Sin.	Cot.	Tan.	Cos.	Sin.	Cot.	Tan.	′
	47°				46°				

44° 44°

′	Sin.	Cos.	Tan.	Cot.	′	′	Sin.	Cos.	Tan.	Cot.	′
0	.69466	.71934	.96569	1.03553	60	30	.70091	.71325	.98270	1.01761	30
1	.69487	.71914	.96625	1.03493	59	31	.70112	.71305	.98327	1.01702	29
2	.69508	.71894	.96681	1.03433	58	32	.70132	.71284	.98384	1.01642	28
3	.69529	.71873	.96738	1.03372	57	33	.70153	.71264	.98441	1.01583	27
4	.69549	.71853	.96794	1.03312	56	34	.70174	.71243	.98499	1.01524	26
5	.69570	.71833	.96850	1.03252	55	35	.70195	.71223	.98556	1.01465	25
6	.69591	.71813	.96907	1.03192	54	36	.70215	.71203	.98613	1.01406	24
7	.69612	.71792	.96963	1.03132	53	37	.70236	.71182	.98671	1.01347	23
8	.69633	.71772	.97020	1.03072	52	38	.70257	.71162	.98728	1.01288	22
9	.69654	.71752	.97076	1.03012	51	39	.70277	.71141	.98786	1.01229	21
10	.69675	.71732	.97133	1.02952	50	40	.70298	.71121	98843	1.01170	20
11	.69696	.71711	.97189	1.02892	49	41	.70319	.71100	.98901	1.01112	19
12	.69717	.71691	.97246	1.02832	48	42	.70339	.71080	.98958	1.01053	18
13	.69737	.71671	.97302	1.02772	47	43	.70360	.71059	.99016	1.00994	17
14	.69758	.71650	.97359	1.02713	46	44	.70381	.71039	.99073	1.00935	16
15	.69779	.71630	.97416	1.02653	45	45	.70401	.71019	.99131	1.00876	15
16	.69800	.71610	.97472	1.02593	44	46	.70422	.70998	.99189	1.00818	14
17	.69821	.71590	.97529	1.02533	43	47	70443	.70978	.99247	1.00759	13
18	.69842	.71569	.97586	1.02474	42	48	.70463	.70957	.99304	1.00701	12
19	.69862	.71549	.97643	1.02414	41	49	.70484	70937	.99362	1.00642	11
20	.69883	.71529	.97700	1.02355	40	50	.70505	.70916	.99420	1.00583	10
21	.69904	.71508	.97756	1.02295	39	51	.70525	.70896	.99478	1.00525	9
22	.69925	.71488	.97813	1.02236	38	52	.70546	.70875	.99536	1.00467	8
23	.69946	.71468	.97870	1.02176	37	53	.70567	.70855	.99594	1.00408	7
24	.69966	.71447	.97927	1.02117	36	54	.70587	.70834	.99652	1.00350	6
25	.69987	.71427	.97984	1.02057	35	55	.70608	.70813	.99710	1.00291	5
26	.70008	.71407	.98041	1.01998	34	56	.70628	.70793	.99768	1.00233	4
27	.70029	.71386	.98098	1.01939	33	57	.70649	.70772	.99826	1.00175	3
28	.70049	.71366	.98155	1.01879	32	58	.70670	.70752	.99884	1.00116	2
29	.70070	.71345	.98213	1.01820	31	59	.70690	.70731	.99942	1.00058	1
30	.70091	.71325	.98270	1.01761	30	60	.70711	.70711	1.00000	1.00000	0
′	Cos.	Sin.	Cot.	Tan.	′	′	Cos.	Sin.	Cot.	Tan.	′

45° 45°

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

′	0° Vers.	0° Ex. sec.	1° Vers.	1° Ex. sec.	2° Vers.	2° Ex. sec.	3° Vers.	3° Ex. sec.	′
0	.00000	.00000	.00015	.00015	.00061	.00061	.00137	.00137	0
1	.00000	.00000	.00016	.00016	.00062	.00062	.00139	.00139	1
2	.00000	.00000	.00016	.00016	.00063	.00063	.00140	.00140	2
3	.00000	.00000	.00017	.00017	.00064	.00064	.00142	.00142	3
4	.00000	.00000	.00017	.00017	.00065	.00065	.00143	.00143	4
5	.00000	.00000	.00018	.00018	.00066	.00066	.00145	.00145	5
6	.00000	.00000	.00018	.00018	.00067	.00067	.00146	.00147	6
7	.00000	.00000	.00019	.00019	.00068	.00068	.00148	.00148	7
8	.00000	.00000	.00020	.00020	.00069	.00069	.00150	.00150	8
9	.00000	.00000	.00020	.00020	.00070	.00070	.00151	.00151	9
10	.00000	.00000	.00021	.00021	.00071	.00072	.00153	.00153	10
11	.00001	.00001	.00021	.00021	.00073	.00073	.00154	.00155	11
12	.00001	.00001	.00022	.00022	.00074	.00074	.00156	.00156	12
13	.00001	.00001	.00023	.00023	.00075	.00075	.00158	.00158	13
14	.00001	.00001	.00023	.00023	.00076	.00076	.00159	.00159	14
15	.00001	.00001	.00024	.00024	.00077	.00077	.00161	.00161	15
16	.00001	.00001	.00024	.00024	.00078	.00078	.00162	.00163	16
17	.00001	.00001	.00025	.00025	.00079	.00079	.00164	.00164	17
18	.00001	.00001	.00026	.00026	.00081	.00081	.00166	.00166	18
19	.00002	.00002	.00026	.00026	.00082	.00082	.00168	.00168	19
20	.00002	.00002	.00027	.00027	.00083	.00083	.00169	.00169	20
21	.00002	.00002	.00028	.00028	.00084	.00084	.00171	.00171	21
22	.00002	.00002	.00028	.00028	00085	.00085	.00173	.00173	22
23	.00002	.00002	.00029	.00029	.00087	.00087	.00174	.00175	23
24	.00002	.00002	.00030	.00030	.00088	.00088	.00176	.00176	24
25	.00003	.00003	.00031	.00031	.00089	.00089	.00178	.00178	25
26	00003	.00003	.00031	.00031	00090	.00090	.00179	.00180	26
27	.00003	.00003	.00032	.00032	.00091	.00091	.00181	.00182	27
28	.00003	.00003	.00033	.00033	.00093	.00093	.00183	.00183	28
29	.00004	.00004	00034	.00034	.00094	.00094	.00185	.00185	29
30	.00004	.00004	.00034	.00034	00095	.00095	00187	.00187	30
31	.00004	.00004	.00035	.00035	.00096	.00097	00188	.00189	31
32	.00004	.00004	.00036	.00036	.00098	.00098	.00190	.00190	32
33	.00005	.00005	.00037	.00037	.00099	.00099	.00192	.00192	33
34	.00005	.00005	.00037	.00037	.00100	.00100	.00194	.00194	34
35	.00005	.00005	.00038	.00038	.00102	.00102	.00196	.00196	35
36	.00005	.00005	.00039	.00039	.00103	.00103	.00197	.00198	36
37	.00006	.00006	.00040	.00040	.00104	.00104	.00199	.00200	37
38	.00006	00006	.00041	.00041	.00106	.00106	.00201	.00201	38
39	.00006	.00006	.00041	.00041	.00107	.00107	.00203	.00203	39
40	.00007	.00007	.00042	.00042	.00108	.00108	.00205	.00205	40
41	.00007	.00007	.00043	.00043	.00110	.00110	.00207	.00207	41
42	.00007	.00007	.00044	.00044	.00111	.00111	.00208	.00209	42
43	00008	.00008	.00045	.00045	.00112	.00113	.00210	.00211	43
44	.00008	.00008	.00046	.00046	.00114	.00114	.00212	.00213	44
45	.00009	.00009	.00047	.00047	.00115	.00115	.00214	00215	45
46	00009	.00009	00048	.00048	.00117	.00117	.00216	.00216	46
47	.00009	.00009	.00048	.00048	.00118	.00118	.00218	.00218	47
47	.00010	.00010	.00049	.00049	.00119	.00120	.00220	.00220	48
49	00010	.00010	.00050	.00050	.00121	.00121	.00222	.00222	49
50	.00011	.00011	.00051	.00051	.00122	.00122	.00224	.00224	50
51	.00011	.00011	.00052	.00052	.00124	.00124	.00226	.00226	51
52	.00011	.00011	.00053	.00053	.00125	.00125	.00228	.00228	52
53	.00012	.00012	.00054	.00054	.00127	.00127	.00230	.00230	53
54	.00012	.00012	.00055	.00055	.00128	.00128	.00232	.00232	54
55	.00013	.00013	.00056	.00056	.00130	.00130	.00234	.00234	55
56	.00013	.00013	.00057	.00057	.00131	.00131	.00236	.00236	56
57	.00014	.00014	.00058	.00058	.00133	00133	.00238	.00238	57
58	.00014	.00014	.00059	.00059	.00134	.00134	.00240	.00240	58
59	.00015	.00015	.00060	00060	.00136	.00136	.00242	.00242	59
60	.00015	.00015	.00061	.00061	.00137	.00137	.00244	.00244	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

′	4° Vers.	4° Ex. sec.	5° Vers.	5° Ex. sec.	6° Vers.	6° Ex. sec.	7° Vers.	7° Ex. sec.	′
0	.00244	.00244	.00381	.00382	.00548	.00551	.00745	.00751	0
1	.00246	.00246	.00383	.00385	.00551	.00554	.00749	.00755	1
2	.00248	.00248	.00386	.00387	.00554	.00557	.00752	.00758	2
3	.00250	.00250	.00388	.00390	.00557	.00560	.00756	.00762	3
4	.00252	.00252	.00391	.00392	.00560	.00563	.00760	.00765	4
5	.00254	.00254	.00393	.00395	.00563	.00566	.00763	.00769	5
6	.00256	.00257	.00396	.00397	.00566	.00569	.00767	.00773	6
7	.00258	.00259	.00398	.00400	.00569	.00573	.00770	.00776	7
8	.00260	.00261	.00401	.00403	.00572	.00576	.00774	.00780	8
9	.00262	00263	.00404	.00405	.00576	.00579	.00778	.00784	9
10	.00264	.00265	.00406	.00408	.00579	.00582	.00781	.00787	10
11	.00266	.00267	.00409	.00411	.00582	.00585	.00785	.00791	11
12	.00269	.00269	.00412	.00413	00585	.00588	.00789	.00795	12
13	.00271	.00271	.00114	.00416	00588	.00592	00792	.00799	13
14	.00273	.00274	.00417	.00419	.00591	.00595	.00796	.00802	14
15	.00275	.00276	.00420	.00421	00594	.00598	.00800	.00806	15
16	.00277	.00278	.00422	.00424	.00598	.00601	.00803	.00810	16
17	.00279	.00280	.00425	.00427	.00601	.00604	.00807	.00813	17
18	.00281	.00282	.00428	.00429	.00604	.00608	.00811	.00817	18
19	.00284	.00284	.00430	.00432	.00607	.00611	.00814	.00821	19
20	.00286	.00287	.00433	.00435	.00610	00614	.00818	.00825	20
21	.00288	.00289	.00436	.00438	.00614	.00617	.00822	.00828	21
22	.00290	.00291	.00438	.00440	.00617	.00621	.00825	.00832	22
23	.00293	.00293	.00441	.00443	.00620	.00624	.00829	.00836	23
24	.00295	.00296	.00444	.00446	.00623	.00627	.00833	.00840	24
25	.00297	.00298	.00447	.00449	.00626	.00630	.00837	.00844	25
26	.00299	.00300	.00449	.00451	.00630	.00634	.00840	.00848	26
27	.00301	.00302	.00452	.00454	.00633	.00637	.00844	.00851	27
28	.00304	.00305	.00455	.00457	.00636	.00640	.00848	.00855	28
29	.00306	.00307	.00458	.00460	.00640	.00644	.00852	.00859	29
30	.00308	.00309	.00460	.00463	.00643	.00647	.00856	.00863	30
31	.00311	.00312	.00463	.00465	.00646	.00650	00859	.00867	31
32	.00313	.00314	.00466	.00468	.00649	.00654	.00863	.00871	32
33	.00315	.00316	.00469	.00471	.00653	.00657	.00867	.00875	33
34	.00317	.00318	.00472	.00474	.00656	.00660	.00871	.00878	34
35	.00320	.00321	.00474	.00477	.00659	.00664	.00875	.00882	35
36	.00322	.00323	.00477	.00480	.00663	.00667	.00878	.00886	36
37	.00324	.00326	.00480	.00482	.00666	.00671	.00882	.00890	37
38	.00327	.00328	.00483	.00485	.00669	.00674	.00886	.00894	38
39	.00329	.00330	.00486	.00488	.00673	.00677	.00890	.00898	39
40	.00332	.00333	.00489	.00491	.00676	.00681	.00894	.00902	40
41	.00334	.00335	.00492	.00494	.00680	.00684	.00898	.00906	41
42	.00336	.00337	.00494	.00497	.00683	.00688	.00902	.00910	42
43	.00339	.00340	.00497	.00500	.00686	.00691	.00906	.00914	43
44	.00341	.00342	.00500	.00503	.00690	.00695	.00909	.00918	44
45	.00343	.00345	.00503	.00506	.00693	.00698	.00913	.00922	45
46	.00346	.00347	.00506	.00509	.00607	.00701	.00917	.00926	46
47	.00348	.00350	.00509	.00512	.00700	.00705	00921	.00930	47
48	00351	.00352	.00512	.00515	.00703	.00708	00925	.00934	48
49	00353	.00354	.00515	.00518	.00707	.00712	.00929	.00938	49
50	.00356	.00357	.00518	.00521	.00710	.00715	.00933	.00942	50
51	.00358	.00359	.00521	.00524	.00714	.00719	00937	.00946	51
52	00361	.00362	.00524	.00527	.00717	.00722	.00941	.00950	52
53	.00363	.00364	.00527	.00530	.00721	.00726	.00945	.00954	53
54	.00365	.00367	.00530	.00533	.00724	.00730	.00949	.00958	54
55	.00368	.00369	.00533	.00536	.00728	.00733	.00953	.00962	55
56	.00370	.00372	.00536	.00539	.00731	.00737	.00957	.00966	56
57	.00373	.00374	.00539	.00542	.00735	.00740	.00961	.00970	57
58	.00375	.00377	.00542	.00545	.00738	.00744	.00965	.00975	58
59	.00378	.00379	00545	00548	.00742	.00747	.00969	.00979	59
60	.00381	.00382	00548	.00551	.00745	.00751	.00973	.00983	60

	8°		9°		10°		11°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	′
0	.00973	.00983	.01231	.01247	.01519	.01543	.01837	.01872	0
1	.00977	.00987	.01236	.01251	.01524	.01548	.01843	.01877	1
2	.00981	.00991	.01240	.01256	.01529	.01553	.01848	.01883	2
3	.00985	.00995	.01245	.01261	.01534	.01558	.01854	.01889	3
4	.00989	.00999	.01249	.01265	.01540	.01564	.01860	.01895	4
5	00994	.01004	.01254	.01270	.01545	.01569	.01865	.01901	5
6	.00998	.01008	.01259	.01275	.01550	.01574	.01871	.01906	6
7	.01002	.01012	.01263	.01279	.01555	.01579	.01876	.01912	7
8	.01006	.01016	.01268	.01284	.01560	.01585	.01382	.01918	8
9	.01010	.01020	.01272	.01289	.01565	.01590	.01888	.01924	9
10	.01014	.01024	.01277	.01294	.01570	.01595	.01893	.01930	10
11	.01018	.01029	.01282	.01298	.01575	.01601	.01899	.01936	11
12	.01022	.01033	.01286	.01303	.01580	.01606	.01904	.01941	12
13	.01027	.01037	.01291	.01308	.01586	.01611	.01910	.01947	13
14	.01031	.01041	.01296	.01313	.01591	.01616	.01916	.01953	14
15	.01035	.01046	.01300	.01318	.01596	.01622	.01921	.01959	15
16	.01039	.01050	.01305	.01322	.01601	.01627	.01927	.01965	16
17	.01043	.01054	.01310	.01327	.01606	.01633	.01933	.01971	17
18	.01047	.01059	.01314	.01332	.01612	.01638	.01939	.01977	18
19	.01052	.01063	.01319	.01337	.01617	.01643	.01944	.01983	19
20	.01056	.01067	.01324	.01342	.01622	.01649	.01950	.01989	20
21	01060	.01071	.01329	.01346	.01627	.01654	.01956	.01995	21
22	01064	.01076	.01333	.01351	.01632	.01659	.01961	.02001	22
23	.01069	.01080	.01338	.01356	.01638	.01665	.01967	.02007	23
24	.01073	.01084	.01343	.01361	.01643	.01670	.01973	.02013	24
25	.01077	.01089	.01348	.01366	.01648	.01676	.01979	.02019	25
26	.01081	.01093	.01352	.01371	.01653	.01681	.01984	.02025	26
27	.01086	.01097	.01357	.01376	.01659	.01687	.01990	.02031	27
28	.01090	.01102	.01362	.01381	.01664	.01692	.01996	.02037	28
29	.01094	.01106	.01367	.01386	.01669	.01698	.02002	.02043	29
30	.01098	.01111	.01371	.01391	.01675	.01703	.02008	.02049	30
31	.01103	.01115	.01376	.01395	.01680	.01709	.02013	.02055	31
32	.01107	.01119	.01381	.01400	.01685	.01714	.02019	.02061	32
33	.01111	.01124	.01386	.01405	.01690	.01720	.02025	.02067	33
34	.01116	.01128	.01391	.01410	.01696	.01725	.02031	.02073	34
35	.01120	.01133	.01396	.01415	.01701	.01731	.02037	.02079	35
36	.01124	.01137	.01400	.01420	.01706	.01736	.02042	.02085	36
37	.01129	.01142	.01405	.01425	.01712	.01742	.02048	.02091	37
38	.01133	.01146	.01410	.01430	.01717	.01747	.02054	.02097	38
39	.01137	.01151	.01415	.01435	.01723	.01753	.02060	.02103	39
40	.01142	.01155	.01420	.01440	.01728	.01758	.02066	.02110	40
41	.01146	.01160	.01425	.01445	.01733	.01764	.02072	.02116	41
42	.01151	.01164	.01430	.01450	.01739	.01769	.02078	.02122	42
43	.01155	.01169	.01435	.01455	.01744	.01775	.02084	.02128	43
44	.01159	01173	.01439	.01461	.01750	.01781	.02090	.02134	44
45	.01164	.01178	.01444	.01466	.01755	01786	.02095	.02140	45
46	.01168	.01182	.01449	.01471	.01760	.01792	.02101	.02146	46
47	.01173	.01187	.01454	.01476	.01766	.01793	.02107	.02153	47
48	.01177	.01191	.01459	.01481	.01771	.01803	.02113	.02159	48
49	.01182	.01196	.01464	.01486	.01777	.01809	.02119	.02165	49
50	.01186	.01200	.01469	.01491	.01782	.01815	.02125	.02171	50
51	.01191	.01205	.01474	.01496	.01788	.01820	.02131	.02178	51
52	.01195	.01209	.01479	.01501	.01793	.01826	.02137	.02184	52
53	.01200	.01214	.01484	.01506	.01799	.01832	.02143	.02190	53
54	.01204	.01219	.01489	.01512	.01804	.01837	.02149	.02196	54
55	.01209	.01223	.01494	.01517	.01810	.01843	.02155	.02203	55
56	.01213	.01228	.01499	.01522	.01815	.01849	.02161	.02209	56
57	.01218	.01233	.01504	.01527	.01821	.01854	.02167	.02215	57
58	.01222	.01237	.01509	.01532	.01826	.01860	.02173	.02221	58
59	.01227	.01242	.01514	.01537	.01832	.01866	.02179	.02228	59
60	01231	.01247	.01519	.01543	.01837	.01872	.02185	.02234	60

′	12° Vers.	12° Ex. sec.	13° Vers.	13° Ex. sec.	14° Vers.	14° Ex. sec.	15° Vers.	15° Ex. sec.	′
0	.02185	.02234	.02563	.02630	.02970	.03061	.03407	.03528	0
1	.02191	.02240	.02570	.02637	.02977	.03069	.03415	.03536	1
2	.02197	.02247	.02576	.02644	.02985	.03076	.03422	.03544	2
3	.02203	.02253	.02583	.02651	.02992	.03084	.03430	.03552	3
4	.02210	.02259	.02589	.02658	.02999	.03091	.03438	.03560	4
5	.02216	.02266	.02596	.02665	.03006	.03099	.03445	.03568	5
6	.02222	.02272	.02602	.02672	.03013	.03106	.03453	.03576	6
7	.02228	.02279	.02609	.02679	.03020	.03114	03460	.03584	7
8	.02234	.02285	.02616	.02686	.03027	.03121	.03468	.03592	8
9	.02240	.02291	.02622	.02693	.03034	.03129	.03476	.03601	9
10	.02246	.02298	.02629	.02700	.03041	.03137	.03483	.03609	10
11	.02252	.02304	.02635	.02707	.03048	.03144	.03491	.03617	11
12	.02258	.02311	.02642	.02714	.03055	.03152	.03498	.03625	12
13	.02265	.02317	.02649	.02721	.03063	.03159	.03506	.03633	13
14	.02271	.02323	.02655	.02728	.03070	.03167	.03514	.03642	14
15	.02277	.02330	.02662	.02735	.03077	.03175	.03521	.03650	15
16	.02283	.02336	.02669	.02742	.03084	.03182	.03529	.03658	16
17	.02289	.02343	.02675	.02749	.03091	.03190	.03537	.03666	17
18	.02295	.02349	.02682	.02756	.03098	.03198	.03544	.03674	18
19	.02302	.02356	.02689	.02763	.03106	.03205	.03552	.03683	19
20	.02308	.02362	.02696	.02770	.03113	.03213	.03560	.03691	20
21	.02314	.02369	.02702	.02777	.03120	.03221	.03567	.03699	21
22	.02320	.02375	.02709	.02784	.03127	.03228	.03575	.03708	22
23	.02327	.02382	.02716	.02791	.03134	.03236	.03583	.03716	23
24	.02333	.02388	.02722	.02799	.03142	.03244	.03590	.03724	24
25	.02339	.02395	.02729	.02806	.03149	.03251	.03598	.03732	25
26	.02345	.02402	.02736	.02813	.03156	.03259	.03606	.03741	26
27	.02352	.02408	.02743	.02820	.03163	.03267	.03614	.03749	27
28	.02358	.02415	.02749	.02827	.03171	.03275	.03621	.03758	28
29	.02364	.02421	.02756	.02834	.03178	.03282	.03629	.03766	29
30	.02370	.02428	.02763	.02842	.03185	.03290	.03637	.03774	30
31	.02377	.02435	.02770	.02849	.03193	.03298	.03645	.03783	31
32	.02383	.02441	.02777	.02856	.03200	.03306	.03653	.03791	32
33	.02389	.02448	.02783	.02863	.03207	.03313	.03660	.03799	33
34	.02396	.02454	.02790	.02870	.03214	.03321	.03668	.03808	34
35	.02402	.02461	.02797	.02878	.03222	.03329	.03676	.03816	35
36	.02408	.02468	.02804	.02885	.03229	.03337	.03684	.03825	36
37	.02415	.02474	.02811	.02892	.03236	.03345	.03692	.03833	37
38	.02421	.02481	.02818	.02899	.03244	.03353	.03699	.03842	38
39	.02427	.02488	.02824	.02907	.03251	.03360	.03707	.03850	39
40	.02434	.02494	.02831	.02914	.03258	.03368	03715	.03858	40
41	.02440	.02501	.02838	.02921	.03266	.03376	.03723	.03867	41
42	.02447	.02508	.02845	.02928	.03273	.03384	.03731	.03875	42
43	.02453	.02515	02852	.02936	.03281	.03392	.03739	.03884	43
44	.02459	.02521	.02859	.02943	.03288	.03400	.03747	.03892	44
45	.02466	.02528	.02866	.02950	.03295	.03408	.03754	.03901	45
46	.02472	.02535	.02873	.02958	.03303	.03416	.03762	.03909	46
47	.02479	.02542	.02880	.02965	.03310	.03424	03770	.03918	47
48	.02485	.02548	.02887	.02972	.03318	.03432	.03778	.03927	48
49	.02492	.02555	.02894	.02980	.03325	.03439	.03786	.03935	49
50	.02498	.02562	.02900	.02987	.03333	.03447	.03794	.03944	50
51	.02504	.02569	.02907	.02994	.03340	.03455	.03802	.03952	51
52	.02511	.02576	.02914	.03002	.03347	.03463	.03810	.03961	52
53	.02517	.02582	.02921	.03009	.03355	.03471	.03818	.03969	53
54	.02524	.02589	.02928	.03017	.03362	.03479	.03826	.03978	54
55	.02530	.02596	.02935	.03024	.03370	.03487	.03834	.03987	55
56	.02537	.02603	.02942	.03032	.03377	.03495	.03842	.03995	56
57	.02543	.02610	.02949	.03039	.03385	.03503	.03850	.04004	57
58	.02550	.02617	.02956	03046	.03392	.03512	.03858	.04013	58
59	.02556	.02624	.02963	.03054	.03400	.03520	.03866	.04021	59
60	.02563	.02630	.02970	.03061	03407	.03528	.03874	.04030	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

	16°		17°		18°		19°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec	′
0	.03874	.04030	.04370	.04569	.04894	.05146	.05448	.05762	0
1	.03882	.04039	.04378	.04578	.04903	.05156	.05458	.05773	1
2	.03890	.04047	.04387	.04588	.04912	.05166	.05467	.05783	2
3	.03898	.04056	.04395	.04597	.04921	.05176	.05477	.05794	3
4	.03906	.04065	.04404	.04606	.04930	.05186	.05486	.05805	4
5	03914	.04073	.04412	.04616	.04939	.05196	.05496	.05815	5
6	03922	.04082	.04421	.04625	.04948	.05206	.05505	.05826	6
7	.03930	.04091	.04429	04635	.04957	.05216	.05515	.05836	7
8	.03938	.04100	.04438	.04644	.04967	.05226	.05524	.05847	8
9	.03946	.04108	.04446	.04653	.04976	.05236	.05534	.05858	9
10	.03954	.04117	.04455	.04663	.04985	.05246	.05543	.05869	10
11	.03963	.04126	.04464	.04672	.04904	.05256	.05553	.05879	11
12	.03971	.04135	.04472	.04682	.05003	.05266	.05562	.05890	12
13	.03979	.04144	.04481	.04691	.05012	.05276	.05572	.05901	13
14	.03987	.04152	.04489	.04700	.05021	.05286	.05582	.05911	14
15	.03995	.04161	.04498	.04710	.05030	.05297	.05591	.05922	15
16	.04003	.04170	.04507	.04719	.05039	.05307	.05601	.05933	16
17	.04011	.04179	.04515	.04729	.05048	.05317	.05610	.05944	17
18	.04019	.04188	.04524	.04738	.05057	.05327	.05620	.05955	18
19	.04028	.04197	.04533	.04748	.05067	.05337	.05630	.05965	19
20	.04036	.04206	.04541	.04757	.05076	.05347	.05639	.05976	20
21	.04044	.04214	.04550	.04767	.05085	.05357	.05649	.05987	21
22	.04052	.04223	.04559	.04776	.05094	.05367	.05658	.05998	22
23	04060	.04232	.04567	.04786	.05103	.05378	.05668	.06009	23
24	.04069	.04241	.04576	.04795	.05112	.05388	.05678	.06020	24
25	.04077	.04250	.04585	.04805	.05122	05398	.05687	.06030	25
26	.04085	.04259	.04593	.04815	.05131	.05408	.05697	.06041	26
27	.04093	.04268	.04602	.04824	.05140	.05418	05707	.06052	27
28	04102	.04277	.04611	04834	.05149	.05429	.05716	.06063	28
29	.04110	.04286	.04620	.04843	.05158	.05439	.05726	.06074	29
30	.04118	.04295	.04628	.04853	.05168	.05449	.05736	.06085	30
31	.04126	.04304	.04637	.04863	.05177	.05460	.05746	.06096	31
32	.04135	.04313	.04646	.04872	.05186	.05470	.05755	.06107	32
33	.04143	.04322	04655	.04882	.05195	.05480	.05765	.06118	33
34	.04151	.04331	.04663	.04891	.05205	.05490	.05775	.06129	34
35	.04159	.04340	.04672	.04901	.05214	.05501	.05785	.06140	35
36	.04168	.04349	.04681	.04911	.05223	.05511	.05794	.06151	36
37	.04176	.04358	.04690	04920	.05232	.05521	.05804	.06162	37
38	.04184	.04367	.04699	.04930	.05242	.05532	.05814	.06173	38
39	.04193	.04376	.04707	.04940	.05251	.05542	.05824	.06184	39
40	.04201	.04385	.04716	.04950	.05260	.05552	.05833	.06195	40
41	.04209	.04394	.04725	.04959	.05270	.05563	.05843	.06206	41
42	.04218	.04403	.04734	.04969	.05279	.05573	.05853	.06217	42
43	.04226	.04413	.04743	.04979	.05288	.05584	.05863	.06228	43
44	.04234	.04422	.04752	.04989	.05298	.05594	.05873	.06239	44
45	.04243	.04431	.04760	.04998	.05307	.05604	.05882	.06250	45
46	.04251	.04440	.04769	.05008	.05316	.05615	.05892	.06261	46
47	.04260	.04449	.04778	.05018	.05326	.05625	.05902	.06272	47
48	.04268	.04458	.04787	.05028	.05335	.05636	.05912	.06283	48
49	.04276	.04468	.04796	.05038	.05344	.05646	.05922	.06295	49
50	.04285	.04477	.04805	.05047	.05354	.05657	.05932	.06306	50
51	.04293	.04486	.04814	.05057	.05363	.05667	.05942	.06317	51
52	.04302	.04495	.04323	.05067	.05373	.05678	.05951	.06328	52
53	.04310	.04504	.04832	.05077	.05382	.05688	.05961	.06339	53
54	.04319	.04514	.04841	.05087	.05391	.05699	.05971	.06350	54
55	.04327	.04523	.04850	.05097	.05401	.05709	.05981	.06362	55
56	.04336	.04532	.04858	.05107	.05410	.05720	.05991	.06373	56
57	.04344	.04541	.04867	.05116	.05420	.05730	.06001	.06384	57
58	.04353	.04551	.04876	.05126	.05429	.05741	.06011	.06395	58
59	.04361	.04560	04885	.05136	.05439	.05751	.06021	.06407	59
60	.04370	.04569	.04894	.05146	.05448	.05762	.06031	.06418	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

	20°		21°		22°		23°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	′
0	.06031	.06418	.06642	.07115	.07282	.07853	.07950	.08636	0
1	.06041	.06429	.06652	.07126	.07293	.07866	.07961	.08649	1
2	.06051	.06440	.06663	.07138	.07303	.07879	.07972	.08663	2
3	.06061	.06452	.06673	.07150	.07314	.07892	.07984	.08676	3
4	.06071	06463	.06684	.07162	.07325	.07904	.07995	.08690	4
5	.06081	.06474	.06694	.07174	.07336	.07917	.08006	.08703	5
6	.06091	.06486	.06705	.07186	.07347	.07930	.08018	.08717	6
7	.06101	06497	.06715	.07199	.07358	.07943	.08029	.08730	7
8	.06111	.06508	.06726	.07211	.07369	.07955	.08041	.08744	8
9	06121	.06520	.06736	.07223	.07380	.07968	.08052	.08757	9
10	.06131	.06531	.06747	.07235	.07391	.07981	.08064	.08771	10
11	.06141	.06542	.06757	.07247	.07402	.07994	.08075	.08784	11
12	.06151	.06554	.06768	.07259	.07413	.08006	.08086	.08798	12
13	.06161	.06565	.06778	.07271	.07424	.08019	.08098	.08811	13
14	.06171	.06577	.06789	.07283	.07435	.08032	.08109	.08825	14
15	.06181	.06588	.06799	.07295	.07446	.08045	.08121	.08839	15
16	.06191	.06600	.06810	.07307	.07457	.08058	.08132	.08852	16
17	.06201	.06611	.06820	.07320	.07468	.08071	.08144	.08866	17
18	.06211	.06622	.06831	.07332	.07479	.08084	.08155	.08880	18
19	.06221	.06634	.06841	.07344	.07490	.08097	.08167	.08893	19
20	.06231	.06645	.06852	.07356	.07501	.08109	.08178	.08907	20
21	.06241	.06657	.06863	.07368	.07512	.08122	.08190	.08921	21
22	.06252	.06668	.06873	.07380	.07523	.08135	.08201	08934	22
23	.06262	.06680	.06884	.07393	.07534	.08148	.08213	.08948	23
24	.06272	.06691	.06894	.07405	.07545	.08161	.08225	.08962	24
25	.06282	.06703	.06905	.07417	.07556	.08174	.08236	.08975	25
26	.06292	.06715	.06916	.07429	.07568	.08087	08248	.08989	26
27	.06302	.06726	.06926	.07442	.07579	.08200	.08259	.09003	27
28	.06312	.06738	.06937	.07454	.07590	.08213	.08271	.09017	28
29	.06323	.06749	.06948	.07466	.07601	.08226	.08282	.09030	29
30	.06333	.06761	.06958	.07479	.07612	.08239	.08294	.09044	30
31	.06343	.06773	.06969	.07491	.07623	.08252	.08306	.09058	31
32	.06353	.06784	.06980	.07503	.07634	.08265	.08317	.09072	32
33	.06363	.06796	.06990	.07516	.07645	.08278	.08329	.09086	33
34	.06374	.06807	.07001	.07528	.07657	.08291	.08340	.09099	34
35	.06384	.06819	.07012	.07540	.07668	.08305	.08352	.09113	35
36	.06394	.06831	.07022	.07553	.07679	.08318	.08364	.09127	36
37	.06404	.06843	.07033	.07565	.07690	.08331	.08375	.09141	37
38	.06415	.06854	.07044	.07578	.07701	.08344	.08387	.09155	38
39	.06425	.06866	.07055	.07590	.07713	.08357	.08399	.09169	39
40	.06435	.06878	.07065	.07602	.07724	.08370	.08410	.09183	40
41	.06445	.06889	.07076	.07615	.07735	.08383	.08422	.09197	41
42	.06456	.06901	.07087	.07627	.07746	.08397	08434	.09211	42
43	.06466	.06913	.07098	.07640	.07757	.08410	.08445	.09224	43
44	.06476	.06925	.07108	.07652	.07769	.08423	.08457	.09238	44
45	06486	.06936	.07119	.07665	.07780	.08436	08469	.09252	45
46	.06497	.06948	.07130	.07677	.07791	.08449	.08481	.09266	46
47	.06507	.06960	.07141	.07690	.07802	.08463	.08492	.09280	47
48	.06517	.06972	.07151	.07702	.07814	.08476	.08504	.09294	48
49	.06528	.06984	.07162	.07715	.07825	.08489	.08516	09308	49
50	.06538	.06995	.07173	.07727	.07836	.08503	.08528	.09323	50
51	.06548	.07007	.07184	.07740	07848	.08516	.08539	.09337	51
52	.06559	.07019	.07195	.07752	07859	.08529	.08551	.09351	52
53	.06569	.07031	.07206	.07765	.07870	.08542	.08563	.09365	53
54	.06580	.07043	.07216	.07778	.07881	.08556	.08575	09379	54
55	.06590	.07055	.07227	.07790	.07893	.08569	.08586	.09393	55
56	.06600	.07067	.07238	.07803	.07904	.08582	.08598	.09407	56
57	.06611	.07079	.07249	.07816	.07915	.08596	.08610	.09421	57
58	.06621	.07091	.07260	.07828	.07927	.08069	.08622	.09435	58
59	.06632	.07103	.07271	.07841	.07938	.08623	08634	.09449	59
60	.06642	.07115	.07282	.07853	.07950	.08636	.08645	.09464	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

	24°		25°		26°		27°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	′
0	08645	.09464	.09369	.10338	.10121	.11260	.10899	.12233	0
1	.08657	.09478	.09382	.10353	.10133	.11276	.10913	.12249	1
2	.08669	.09492	.09394	.10368	.10146	.11292	.10926	.12266	2
3	.08681	.09506	.09406	.10383	.10159	.11308	.10939	.12283	3
4	.08693	.09520	.09418	.10398	.10172	.11323	.10952	.12299	4
5	.08705	.09535	.09431	.10413	.10184	.11339	.10965	.12316	5
6	.08717	.09549	.09443	.10428	.10197	11355	.10979	.12333	6
7	.08728	.09563	.09455	.10443	.10210	.11371	.10992	.12349	7
8	.08740	.09577	09468	.10458	.10223	.11387	.11005	.12366	8
9	.08752	.09592	.09480	.10473	.10236	.11403	.11019	.12383	9
10	.08764	.09606	.09493	.10488	.10248	.11419	.11032	.12400	10
11	.08776	.09620	.09505	.10503	.10261	.11435	.11045	.12416	11
12	.08788	.09635	.09517	.10518	.10274	.11451	.11058	.12433	12
13	.08800	.09649	.09530	.10533	.10287	.11467	11072	.12450	13
14	.08812	.09663	.09542	.10549	.10300	.11483	.11085	.12467	14
15	.08824	.09678	09554	.10564	.10313	.11499	.11098	.12484	15
16	.08836	.09692	.09567	.10579	.10326	11515	.11112	.12501	16
17	.08848	.09707	.09579	.10594	.10338	.11531	.11125	.12518	17
18	.08860	.09721	.09592	.10609	.10351	.11547	.11138	.12534	18
19	.08872	.09735	.09604	.10625	.10364	.11563	.11152	.12551	19
20	.08884	.09750	.09617	.10640	.10377	.11579	.11165	.12568	20
21	.08896	.09764	.09629	.10655	.10390	.11595	.11178	.12585	21
22	.08908	.09779	.09642	.10670	.10403	.11611	.11192	.12602	22
23	.08920	.09793	.09654	.10686	.10416	.11627	.11205	.12619	23
24	.08932	.09808	.09666	.10701	10429	.11643	.11218	12636	24
25	.08944	.09822	.09679	.10716	.10442	.11659	.11232	.12653	25
26	.08956	.09837	.09691	.10731	.10455	.11675	.11245	.12670	26
27	.08968	.09851	.09704	.10747	.10468	.11691	.11259	.12687	27
28	.08980	.09866	.09716	.10762	.10481	.11708	.11272	.12704	28
29	.08992	.09880	.09729	.10777	.10494	.11724	.11285	.12721	29
30	.09004	.09895	.09741	.10793	.10507	.11740	.11299	.12738	30
31	.09016	.09909	.09754	.10808	.10520	.11756	.11312	.12755	31
32	.09028	.09924	.09767	.10824	.10533	.11772	.11326	.12772	32
33	.09040	.09939	.09779	.10839	.10546	.11789	.11339	.12789	33
34	.09052	.09953	.09792	.10854	.10559	.11805	.11353	.12807	34
35	.09064	.09968	.09804	.10870	.10572	.11821	.11366	.12824	35
36	.09076	.09982	09817	.10885	.10585	.11838	.11380	.12841	36
37	.09089	.09997	09829	.10901	.10598	.11854	.11393	.12858	37
38	.09101	.10012	.09842	.10916	.10611	.11870	.11407	.12875	38
39	.09113	.10026	.09854	.10932	.10624	.11886	.11420	.12892	39
40	.09125	.10041	.09867	.10947	.10637	.11903	.11434	.12910	40
41	.09137	.10055	.09880	.10963	.10650	.11919	.11447	.12927	41
42	.09149	.10071	.09892	.10978	.10663	.11936	.11461	.12944	42
43	.09161	.10085	.09905	.10994	.10676	.11952	.11474	.12961	43
44	.09174	.10100	.09918	.11009	.10689	.11968	.11488	.12979	44
45	.09186	.10115	.09930	.11025	.10702	.11985	.11501	.12996	45
46	.09198	.10130	.09943	.11041	.10715	.12001	.11515	.13013	46
47	.09210	.10144	.09955	.11056	.10728	.12018	.11528	.13031	47
48	.09222	.10159	.09968	.11072	.10741	.12034	.11542	.13048	48
49	.09234	.10174	.09981	.11087	.10755	.12051	.11555	13065	49
50	.09247	.10189	.09993	.11103	.10768	.12067	.11569	.13083	50
51	.09259	.10204	.10006	.11119	.10781	.12084	.11583	.13100	51
52	.09271	.10218	.10019	.11134	10794	.12100	.11596	.13117	52
53	.09283	.10233	.10032	.11150	.10807	.12117	11610	.13135	53
54	.09296	.10248	.10044	.11166	10820	.12133	.11623	13152	54
55	.09308	.10263	.10057	.11181	.10833	.12150	.11637	.13170	55
56	.09320	.10278	.10070	.11197	.10847	.12166	.11651	.13187	56
57	.09332	.10293	.10082	.11213	.10860	.12183	.11664	.13205	57
58	.09345	.10308	.10095	.11229	.10873	.12199	.11678	.13222	58
59	.09357	.10323	.10108	.11244	.10886	.12216	.11692	.13240	59
60	.09369	.10338	.10121	.11260	.10899	.12233	.11705	.13257	60

	28°		29°		30°		31°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	′
0	.11705	.13257	.12538	.14335	.13397	.15470	.14283	.16663	0
1	.11719	.13275	.12552	.14354	.13412	.15489	.14298	.16684	1
2	.11733	.13292	.12566	.14372	.13427	.15509	.14313	.16704	2
3	.11746	.13310	.12580	.14391	.13441	.15528	.14328	.16725	3
4	.11760	.13327	.12595	.14409	.13456	.15548	.14343	.16745	4
5	.11774	.13345	.12609	.14428	.13470	.15567	.14358	.16766	5
6	.11787	.13362	.12623	.14446	.13485	.15587	.14373	.16786	6
7	.11801	.13380	.12637	.14465	.13499	.15606	.14388	.16806	7
8	.11815	.13398	.12651	.14483	.13514	.15626	.14403	.16827	8
9	.11828	.13415	.12665	.14502	.13529	.15645	.14418	.16848	9
10	.11842	.13433	.12679	.14521	.13543	.15665	.14433	.16868	10
11	.11856	.13451	.12694	.14539	.13558	.15684	.14449	.16889	11
12	.11870	.13468	.12708	.14558	.13573	.15704	.14464	.16909	12
13	.11883	.13486	.12722	.14576	.13587	.15724	.14479	.16930	13
14	.11897	.13504	.12736	.14595	.13602	.15743	.14494	.16950	14
15	.11911	.13521	.12750	.14614	.13616	.15763	.14509	.16971	15
16	.11925	.13539	.12765	.14632	.13631	.15782	.14524	.16992	16
17	.11938	.13557	.12779	.14651	.13646	.15802	.14539	.17012	17
18	.11952	.13575	.12793	.14670	.13660	.15822	.14554	.17033	18
19	.11966	.13593	.12807	.14689	.13675	.15841	.14569	.17054	19
20	.11980	.13610	.12822	.14707	.13690	.15861	.14584	.17075	20
21	.11994	.13628	.12836	.14726	.13705	.15881	.14599	.17095	21
22	.12007	.13646	.12850	.14745	.13719	.15901	.14615	.17116	22
23	.12021	.13664	.12864	.14764	.13734	.15920	.14630	.17137	23
24	.12035	.13682	.12879	.14782	.13749	.15940	.14645	.17158	24
25	.12049	.13700	.12893	.14801	.13763	.15960	.14660	.17178	25
26	.12063	.13718	.12907	.14820	.13778	.15980	.14675	.17199	26
27	.12077	.13735	.12921	.14839	.13793	.16000	.14690	.17220	27
28	.12091	.13753	.12936	.14858	.13808	.16019	.14706	.17241	28
29	.12104	.13771	.12950	.14877	.13822	.16039	.14721	.17262	29
30	.12118	.13789	.12964	.14896	.13837	.16059	.14736	.17283	30
31	.12132	.13807	.12979	.14914	.13852	.16079	.14751	.17304	31
32	.12146	.13825	.12993	.14933	.13867	.16099	.14766	.17325	32
33	.12160	.13843	.13007	.14952	.13881	.16119	.14782	.17346	33
34	12174	.13861	.13022	.14971	.13896	.16139	.14797	.17367	34
35	.12188	.13879	.13036	.14990	.13911	.16159	.14812	.17388	35
36	.12202	.13897	.13051	.15009	.13926	.16179	.14827	.17409	36
37	.12216	.13916	.13065	.15028	.13941	.16199	.14843	.17430	37
38	.12230	.13934	.13079	.15047	.13955	.16219	.14858	.17451	38
39	.12244	13952	.13094	.15066	.18970	.16239	.14873	.17472	39
40	.12257	.13970	.13108	.15085	13985	.16259	.14888	.17493	40
41	.12271	.13988	.13122	.15105	.14000	.16279	.14904	.17514	41
42	.12285	.14006	.13137	.15124	.14015	.16299	.14919	.17535	42
43	.12299	.14024	.13151	.15143	.14030	.16319	.14934	.17556	43
44	.12313	.14042	.13166	.15162	.14044	.16339	.14949	.17577	44
45	.12327	.14061	.13180	.15181	.14059	16359	.14965	.17598	45
46	.12341	.14079	.13195	.15200	14074	.16380	.14980	.17620	46
47	.12355	.14097	.13209	.15219	.14089	.16400	.14995	.17641	47
48	.12369	.14115	.13223	.15239	.14104	.16420	.15011	.17662	48
49	12383	.14134	.13238	.15258	.14119	.16440	.15026	.17683	49
50	.12397	.14152	.13252	.15277	.14134	.16460	15041	.17704	50
51	.12411	.14170	.13267	.15296	.14149	16481	.15057	.17726	51
52	.12425	.14188	.13281	.15315	.14164	.16501	.15072	.17747	52
53	.12439	.14207	.13296	.15335	.14179	.16521	.15087	.17768	53
54	.12454	.14225	.13310	.15354	.14194	.16541	.15103	.17790	54
55	.12468	.14243	.13325	.15373	.14208	.16562	.15118	.17811	55
56	.12482	.14262	.13339	.15393	.14223	.16582	.15134	.17832	56
57	.12496	.14280	.13354	.15412	.14238	.16602	.15149	.17854	57
58	.12510	.14299	.13368	.15431	.14253	.16623	.15164	.17875	58
59	.12524	.14317	.13383	.15451	.14268	.16643	.15180	.17896	59
60	.12538	.14335	.13397	.15470	.14283	.16663	.15195	.17918	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

′	32° Vers.	32° Ex. sec.	33° Vers.	33° Ex. sec.	34° Vers.	34° Ex. sec.	35° Vers.	35° Ex. sec.	′
0	.15195	.17918	.16133	.19236	.17096	.20622	.18085	.22077	0
1	.15211	.17939	.16149	.19259	.17113	.20645	.18101	.22102	1
2	.15226	.17961	.16165	.19281	.17129	.20669	.18118	.22127	2
3	.15241	.17982	.16181	.19304	.17145	.20693	.18135	.22152	3
4	.15257	.18004	.16196	.19327	.17161	.20717	.18152	.22177	4
5	.15272	.18025	.16212	.19349	.17178	.20740	.18168	.22202	5
6	.15288	.18047	.16228	.19372	.17194	.20764	.18185	.22227	6
7	.15303	.18068	.16244	.19394	.17210	.20788	.18202	.22252	7
8	.15319	.18090	.16260	.19417	.17227	.20812	.18218	.22277	8
9	.15334	.18111	.16276	.19440	.17243	.20836	.18235	.22302	9
10	.15350	.18133	.16292	.19463	.17259	.20859	.18252	.22327	10
11	.15365	.18155	.16308	.19485	.17276	.20883	.18269	.22352	11
12	.15381	.18176	.16324	.19508	.17292	.20907	.18286	.22377	12
13	.15396	.18198	.16340	.19531	.17308	.20931	.18302	.22402	13
14	.15412	.18220	.16355	.19554	.17325	.20955	.18319	.22428	14
15	.15427	.18241	.16371	.19576	.17341	.20979	.18336	.22453	15
16	.15443	.18263	.16387	.19599	.17357	.21003	.18353	.22478	16
17	.15458	.18285	.16403	.19622	.17374	.21027	.18369	.22503	17
18	.15474	.18307	.16419	.19645	.17390	.21051	.18386	.22528	18
19	.15489	.18328	.16435	.19668	.17407	.21075	.18403	.22554	19
20	.15505	.18350	.16451	.19691	.17423	.21099	.18420	.22579	20
21	.15520	.18372	.16467	.19713	.17439	.21123	.18437	.22604	21
22	.15536	.18394	.16483	.19736	.17456	.21147	.18454	.22629	22
23	.15552	.18416	.16499	.19759	.17472	.21171	.18470	.22655	23
24	.15567	.18437	.16515	.19782	.17489	.21195	.18487	.22680	24
25	.15583	.18459	.16531	.19805	.17505	.21220	.18504	.22706	25
26	.15598	.18481	.16547	.19828	.17522	.21244	.18521	.22731	26
27	.15614	.18503	.16563	.19851	.17538	.21268	.18538	.22756	27
28	.15630	.18525	.16579	.19874	.17554	.21292	.18555	.22782	28
29	.15645	.18547	.16595	.19897	.17571	.21316	.18572	.22807	29
30	.15661	.18569	.16611	.19920	.17587	.21341	.18588	.22833	30
31	.15676	.18591	.16627	.19944	.17604	.21365	.18605	.22858	31
32	.15692	.18613	.16644	.19967	.17620	.21389	.18622	.22884	32
33	.15708	.18635	.16660	.19990	.17637	.21414	.18639	.22909	33
34	.15723	.18657	.16676	.20013	.17653	.21438	.18656	.22935	34
35	.15739	.18679	.16692	.20036	.17670	.21462	.18673	.22960	35
36	.15755	.18701	.16708	.20059	.17686	.21487	.18690	.22986	36
37	.15770	.18723	.16724	.20083	.17703	.21511	.18707	.23012	37
38	.15786	.18745	.16740	.20106	.17719	.21535	.18724	.23037	38
39	.15802	.18767	.16756	.20129	.17736	.21560	.18741	.23063	39
40	.15818	.18790	.16772	.20152	.17752	.21584	.18758	.23089	40
41	.15833	.18812	.16788	.20176	.17769	.21609	.18775	.23114	41
42	.15849	.18834	.16805	.20199	.17786	.21633	.18792	.23140	42
43	.15865	.18856	.16821	.20222	.17802	.21658	.18809	.23166	43
44	.15880	.18878	.16837	.20246	.17819	.21682	.18826	.23192	44
45	.15896	.18901	.16853	.20269	.17835	.21707	.18843	.23217	45
46	.15912	.18923	.16869	.20292	.17852	.21731	.18860	.23243	46
47	.15928	.18945	.16885	.20316	.17868	.21756	.18877	.23269	47
48	.15943	.18967	.16902	.20339	.17885	.21781	.18894	.23295	48
49	.15959	.18990	.16918	.20363	.17902	.21805	.18911	.23321	49
50	.15975	.19012	.16934	.20386	.17918	.21830	.18928	.23347	50
51	.15991	.19034	.16950	.20410	.17935	.21855	.18945	.23373	51
52	.16006	.19057	.16966	.20433	.17952	.21879	.18962	.23399	52
53	.16022	.19079	.16983	.20457	.17968	.21904	.18979	.23424	53
54	.18038	.19102	.16999	.20480	.17985	.21929	.18996	.23450	54
55	.16054	.19124	.17015	.20504	.18001	.21953	.19013	.23476	55
56	.16070	.19146	.17031	.20527	.18018	.21978	.19030	.23502	56
57	.16085	.19169	.17047	.20551	.18035	.22003	.19047	.23529	57
58	.16101	.19191	.17064	.20575	.18051	.22028	.19064	.23555	58
59	.16117	.19214	.17080	.20598	.18068	.22053	.19081	.23581	59
60	.16133	.19236	.17096	.20622	.18085	.22077	.19098	.23607	60

	36°		37°		38°		39°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	′
0	.19098	.23607	.20136	.25214	.21199	.26902	.22285	.28676	0
1	.19115	.23633	.20154	.25241	.21217	.26931	.22304	.28706	1
2	.19133	.23659	.20171	.25269	.21235	.26960	.22322	.28737	2
3	.19150	.23685	.20189	.25296	.21253	.26988	.22340	.28767	3
4	.19167	.23711	.20207	.25324	.21271	.27017	.22359	.28797	4
5	.19184	.23738	.20224	.25351	.21289	.27046	.22377	.28828	5
6	.19201	.23764	.20242	.25379	.21307	.27075	.22395	.28858	6
7	.19218	.23790	.20259	.25406	.21324	.27104	.22414	.28889	7
8	.19235	.23816	.20277	.25434	.21342	.27133	.22432	.28919	8
9	.19252	.23843	.20294	.25462	.21360	.27162	.22450	.28950	9
10	.19270	.23869	.20312	.25489	.21378	.27191	.22469	.28980	10
11	.19287	.23895	.20329	.25517	.21396	.27221	.22487	.29011	11
12	.19304	.23922	.20347	.25545	.21414	.27250	.22506	.29042	12
13	.19321	.23948	.20365	.25572	.21432	.27279	.22524	.29072	13
14	.19338	.23975	.20382	.25600	.21450	.27308	.22542	.29103	14
15	.19356	.24001	.20400	.25628	.21468	.27337	.22561	.29133	15
16	.19373	.24028	.20417	.25656	.21486	.27366	.22579	.29164	16
17	.19390	.24054	.20435	.25683	.21504	.27396	.22598	.29195	17
18	.19407	.24081	.20453	.25711	.21522	.27425	.22616	.29226	18
19	.19424	.24107	.20470	.25739	.21540	.27454	.22634	.29256	19
20	.19442	.24134	.20488	.25767	.21558	.27483	.22653	.29287	20
21	.19459	.24160	.20506	.25795	.21576	.27513	.22671	.29318	21
22	.19476	.24187	.20523	.25823	.21595	.27542	.22690	.29349	22
23	.19493	.24213	.20541	.25851	.21613	.27572	.22708	.29380	23
24	.19511	.24240	.20559	.25879	.21631	.27601	.22727	.29411	24
25	.19528	.24267	.20576	.25907	.21649	.27630	.22745	.29442	25
26	.19545	.24293	.20594	.25935	.21667	.27660	.22764	.29473	26
27	.19562	.24320	.20612	.25963	.21685	.27689	.22782	.29504	27
28	.19580	.24347	.20629	.25991	.21703	.27719	.22801	.29535	28
29	.19597	.24373	.20647	.26019	.21721	.27748	.22819	.29566	29
30	.19614	.24400	.20665	.26047	.21739	.27778	.22838	.29597	30
31	.19632	.24427	.20682	.26075	.21757	.27807	.22856	.29628	31
32	.19649	.24454	.20700	.26104	.21775	.27837	.22875	.29659	32
33	.19666	.24481	.20718	.26132	.21794	.27867	.22893	.29690	33
34	.19684	.24508	.20736	.26160	.21812	.27896	.22912	.29721	34
35	.19701	.24534	.20753	.26188	.21830	.27926	.22930	.29752	35
36	.19718	.24561	.20771	.26216	.21848	.27956	.22949	.29784	36
37	.19736	.24588	.20789	.26245	.21866	.27985	.22967	.29815	37
38	.19753	.24615	.20807	.26273	.21884	.28015	.22986	.29846	38
39	.19770	.24642	.20824	.26301	.21902	.28045	.23004	.29877	39
40	.19788	.24669	.20842	.26330	.21921	.28075	.23023	.29909	40
41	.19805	.24696	.20860	.26358	.21939	.28105	.23041	.29940	41
42	.19822	.24723	.20878	.26387	.21957	.28134	.23060	.29971	42
43	.19840	.24750	.20895	.26415	.21975	.28164	.23079	.30003	43
44	.19857	.24777	.20913	.26443	.21993	.28194	.23097	.30034	44
45	.19875	.24804	.20931	.26472	.22012	.28224	.23116	.30066	45
46	.19892	.24832	.20949	.26500	.22030	.28254	.23134	.30097	46
47	.19909	24859	.20967	.26529	.22048	.28284	.23153	.30129	47
48	.19927	.24886	.20985	.26557	.22066	.28314	.23172	.30160	48
49	.19944	.24913	.21002	.26586	.22084	.28344	.23190	.30192	49
50	.19962	.24940	.21020	.26615	.22103	.28374	.23209	.30223	50
51	.19979	.24967	.21038	.26643	.22121	.28404	.23228	.30255	51
52	.19997	.24995	.21056	.26672	.22139	.28434	.23246	.30287	52
53	.20014	.25022	.21074	.26701	.22157	.28464	.23265	.30318	53
54	.20032	.25049	.21092	.26729	.22176	.28495	.23283	.30350	54
55	.20049	.25077	.21109	.26758	.22194	.28525	.23302	.30382	55
56	.20066	.25104	.21127	.26787	.22212	.28555	.23321	.30413	56
57	.20084	.25131	.21145	.26815	.22231	.28585	.23339	.30445	57
58	.20101	.25159	.21163	.26844	.22249	.28615	.23358	.30477	58
59	.20119	.25186	.21181	.26873	.22267	.28646	.23377	.30509	59
60	.20136	.25214	.21199	.26902	.22285	.28676	.23396	.30541	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

	40°		41°		42°		43°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.23396	.30541	.24529	.32501	.25686	.34563	.26865	.36733	0
1	.23414	.30573	.24548	.32535	.25705	.34599	.26884	.36770	1
2	.23433	.30605	.24567	.32568	.25724	.34634	.26904	.36807	2
3	.23452	.30636	.24586	.32602	.25744	.34669	.26924	.36844	3
4	.23470	.30668	.24605	.32636	.25763	.34704	.26944	.36881	4
5	.23489	.30700	.24625	.32669	.25783	.34740	.26964	.36919	5
6	.23508	.30732	.24644	.32703	.25802	.34775	.26984	.36956	6
7	.23527	.30764	.24663	.32737	.25822	.34811	.27004	.36993	7
8	.23545	.30796	.24682	.32770	.25841	.34846	.27024	.37030	8
9	.23564	.30829	.24701	.32804	.25861	.34882	.27043	.37068	9
10	.23583	.30861	.24720	.32838	.25880	.34917	.27063	.37105	10
11	.23602	.30893	.24739	.32872	.25900	.34953	.27083	.37143	11
12	.23620	.30925	.24759	.32905	.25920	.34988	.27103	.37180	12
13	.23639	.30957	.24778	.32939	.25939	.35024	.27123	.37218	13
14	.23658	.30989	.24797	.32973	.25959	.35060	.27143	.37255	14
15	.23677	.31022	.24816	.33007	.25978	.35095	.27163	.37293	15
16	.23696	.31054	.24835	.33041	.25998	.35131	.27183	.37330	16
17	.23714	.31086	.24854	.33075	.26017	.35167	.27203	.37368	17
18	.23733	.31119	.24874	.33109	.26037	.35203	.27223	.37406	18
19	.23752	.31151	.24893	.33143	.26056	.35238	.27243	.37443	19
20	.23771	.31183	.24912	.33177	.26076	.35274	.27263	.37481	20
21	.23790	.31216	.24931	.33211	.26096	.35310	.27283	.37519	21
22	.23808	.31248	.24950	.33245	.26115	.35346	.27303	.37556	22
23	.23827	.31281	.24970	.33279	.26135	.35382	.27323	.37594	23
24	.23846	.31313	.24989	.33314	.26154	.35418	.27343	.37632	24
25	.23865	.31346	.25008	.33348	.26174	.35454	.27363	.37670	25
26	.23884	.31378	.25027	.33382	.26194	.35490	.27383	.37708	26
27	.23903	.31411	.25047	.33416	.26213	.35526	.27403	.37746	27
28	.23922	.31443	.25066	.33451	.26233	.35562	.27423	.37784	28
29	.23941	.31476	.25085	.33485	.26253	.35598	.27443	.37822	29
30	.23959	.31509	.25104	.33519	.26272	.35634	.27463	.37860	30
31	.23978	.31541	.25124	.33554	.26292	.35670	.27483	.37898	31
32	.23997	.31574	.25143	.33588	.26312	.35707	.27503	.37936	32
33	.24016	.31607	.25162	.33622	.26331	.35743	.27523	.37974	33
34	.24035	.31640	.25182	.33657	.26351	.35779	.27543	.38012	34
35	.24054	.31672	.25201	.33691	.26371	.35815	.27563	.38051	35
36	.24073	.31705	.25220	.33726	.26390	.35852	.27583	.38089	36
37	.24092	.31738	.25240	.33760	.26410	.35888	.27603	.38127	37
38	.24111	.31771	.25259	.33795	.26430	.35924	.27623	.38165	38
39	.24130	.31804	.25278	.33830	.26449	.35961	.27643	.38204	39
40	.24149	.31837	.25297	.33864	.26469	.35997	.27663	.38242	40
41	.24168	.31870	.25317	.33899	.26489	.36034	.27683	.38280	41
42	.24187	.31903	.25336	.33934	.26509	.36070	.27703	.38319	42
43	.24206	.31936	.25356	.33968	.26528	.36107	.27723	.38357	43
44	.24225	.31969	.25375	.34003	.26548	.36143	.27743	.38396	44
45	.24244	.32002	.25394	.34038	.26568	.36180	.27764	.38434	45
46	.24262	.32035	.25414	.34073	.26588	.36217	.27784	.38473	46
47	.24281	.32068	.25433	.34108	.26607	.36253	.27804	.38512	47
48	.24300	.32101	.25452	.34142	.26627	.36290	.27824	.38550	48
49	.24320	.32134	.25472	.34177	.26647	.36327	.27844	.38589	49
50	.24339	.32168	.25491	.34212	.26667	.36363	.27864	.38628	50
51	.24358	.32201	.25511	.34247	.26686	.36400	.27884	.38666	51
52	.24377	.32234	.25530	.34282	.26706	.36437	.27905	.38705	52
53	.24396	.32267	.25549	.34317	.26726	.36474	.27925	.38744	53
54	.24415	.32301	.25569	.34352	.26746	.36511	.27945	.38783	54
55	.24434	.32334	.25588	.34387	.26766	.36548	.27965	.38822	55
56	.24453	.32368	.25608	.34423	.26785	.36585	.27985	.38860	56
57	.24472	.32401	.25627	.34458	.26805	.36622	.28005	.38899	57
58	.24491	.32434	.25647	.34493	.26825	.36659	.28026	.38938	58
59	.24510	.32468	.25666	.34528	.26845	.36696	.28046	.38977	59
60	.24529	.32501	.25686	.34563	.26865	.36733	.28066	.39016	60

	44°		45°		46°		47°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	′
0	.28066	.39016	.29289	.41421	.30534	.43956	.31800	.46628	0
1	.28086	.39055	.29310	.41463	.30555	.43999	.31821	.46674	1
2	.28106	.39095	.29330	.41504	.30576	.44042	.31843	.46719	2
3	.28127	.39134	.29351	.41545	.30597	.44086	.31864	.46765	3
4	.28147	.39173	.29372	.41586	.30618	.44129	.31885	.46811	4
5	.28167	.39212	.29392	.41627	.30639	.44173	.31907	.46857	5
6	.28187	.39251	.29413	.41669	.30660	.44217	.31928	.46903	6
7	.28208	.39291	.29433	.41710	.30681	.44260	.31949	.46949	7
8	.28228	.39330	29454	.41752	.30702	.44304	.31971	.46995	8
9	.28248	.39369	.29475	.41793	.30723	.44347	.31992	.47041	9
10	.28268	.39409	.29495	.41835	.30744	.44391	.32013	.47087	10
11	.28289	.39448	.29516	.41876	.30765	.44435	.32035	.47134	11
12	.28309	.39487	.29537	.41918	.30786	.44479	.32056	.47180	12
13	.28329	.39527	.29557	.41959	.30807	.44523	.32077	.47226	13
14	.28350	.39566	.29578	.42001	.30828	.44567	.32099	.47272	14
15	.28370	.39606	.29599	.42042	.30849	.44610	.32120	.47319	15
16	.28390	.39646	.29619	.42084	.30870	.44654	.32141	.47365	16
17	.28410	.39685	.29640	.42126	.30891	.44698	.32163	.47411	17
18	.28431	.39725	.29661	.42168	.30912	.44742	.32184	.47458	18
19	.28451	.39764	.29681	.42210	.30933	.44787	.32205	.47504	19
20	.28471	.39804	.29702	.42251	.30954	.44831	.32227	.47551	20
21	.28492	.39844	.29723	.42293	.30975	.44875	.32248	.47598	21
22	.28512	.39884	.29743	.42335	.30996	.44919	.32270	.47644	22
23	.28532	.39924	.29764	.42377	.31017	.44963	.32291	.47691	23
24	.28553	.39963	.29785	.42419	.31038	.45007	.32312	.47738	24
25	.28573	.40003	.29805	.42461	.31059	.45052	.32334	.47784	25
26	.28593	.40043	.29826	.42503	.31080	.45096	.32355	.47831	26
27	.28614	.40083	.29847	.42545	.31101	.45141	.32377	.47878	27
28	.28634	.40123	.29868	.42587	.31122	.45185	.32398	.47925	28
29	.28655	.40163	.29888	.42630	.31143	.45229	.32420	.47972	29
30	.28675	.40203	.29909	.42672	.31165	.45274	.32441	.48019	30
31	.28695	.40243	.29930	.42714	.31186	.45319	.32462	.48066	31
32	.28716	.40283	.29951	.42756	.31207	.45363	.32484	.48113	32
33	.28736	.40324	.29971	.42799	.31228	.45408	.32505	.48160	33
34	.28757	.40364	.29992	.42841	.31249	.45452	.32527	.48207	34
35	.28777	.40404	.30013	.42883	.31270	.45497	.32548	.48254	35
36	.28797	.40444	.30034	.42926	.31291	.45542	.32570	.48301	36
37	.28818	.40485	.30054	.42968	.31312	.45587	.32591	.48349	37
38	.28838	.40525	.30075	.43011	.31334	.45631	.32613	.48396	38
39	.28859	.40565	.30096	.43053	.31355	.45676	.32634	.48443	39
40	.28879	.40606	.30117	.43096	.31376	.45721	.32656	.48491	40
41	.28900	.40646	.30138	.43139	.31397	.45766	.32677	.48538	41
42	.28920	.40687	.30158	.43181	.31418	.45811	.32699	.48586	42
43	.28941	.40727	.30179	.43224	.31439	.45856	.32720	.48633	43
44	.28961	.40768	.30200	.43267	.31461	.45901	.32742	.48681	44
45	.28981	.40808	.30221	.43310	.31482	.45946	.32763	.48728	45
46	.29002	.40849	.30242	.43352	.31503	.45992	.32785	.48776	46
47	.29022	.40890	.30263	.43395	.31524	.46037	.32806	.48824	47
48	.29043	.40930	.30283	.43438	.31545	.46082	.32828	.48871	48
49	.29063	.40971	.30304	.43481	.31567	.46127	.32849	.48919	49
50	.29084	.41012	.30325	.43524	.31588	.46173	.32871	.48967	50
51	.29104	.41053	.30346	.43567	.31609	.46218	.32893	.49015	51
52	.29125	.41093	.30367	.43610	.31630	.46263	.32914	.49063	52
53	.29145	.41134	.30388	.43653	.31651	.46309	.32936	.49111	53
54	.29166	.41175	.30409	.43696	.31673	.46354	.32957	.49159	54
55	.29187	.41216	.30430	.43739	.31694	.46400	.32979	.49207	55
56	.29207	.41257	.30451	.43783	.31715	.46445	.33001	.49255	56
57	.29228	.41298	.30471	.43826	.31736	.46491	.33022	.49303	57
58	.29248	.41339	.30492	.43869	.31758	.46537	.33044	.49351	58
59	.29269	.41380	.30513	.43912	.31779	.46582	.33065	.49399	59
60	.29289	.41421	.30534	.43956	.31800	.46628	.33087	.49448	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

′	48° Vers.	48° Ex. sec.	49° Vers.	49° Ex. sec.	50° Vers.	50° Ex. sec.	51° Vers.	51° Ex. sec.	′
0	.33087	.49448	.34394	.52425	.35721	.55572	.37068	.58902	0
1	.33109	.49496	.34416	.52476	.35744	.55626	.37091	.58959	1
2	.33130	.49544	.34438	.52527	.35766	.55680	.37113	.59016	2
3	.33152	.49593	.34460	.52579	.35788	.55734	.37136	.59073	3
4	.33173	.49641	.34482	.52630	.35810	.55789	.37158	.59130	4
5	.33195	.49690	.34504	.52681	.35833	.55843	.37181	.59188	5
6	.33217	.49738	.34526	.52732	.35855	.55897	.37204	.59245	6
7	.33238	.49787	.34548	.52784	.35877	.55951	.37226	.59302	7
8	.33260	.49835	.34570	.52835	.35900	.56005	.37249	.59360	8
9	.33282	.49884	.34592	.52886	.35922	.56060	.37272	.59418	9
10	.33303	.49933	.34614	.52938	.35944	.56114	.37294	.59475	10
11	.33325	.49981	.34636	.52989	.35967	.56169	.37317	.59533	11
12	.33347	.50030	.34658	.53041	.35989	.56223	.37340	.59590	12
13	.33368	.50079	.34680	.53092	.36011	.56278	.37362	.59648	13
14	.33390	.50128	.34702	.53144	.36034	.56332	.37385	.59706	14
15	.33412	.50177	.34724	.53196	.36056	.56387	.37408	.59764	15
16	.33434	.50226	.34746	.53247	.36078	.56442	.37430	.59822	16
17	.33455	.50275	.34768	.53299	.36101	.56497	.37453	.59880	17
18	.33477	.50324	.34790	.53351	.36123	.56551	.37476	.59938	18
19	.33499	.50373	.34812	.53403	.36146	.56606	.37498	.59996	19
20	.33520	.50422	.34834	.53455	.36168	.56661	.37521	.60054	20
21	.33542	.50471	.34856	.53507	.36190	.56716	.37544	.60112	21
22	.33564	.50521	.34878	.53559	.36213	.56771	.37567	.60171	22
23	.33586	.50570	.34900	.53611	.36235	.56826	.37589	.60229	23
24	.33607	.50619	.34923	.53663	.36258	.56881	.37612	.60287	24
25	.33629	.50669	.34945	.53715	.36280	.56937	.37635	.60346	25
26	.33651	.50718	.34967	.53768	.36302	.56992	.37658	.60404	26
27	.33673	.50767	.34989	.53820	.36325	.57047	.37680	.60463	27
28	.33694	.50817	.35011	.53872	.36347	.57103	.37703	.60521	28
29	.33716	.50866	.35033	.53924	.36370	.57158	.37726	.60580	29
30	.33738	.50916	.35055	.53977	.36392	.57213	.37749	.60639	30
31	.33760	.50966	.35077	.54029	.36415	.57269	.37771	.60698	31
32	.33782	.51015	.35099	.54082	.36437	.57324	.37794	.60756	32
33	.33803	.51065	.35122	.54134	.36460	.57380	.37817	.60815	33
34	.33825	.51115	.35144	.54187	.36482	.57436	.37840	.60874	34
35	.33847	.51165	.35166	.54240	.36504	.57491	.37862	.60933	35
36	.33869	.51215	.35188	.54292	.36527	.57547	.37885	.60992	36
37	.33891	.51265	.35210	.54345	.36549	.57603	.37908	.61051	37
38	.33912	.51314	.35232	.54398	.36572	.57659	.37931	.61111	38
39	.33934	.51364	.35254	.54451	.36594	.57715	.37954	.61170	39
40	.33956	.51415	.35277	.54504	.36617	.57771	.37976	.61229	40
41	.33978	.51465	.35299	.54557	.36639	.57827	.37999	.61288	41
42	.34000	.51515	.35321	.54610	.36662	.57883	.38022	.61348	42
43	.34022	.51565	.35343	.54663	.36684	.57939	.38045	.61407	43
44	.34044	.51615	.35365	.54716	.36707	.57995	.38068	.61467	44
45	.34065	.51665	.35388	.54769	.36729	.58051	.38091	.61526	45
46	.34087	.51716	.35410	.54822	.36752	.58108	.38113	.61586	46
47	.34109	.51766	.35432	.54876	.36775	.58164	.38136	.61646	47
48	.34131	.51817	.35454	.54929	.36797	.58221	.38159	.61705	48
49	.34153	.51867	.35476	.54982	.36820	.58277	.38182	.61765	49
50	.34175	.51918	.35499	.55036	.36842	.58333	.38205	.61825	50
51	.34197	.51968	.35521	.55089	.36865	.58390	.38228	.61885	51
52	.34219	.52019	.35543	.55143	.36887	.58447	.38251	.61945	52
53	.34241	.52069	.35565	.55196	.36910	.58503	.38274	.62005	53
54	.34262	.52120	.35588	.55250	.36932	.58560	.38296	.62065	54
55	.34284	.52171	.35610	.55303	.36955	.58617	.38319	.62125	55
56	.34306	.52222	.35632	.55357	.36978	.58674	.38342	.62185	56
57	.34328	.52273	.35654	.55411	.37000	.58731	.38365	.62246	57
58	.34350	.52323	.35677	.55465	.37023	.58788	.38388	.62306	58
59	.34372	.52374	.35699	.55518	.37045	.58845	.38411	.62366	59
60	.34394	.52425	.35721	.55572	.37068	.58902	.38434	.62427	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

	52°		53°		54°		55°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.38434	.62427	.39819	.66164	.41221	.70130	.42642	.74345	0
1	.38457	.62487	.39842	.66228	.41245	.70198	.42666	.74417	1
2	.38480	.62548	.39865	.66292	.41269	.70267	.42690	.74490	2
3	.38503	.62609	.39888	.66357	.41292	.70335	.42714	.74562	3
4	.38526	.62669	.39911	.66421	.41316	.70403	.42738	.74635	4
5	.38549	.62730	.39935	.66486	.41339	.70472	.42762	.74708	5
6	.38571	.62791	.39958	.66550	.41363	.70540	.42785	.74781	6
7	.38594	.62852	.39981	.66615	.41386	.70609	.42809	.74854	7
8	.38617	.62913	.40005	.66679	.41410	.70677	.42833	.74927	8
9	.38640	.62974	.40028	.66744	.41433	.70746	.42857	.75000	9
10	.38663	.63035	.40051	.66809	.41457	.70815	.42881	.75073	10
11	.38686	.63096	.40074	.66873	.41481	.70884	.42905	.75146	11
12	.38709	.63157	.40098	.66938	.41504	.70953	.42929	.75219	12
13	.38732	.63218	.40121	.67003	.41528	.71022	.42953	.75293	13
14	.38755	.63279	.40144	.67068	.41551	.71091	.42976	.75366	14
15	.38778	.63341	.40168	.67133	.41575	.71160	.43000	.75440	15
16	.38801	.63402	.40191	.67199	.41599	.71229	.43024	.75513	16
17	.38824	.63464	.40214	.67264	.41622	.71298	.43048	.75587	17
18	.38847	.63525	.40237	.67329	.41646	.71368	.43072	.75661	18
19	.38870	.63587	.40261	.67394	.41670	.71437	.43096	.75734	19
20	.38893	.63648	.40284	.67460	.41693	.71506	.43120	.75808	20
21	.38916	.63710	.40307	.67525	.41717	.71576	.43144	.75882	21
22	.38939	.63772	.40331	.67591	.41740	.71646	.43168	.75956	22
23	.38962	.63834	.40354	.67656	.41764	.71715	.43192	.76031	23
24	.38985	.63895	.40378	.67722	.41788	.71785	.43216	.76105	24
25	.39009	.63957	.40401	.67788	.41811	.71855	.43240	.76179	25
26	.39032	.64019	.40424	.67853	.41835	.71925	.43264	.76253	26
27	.39055	.64081	.40448	.67919	.41859	.71995	.43287	.76328	27
28	.39078	.64144	.40471	.67985	.41882	.72065	.43311	.76402	28
29	.39101	.64206	.40494	.68051	.41906	.72135	.43335	.76477	29
30	.39124	.64268	.40518	.68117	.41930	.72205	.43359	.76552	30
31	.39147	.64330	.40541	.68183	.41953	.72275	.43383	.76626	31
32	.39170	.64393	.40565	.68250	.41977	.72346	.43407	.76701	32
33	.39193	.64455	.40588	.68316	.42001	.72416	.43431	.76776	33
34	.39216	.64518	.40611	.68382	.42024	.72487	.43455	.76851	34
35	.39239	.64580	.40635	.68449	.42048	.72557	.43479	.76926	35
36	.39262	.64643	.40658	.68515	.42072	.72628	.43503	.77001	36
37	.39286	.64705	.40682	.68582	.42096	.72698	.43527	.77077	37
38	.39309	.64768	.40705	.68648	.42119	.72769	.43551	.77152	38
39	.39332	.64831	.40728	.68715	.42143	.72840	.43575	.77227	39
40	.39355	.64894	.40752	.68782	.42167	.72911	.43599	.77303	40
41	.39378	.64957	.40775	.68848	.42191	.72982	.43623	.77378	41
42	.39401	.65020	.40799	.68915	.42214	.73053	.43647	.77454	42
43	.39424	.65083	.40822	.68982	.42238	.73124	.43671	.77530	43
44	.39447	.65146	.40846	.69049	.42262	.73195	.43695	.77606	44
45	.39471	.65209	.40869	.69116	.42285	.73267	.43720	.77681	45
46	.39494	.65272	.40893	.69183	.42309	.73338	.43744	.77757	46
47	.39517	.65336	.40916	.69250	.42333	.73409	.43768	.77833	47
48	.39540	.65399	.40939	.69318	.42357	.73481	.43792	.77910	48
49	.39563	.65462	.40963	.69385	.42381	.73552	.43816	.77986	49
50	.39586	.65526	.40986	.69452	.42404	.73624	.43840	.78062	50
51	.39610	.65589	.41010	.69520	.42428	.73696	.43864	.78138	51
52	.39633	.65653	.41033	.69587	.42452	.73768	.43888	.78215	52
53	.39656	.65717	.41057	.69655	.42476	.73840	.43912	.78291	53
54	.39679	.65780	.41080	.69723	.42499	.73911	.43936	.78368	54
55	.39702	.65844	.41104	.69790	.42523	.73983	.43960	.78445	55
56	.39726	.65908	.41127	.69858	.42547	.74056	.43984	.78521	56
57	.39749	.65972	.41151	.69926	.42571	.74128	.44008	.78598	57
58	.39772	.66036	.41174	.69994	.42595	.74200	.44032	.78675	58
59	.39795	.66100	.41198	.70062	.42619	.74272	.44057	.78752	59
60	.39819	.66164	.41221	.70130	.42642	.74345	.44081	.78829	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

′	56° Vers.	56° Ex. sec.	57° Vers.	57° Ex. sec.	58° Vers.	58° Ex. sec.	59° Vers.	59° Ex. sec.	′
0	.44081	.78829	.45536	.83608	.47008	.88708	.48496	.94160	0
1	.44105	.78906	.45560	.83690	.47033	.88796	.48521	.94254	1
2	.44129	.78984	.45585	.83773	.47057	.88884	.48546	.94349	2
3	.44153	.79061	.45609	.83855	.47082	.88972	.48571	.94443	3
4	.44177	.79138	.45634	.83938	.47107	.89060	.48596	.94537	4
5	.44201	.79216	.45658	.84020	.47131	.89148	.48621	.94632	5
6	.44225	.79293	.45683	.84103	.47156	.89237	.48646	.94726	6
7	.44250	.79371	.45707	.84186	.47181	.89325	.48671	.94821	7
8	.44274	.79449	.45731	.84269	.47206	.89414	.48696	.94916	8
9	.44298	.79527	.45756	.84352	.47230	.89503	.48721	.95011	9
10	.44322	.79604	.45780	.84435	.47255	.89591	.48746	.95106	10
11	.44346	.79682	.45805	.84518	.47280	.89680	.48771	.95201	11
12	.44370	.79761	.45829	.84601	.47304	.89769	.48796	.95296	12
13	.44395	.79839	.45854	.84685	.47329	.89858	.48821	.95392	13
14	.44419	.79917	.45878	.84768	.47354	.89948	.48846	.95487	14
15	.44443	.79995	.45903	.84852	.47379	.90037	.48871	.95583	15
16	.44467	.80074	.45927	.84935	.47403	.90126	.48896	.95678	16
17	.44491	.80152	.45951	.85019	.47428	.90216	.48921	.95774	17
18	.44516	.80231	.45976	.85103	.47453	.90305	.48946	.95870	18
19	.44540	.80309	.46000	.85187	.47478	.90395	.48971	.95966	19
20	.44564	.80388	.46025	.85271	.47502	.90485	.48996	.96062	20
21	.44588	.80467	.46049	.85355	.47527	.90575	.49021	.96158	21
22	.44612	.80546	.46074	.85439	.47552	.90665	.49046	.96255	22
23	.44637	.80625	.46098	.85523	.47577	.90755	.49071	.96351	23
24	.44661	.80704	.46123	.85608	.47601	.90845	.49096	.96448	24
25	.44685	.80783	.46147	.85692	.47626	.90935	.49121	.96544	25
26	.44709	.80862	.46172	.85777	.47651	.91026	.49146	.96641	26
27	.44734	.80942	.46196	.85861	.47676	.91116	.49171	.96738	27
28	.44758	.81021	.46221	.85946	.47701	.91207	.49196	.96835	28
29	.44782	.81101	.46246	.86031	.47725	.91297	.49221	.96932	29
30	.44806	.81180	.46270	.86116	.47750	.91388	.49246	.97029	30
31	.44831	.81260	.46295	.86201	.47775	.91479	.49271	.97127	31
32	.44855	.81340	.46319	.86286	.47800	.91570	.49296	.97224	32
33	.44879	.81419	.46344	.86371	.47825	.91661	.49321	.97322	33
34	.44903	.81499	.46368	.86457	.47849	.91752	.49346	.97420	34
35	.44928	.81579	.46393	.86542	.47874	.91844	.49372	.97517	35
36	.44952	.81659	.46417	.86627	.47899	.91935	.49397	.97615	36
37	.44976	.81740	.46442	.86713	.47924	.92027	.49422	.97713	37
38	.45001	.81820	.46466	.86799	.47949	.92118	.49447	.97811	38
39	.45025	.81900	.46491	.86885	.47974	.92210	.49472	.97910	39
40	.45049	.81981	.46516	.86970	.47998	.92302	.49497	.98008	40
41	.45073	.82061	.46540	.87056	.48023	.92394	.49522	.98107	41
42	.45098	.82142	.46565	.87142	.48048	.92486	.49547	.98205	42
43	.45122	.82222	.46589	.87229	.48073	.92578	.49572	.98304	43
44	.45146	.82303	.46614	.87315	.48098	.92670	.49597	.98403	44
45	.45171	.82384	.46639	.87401	.48123	.92762	.49623	.98502	45
46	.45195	.82465	.46663	.87488	.48148	.92855	.49648	.98601	46
47	.45219	.82546	.46688	.87574	.48172	.92947	.49673	.98700	47
48	.45244	.82627	.46712	.87661	.48197	.93040	.49698	.98799	48
49	.45268	.82709	.46737	.87748	.48222	.93133	.49723	.98899	49
50	.45292	.82790	.46762	.87834	.48247	.93226	.49748	.98998	50
51	.45317	.82871	.46786	.87921	.48272	.93319	.49773	.99098	51
52	.45341	.82953	.46811	.88008	.48297	.93412	.49799	.99198	52
53	.45365	.83034	.46836	.88095	.48322	.93505	.49824	.99298	53
54	.45390	.83116	.46860	.88183	.48347	.93598	.49849	.99398	54
55	.45414	.83198	.46885	.88270	.48372	.93692	.49874	.99498	55
56	.45439	.83280	.46909	.88357	.48396	.93785	.49899	.99598	56
57	.45463	.83362	.46934	.88445	.48421	.93879	.49924	.99698	57
58	.45487	.83444	.46959	.88532	.48446	.93973	.49950	.99799	58
59	.45512	.83526	.46983	.88620	.48471	.94066	.49975	.99899	59
60	.45536	.83608	.47008	.88708	.48496	.94160	.50000	1.00000	60

	60°		61°		62°		63°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	′
0	.50000	1.00000	.51519	1.06267	.53053	1.13005	.54601	1.20269	0
1	.50025	1.00101	.51544	1.06375	.53079	1.13122	.54627	1.20395	1
2	.50050	1.00202	.51570	1.06483	.53104	1.13239	.54653	1.20521	2
3	.50076	1.00303	.51595	1.06592	.53130	1.13356	.54679	1.20647	3
4	.50101	1.00404	.51621	1.06701	.53156	1.13473	.54705	1.20773	4
5	.50126	1.00505	.51646	1.06809	.53181	1.13590	.54731	1.20900	5
6	.50151	1.00607	.51672	1.06918	.53207	1.13707	.54757	1.21026	6
7	.50176	1.00708	.51697	1.07027	.53233	1.13825	.54782	1.21153	7
8	.50202	1.00810	.51723	1.07137	.53258	1.13942	.54808	1.21280	8
9	.50227	1.00912	.51748	1.07246	.53284	1.14060	.54834	1.21407	9
10	.50252	1.01014	.51774	1.07356	.53310	1.14178	.54860	1.21535	10
11	.50277	1.01116	.51799	1.07465	.53336	1.14296	.54886	1.21662	11
12	.50303	1.01218	.51825	1.07575	.53361	1.14414	.54912	1.21790	12
13	.50328	1.01320	.51850	1.07685	.53387	1.14533	.54938	1.21918	13
14	.50353	1.01422	.51876	1.07795	.53413	1.14651	.54964	1.22045	14
15	.50378	1.01525	.51901	1.07905	.53439	1.14770	.54990	1.22174	15
16	.50404	1.01628	.51927	1.08015	.53464	1.14889	.55016	1.22302	16
17	.50429	1.01730	.51952	1.08126	.53490	1.15008	.55042	1.22430	17
18	.50454	1.01833	.51978	1.08236	.53516	1.15127	.55068	1.22559	18
19	.50479	1.01936	.52003	1.08347	.53542	1.15246	.55094	1.22688	19
20	.50505	1.02039	.52029	1.08458	.53567	1.15366	.55120	1.22817	20
21	.50530	1.02143	.52054	1.08569	.53593	1.15485	.55146	1.22946	21
22	.50555	1.02246	.52080	1.08680	.53619	1.15605	.55172	1.23075	22
23	.50581	1.02349	.52105	1.08791	.53645	1.15725	.55198	1.23205	23
24	.50606	1.02453	.52131	1.08903	.53670	1.15845	.55224	1.23334	24
25	.50631	1.02557	.52156	1.09014	.53696	1.15965	.55250	1.23464	25
26	.50656	1.02661	.52182	1.09126	.53722	1.16085	.55276	1.23594	26
27	.50682	1.02765	.52207	1.09238	.53748	1.16206	.55302	1.23724	27
28	.50707	1.02869	.52233	1.09350	.53774	1.16326	.55328	1.23855	28
29	.50732	1.02973	.52259	1.09462	.53799	1.16447	.55354	1.23985	29
30	.50758	1.03077	.52284	1.09574	.53825	1.16568	.55380	1.24116	30
81	.50783	1.03182	.52310	1.09686	.53851	1.16689	.55406	1.24247	31
32	.50808	1.03286	.52335	1.09799	.53877	1.16810	.55432	1.24378	32
33	.50834	1.03391	.52361	1.09911	.53903	1.16932	.55458	1.24509	33
34	.50859	1.03496	.52386	1.10024	.53928	1.17053	.55484	1.24640	34
35	.50884	1.03601	.52412	1.10137	.53954	1.17175	.55510	1.24772	35
36	.50910	1.03706	.52438	1.10250	.53980	1.17297	.55536	1.24903	36
37	.50935	1.03811	.52463	1.10363	.54006	1.17419	.55563	1.25035	37
38	.50960	1.03916	.52489	1.10477	.54032	1.17541	.55589	1.25167	38
39	.50986	1.04022	.52514	1.10590	.54058	1.17663	.55615	1.25300	39
40	.51011	1.04128	.52540	1.10704	.54083	1.17786	.55641	1.25432	40
41	.51036	1.04233	.52566	1.10817	.54109	1.17909	.55667	1.25565	41
42	.51062	1.04339	.52591	1.10931	.54135	1.18031	.55693	1.25697	42
43	.51087	1.04445	.52617	1.11045	.54161	1.18154	.55719	1.25830	43
44	.51113	1.04551	.52642	1.11159	.54187	1.18277	.55745	1.25963	44
45	.51138	1.04658	.52668	1.11274	.54213	1.18401	.55771	1.26097	45
46	.51163	1.04764	.52694	1.11388	.54238	1.18524	.55797	1.26230	46
47	.51189	1.04870	.52719	1.11503	.54264	1.18648	.55823	1.26364	47
48	.51214	1.04977	.52745	1.11617	.54290	1.18772	.55849	1.26498	48
49	.51239	1.05084	.52771	1.11732	.54316	1.18895	.55876	1.26632	49
50	.51265	1.05191	.52796	1.11847	.54342	1.19019	.55902	1.26766	50
51	.51290	1.05298	.52822	1.11963	.54368	1.19144	.55928	1.26900	51
52	.51316	1.05405	.52848	1.12078	.54394	1.19268	.55954	1.27035	52
53	.51341	1.05512	.52873	1.12193	.54420	1.19393	.55980	1.27169	53
54	.51366	1.05619	.52899	1.12309	.54446	1.19517	.56006	1.27304	54
55	.51392	1.05727	.52924	1.12425	.54471	1.19642	.56032	1.27439	55
56	.51417	1.05835	.52950	1.12540	.54497	1.19767	.56058	1.27574	56
57	.51443	1.05942	.52976	1.12657	.54523	1.19892	.56084	1.27710	57
58	.51468	1.06050	.53001	1.12773	.54549	1.20018	.56111	1.27845	58
59	.51494	1.06158	.53027	1.12889	.54575	1.20143	.56137	1.27981	59
60	.51519	1.06267	.53053	1.13005	.54601	1.20269	.56163	1.28117	60

	64°		65°		66°		67°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	′
0	.56163	1.28117	.57738	1.36620	.59326	1.45859	.60927	1.55930	0
1	.56189	1.28253	.57765	1.36768	.59353	1.46020	.60954	1.56106	1
2	.56215	1.28390	.57791	1.36916	.59379	1.46181	.60980	1.56282	2
3	.56241	1.28526	.57817	1.37064	.59406	1.46342	.61007	1.56458	3
4	.56267	1.28663	.57844	1.37212	.59433	1.46504	.61034	1.56634	4
5	.56294	1.28800	.57870	1.37361	.59459	1.46665	.61061	1.56811	5
6	.56320	1.28937	.57896	1.37509	.59486	1.46827	.61088	1.56988	6
7	.56346	1.29074	.57923	1.37658	.59512	1.46989	.61114	1.57165	7
8	.56372	1.29211	.57949	1.37808	.59539	1.47152	.61141	1.57342	8
9	.56398	1.29349	.57976	1.37957	.59566	1.47314	.61168	1.57520	9
10	.56425	1.29487	.58002	1.38107	.59592	1.47477	.61195	1.57698	10
11	.56451	1.29625	.58028	1.38256	.59619	1.47640	.61222	1.57876	11
12	.56477	1.29763	.58055	1.38406	.59645	1.47804	.61248	1.58054	12
13	.56503	1.29901	.58081	1.38556	.59672	1.47967	.61275	1.58233	13
14	.56529	1.30040	.58108	1.38707	.59699	1.48131	.61302	1.58412	14
15	.56555	1.30179	.58134	1.38857	.59725	1.48295	.61329	1.58591	15
16	.56582	1.30318	.58160	1.39008	.59752	1.48459	.61356	1.58771	16
17	.56608	1.30457	.58187	1.39159	.59779	1.48624	.61383	1.58950	17
18	.56634	1.30596	.58213	1.39311	.59805	1.48789	.61409	1.59130	18
19	.56660	1.30735	.58240	1.39462	.59832	1.48954	.61436	1.59311	19
20	.56687	1.30875	.58266	1.39614	.59859	1.49119	.61463	1.59491	20
21	.56713	1.31015	.58293	1.39766	.59885	1.49284	.61490	1.59672	21
22	.56739	1.31155	.58319	1.39918	.59912	1.49450	.61517	1.59853	22
23	.56765	1.31295	.58345	1.40070	.59938	1.49616	.61544	1.60035	23
24	.56791	1.31436	.58372	1.40222	.59965	1.49782	.61570	1.60217	24
25	.56818	1.31576	.58398	1.40375	.59992	1.49948	.61597	1.60399	25
26	.56844	1.31717	.58425	1.40528	.60018	1.50115	.61624	1.60581	26
27	.56870	1.31858	.58451	1.40681	.60045	1.50282	.61651	1.60763	27
28	.56896	1.31999	.58478	1.40835	.60072	1.50449	.61678	1.60946	28
29	.56923	1.32140	.58504	1.40988	.60098	1.50617	.61705	1.61129	29
30	.56949	1.32282	.58531	1.41142	.60125	1.50784	.61732	1.61313	30
31	.56975	1.32424	.58557	1.41296	.60152	1.50952	.61759	1.61496	31
32	.57001	1.32566	.58584	1.41450	.60178	1.51120	.61785	1.61680	32
33	.57028	1.32708	.58610	1.41605	.60205	1.51289	.61812	1.61864	33
34	.57054	1.32850	.58637	1.41760	.60232	1.51457	.61839	1.62049	34
35	.57080	1.32993	.58663	1.41914	.60259	1.51626	.61866	1.62234	35
36	.57106	1.33135	.58690	1.42070	.60285	1.51795	.61893	1.62419	36
37	.57133	1.33278	.58716	1.42225	.60312	1.51965	.61920	1.62604	37
38	.57159	1.33422	.58743	1.42380	.60339	1.52134	.61947	1.62790	38
39	.57185	1.33565	.58769	1.42536	.60365	1.52304	.61974	1.62976	39
40	.57212	1.33708	.58796	1.42692	.60392	1.52474	.62001	1.63162	40
41	.57238	1.33852	.58822	1.42848	.60419	1.52645	.62027	1.63348	41
42	.57264	1.33996	.58849	1.43005	.60445	1.52815	.62054	1.63535	42
43	.57291	1.34140	.58875	1.43162	.60472	1.52986	.62081	1.63722	43
44	.57317	1.34284	.58902	1.43318	.60499	1.53157	.62108	1.63909	44
45	.57343	1.34429	.58928	1.43476	.60526	1.53329	.62135	1.64097	45
46	.57369	1.34573	.58955	1.43633	.60552	1.53500	.62162	1.64285	46
47	.57396	1.34718	.58981	1.43790	.60579	1.53672	.62189	1.64473	47
48	.57422	1.34863	.59008	1.43948	.60606	1.53845	.62216	1.64662	48
49	.57448	1.35009	.59034	1.44106	.60633	1.54017	.62243	1.64851	49
50	.57475	1.35154	.59061	1.44264	.60659	1.54190	.62270	1.65040	50
51	.57501	1.35300	.59087	1.44423	.60686	1.54363	.62297	1.65229	51
52	.57527	1.35446	.59114	1.44582	.60713	1.54536	.62324	1.65419	52
53	.57554	1.35592	.59140	1.44741	.60740	1.54709	.62351	1.65609	53
54	.57580	1.35738	.59167	1.44900	.60766	1.54883	.62378	1.65799	54
55	.57606	1.35885	.59194	1.45059	.60793	1.55057	.62405	1.65989	55
56	.57633	1.36031	.59220	1.45219	.60820	1.55231	.62431	1.66180	56
57	.57659	1.36178	.59247	1.45378	.60847	1.55405	.62458	1.66371	57
58	.57685	1.36325	.59273	1.45539	.60873	1.55580	.62485	1.66563	58
59	.57712	1.36473	.59300	1.45699	.60900	1.55755	.62512	1.66755	59
60	.57738	1.36620	.59326	1.45859	.60927	1.55930	.62539	1.66947	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

	68°		69°		70°		71°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	′
0	.62539	1.66947	.64163	1.79043	.65798	1.92380	.67443	2.07155	0
1	.62566	1.67139	.64190	1.79254	.65825	1.92614	.67471	2.07415	1
2	.62593	1.67332	.64218	1.79466	.65853	1.92849	.67498	2.07675	2
3	.62620	1.67525	.64245	1.79679	.65880	1.93083	.67526	2.07936	3
4	.62647	1.67718	.64272	1.79891	.65907	1.93318	.67553	2.08197	4
5	.62674	1.67911	.64299	1.80104	.65935	1.93554	.67581	2.08459	5
6	.62701	1.68105	.64326	1.80318	.65962	1.93790	.67608	2.08721	6
7	.62728	1.68299	.64353	1.80531	.65989	1.94026	.67636	2.08983	7
8	.62755	1.68494	.64381	1.80746	.66017	1.94263	.67663	2.09246	8
9	.62782	1.68689	.64408	1.80960	.66044	1.94500	.67691	2.09510	9
10	.62809	1.68884	.64435	1.81175	.66071	1.94737	.67718	2.09774	10
11	.62836	1.69079	.64462	1.81390	.66099	1.94975	.67746	2.10038	11
12	.62863	1.69275	.64489	1.81605	.66126	1.95213	.67773	2.10303	12
13	.62890	1.69471	.64517	1.81821	.66154	1.95452	.67801	2.10568	13
14	.62917	1.69667	.64544	1.82037	.66181	1.95691	.67829	2.10834	14
15	.62944	1.69864	.64571	1.82254	.66208	1.95931	.67856	2.11101	15
16	.62971	1.70061	.64598	1.82471	.66236	1.96171	.67884	2.11367	16
17	.62998	1.70258	.64625	1.82688	.66263	1.96411	.67911	2.11635	17
18	.63025	1.70455	.64653	1.82906	.66290	1.96652	.67939	2.11903	18
19	.63052	1.70653	.64680	1.83124	.66318	1.96893	.67966	2.12171	19
20	.63079	1.70851	.64707	1.83342	.66345	1.97135	.67994	2.12440	20
21	.63106	1.71050	.64734	1.83561	.66373	1.97377	.68021	2.12709	21
22	.63133	1.71249	.64761	1.83780	.66400	1.97619	.68049	2.12979	22
23	.63161	1.71448	.64789	1.83999	.66427	1.97862	.68077	2.13249	23
24	.63188	1.71647	.64816	1.84219	.66455	1.98106	.68104	2.13520	24
25	.63215	1.71847	.64843	1.84439	.66482	1.98349	.68132	2.13791	25
26	.63242	1.72047	.64870	1.84659	.66510	1.98594	.68159	2.14063	26
27	.63269	1.72247	.64898	1.84880	.66537	1.98838	.68187	2.14335	27
28	.63296	1.72448	.64925	1.85102	.66564	1.99083	.68214	2.14608	28
29	.63323	1.72649	.64952	1.85323	.66592	1.99329	.68242	2.14881	29
30	.63350	1.72850	.64979	1.85545	.66619	1.99574	.68270	2.15155	30
31	.63377	1.73052	.65007	1.85767	.66647	1.99821	.68297	2.15429	31
32	.63404	1.73254	.65034	1.85990	.66674	2.00067	.68325	2.15704	32
33	.63431	1.73456	.65061	1.86213	.66702	2.00315	.68352	2.15979	33
34	.63458	1.73659	.65088	1.86437	.66729	2.00562	.68380	2.16255	34
35	.63485	1.73862	.65116	1.86661	.66756	2.00810	.68408	2.16531	35
36	.63512	1.74065	.65143	1.86885	.66784	2.01059	.68435	2.16808	36
37	.63539	1.74269	.65170	1.87109	.66811	2.01308	.68463	2.17085	37
38	.63566	1.74473	.65197	1.87334	.66839	2.01557	.68490	2.17363	38
39	.63594	1.74677	.65225	1.87560	.66866	2.01807	.68518	2.17641	39
40	.63621	1.74881	.65252	1.87785	.66894	2.02057	.68546	2.17920	40
41	.63648	1.75086	.65279	1.88011	.66921	2.02308	.68573	2.18199	41
42	.63675	1.75292	.65306	1.88238	.66949	2.02559	.68601	2.18479	42
43	.63702	1.75497	.65334	1.88465	.66976	2.02810	.68628	2.18759	43
44	.63729	1.75703	.65361	1.88692	.67003	2.03062	.68656	2.19040	44
45	.63756	1.75909	.65388	1.88920	.67031	2.03315	.68684	2.19322	45
46	.63783	1.76116	.65416	1.89148	.67058	2.03568	.68711	2.19604	46
47	.63810	1.76323	.65443	1.89376	.67086	2.03821	.68739	2.19886	47
48	.63838	1.76530	.65470	1.89605	.67113	2.04075	.68767	2.20169	48
49	.63865	1.76737	.65497	1.89834	.67141	2.04329	.68794	2.20453	49
50	.63892	1.76945	.65525	1.90063	.67168	2.04584	.68822	2.20737	50
51	.63919	1.77154	.65552	1.90293	.67196	2.04839	.68849	2.21021	51
52	.63946	1.77362	.65579	1.90524	.67223	2.05094	.68877	2.21306	52
53	.63973	1.77571	.65607	1.90754	.67251	2.05350	.68905	2.21592	53
54	.64000	1.77780	.65634	1.90986	.67278	2.05607	.68932	2.21878	54
55	.64027	1.77990	.65661	1.91217	.67306	2.05864	.68960	2.22165	55
56	.64055	1.78200	.65689	1.91449	.67333	2.06121	.68988	2.22452	56
57	.64082	1.78410	.65716	1.91681	.67361	2.06379	.69015	2.22740	57
58	.64109	1.78621	.65743	1.91914	.67388	2.06637	.69043	2.23028	58
59	.64136	1.78832	.65771	1.92147	.67416	2.06896	.69071	2.23317	59
60	.64163	1.79043	.65798	1.92380	.67443	2.07155	.69098	2.23607	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

′	72° Vers.	72° Ex. sec.	73° Vers.	73° Ex. sec.	74° Vers.	74° Ex. sec.	75° Vers.	75° Ex. sec.	′
0	.69098	2.23607	.70763	2.42030	.72436	2.62796	.74118	2.86370	0
1	.69126	2.23897	.70791	2.42356	.72464	2.63164	.74146	2.86790	1
2	.69154	2.24187	.70818	2.42683	.72492	2.63533	.74174	2.87211	2
3	.69181	2.24478	.70846	2.43010	.72520	2.63903	.74202	2.87633	3
4	.69209	2.24770	.70874	2.43337	.72548	2.64274	.74231	2.88056	4
5	.69237	2.25062	.70902	2.43666	.72576	2.64645	.74259	2.88479	5
6	.69264	2.25355	.70930	2.43995	.72604	2.65018	.74287	2.88904	6
7	.69292	2.25648	.70958	2.44324	.72632	2.65391	.74315	2.89330	7
8	.69320	2.25942	.70985	2.44655	.72660	2.65765	.74343	2.89756	8
9	.69347	2.26237	.71013	2.44986	.72688	2.66140	.74371	2.90184	9
10	.69375	2.26531	.71041	2.45317	.72716	2.66515	.74399	2.90613	10
11	.69403	2.26827	.71069	2.45650	.72744	2.66892	.74427	2.91042	11
12	.69430	2.27123	.71097	2.45983	.72772	2.67269	.74455	2.91473	12
13	.69458	2.27420	.71125	2.46316	.72800	2.67647	.74484	2.91904	13
14	.69486	2.27717	.71153	2.46651	.72828	2.68025	.74512	2.92337	14
15	.69514	2.28015	.71180	2.46986	.72856	2.68405	.74540	2.92770	15
16	.69541	2.28313	.71208	2.47321	.72884	2.68785	.74568	2.93204	16
17	.69569	2.28612	.71236	2.47658	.72912	2.69167	.74596	2.93640	17
18	.69597	2.28912	.71264	2.47995	.72940	2.69549	.74624	2.94076	18
19	.69624	2.29212	.71292	2.48333	.72968	2.69931	.74652	2.94514	19
20	.69652	2.29512	.71320	2.48671	.72996	2.70315	.74680	2.94952	20
21	.69680	2.29814	.71348	2.49010	.73024	2.70700	.74709	2.95392	21
22	.69708	2.30115	.71375	2.49350	.73052	2.71085	.74737	2.95832	22
23	.69735	2.30418	.71403	2.49691	.73080	2.71471	.74765	2.96274	23
24	.69763	2.30721	.71431	2.50032	.73108	2.71858	.74793	2.96716	24
25	.69791	2.31024	.71459	2.50374	.73136	2.72246	.74821	2.97160	25
26	.69818	2.31328	.71487	2.50716	.73164	2.72635	.74849	2.97604	26
27	.69846	2.31633	.71515	2.51060	.73192	2.73024	.74878	2.98050	27
28	.69874	2.31939	.71543	2.51404	.73220	2.73414	.74906	2.98497	28
29	.69902	2.32244	.71571	2.51748	.73248	2.73806	.74934	2.98944	29
30	.69929	2.32551	.71598	2.52094	.73276	2.74198	.74962	2.99393	30
31	.69957	2.32858	.71626	2.52440	.73304	2.74591	.74990	2.99843	31
32	.69985	2.33166	.71654	2.52787	.73332	2.74984	.75018	3.00293	32
33	.70013	2.33474	.71682	2.53134	.73360	2.75379	.75047	3.00745	33
34	.70040	2.33783	.71710	2.53482	.73388	2.75775	.75075	3.01198	34
35	.70068	2.34092	.71738	2.53831	.73416	2.76171	.75103	3.01652	35
36	.70096	2.34403	.71766	2.54181	.73444	2.76568	.75131	3.02107	36
37	.70124	2.34713	.71794	2.54531	.73472	2.76966	.75159	3.02563	37
38	.70151	2.35025	.71822	2.54883	.73500	2.77365	.75187	3.03020	38
39	.70179	2.35336	.71850	2.55235	.73529	2.77765	.75216	3.03479	39
40	.70207	2.35649	.71877	2.55587	.73557	2.78166	.75244	3.03938	40
41	.70235	2.35962	.71905	2.55940	.73585	2.78568	.75272	3.04398	41
42	.70263	2.36276	.71933	2.56294	.73613	2.78970	.75300	3.04860	42
43	.70290	2.36590	.71961	2.56649	.73641	2.79374	.75328	3.05322	43
44	.70318	2.36905	.71989	2.57005	.73669	2.79778	.75356	3.05786	44
45	.70346	2.37221	.72017	2.57361	.73697	2.80183	.75385	3.06251	45
46	.70374	2.37537	.72045	2.57718	.73725	2.80589	.75413	3.06717	46
47	.70401	2.37854	.72073	2.58076	.73753	2.80996	.75441	3.07184	47
48	.70429	2.38171	.72101	2.58434	.73781	2.81404	.75469	3.07652	48
49	.70457	2.38489	.72129	2.58794	.73809	2.81813	.75497	3.08121	49
50	.70485	2.38808	.72157	2.59154	.73837	2.82223	.75526	3.08591	50
51	.70513	2.39128	.72185	2.59514	.73865	2.82633	.75554	3.09063	51
52	.70540	2.39448	.72213	2.59876	.73893	2.83045	.75582	3.09535	52
53	.70568	2.39768	.72241	2.60238	.73921	2.83457	.75610	3.10009	53
54	.70596	2.40089	.72269	2.60601	.73950	2.83871	.75639	3.10484	54
55	.70624	2.40411	.72296	2.60965	.73978	2.84285	.75667	3.10960	55
56	.70652	2.40734	.72324	2.61330	.74006	2.84700	.75695	3.11437	56
57	.70679	2.41057	.72352	2.61695	.74034	2.85116	.75723	3.11915	57
58	.70707	2.41381	.72380	2.62061	.74062	2.85533	.75751	3.12394	58
59	.70735	2.41705	.72408	2.62428	.74090	2.85951	.75780	3.12875	59
60	.70763	2.42030	.72436	2.62796	.74118	2.86370	.75808	3.13357	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

	76°		77°		78°		79°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	′
0	.75808	3.13357	.77505	3.44541	.79209	3.80973	.80919	4.24084	0
1	.75836	3.13839	.77533	3.45102	.79237	3.81633	.80948	4.24870	1
2	.75864	3.14323	.77562	3.45664	.79266	3.82294	.80976	4.25658	2
3	.75892	3.14809	.77590	3.46228	.79294	3.82956	.81005	4.26448	3
4	.75921	3.15295	.77618	3.46793	.79323	3.83621	.81033	4.27241	4
5	.75949	3.15782	.77647	3.47360	.79351	3.84288	.81062	4.28036	5
6	.75977	3.16271	.77675	3.47928	.79380	3.84956	.81090	4.28833	6
7	.76005	3.16761	.77703	3.48498	.79408	3.85627	.81119	4.29634	7
8	.76034	3.17252	.77732	3.49069	.79437	3.86299	.81148	4.30436	8
9	.76062	3.17744	.77760	3.49642	.79465	3.86973	.81176	4.31241	9
10	.76090	3.18238	.77788	3.50216	.79493	3.87649	.81205	4.32049	10
11	.76118	3.18733	.77817	3.50791	.79522	3.88327	.81233	4.32859	11
12	.76147	3.19228	.77845	3.51368	.79550	3.89007	.81262	4.33671	12
13	.76175	3.19725	.77874	3.51947	.79579	3.89689	.81290	4.34486	13
14	.76203	3.20224	.77902	3.52527	.79607	3.90373	.81319	4.35304	14
15	.76231	3.20723	.77930	3.53109	.79636	3.91058	.81348	4.36124	15
16	.76260	3.21224	.77959	3.53692	.79664	3.91746	.81376	4.36947	16
17	.76288	3.21726	.77987	3.54277	.79693	3.92436	.81405	4.37772	17
18	.76316	3.22229	.78015	3.54863	.79721	3.93128	.81433	4.38600	18
19	.76344	3.22734	.78044	3.55451	.79750	3.93821	.81462	4.39430	19
20	.76373	3.23239	.78072	3.56041	.79778	3.94517	.81491	4.40263	20
21	.76401	3.23746	.78101	3.56632	.79807	3.95215	.81519	4.41099	21
22	.76429	3.24255	.78129	3.57224	.79835	3.95914	.81548	4.41937	22
23	.76458	3.24764	.78157	3.57819	.79864	3.96616	.81576	4.42778	23
24	.76486	3.25275	.78186	3.58414	.79892	3.97320	.81605	4.43622	24
25	.76514	3.25787	.78214	3.59012	.79921	3.98025	.81633	4.44468	25
26	.76542	3.26300	.78242	3.59611	.79949	3.98733	.81662	4.45317	26
27	.76571	3.26814	.78271	3.60211	.79978	3.99443	.81691	4.46169	27
28	.76599	3.27330	.78299	3.60813	.80006	4.00155	.81719	4.47023	28
29	.76627	3.27847	.78328	3.61417	.80035	4.00869	.81748	4.47881	29
30	.76655	3.28366	.78356	3.62023	.80063	4.01585	.81776	4.48740	30
31	.76684	3.28885	.78384	3.62630	.80092	4.02303	.81805	4.49603	31
32	.76712	3.29406	.78413	3.63238	.80120	4.03024	.81834	4.50468	32
33	.76740	3.29929	.78441	3.63849	.80149	4.03746	.81862	4.51337	33
34	.76769	3.30452	.78470	3.64461	.80177	4.04471	.81891	4.52208	34
35	.76797	3.30977	.78498	3.65074	.80206	4.05197	.81919	4.53081	35
36	.76825	3.31503	.78526	3.65690	.80234	4.05926	.81948	4.53958	36
37	.76854	3.32031	.78555	3.66307	.80263	4.06657	.81977	4.54837	37
38	.76882	3.32560	.78583	3.66925	.80291	4.07390	.82005	4.55720	38
39	.76910	3.33090	.78612	3.67545	.80320	4.08125	.82034	4.56605	39
40	.76938	3.33622	.78640	3.68167	.80348	4.08863	.82063	4.57493	40
41	.76967	3.34154	.78669	3.68791	.80377	4.09602	.82091	4.58383	41
42	.76995	3.34689	.78697	3.69417	.80405	4.10344	.82120	4.59277	42
43	.77023	3.35224	.78725	3.70044	.80434	4.11088	.82148	4.60174	43
44	.77052	3.35761	.78754	3.70673	.80462	4.11835	.82177	4.61073	44
45	.77080	3.36299	.78782	3.71303	.80491	4.12583	.82206	4.61976	45
46	.77108	3.36839	.78811	3.71935	.80520	4.13334	.82234	4.62881	46
47	.77137	3.37380	.78839	3.72569	.80548	4.14087	.82263	4.63790	47
48	.77165	3.37923	.78868	3.73205	.80577	4.14842	.82292	4.64701	48
49	.77193	3.38466	.78896	3.73843	.80605	4.15599	.82320	4.65616	49
50	.77222	3.39012	.78924	3.74482	.80634	4.16359	.82349	4.66533	50
51	.77250	3.39558	.78953	3.75123	.80662	4.17121	.82377	4.67454	51
52	.77278	3.40106	.78981	3.75766	.80691	4.17886	.82406	4.68377	52
53	.77307	3.40656	.79010	3.76411	.80719	4.18652	.82435	4.69304	53
54	.77335	3.41206	.79038	3.77057	.80748	4.19421	.82463	4.70234	54
55	.77363	3.41759	.79067	3.77705	.80776	4.20193	.82492	4.71166	55
56	.77392	3.42312	.79095	3.78355	.80805	4.20966	.82521	4.72102	56
57	.77420	3.42867	.79123	3.79007	.80833	4.21742	.82549	4.73041	57
58	.77448	3.43424	.79152	3.79661	.80862	4.22521	.82578	4.73983	58
59	.77477	3.43982	.79180	3.80316	.80891	4.23301	.82607	4.74929	59
60	.77505	8.44541	.79209	3.80973	.80919	4.24084	.82635	4.75877	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

′	80° Vers.	80° Ex. sec.	81° Vers.	81° Ex. sec.	82° Vers.	82° Ex. sec.	83° Vers.	83° Ex. sec.	′
0	.82635	4.75877	.84357	5.39245	.86083	6.18530	.87813	7.20551	0
1	.82664	4.76829	.84385	5.40422	.86112	6.20020	.87842	7.22500	1
2	.82692	4.77784	.84414	5.41602	.86140	6.21517	.87871	7.24457	2
3	.82721	4.78742	.84443	5.42787	.86169	6.23019	.87900	7.26425	3
4	.82750	4.79703	.84471	5.43977	.86198	6.24529	.87929	7.28402	4
5	.82778	4.80667	.84500	5.45171	.86227	6.26044	.87957	7.30388	5
6	.82807	4.81635	.84529	5.46369	.86256	6.27566	.87986	7.32384	6
7	.82836	4.82606	.84558	5.47572	.86284	6.29095	.88015	7.34390	7
8	.82864	4.83581	.84586	5.48779	.86313	6.30630	.88044	7.36405	8
9	.82893	4.84558	.84615	5.49991	.86342	6.32171	.88073	7.38431	9
10	.82922	4.85539	.84644	5.51208	.86371	6.33719	.88102	7.40466	10
11	.82950	4.86524	.84673	5.52429	.86400	6.35274	.88131	7.42511	11
12	.82979	4.87511	.84701	5.53655	.86428	6.36835	.88160	7.44566	12
13	.83008	4.88502	.84730	5.54886	.86457	6.38403	.88188	7.46632	13
14	.83036	4.89497	.84759	5.56121	.86486	6.39978	.88217	7.48707	14
15	.83065	4.90495	.84788	5.57361	.86515	6.41560	.88246	7.50793	15
16	.83094	4.91496	.84816	5.58606	.86544	6.43148	.88275	7.52889	16
17	.83122	4.92501	.84845	5.59855	.86573	6.44743	.88304	7.54996	17
18	.83151	4.93509	.84874	5.61110	.86601	6.46346	.88333	7.57113	18
19	.83180	4.94521	.84903	5.62369	.86630	6.47955	.88362	7.59241	19
20	.83208	4.95536	.84931	5.63633	.86659	6.49571	.88391	7.61379	20
21	.83237	4.96555	.84960	5.64902	.86688	6.51194	.88420	7.63528	21
22	.83266	4.97577	.84989	5.66176	.86717	6.52825	.88448	7.65688	22
23	.83294	4.98603	.85018	5.67454	.86746	6.54462	.88477	7.67859	23
24	.83323	4.99633	.85046	5.68738	.86774	6.56107	.88506	7.70041	24
25	.83352	5.00666	.85075	5.70027	.86803	6.57759	.88535	7.72234	25
26	.83380	5.01703	.85104	5.71321	.86832	6.59418	.88564	7.74438	26
27	.83409	5.02743	.85133	5.72620	.86861	6.61085	.88593	7.76653	27
28	.83438	5.03787	.85162	5.73924	.86890	6.62759	.88622	7.78880	28
29	.83467	5.04834	.85190	5.75233	.86919	6.64441	.88651	7.81118	29
30	.83495	5.05886	.85219	5.76547	.86947	6.66130	.88680	7.83367	30
31	.83524	5.06941	.85248	5.77866	.86976	6.67826	.88709	7.85628	31
32	.83553	5.08000	.85277	5.79191	.87005	6.69530	.88737	7.87901	32
33	.83581	5.09062	.85305	5.80521	.87034	6.71242	.88766	7.90186	33
34	.83610	5.10129	.85334	5.81856	.87063	6.72962	.88795	7.92482	34
35	.83639	5.11199	.85363	5.83196	.87092	6.74689	.88824	7,94791	35
36	.83667	5.12273	.85392	5.84542	.87120	6.76424	.88853	7.97111	36
37	.83696	5.13350	.85420	5.85893	.87149	6.78167	.88882	7.99444	37
38	.83725	5.14432	.85449	5.87250	.87178	6.79918	.88911	8.01788	38
39	.83754	5.15517	.85478	5.88612	.87207	6.81677	.88940	8.04146	39
40	.83782	5.16607	.85507	5.89979	.87236	6.83443	.88969	8.06515	40
41	.83811	5.17700	.85536	5.91352	.87265	6.85218	.88998	8.08897	41
42	.83840	5.18797	.85564	5.92731	.87294	6.87001	.89027	8.11292	42
43	.83868	5.19898	.85593	5.94115	.87322	6.88792	.89055	8.13699	43
44	.83897	5.21004	.85622	5.95505	.87351	6.90592	.89084	8.16120	44
45	.83926	5.22113	.85651	5.96900	.87380	6.92400	.89113	8.18553	45
46	.83954	5.23226	.85680	5.98301	.87409	6.94216	.89142	8.20999	46
47	.83983	5.24343	.85708	5.99708	.87438	6.96040	.89171	8.23459	47
48	.84012	5.25464	.85737	6.01120	.87467	6.97873	.89200	8.25931	48
49	.84041	5.26590	.85766	6.02538	.87496	6.99714	.89229	8.28417	49
50	.84069	5.27719	.85795	6.03962	.87524	7.01565	.89258	8.30917	50
51	.84098	5.28853	.85823	6.05392	.87553	7.03423	.89287	8.33430	51
52	.84127	5.29991	.85852	6.06828	.87582	7.05291	.89316	8.35957	52
53	.84155	5.31133	.85881	6.08269	.87611	7.07167	.89345	8.38497	53
54	.84184	5.32279	.85910	6.09717	.87640	7.09052	.89374	8.41052	54
55	.84213	5.33429	.85939	6.11171	.87669	7.10946	.89403	8.43620	55
56	.84242	5.34584	.85967	6.12630	.87698	7.12849	.89431	8.46203	56
57	.84270	5.35743	.85996	6.14096	.87726	7.14760	.89460	8.48800	57
58	.84299	5.36906	.86025	6.15568	.87755	7.16681	.89489	8.51411	58
59	.84328	5.38073	.86054	6.17046	.87784	7.18612	.89518	8.54037	59
60	.84357	5.39245	.86083	6.18530	.87813	7.20551	.89547	8.56677	60

′	84° Vers.	84° Ex. sec.	85° Vers.	85° Ex. sec.	86° Vers.	86° Ex. sec.	′
0	.89547	8.56677	.91284	10.47371	.93024	13.33559	0
1	.89576	8.59332	.91313	10.51199	.93053	13.39547	1
2	.89605	8.62002	.91342	10.55052	.93082	13.45586	2
3	.89634	8.64687	.91371	10.58932	.93111	13.51676	3
4	.89663	8.67387	.91400	10.62837	.93140	13.57817	4
5	.89692	8.70103	.91429	10.66769	.93169	13.64011	5
6	.89721	8.72833	.91458	10.70728	.93198	13.70258	6
7	.89750	8.75579	.91487	10.74714	.93227	13.76558	7
8	.89779	8.78341	.91516	10.78727	.93257	13.82913	8
9	.89808	8.81119	.91545	10.82768	.93286	13.89323	9
10	.89836	8.83912	.91574	10.86837	.93315	13.95788	10
11	.89865	8.86722	.91603	10.90934	.93344	14.02310	11
12	.89894	8.89547	.91632	10.95060	.93373	14.08890	12
13	.89923	8.92389	.91661	10.99214	.93402	14.15527	13
14	.89952	8.95248	.91690	11.03397	.93431	14.22223	14
15	.89981	8.98123	.91719	11.07610	.93460	14.28979	15
16	.90010	9.01015	.91748	11.11852	.93489	14.35795	16
17	.90039	9.03923	.91777	11.16125	.93518	14.42672	17
18	.90068	9.06849	.91806	11.20427	.93547	14.49611	18
19	.90097	9.09792	.91835	11.24761	.93576	14.56614	19
20	.90126	9.12752	.91864	11.29125	.93605	14.63679	20
21	.90155	9.15730	.91893	11.33521	.93634	14.70810	21
22	.90184	9.18725	.91922	11.37948	.93663	14.78005	22
23	.90213	9.21739	.91951	11.42408	.93692	14.85268	23
24	.90242	9.24770	.91980	11.46900	.93721	14.92597	24
25	.90271	9.27819	.92009	11.51424	.93750	14.99995	25
26	.90300	9.30887	.92038	11.55982	.93779	15.07462	26
27	.90329	9.33973	.92067	11.60572	.93808	15.14999	27
28	.90358	9.37077	.92096	11.65197	.93837	15.22607	28
29	.90386	9.40201	.92125	11.69856	.93866	15.30287	29
30	.90415	9.43343	.92154	11.74550	.93895	15.38041	30
31	.90444	9.46505	.92183	11.79278	.93924	15.45869	31
32	.90473	9.49685	.92212	11.84042	.93953	15.53772	32
33	.90502	9.52886	.92241	11.88841	.93982	15.61751	33
34	.90531	9.56106	.92270	11.93677	.94011	15.69808	34
35	.90560	9.59346	.92299	11.98549	.94040	15.77944	35
36	.90589	9.62605	.92328	12.03458	.94069	15.86159	36
37	.90618	9.65885	.92357	12.08040	.94098	15.94456	37
38	.90647	9.69186	.92386	12.13388	.94127	16.02835	38
39	.90676	9.72507	.92415	12.18411	.94156	16.11297	39
40	.90705	9.75849	.92444	12.23472	.94186	16.19843	40
41	.90734	9.79212	.92473	12.28572	.94215	16.28476	41
42	.90763	9.82596	.92502	12.33712	.94244	16.37196	42
43	.90792	9.86001	.92531	12.38891	.94273	16.46005	43
44	.90821	9.89428	.92560	12.44112	.94302	16.54903	44
45	.90850	9.92877	.92589	12.49373	.94331	16.63893	45
46	.90879	9.96348	.92618	12.54676	.94360	16.72975	46
47	.90908	9.99841	.92647	12.60021	.94389	16.82152	47
48	.90937	10.03356	.92676	12.65408	.94418	16.91424	48
49	.90966	10.06894	.92705	12.70838	.94447	17.00794	49
50	.90995	10.10455	.92734	12.76312	.94476	17.10262	50
51	.91024	10.14039	.92763	12.81829	.94505	17.19830	51
52	.91053	10.17646	.92792	12.87391	.94534	17.29501	52
53	.91082	10.21277	.92821	12.92999	.94563	17.39274	53
54	.91111	10.24932	.92850	12.98651	.94592	17.49153	54
55	.91140	10.28610	.92879	13.04350	.94621	17.59139	55
56	.91169	10.32313	.92908	13.10096	.94650	17.69233	56
57	.91197	10.36040	.92937	13.15889	.94679	17.79438	57
58	.91226	10.39792	.92966	13.21730	.94708	17.89755	58
59	.91255	10.43569	.92995	13.27620	.94737	18.00185	59
60	.91284	10.47371	.93024	13.33559	.94766	18.10732	60

TABLE 11.—NATURAL VERSED SINES AND EXTERNAL SECANTS.

	87°		88°		89°		
′	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	′
0	.94766	18.10732	.96510	27.65371	.98255	56.29869	0
1	.94795	18.21397	.96539	27.89440	.98284	57.26976	1
2	.94825	18.32182	.96568	28.13917	.98313	58.27431	2
3	.94854	18.43088	.96597	28.38812	.98342	59.31411	3
4	.94883	18.54119	.96626	28.64137	.98371	60.39105	4
5	.94912	18.65275	.96655	28.89903	.98400	61.50715	5
6	.94941	18.76560	.96684	29.16120	.98429	62.66460	6
7	.94970	18.87976	.96714	29.42802	.98458	63.86572	7
8	.94999	18.99524	.96743	29.69960	.98487	65.11304	8
9	.95028	19.11208	.96772	29.97607	.98517	66.40927	9
10	.95057	19.23028	.96801	30.25758	.98546	67.75736	10
11	.95086	19.34989	.96830	30.54425	.98575	69.16047	11
12	.95115	19.47093	.96859	30.83623	.98604	70.62285	12
13	.95144	19.59341	.96888	31.13366	.98633	72.14583	13
14	.95173	19.71737	.96917	31.43671	.98662	73.73586	14
15	.95202	19.84283	.96946	31.74554	.98691	75.39655	15
16	.95231	19.96982	.96975	32.06030	.98720	77.13274	16
17	.95260	20.09838	.97004	32.38118	.98749	78.94968	17
18	.95289	20.22852	.97033	32.70835	.98778	80.85315	18
19	.95318	20.36027	.97062	33.04199	.98807	82.84947	19
20	.95347	20.49368	.97092	33.38232	.98836	84.94561	20
21	.95377	20.62876	.97121	33.72952	.98866	87.14924	21
22	.95406	20.76555	.97150	34.08380	.98895	89.46886	22
23	.95435	20.90409	.97179	34.44539	.98924	91.91387	23
24	.95464	21.04440	.97208	34.81452	.98953	94.49471	24
25	.95493	21.18653	.97237	35.19141	.98982	97.22303	25
26	.95522	21.33050	.97266	35.57633	.99011	100.1119	26
27	.95551	21.47635	.97295	35.96953	.99040	103.1757	27
28	.95580	21.62413	.97324	36.37127	.99069	106.4311	28
29	.95609	21.77386	.97353	36.78185	.99098	109.8966	29
30	.95638	21.92559	.97382	37.20155	.99127	113.5930	30
31	.95667	22.07935	.97411	37.63068	.99156	117.5444	31
32	.95696	22.23520	.97440	38.06957	.99186	121.7780	32
33	.95725	22.39316	.97470	38.51855	.99215	126.3253	33
34	.95754	22.55328	.97499	38.97797	.99244	131.2223	34
35	.95783	22.71563	.97528	39.44820	.99278	136.5111	35
36	.95812	22.88022	.97557	39.92963	.99302	142.2406	36
37	.95842	23.04712	.97586	40.42266	.99331	148.4684	37
38	.95871	23.21637	.97615	40.92772	.99360	155.2623	38
39	.95900	23.38802	.97644	41.44525	.99389	162.7033	39
40	.95929	23.56212	.97673	41.97571	.99418	170.8883	40
41	.95958	23.73873	.97702	42.51961	.99447	179.9350	41
42	.95987	23.91790	.97731	43.07746	.99476	189.9868	42
43	.96016	24.09969	.97760	43.64980	.99505	201.2212	43
44	.96045	24.28414	.97789	44.23720	.99535	213.8600	44
45	.96074	24.47134	.97819	44.84026	.99564	228.1839	45
46	.96103	24.66132	.97848	45.45963	.99593	244.5540	46
47	.96132	24.85417	.97877	46.09596	.99622	263.4427	47
48	.96161	25.04994	.97906	46.74997	.99651	285.4795	48
49	.96190	25.24869	.97935	47.42241	.99680	311.5230	49
50	.96219	25.45051	.97964	48.11406	.99709	342.7752	50
51	.96248	25.65546	.97993	48.82576	.99738	380.9723	51
52	.96277	25.86360	.98022	49.55840	.99767	428.7187	52
53	.96307	26.07503	.98051	50.31290	.99796	490.1070	53
54	.96336	26.28981	.98080	51.09027	.99825	571.9581	54
55	.96365	26.50804	.98109	51.89156	.99855	686.5496	55
56	.96394	26.72978	.98138	52.71790	.99884	858.4369	56
57	.96423	26.95513	.98168	53.57046	.99913	1144.916	57
58	.96452	27.18417	.98197	54.45053	.99942	1717.874	58
59	.96481	27.41700	.98226	55.35946	.99971	3436.747	59
60	.96510	27.65371	.98255	56.29869	1.00000	Infinite	60

 12.—CUBIC YARDS PER 100 FEET. SLOPES ½ : 1.

Depth	Base 12	Base 14	Base 16	Base 18	Base 22	Base 24	Base 26	Base 28
1	45	53	60	68	82	90	97	105
2	93	107	122	137	167	181	196	211
3	142	163	186	208	253	275	297	319
4	193	222	252	281	341	370	400	430
5	245	282	319	356	431	468	505	542
6	300	344	389	433	522	567	611	656
7	356	408	460	512	616	668	719	771
8	415	474	533	593	711	770	830	889
9	475	542	608	675	808	875	942	1008
10	537	611	685	759	907	981	1056	1130
11	601	682	764	845	1008	1090	1171	1253
12	667	756	844	933	1111	1200	1289	1378
13	734	831	926	1023	1216	1312	1408	1505
14	804	907	1010	1115	1322	1426	1530	1633
15	875	986	1096	1208	1431	1542	1653	1764
16	948	1067	1184	1304	1541	1659	1778	1896
17	1023	1149	1274	1401	1653	1779	1905	2031
18	1100	1233	1366	1500	1767	1900	2033	2167
19	1179	1319	1460	1601	1882	2023	2164	2305
20	1259	1407	1555	1704	2000	2148	2296	2444
21	1342	1497	1653	1808	2119	2275	2431	2586
22	1426	1589	1752	1915	2241	2404	2567	2730
23	1512	1682	1853	2023	2364	2534	2705	2875
24	1600	1778	1955	2133	2489	2667	2844	3022
25	1690	1875	2060	2245	2616	2801	2986	3171
26	1781	1974	2166	2359	2744	2937	3130	3322
27	1875	2075	2274	2475	2875	3075	3275	3475
28	1970	2178	2384	2593	3007	3215	3422	3630
29	2068	2282	2496	2712	3142	3356	3571	3786
30	2167	2389	2610	2833	3278	3500	3722	3944
31	2268	2497	2726	2956	3416	3645	3875	4105
32	2370	2607	2844	3081	3556	3793	4030	4267
33	2475	2719	2964	3208	3697	3942	4186	4431
34	2581	2833	3085	3337	3841	4093	4344	4596
35	2690	2949	3208	3468	3986	4245	4505	4764
36	2800	3067	3333	3600	4133	4400	4667	4933
37	2912	3186	3460	3734	4282	4556	4831	5105
38	3026	3307	3589	3870	4433	4715	4996	5278
39	3142	3431	3719	4008	4586	4875	5164	5453
40	3259	3556	3852	4148	4741	5037	5333	5630
41	3379	3682	3986	4290	4897	5201	5505	5808
42	3500	3811	4122	4433	5056	5367	5678	5989
43	3623	3942	4260	4579	5216	5534	5853	6171
44	3748	4074	4400	4726	5378	5704	6030	6356
45	3875	4208	4541	4875	5542	5875	6208	6542
46	4004	4344	4684	5026	5707	6048	6389	6730
47	4134	4482	4830	5179	5875	6223	6571	6919
48	4267	4622	4978	5333	6044	6400	6756	7111
49	4401	4764	5127	5490	6216	6579	6942	7305
50	4537	4907	5278	5648	6389	6759	7130	7500
51	4675	5053	5430	5808	6564	6942	7319	7697
52	4815	5200	5584	5970	6741	7126	7511	7896
53	4956	5349	5741	6134	6919	7312	7705	8097
54	5100	5500	5900	6300	7100	7500	7900	8300
55	5245	5653	6060	6468	7282	7690	8097	8505
56	5393	5807	6222	6637	7467	7881	8296	8711
57	5542	5964	6386	6808	7653	8075	8497	8919
58	5693	6122	6552	6981	7841	8270	8700	9130
59	5845	6282	6719	7156	8031	8468	8905	9342
60	6000	6444	6889	7333	8222	8667	9111	9556

Depth	Base 12	Base 14	Base 16	Base 18	Base 22	Base 24	Base 26	Base 28
1	46	54	61	69	83	91	98	106
2	96	111	126	141	170	185	200	215
3	150	172	194	217	261	283	306	328
4	207	237	267	296	356	385	415	444
5	269	306	343	380	454	491	528	565
6	333	378	422	467	556	600	644	689
7	402	454	506	557	661	713	765	817
8	474	533	593	652	770	830	889	948
9	550	617	683	750	883	950	1017	1083
10	630	704	778	852	1000	1074	1148	1222
11	713	794	876	957	1120	1202	1283	1365
12	800	889	978	1067	1244	1333	1422	1511
13	891	987	1083	1180	1372	1469	1565	1661
14	985	1089	1193	1296	1504	1607	1711	1815
15	1083	1194	1306	1417	1639	1750	1861	1972
16	1185	1304	1422	1541	1779	1896	2015	2133
17	1291	1417	1543	1669	1920	2046	2172	2298
18	1400	1533	1667	1800	2067	2200	2333	2467
19	1513	1654	1794	1935	2217	2357	2498	2639
20	1630	1778	1926	2074	2370	2519	2667	2815
21	1750	1906	2061	2217	2528	2683	2839	2994
22	1874	2037	2200	2363	2689	2852	3015	3178
23	2002	2172	2343	2513	2854	3024	3194	3365
24	2133	2311	2489	2667	3022	3200	3378	3556
25	2269	2454	2639	2824	3194	3380	3565	3750
26	2407	2600	2793	2985	3370	3563	3756	3948
27	2550	2750	2950	3150	3550	3750	3950	4151
28	2696	2904	3111	3319	3733	3941	4148	4356
29	2846	3061	3276	3491	3920	4135	4350	4565
30	3000	3222	3444	3667	4111	4333	4556	4778
31	3157	3387	3617	3846	4306	4535	4765	4994
32	3319	3556	3793	4030	4504	4741	4978	5215
33	3483	3728	3972	4217	4706	4950	5194	5439
34	3652	3904	4156	4407	4911	5163	5415	5667
35	3824	4083	4343	4602	5120	5380	5639	5898
36	4000	4267	4533	4800	5333	5600	5867	6133
37	4180	4454	4728	5002	5550	5824	6098	6372
38	4363	4644	4926	5207	5770	6052	6333	6615
39	4550	4839	5128	5417	5994	6283	6572	6861
40	4741	5037	5333	5630	6222	6519	6815	7111
41	4935	5239	5543	5846	6454	6757	7061	7365
42	5133	5444	5756	6067	6689	7000	7311	7622
43	5335	5654	5972	6291	6928	7246	7565	7883
44	5541	5867	6193	6519	7170	7496	7822	8148
45	5750	6083	6417	6750	7417	7750	8083	8417
46	5963	6304	6644	6985	7667	8007	8348	8689
47	6180	6528	6876	7224	7920	8269	8617	8965
48	6400	6756	7111	7467	8178	8533	8889	9244
49	6624	6987	7350	7713	8439	8802	9165	9528
50	6852	7222	7593	7963	8704	9074	9444	9815
51	7083	7461	7839	8217	8972	9350	9728	10106
52.	7319	7704	8089	8474	9244	9630	10015	10400
53	7557	7950	8343	8735	9520	9913	10306	10698
54	7800	8200	8600	9000	9800	10200	10600	11000
55	8046	8454	8861	9269	10083	10491	10898	11306
56	8296	8711	9126	9541	10370	10785	11200	11615
57	8550	8972	9394	9817	10661	11083	11506	11928
58	8807	9237	9667	10096	10956	11385	11815	12244
59	9069	9506	9943	10380	11254	11691	12128	12565
60	9333	9778	10222	10667	11556	12000	12444	12889

Depth	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	48	56	63	70	78	107	115	122
2	104	119	133	148	163	222	237	252
3	167	189	211	233	256	344	367	389
4	237	267	296	326	356	474	504	533
5	315	352	389	426	463	611	648	685
6	400	444	489	533	578	756	800	844
7	493	544	596	648	700	907	959	1011
8	593	652	711	770	830	1067	1126	1185
9	700	767	833	900	967	1233	1300	1367
10	815	889	963	1037	1111	1407	1481	1556
11	937	1019	1100	1181	1263	1589	1670	1752
12	1067	1156	1244	1333	1422	1778	1867	1956
13	1204	1300	1396	1493	1589	1974	2070	2167
14	1348	1452	1556	1659	1763	2178	2281	2385
15	1500	1611	1722	1833	1944	2389	2500	2611
16	1659	1778	1896	2015	2133	2607	2726	2844
17	1826	1952	2078	2204	2330	2833	2959	3085
18	2000	2133	2267	2400	2533	3067	3200	3333
19	2181	2322	2463	2604	2744	3307	3448	3589
20	2370	2519	2667	2815	2963	3556	3704	3852
21	2567	2722	2878	3033	3189	3811	3967	4122
22	2770	2933	3096	3259	3422	4074	4237	4444
23	2981	3152	3322	3493	3663	4344	4515	4685
24	3200	3378	3556	3733	3911	4622	4800	4978
25	3426	3611	3796	3981	4167	4907	5093	5278
26	3659	3852	4044	4237	4430	5200	5393	5585
27	3900	4100	4300	4500	4700	5500	5700	5900
28	4148	4356	4563	4770	4978	5807	6015	6222
29	4404	4619	4833	5048	5263	6122	6337	6552
30	4667	4889	5111	5333	5556	6444	6667	6889
31	4937	5167	5396	5626	5856	6774	7004	7233
32	5215	5452	5689	5926	6163	7111	7348	7585
33	5500	5744	5989	6233	6478	7456	7700	7944
34	5793	6044	6296	6548	6800	7807	8059	8311
35	6093	6352	6611	6870	7130	8167	8426	8685
36	6400	6667	6933	7200	7467	8533	8800	9067
37	6715	6989	7263	7537	7811	8907	9181	9456
38	7037	7319	7600	7881	8163	9289	9570	9852
39	7367	7656	7944	8233	8522	9678	9967	10256
40	7704	8000	8296	8593	8889	10074	10370	10667
41	8048	8352	8656	8959	9263	10478	10781	11085
42	8400	8711	9022	9333	9644	10889	11200	11511
43	8759	9078	9396	9715	10033	11307	11626	11944
44	9126	9452	9778	10104	10430	11733	12059	12385
45	9500	9833	10167	10500	10833	12167	12500	12833
46	9881	10222	10563	10904	11244	12607	12948	13289
47	10270	10619	10967	11315	11663	13056	13404	13752
48	10667	11022	11378	11733	12089	13511	13867	14222
49	11070	11433	11796	12159	12522	13974	14337	14700
50	11481	11852	12222	12593	12963	14444	14815	15185
51	11900	12278	12656	13033	13411	14922	15300	15678
52	12326	12711	13096	13481	13867	15407	15793	16178
53	12759	13152	13544	13937	14330	15900	16293	16685
54	13200	13600	14000	14400	14800	16400	16800	17200
55	13648	14056	14463	14870	15278	16907	17315	17722
56	14104	14519	14933	15348	15763	17422	17837	18252
57	14567	14989	15411	15833	16256	17944	18367	18789
58	15037	15467	15896	16326	16756	18474	18904	19333
59	15515	15952	16389	16826	17263	19011	19448	19885
60	16000	16444	16889	17333	17778	19556	20000	20444

Depth	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	50	57	65	72	80	109	117	124
2	111	126	141	156	170	230	244	259
3	183	206	228	250	272	361	383	406
4	267	296	326	356	385	504	533	563
5	361	398	435	472	509	657	694	731
6	467	511	556	600	644	822	867	911
7	583	635	687	739	791	998	1050	1102
8	711	770	830	889	948	1185	1244	1304
9	850	917	983	1050	1116	1383	1450	1517
10	1000	1074	1148	1222	1296	1593	1667	1741
11	1161	1243	1324	1406	1487	1813	1894	1976
12	1333	1422	1511	1600	1689	2044	2133	2222
13	1517	1613	1709	1806	1902	2287	2383	2480
14	1711	1815	1919	2022	2126	2541	2644	2748
15	1917	2028	2139	2250	2361	2806	2917	3028
16	2133	2252	2370	2489	2607	3081	3200	3319
17	2361	2487	2613	2739	2865	3369	3494	3620
18	2600	2733	2867	3000	3133	3667	3800	3933
19	2850	2991	3131	3272	3413	3976	4117	4257
20	3111	3259	3407	3556	3704	4296	4444	4592
21	3383	3539	3694	3850	4005	4628	4783	4939
22	3667	3830	3993	4156	4318	4970	5133	5296
23	3961	4131	4302	4472	4642	5324	5494	5665
24	4267	4444	4622	4800	4978	5689	5867	6044
25	4583	4769	4954	5139	5324	6065	6250	6435
26	4911	5104	5296	5489	5681	6452	6644	6837
27	5250	5450	5650	5850	6050	6850	7050	7250
28	5600	5807	6015	6222	6430	7259	7467	7674
29	5961	6176	6391	6606	6820	7680	7894	8109
30	6333	6556	6778	7000	7222	8111	8333	8555
31	6717	6946	7176	7406	7635	8554	8783	9013
32	7111	7348	7585	7822	8059	9007	9244	9482
33	7517	7761	8006	8250	8494	9472	9717	9962
34	7933	8185	8437	8689	8941	9948	10200	10452
35	8361	8620	8880	9139	9398	10435	10694	10954
36	8800	9067	9333	9600	9867	10933	11200	11467
37	9250	9524	9798	10072	10346	11443	11717	11991
38	9711	9993	10274	10556	10837	11963	12244	12526
39	10183	10472	10761	11050	11339	12494	12783	13072
40	10667	10963	11259	11556	11852	13037	13333	13630
41	11161	11465	11769	12072	12376	13591	13894	14198
42	11667	11978	12289	12600	12911	14156	14467	14778
43	12183	12502	12820	13139	13457	14731	15050	15369
44	12711	13037	13363	13689	14015	15319	15644	15970
45	13250	13583	13917	14250	14583	15917	16250	16583
46	13800	14141	14481	14822	15163	16526	16867	17207
47	14361	14709	15057	15406	15754	17146	17494	17843
48	14933	15289	15644	16000	16356	17778	18133	18489
49	15517	15880	16243	16606	16968	18420	18783	19146
50	16111	16481	16852	17222	17592	19074	19444	19815
51	16717	17094	17472	17850	18228	19739	20117	20494
52	17333	17719	18104	18489	18874	20415	20800	21185
53	17961	18354	18746	19139	19531	21102	21494	21887
54	18600	19000	19400	19800	20200	21800	22200	22600
55	19250	19657	20065	20472	20880	22509	22917	23324
56	19911	20326	20741	21156	21570	23230	23644	24059
57	20583	21006	21428	21850	22272	23961	24383	24805
58	21267	21696	22126	22556	22985	24704	25133	25563
59	21961	22398	22835	23272	23709	25457	25894	26332
60	22667	23111	23556	24000	24444	26222	26667	27111

Depth	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	52	59	67	74	81	111	119	126
2	119	133	148	163	178	237	252	267
3	200	222	244	267	289	378	400	422
4	296	326	356	385	415	533	563	593
5	407	444	481	519	556	704	741	778
6	533	578	622	667	711	889	933	978
7	674	726	778	830	881	1089	1141	1193
8	830	889	948	1007	1067	1304	1363	1422
9	1000	1067	1133	1200	1267	1533	1600	1667
10	1185	1259	1333	1407	1481	1778	1852	1926
11	1385	1467	1548	1630	1711	2037	2119	2200
12	1600	1689	1778	1867	1956	2311	2400	2489
13	1830	1926	2022	2119	2215	2600	2696	2793
14	2074	2178	2281	2385	2489	2904	3007	3111
15	2333	2444	2556	2667	2778	3222	3333	3444
16	2607	2726	2844	2963	3081	3556	3674	3793
17	2896	3022	3148	3274	3400	3904	4030	4156
18	3200	3333	3467	3600	3733	4267	4400	4533
19	3519	3659	3800	3941	4081	4644	4785	4926
20	3852	4000	4148	4296	4444	5037	5185	5333
21	4200	4356	4511	4667	4822	5444	5600	5756
22	4563	4730	4889	5052	5215	5867	6030	6193
23	4941	5111	5281	5452	5622	6304	6474	6644
24	5333	5511	5689	5867	6044	6756	6933	7111
25	5741	5926	6111	6296	6481	7222	7407	7593
26	6163	6356	6548	6741	6933	7704	7896	8089
27	6600	6800	7000	7200	7400	8200	8400	8600
28	7052	7259	7467	7674	7881	8711	8919	9126
29	7519	7733	7948	8163	8378	9237	9452	9667
30	8000	8222	8444	8667	8889	9778	10000	10222
31	8496	8726	8956	9185	9415	10333	10563	10793
32	9007	9244	9481	9719	9956	10904	11141	11378
33	9533	9778	10022	10267	10511	11489	11733	11978
34	10074	10326	10578	10830	11081	12089	12341	12593
35	10630	10889	11148	11407	11667	12704	12963	13222
36	11200	11467	11733	12000	12267	13333	13600	13867
37	11785	12059	12333	12607	12881	13978	14252	14526
38	12385	12667	12948	13230	13511	14637	14919	15200
39	13000	13289	13578	13867	14156	15311	15600	15889
40	13630	13926	14222	14519	14815	16000	16296	16593
41	14274	14578	14881	15185	15489	16704	17007	17311
42	14933	15244	15556	15867	16178	17422	17733	18044
43	15607	15926	16224	16563	16881	18156	18474	18793
44	16296	16622	16948	17274	17600	18904	19230	19556
45	17000	17333	17667	18000	18333	19667	20000	20333
46	17719	18059	18400	18741	19081	20444	20785	21126
47	18452	18800	19148	19496	19844	21237	21585	21933
48	19200	19556	19911	20267	20622	22044	22400	22756
49	19963	20326	20689	21052	21415	22867	23230	23593
50	20741	20711	21481	21852	22222	23704	24074	24444
51	21533	21911	22289	22667	23044	24556	24933	25311
52	22341	22726	23111	23496	23881	25422	25807	26193
53	23163	23556	23948	24341	24733	26304	26696	27089
54	24000	24400	24800	25200	25600	27200	27600	28000
55	24852	25259	25667	26074	26481	28111	28519	28926
56	25719	26133	26548	26963	27378	29037	29452	29867
57	26600	27022	27444	27867	28289	29978	30400	30822
58	27496	27926	28356	28785	29215	30933	31363	31793
59	28407	28844	29281	29719	30156	31904	32341	32778
60	29333	29778	30222	30667	31111	32889	33333	33778

Depth	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	56	63	70	78	85	115	122	130
2	133	148	163	178	193	252	267	281
3	233	256	278	300	322	411	433	456
4	356	385	415	444	474	593	622	652
5	500	537	574	611	648	796	833	870
6	667	711	756	800	844	1022	1067	1111
7	856	907	959	1011	1063	1270	1322	1374
8	1067	1126	1185	1244	1304	1541	1600	1659
9	1300	1367	1433	1500	1567	1833	1900	1967
10	1556	1630	1704	1778	1852	2148	2222	2296
11	1833	1915	1996	2078	2159	2485	2567	2648
12	2133	2222	2311	2400	2489	2844	2933	3022
13	2456	2552	2648	2744	2841	3226	3322	3419
14	2800	2904	3007	3111	3215	3630	3733	3837
15	3167	3278	3389	3500	3611	4056	4167	4278
16	3556	3674	3793	3911	4030	4504	4622	4741
17	3967	4093	4219	4344	4470	4974	5100	5226
18	4400	4533	4667	4800	4933	5467	5600	5733
19	4856	4996	5137	5278	5419	5981	6122	6263
20	5333	5481	5630	5778	5926	6519	6667	6815
21	5833	5989	6144	6300	6456	7078	7233	7389
22	6356	6519	6681	6844	7007	7659	7822	7985
23	6900	7070	7241	7411	7581	8263	8433	8504
24	7467	7644	7822	8000	8178	8889	9067	9144
25	8056	8241	8426	8611	8796	9537	9722	9807
26	8667	8859	9052	9244	9437	10207	10400	10593
27	9300	9500	9700	9900	10100	10900	11100	11300
28	9956	10163	10370	10578	10785	11615	11822	12030
29	10633	10848	11063	11278	11493	12352	12567	12781
30	11333	11556	11778	12000	12222	13111	13333	13556
31	12056	12285	12515	12744	12974	13893	14122	14352
32	12800	13037	13274	13511	13748	14696	14933	15170
33	13567	13811	14056	14300	14544	15522	15767	16011
34	14356	14607	14859	15111	15363	16370	16622	16874
35	15167	15426	15685	15944	16204	17241	17500	17759
36	16000	16267	16533	16800	17067	18133	18400	18667
37	16856	17130	17404	17678	17952	19048	19322	19596
38	17733	18015	18296	18578	18859	19985	20267	20548
39	18633	18922	19211	19500	19789	20944	21233	21522
40	19556	19852	20148	20444	20741	21926	22222	22516
41	20500	20804	21107	21411	21715	22930	23233	23537
42	21467	21778	22089	22400	22711	23956	24267	24578
43	22456	22774	23093	23411	23730	25004	25322	25641
44	23467	23793	24119	24444	24770	26074	26400	26726
45	24500	24833	25167	25500	25833	27167	27500	27833
46	25556	25896	26237	26578	26919	28281	28622	28963
47	26633	26981	27330	27678	28026	29419	29767	30115
48	27733	28089	28444	28800	29156	30578	30938	31289
49	28856	29219	29581	29944	30307	31759	32122	32485
50	30000	30370	30741	31111	31481	32963	33333	33704
51	31167	31544	31922	32300	32678	34189	34567	34944
52	32356	32741	33126	33511	33896	35437	35822	36207
53	33567	33959	34352	34744	35137	36707	37100	37493
54	34800	35200	35600	36000	36400	38000	38400	38800
55	36056	36463	36870	37278	37685	39315	39722	40130
56	37333	37748	38163	38578	38993	40652	41067	41481
57	38633	39056	39478	39900	40322	42011	42433	42856
58	39956	40385	40815	41244	41674	43393	43822	44252
59	41300	41737	42174	42611	43048	44796	45233	45670
60	42667	43111	43556	44000	44444	46222	46667	47111

TABLE 13.—CUBIC YARDS IN 100 FEET LENGTH.

Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.
1	3.7	51	188.9	101	374.1	151	559.3	201	744.4
2	7.4	52	192.6	102	377.8	152	563.0	202	748.2
3	11.1	53	196.3	103	381.5	153	566.7	203	751.9
4	14.8	54	200.0	104	385.2	154	570.4	204	755.6
5	18.5	55	203.7	105	388.9	155	574.1	205	759.3
6	22.2	56	207.4	106	392.6	156	577.8	206	763.0
7	25.9	57	211.1	107	396.3	157	581.5	207	766.7
8	29.6	58	214.8	108	400.0	158	585.2	208	770.4
9	33.3	59	218.5	109	403.7	159	588.9	209	774.1
10	37.0	60	222.2	110	407.4	160	592.6	210	777.8
11	40.7	61	225.9	111	411.1	161	596.3	211	781.5
12	44.4	62	229.6	112	414.8	162	600.0	212	785.2
13	48.1	63	233.3	113	418.5	163	603.7	213	788.9
14	51.9	64	237.0	114	422.2	164	607.4	214	792.6
15	55.6	65	240.7	115	425.9	165	611.1	215	796.3
16	59.3	66	244.4	116	429.6	166	614.8	216	800.0
17	63.0	67	248.2	117	433.3	167	618.5	217	803.7
18	66.7	68	251.9	118	437.0	168	622.2	218	807.4
19	70.4	69	255.6	119	440.7	169	625.9	219	811.1
20	74.1	70	259.3	120	444.4	170	629.6	220	814.8
21	77.8	71	263.0	121	448.2	171	633.3	221	818.5
22	81.5	72	266.7	122	451.9	172	637.0	222	822.2
23	85.2	73	270.4	123	455.6	173	640.7	223	825.9
24	88.9	74	274.1	124	459.3	174	644.4	224	829.6
25	92.6	75	277.8	125	463.0	175	648.2	225	833.3
26	96.3	76	281.5	126	466.7	176	651.9	226	837.0
27	100.0	77	285.2	127	470.4	177	655.6	227	840.7
28	103.7	78	288.9	128	474.1	178	659.3	228	844.4
29	107.4	79	292.6	129	477.8	179	663.0	229	848.2
30	111.1	80	296.3	130	481.5	180	666.7	230	851.9
31	114.8	81	300.0	131	485.2	181	670.4	231	855.6
32	118.5	82	303.7	132	488.9	182	674.1	232	859.3
33	122.2	83	307.4	133	492.6	183	677.8	233	863.0
34	125.9	84	311.1	134	496.3	184	681.5	234	866.7
35	129.6	85	314.8	135	500.0	185	685.2	235	870.4
36	133.3	86	318.5	136	503.7	186	688.9	236	874.1
37	137.0	87	322.2	137	507.4	187	692.6	237	877.8
38	140.7	88	325.9	138	511.1	188	696.3	238	881.5
39	144.4	89	329.6	139	514.8	189	700.0	239	885.2
40	148.2	90	333.3	140	518.5	190	703.7	240	888.9
41	151.9	91	337.0	141	522.2	191	707.4	241	892.6
42	155.6	92	340.7	142	525.9	192	711.1	242	896.3
43	159.3	93	344.4	143	529.6	193	714.8	243	900.0
44	163.0	94	348.2	144	533.3	194	718.5	244	903.7
45	166.7	95	351.9	145	537.0	195	722.2	245	907.4
46	170.4	96	355.6	146	540.7	196	725.9	246	911.1
47	174.1	97	359.3	147	544.4	197	729.6	247	914.8
48	177.8	98	363.0	148	548.2	198	733.3	248	918.5
49	181.5	99	366.7	149	551.9	199	737.0	249	922.2
50	185.2	100	370.4	150	555.6	200	740.7	250	925.9

Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.
251	929.6	301	1114.8	351	1300.0	401	1485.2	451	1670.4
252	933.3	302	1118.5	352	1303.7	402	1488.9	452	1674.1
253	937.0	303	1122.2	353	1307.4	403	1492.6	453	1677.8
254	940.7	304	1125.9	354	1311.1	404	1496.3	454	1681.5
255	944.4	305	1129.6	355	1314.8	405	1500.0	455	1685.2
256	948.2	306	1133.3	356	1318.5	406	1503.7	456	1688.9
257	951.9	307	1137.0	357	1322.2	407	1507.4	457	1692.6
258	955.6	308	1140.7	358	1325.9	408	1511.1	458	1696.3
259	959.3	309	1144.4	359	1329.6	409	1514.8	459	1700.0
260	963.0	310	1148.2	360	1333.3	410	1518.5	460	1703.7
261	966.7	311	1151.9	361	1337.0	411	1522.2	461	1707.4
262	970.4	312	1155.6	362	1340.7	412	1525.9	462	1711.1
263	974.1	313	1159.3	363	1344.4	413	1529.6	463	1714.8
264	977.8	314	1163.0	364	1348.2	414	1533.3	464	1718.5
265	981.5	315	1166.7	365	1351.9	415	1537.0	465	1722.2
266	985.2	316	1170.4	366	1355.6	416	1540.7	466	1725.9
267	988.9	317	1174.1	367	1359.3	417	1544.4	467	1729.6
268	992.6	318	1177.8	368	1363.0	418	1548.2	468	1733.3
269	996.3	319	1181.5	369	1366.7	419	1551.9	469	1737.0
270	1000.0	320	1185.2	370	1370.4	420	1555.6	470	1740.7
271	1003.7	321	1188.9	371	1374.1	421	1559.3	471	1744.4
272	1007.4	322	1192.6	372	1377.8	422	1563.0	472	1748.2
273	1011.1	323	1196.3	373	1381.5	423	1566.7	473	1751.9
274	1014.8	324	1200.0	374	1385.2	424	1570.4	474	1755.6
275	1018.5	325	1203.7	375	1388.9	425	1574.1	475	1759.3
276	1022.2	326	1207.4	376	1392.6	426	1577.8	476	1763.0
277	1025.9	327	1211.1	377	1396.3	427	1581.5	477	1766.7
278	1029.6	328	1214.8	378	1400.0	428	1585.2	478	1770.4
279	1033.3	329	1218.5	379	1403.7	429	1588.9	479	1774.1
280	1037.0	330	1222.2	380	1407.4	430	1592.6	480	1777.8
281	1040.7	331	1225.9	381	1411.1	431	1596.3	481	1781.5
282	1044.4	332	1229.6	382	1414.8	432	1600.0	482	1785.2
283	1048.2	333	1233.3	383	1418.5	433	1603.7	483	1788.9
284	1051.9	334	1237.0	384	1422.2	434	1607.4	484	1792.6
285	1055.6	335	1240.7	385	1425.9	435	1611.1	485	1796.3
286	1059.3	336	1244.4	386	1429.6	436	1614.8	486	1800.0
287	1063.0	337	1248.2	387	1433.3	437	1618.5	487	1803.7
288	1066.7	338	1251.9	388	1437.0	438	1622.2	488	1807.4
289	1070.4	339	1255.6	389	1440.7	439	1625.9	489	1811.1
290	1074.1	340	1259.3	390	1444.4	440	1629.6	490	1814.8
291	1077.8	341	1263.0	391	1448.2	441	1633.3	491	1818.5
292	1081.5	342	1266.7	392	1451.9	442	1637.0	492	1822.2
293	1085.2	343	1270.4	393	1455.6	443	1640.7	493	1825.9
294	1088.9	344	1274.1	394	1459.3	444	1644.4	494	1829.6
295	1092.6	345	1277.8	395	1463.0	445	1648.2	495	1833.3
296	1096.3	346	1281.5	396	1466.7	446	1651.9	496	1837.0
297	1100.0	347	1285.2	397	1470.4	447	1655.6	497	1840.7
298	1103.7	348	1288.9	398	1474.1	448	1659.3	498	1844.4
299	1107.4	349	1292.6	399	1477.8	449	1663.0	499	1848.2
300	1111.1	350	1296.3	400	1481.5	450	1666.7	500	1851.9

Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.
501	1855.6	551	2040.7	601	2225.9	651	2411.1	701	2596.3
502	1859.3	552	2044.4	602	2229.6	652	2414.8	702	2600.0
503	1863.0	553	2048.2	603	2233.3	653	2418.5	703	2603.7
504	1866.7	554	2051.9	604	2237.0	654	2422.2	704	2607.4
505	1870.4	555	2055.6	605	2240.7	655	2425.9	705	2611.1
506	1874.1	556	2059.3	606	2244.4	656	2429.6	706	2614.8
507	1877.8	557	2063.0	607	2248.2	657	2433.3	707	2618.5
508	1881.5	558	2066.7	608	2251.9	658	2437.0	708	2622.2
509	1885.2	559	2070.4	609	2255.6	659	2440.7	709	2625.9
510	1888.9	560	2074.1	610	2259.3	660	2444.4	710	2629.6
511	1892.6	561	2077.8	611	2263.0	661	2448.2	711	2633.3
512	1896.3	562	2081.5	612	2266.7	662	2451.9	712	2637.0
513	1900.0	563	2085.2	613	2270.4	663	2455.6	713	2640.7
514	1903.7	564	2088.9	614	2274.1	664	2459.3	714	2644.4
515	1907.4	565	2092.6	615	2277.8	665	2463.0	715	2648.2
516	1911.1	566	2096.3	616	2281.5	666	2466.7	716	2651.9
517	1914.8	567	2100.0	617	2285.2	667	2470.4	717	2655.6
518	1918.5	568	2103.7	618	2288.9	668	2474.1	718	2659.3
519	1922.2	569	2107.4	619	2292.6	669	2477.8	719	2663.0
520	1925.9	570	2111.1	620	2296.3	670	2481.5	720	2666.7
521	1929 6	571	2114.8	621	2300.0	671	2485.2	721	2670.4
522	1933.3	572	2118.5	622	2303.7	672	2488.9	722	2674.1
523	1937.0	573	2122.2	623	2307.4	673	2492.6	723	2677.8
524	1940.7	574	2125.9	624	2311.1	674	2496.3	724	2681.5
525	1944.4	575	2129.6	625	2314.8	675	2500.0	725	2685.2
526	1948.2	576	2133.3	626	2318.5	676	2503.7	726	2688.9
527	1951.9	577	2137.0	627	2322.2	677	2507.4	727	2692.6
528	1955.6	578	2140.7	628	2325.9	678	2511.1	728	2696.3
529	1959.3	579	2144.4	629	2329.6	679	2514.8	729	2700.0
530	1963.0	580	2148 2	630	2333.3	680	2518.5	730	2703.7
531	1966.7	581	2151.9	631	2337.0	681	2522.2	731	2707.4
532	1970.4	582	2155.6	632	2340.7	682	2525.9	732	2711.1
533	1974.1	583	2159.3	633	2344.4	683	2529.6	733	2714.8
534	1977.8	584	2163.0	634	2348.2	684	2533.3	734	2718.5
535	1981.5	585	2166.7	635	2351.9	685	2537.0	735	2722.2
536	1985.2	586	2170.4	636	2355.6	686	2540 7	736	2725.9
537	1988.9	587	2174.1	637	2359.3	687	2544.4	737	2729.6
538	1992.6	588	2177.8	638	2363.0	688	2548.2	738	2733.3
539	1996.3	589	2181.5	639	2366.7	689	2551.9	739	2737.0
540	2000.0	590	2185.2	640	2370.4	690	2555.6	740	2740.7
541	2003.7	591	2188.9	641	2374.1	691	2559.3	741	2744.4
542	2007.4	592	2192.6	642	2377.8	692	2563.0	742	2748.2
543	2011.1	593	2196.3	643	2381.5	693	2566.7	743	2751.9
544	2014.8	594	2200.0	644	2385.2	694	2570.4	744	2755.6
545	2018.5	595	2203.7	645	2388.9	695	2574.1	745	2759.3
546	2022.2	596	2207.4	646	2392.6	696	2577.8	746	2763.0
547	2025.9	597	2211.1	647	2396.3	697	2581.5	747	2766.7
548	2029.6	598	2214.8	648	2400.0	698	2585.2	748	2770.4
549	2033.3	599	2218.5	649	2403.7	699	2588.9	749	2774.1
550	2037.0	600	2222.2	650	2407.4	700	2592.6	750	2777.8

Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.
751	2781.5	801	2966.7	851	3151.9	901	3337.0	951	3522.2
752	2785.2	802	2970.4	852	3155.6	902	3340.7	952	3525.9
753	2788.9	803	2974.1	853	3159.3	903	3344.4	953	3529.6
754	2792.6	804	2977.8	854	3163.0	904	3348.2	954	3533.3
755	2796.3	805	2981.5	855	3166.7	905	3351.9	955	3537.0
756	2800.0	806	2985.2	856	3170.4	906	3355.6	956	3540.7
757	2803.7	807	2988.9	857	3174.1	907	3359.3	957	3544.4
758	2807.4	808	2992.6	858	3177.8	908	3363.0	958	3548.2
759	2811.1	809	2996.3	859	3181.5	909	3366.7	959	3551.9
760	2814.8	810	3000.0	860	3185.2	910	3370.4	960	3555.6
761	2818.5	811	3003 7	861	3188.9	911	3374.1	961	3559.3
762	2822.2	812	3007.4	862	3192.6	912	3377.8	962	3563.0
763	2825.9	813	3011.1	863	3196.3	913	3381.5	963	3566.7
764	2829.6	814	3014.8	864	3200.0	914	3385.2	964	3570.4
765	2833 3	815	3018.5	865	3203.7	915	3388.9	965	3574.1
766	2837.0	816	3022.2	866	3207.4	916	3392.6	966	3577.8
767	2840.7	817	3025.9	867	3211.1	917	3396.3	967	3581.5
768	2844.4	818	3029.6	868	3214.8	918	3400.0	968	3585.2
769	2848.2	819	3033.3	869	3218.5	919	3403.7	969	3588.9
770	2851.9	820	3037.0	870	3222.2	920	3407.4	970	3592.6
771	2855.6	821	3040.7	871	3225.9	921	3411.1	971	3596.3
772	2859.3	822	3044.4	872	3229.6	922	3414.8	972	3600.0
773	2863.0	823	3048.2	873	3233.3	923	3418.5	973	3603.7
774	2866.7	824	3051.9	874	3237.0	924	3422.2	974	3607.4
775	2870.4	825	3055.6	875	3240.7	925	3425.9	975	3611.1
776	2874.1	826	3059.3	876	3244.4	926	3429.6	976	3614.8
777	2877.8	827	3063.0	877	3248.2	927	3433.3	977	3618.5
778	2881.5	828	3066.7	878	3251.9	928	3437.0	978	3622.2
779	2885.2	829	3070.4	879	3255.6	929	3440.7	979	3625.9
780	2888.9	830	3074.1	880	3259.3	930	3444.4	980	3629.6
781	2892.6	831	3077.8	881	3263.0	931	3448.2	981	3633.3
782	2896.3	832	3081.5	882	3266.7	932	3451.9	982	3637.0
783	2900.0	833	3085.2	883	3270.4	933	3455.6	983	3640.7
784	2903.7	834	3088.9	884	3274.1	934	3459.3	984	3644.4
785	2907.4	835	3092.6	885	3277.8	935	3463.0	985	3648.2
786	2911.1	836	3096.3	886	3281.5	936	3466.7	986	3651.9
787	2914.8	837	3100.0	887	3285.2	937	3470.4	987	3655.6
788	2918.5	838	3103.7	888	3288.9	938	3474.1	988	3659.3
789	2922.2	839	3107.4	889	3292.6	939	3477.8	989	3663.0
790	2925.9	840	3111.1	890	3296.3	940	3481.5	990	3666.7
791	2929.6	841	3114.8	891	3300.0	941	3485.2	991	3670.4
792	2933.3	842	3118.5	892	3303.7	942	3488.9	992	3674.1
793	2937.0	843	3122.2	893	3307.4	943	3492.6	993	3677.8
794	2940.7	844	3125.9	894	3311.1	944	3496.3	994	3681.5
795	2944.4	845	3129.6	895	3314.8	945	3500.0	995	3685.2
796	2948.2	846	3133.3	896	3318.5	946	3503.7	996	3688.9
797	2951.9	847	3137.0	897	3322.2	947	3507.4	997	3692.6
798	2955.6	848	3140.7	898	3325.9	948	3511.1	998	3696.3
799	2959.3	849	3144.4	899	3329.6	949	3514.8	999	3700.0
800	2963.0	850	3148.2	900	3333.3	950	3518.5	1000	3703.7

TABLE 14.—TRIGONOMETRIC FORMULAS.

RIGHT TRIANGLES.

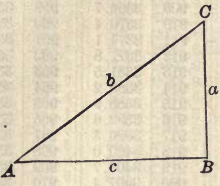

FIG. 98.

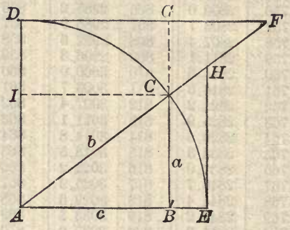

FIG. 99.

In Fig 99, let DCE be the arc of a quadrant, ABC a right triangle, the angle BAC subtended by the arc $CE = A$, and consider the radius $AC =$ unity. Then

$BC = \sin A.$	$AF = \text{cosec} A.$
$AB = \cos A.$	$BE = \text{versin} A.$
$HE = \tan A.$	$DI = \text{coversin} A.$
$DF = \cot A.$	$CH = \text{exsec} A.$
$AH = \sec A.$	$CF = \text{coexsec} A.$

Using the small letters a, b, c, to represent the sides of a right triangle in Fig. 98 or 99, we may write

$$\sin A = \frac{a}{b}; \quad \text{cosec} A = \frac{b}{a}; \quad \therefore \sin A = \frac{1}{\text{cosec} A}.$$

$$\cos A = \frac{c}{b}; \quad \sec A = \frac{b}{c}; \quad \therefore \cos A = \frac{1}{\sec A}.$$

$$\tan A = \frac{a}{c}; \quad \cot A = \frac{c}{a}; \quad \therefore \tan A = \frac{1}{\cot A}.$$

FORMULAS FOR LOGARITHMIC COMPUTATION.

Given one side, a, and the three angles A, B, and C.

The "sine proportion" states that each side of a triangle is proportional to the sine of the angle opposite it.

Then, $b = \dfrac{a \sin B}{\sin A}$ and $C = \dfrac{a \sin C}{\sin A}$.

$$\text{Area} = \frac{a^2 \sin B \sin C}{2 \sin (B + C)}$$

Given two sides a and b and the included angle C.

First method:—Determining the angles first.

$$\tfrac{1}{2}(A + B) = \tfrac{1}{2}(180 - C)$$

$$\tan \tfrac{1}{2}(A - B) = \frac{a - b}{a + b} \tan \tfrac{1}{2}(A + B).$$

$$A = \tfrac{1}{2}(A + B) + \tfrac{1}{2}(A - B)$$

$$B = \tfrac{1}{2}(A + B) - \tfrac{1}{2}(A - B).$$

The third side, c, can now be determined by the sine proportion.

Second method:—Determining the third side first.

$$\tan x = \frac{2 \sin \frac{1}{2} C}{a - b} \sqrt{a\,b}.$$

$$c = \frac{a - b}{\cos x}.$$

The angles A and B can now be found by the sine proportion

$$\text{Area} = \tfrac{1}{2} a\,b \sin C.$$

Given the three sides a, b, and c.

Let $s = \tfrac{1}{2}(a + b + c)$.

Then $$*\tan \tfrac{1}{2} A = \frac{\sqrt{\frac{1}{s}(s - a)(s - b)(s - c)}}{s - a}$$

$$*\tan \tfrac{1}{2} B = \frac{\sqrt{\frac{1}{s}(s - a)(s - b)(s - c)}}{s - b}$$

$$*\tan \tfrac{1}{2} C = \frac{\sqrt{\frac{1}{s}(s - a)(s - b)(s - c)}}{s - c}$$

$$\text{Area} = \sqrt{s(s - a)(s - b)(s - c)}$$

* It will be noted that the numerator is the same in each case and that the denominators are quantities whose logarithms are known and hence two additional logarithmic operations over that required for one angle gives all three angles and a complete check on the entire computation since $A + B + c = 180°$.

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