Handbook for surveyors

Merriman Mansfield
Title: Handbook for surveyors

Author: Merriman Mansfield

This is an exact replica of a book. The book reprint was manually improved by a team of professionals, as opposed to automatic/OCR processes used by some companies. However, the book may still have imperfections such as missing pages, poor pictures, errant marks, etc. that were a part of the original text. We appreciate your understanding of the imperfections which can not be improved, and hope you will enjoy reading this book.
ENGINEERING LIBRARY
Copyright, 1895,
BY
MANSFIELD MERRIMAN
AND
JOHN P. BROOKS.

PRESS OF
BRAUNWORTH & CO.,
BOOK MANUFACTURERS
BROOKLYN, N. Y.
PREFACE TO FIRST EDITION.

This work is designed for the use of classes in technical schools, and also as a field book for surveyors. It is intended to embrace in concise form the ground that a student should cover in surveying before taking up the subject of railroad location. Hence it includes the fundamental theoretical principles, land and town surveying, leveling and simple triangulation, and topography. The attempt has been made to discuss each of these topics clearly and concisely, and in accordance with the best modern methods.

The need of the volume arose merely from the fact that no text-book on elementary surveying in pocket-book form can now be found in the market. While in the field a student should have a book of tables ever at hand, and if these are combined with the text a double advantage is often found, particularly in adjusting instruments and in ruling forms for notes.

In arranging the order of presentation the rule has been as far as possible to proceed from the simple to the complex in a natural order. For instance, the most difficult thing in surveying is the determination of a true meridian, and hence in this volume it comes last of all, although in most other books it is presented at an early stage.

As all persons likely to use the volume have access to surveying instruments, no illustrations of these are given. The effort has been made, however, to set forth methods of testing and comparing instruments more fully than is usually done in elementary books. As an instance of this, attention is called to the determination of the eccentricity of the graduated circle of a transit given in Article 27.

The old terms "latitude" and "departure," borrowed from navigation, are not here used, but instead "latitude difference" and "longitude difference" are employed, as is universally
done in geodetic surveying; the terms "latitude" and "longitude" are moreover used in the same sense as in geodesy and astronomy. That this method has advantages the experience of many years of teaching may bear witness.

The first field work done by a student is usually plotted to a large scale, and hence in Chapter IV the effort is made to clearly distinguish between large-scale and small-scale topography. Both the transit and the plane-table method of stadia work are presented, but preference is given to the former. Hydrographic and mine surveying are briefly outlined, the latter being with especial reference to the practice in the anthracite regions of Pennsylvania.

The tables of natural functions are given to five decimal places, while logarithms and logarithmic functions are given to six decimals. The old-fashioned traverse table is omitted, as it is of little value when sines and cosines are at hand. The tables for stadia reductions are those computed by Professor Arthur Winslow for two minute intervals of vertical angles. For assistance in compiling Tables III, V, and VI, acknowledgments are due to the United States Coast and Geodetic Survey.

NOTE TO FIFTH EDITION.

This edition is mainly characterized by new tables of positions of Polaris and by a new chart of lines of equal magnetic declination, the copy for which has been kindly furnished by the U. S. Coast and Geodetic Survey.

A few minor revisions have been made here and there. All known errors have been corrected.
CONTENTS.

CHAPTER I.
FUNDAMENTAL PRINCIPLES.

ART.  PAGE
1. Geometry and Trigonometry ........................................... 7
2. Lines, Angles, and Azimuths ........................................... 10
3. Coordinates; Latitudes and Longitudes ............................ 13
4. Areas of Triangles and Trapezoids .................................. 15
5. Areas of Polygons ...................................................... 17
6. Computation of Areas .................................................. 20
7. Division of Land ....................................................... 23
8. Inaccessible Distances .................................................. 25
9. Elevations and Heights ................................................ 27
10. Errors of Measurements ............................................... 29

CHAPTER II.
LAND SURVEYING.

ART.  PAGE
11. Chains and Tapes ..................................................... 32
12. The Transit ............................................................ 35
13. The Magnetic Needle .................................................. 40
14. Field Work ............................................................ 44
15. Survey of a Farm ....................................................... 47
16. Office Work ........................................................... 53
17. Random Lines ........................................................ 57
18. Resurveys ............................................................. 59
19. Traversing .............................................................. 62
20. United States Public-Land Surveys .................................. 64

CHAPTER III.
LEVELING AND TRIANGULATION.

ART.  PAGE
21. The Level ............................................................. 67
22. Adjustments of the Level ............................................. 68
23. Comparison of Levels ............................................... 70
24. Leveling .............................................................. 73
25. Contours and Profiles ................................................. 75
26. Adjustments of the Transit .......................................... 78
27. Comparison of Transits ............................................... 81
ART. & PAGE
28. Standard Tapes.................................................. 84
29. Base Lines.......................................................... 87
30. Triangulation Work............................................... 90

CHAPTER IV.
TOPOGRAPHIC SURVEYING.
31. Large-Scale Topography........................................ 94
32. Small-Scale Topography.......................................... 98
33. Theory of the Stadia............................................. 100
34. Stadia Reductions............................................... 104
35. Field Work with the Stadia.................................... 107
36. Office Work....................................................... 110
37. The Plane Table.................................................. 113
38. Hydrographic Surveying........................................ 115
39. Mine Surveying................................................... 119
40. The True Meridian............................................... 124
41. Isogonic Chart of United States for 1915.................... 123
42. Azimuth by Altitude of the Sun............................... 243

TABLES.
I. Natural Sines and Cosines...................................... 129
II. Natural Tangents and Cotangents.............................. 130
   Lengths of Circular Arcs.................................... 151
III. Daily Variation of the Magnetic Needle..................... 152
IV. Degrees of Longitude and Time................................ 153
V. Elongations and Culminations of Polaris..................... 154
VI. Azimuths of Polaris at Elongation........................... 156
VII. Metric and English Measures................................ 158
VIII. Length of Arcs of Latitude and Longitude............... 159
IX. Reduction of Inclined Distances to the Horizontal......... 160
X. Stadia Reductions for Reading 100............................ 161
XI. Logarithms of Numbers....................................... 169
   Constant Numbers and their Logarithms..................... 196
XII. Logarithmic Sines, Cosines, Tangents, and Cotangents.... 197
XIII. Mean Refractions............................................ 245
CHAPTER I.

FUNDAMENTAL PRINCIPLES.


Geometry and Surveying were originally synonymous, as the etymology of the former word indicates. They originated in Egypt, where monuments and boundary lines were annually obliterated by the inundation of the Nile. Euclid, professor of mathematics at Alexandria about 250 B.C., wrote a treatise on geometry which has never been equaled in logical methods. Geometry furnishes the principles on which the operations of surveying are founded, whereby line and angle measurements, the computation of areas, and the construction of maps are effected. Arithmetic and Trigonometry are the tools by which the principles of Geometry are applied.

The following theorems of plane geometry are perhaps those of greatest importance, but many others are constantly used in the field practice of engineers:

If two straight lines intersect, the opposite angles are equal. Straight lines parallel to the same straight line are parallel to each other.

The sum of the interior angles of a polygon is equal to twice as many right angles as the polygon has sides minus four right angles.

The sum of the exterior angles formed by producing the sides of a polygon is equal to four right angles.

The square upon the hypothenuse of a right-angled triangle is equal to the sum of the squares upon the other two sides.

Angles at the center of a circle are in the same ratio as their intercepted arcs.

An angle at the circumference of a circle is measured by one half the arc intercepted by its sides.
If the angles of two triangles are equal each to each, the homologous sides are proportional and the triangles are similar.

The areas of similar polygons are as the squares of their homologous sides.

The area of a triangle is measured by one half the product of its base and altitude. The area of a trapezoid is measured by one half the product of the sum of its parallel sides by its altitude.

The area of a sector of a circle is measured by one half the product of its arc and radius.

The circumference of a circle is equal to its diameter multiplied by 3.1415927. The area of a circle is equal to the square of its radius multiplied by 3.1415927.

Trigonometry, or the solution of triangles by means of sines and tangents of the angles, originated in the thirteenth century, previous computations having been made with chords. The following rules for the solution of oblique triangles are here given for reference, but it should be remembered that no surveyor can attain success unless he is thoroughly conversant with all of them without the necessity of referring to a book.

In any triangle let \( a, b, c \), be the sides opposite the angles \( A, B, C \). These sides are proportional to the sines of opposite angles. The value of each side may be expressed in three ways in terms of the other sides and angles; thus,

\[
a = b \frac{\sin A}{\sin B} = c \frac{\sin A}{\sin C} = \sqrt{b^2 + c^2 - 2bc \cos A};
\]

\[
b = a \frac{\sin B}{\sin A} = c \frac{\sin B}{\sin C} = \sqrt{a^2 + c^2 - 2ac \cos B};
\]

\[
c = a \frac{\sin C}{\sin A} = b \frac{\sin C}{\sin B} = \sqrt{a^2 + b^2 - 2ab \cos C}.
\]

Also each angle may be expressed as follows:

\[
\sin A = \frac{a}{b} \sin B = \frac{a}{c} \sin C, \quad \cos A = \frac{b^2 + c^2 - a^2}{2bc};
\]
\[
\sin B = \frac{b}{a} \sin A = \frac{b}{c} \sin C, \quad \cos B = \frac{a^2 + c^2 - b^2}{2ac};
\]
\[
\sin C = \frac{c}{a} \sin A = \frac{c}{b} \sin B, \quad \cos C = \frac{a^2 + b^2 - c^2}{2ab}.
\]

If \( A \) be made a right angle these reduce to the formulas for right triangles, which are too well known to be repeated here.

When two sides and their included angle are given, as \( a, b, C \), then the formulas
\[
\cot A = \frac{b}{a \sin C} - \cot C, \quad \cot B = \frac{a}{b \sin C} - \cot C,
\]
determine \( A \) and \( B \), while as a check, \( A + B + C = 180^\circ \); the third side is then found from
\[
c = a \sin C / \sin A.
\]

When the three sides \( a, b, c \) are given, the cosines of the angles can be independently computed from the formulas above given. But some prefer to divide the triangle into two right-angled triangles by dropping a perpendicular from \( A \) upon the base \( a \), thus dividing it into two segments, \( a_1 \) and \( a_2 \). The sum of these segments is \( a \), their difference is
\[
a_1 - a_2 = \frac{(b + c)(b - c)}{a}.
\]

Let this difference be called \( \delta \); then
\[
a_1 = \frac{1}{2}(a + \delta) \quad \text{and} \quad a_2 = \frac{1}{2}(a - \delta).
\]
Lastly the angles are found by
\[
\cos B = a_2 / c, \quad \cos C = a_1 / b_1, \quad \text{and} \quad \sin A = a \sin B / b;
\]
as a check \( A + B + C = 180^\circ \).

While the above expressions are sufficient for the solution of all plane triangles, there are other formulas more convenient for logarithmic computation for certain special cases. Tables of natural functions are generally used in ordinary surveying, particularly in the field, while logarithmic tables are perhaps better for rapid work in the office. The young surveyor should be prepared to solve triangles quickly and rapidly by either method.
In all kinds of computations a neat and orderly arrangement should be followed, and it is recommended that all problems given in these pages, as well as those arising in field practice, should be solved in ink in a special book and be preserved for reference. Check computations should in all cases be made; this can be done by finding the same quantity in different ways, by computing the three angles independently and taking their sum, or by using both natural functions and logarithmic tables.

Prob. 1. Given $a = 227.52$ feet, $b = 168.00$ feet, $C = 137^\circ 25'$; to compute independently the angles $A$ and $B$.

Art. 2. Lines, Angles, and Azimuths.

The measurement of a line consists in finding how many times it contains the unit of measure. For several centuries the Gunter’s chain of 66 feet has been the English linear unit for land measurements; it is divided into 100 parts, called links, and lengths are expressed in chains and links, the latter being written as decimals of a chain; thus 12 chains and 72 links is 12.72 chains. Although this chain is rapidly going out of use, the young surveyor should be acquainted with it, since a large part of the land records in the United States is based upon it.

In computing areas the chain has the advantage that square chains are easily reduced to acres by moving the decimal point one place to the left. This is because 66 feet $\times$ 66 feet = 4356 square feet, which is one tenth of an acre. For example, a rectangular lot 6.48 chains long and 2.15 chains wide contains 13.932 square chains, or 1.3932 acres.

The unit of linear measure now generally used in the United States is the foot. In measuring lines a chain 100 feet long, divided into 100 links, is used, and distances are recorded in feet, decimals of a foot being estimated when possible. Tapes of various kinds, with the foot divided decimally, are also used, especially in cities where precise measurements are necessary.

Custom and civil laws have decided that the length of the