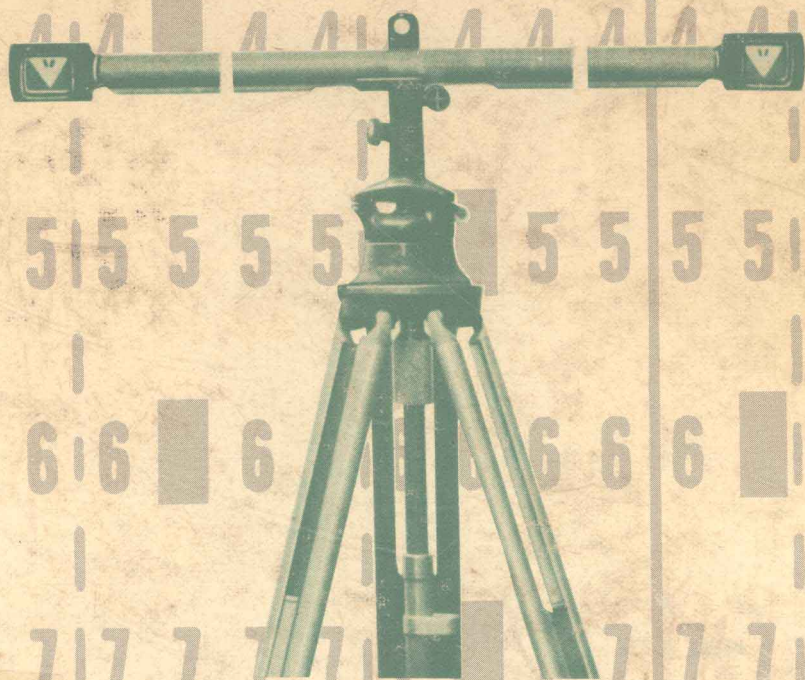


# **ELEMENTARY SURVEYING 5th Ed.**



**Russell C. Brinker**

# *Elementary Surveying*

**FIFTH EDITION**

***RUSSELL C. BRINKER***

*Professor of Civil Engineering  
New Mexico State University*

**INTERNATIONAL TEXTBOOK COMPANY**  
*Scranton, Pennsylvania*

R-K-RI

Standard Book Number 7002 2243 ×

***Copyright ©, 1969, by International Textbook Company***

All rights reserved. No part of the material protected by this copyright notice may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording, or by any informational storage and retrieval system, without written permission from the copyright owner. Printed in the United States of America by The Haddon Craftsmen, Inc., Scranton, Pennsylvania. Library of Congress Catalog Card Number: 69-16621.

***INTERNATIONAL TEXTBOOKS IN CIVIL ENGINEERING***

Consulting Editor

***RUSSELL C. BRINKER***

Professor of Civil Engineering  
New Mexico State University

***Elementary  
Surveying***

# *Preface*

The fifth edition of *ELEMENTARY SURVEYING* continues the approach of the third and fourth editions which emphasized fundamental theory and procedures while still giving practical hints and illustrations not covered generally or at all elsewhere. Many remarks made in the fourth edition Preface apply also to this revision and are noted again.

Slight to major changes or additions have been made in every chapter including

- 1) Expanded information on government agencies and mapping.
- 2) Data on automatic reading and recording systems plus more suggestions on notekeeping.
- 3) Rewritten and updated material on the tellurometer, electro-tape, and geodimeter with a new table on the characteristics of all known electronic distance measuring instruments.
- 4) Discussion of the laser and its applications in several chapters, and the airborne profile recorder.
- 5) New instrument illustrations.
- 6) An interlocking 2-loop level circuit adjustment with an example.
- 7) A new chart on the distribution of magnetic declinations.
- 8) Analysis of the number of instrument pointings to balance sighting and reading errors.
- 9) Description of the angles-to-the-right method.
- 10) An illustrative calculation of latitudes and departures using natural functions (but retaining the example with logarithms), and a Fortran program with output listing.
- 11) Five (instead of three) methods of traverse adjustment.
- 12) Additional material on contours.
- 13) Some rearrangement of instrument adjustment items.
- 14) Updated field astronomy example solutions with new technical and general points of interest.

- 15) Completely rewritten chapter on Photogrammetry.
- 16) A listing of slope staking steps and numerical example.
- 17) Circular curve layout by tangent offsets with a problem illustration.
- 18) Revision of the sight distance formula and examples to fit the changed height-of-eye specification.
- 19) Mention of the mass diagram.
- 20) Improved optical alignment equipment and utilization of the laser.
- 21) A new chapter on State Plane Coordinates, with numerical example, in Appendix A.
- 22) An increased number of problems at the end of each chapter and the data changed for old ones to provide over 1,000 homework problems (up from 653 and enough for many semesters without repeating). A solutions manual is available for the first time. Some problems are carried through several chapters so progressive steps in their completion can be followed.
- 23) Elimination of the log tables and enlargement of the natural function tables from 5 to 7 places for accuracy in handling desk calculator computations requiring 5 significant figures.

Stress in text and problems is placed upon the theory of errors and optics; correlation of theory and practical field methods; elimination of typical errors and mistakes; significant figures; use of basic values such as  $\sin 1 \text{ min} = 0.0003$  and  $\sin 1^\circ = 0.01\frac{3}{4}$  in solving ordinary problems without tables or slide rule; and the interdependence of field, computation, and mapping requirements.

Engineers, architects, geologists, and foresters must be able to make measurements and analyze the precision and accuracy of the results obtained by other people. They should be qualified to properly locate and set machinery; to lay out houses, buildings, and other common structures; and to understand and prepare simple topographic maps. Each of these areas is discussed, and proper field procedures to obtain a desired precision are noted.

A few cost figures are introduced so that students will learn early in their college work to associate the three bases of engineering practice—theory, application, and costs. All surveying is a constant fight to eliminate or isolate errors and mistakes. In each chapter the student is reminded of this point, through lists of typical errors and mistakes.

Although the third, fourth, and fifth editions retain the title *ELEMENTARY SURVEYING*, the material goes beyond the elementary stage in length and scope. The large number of chapters, however, permits inclusion or omission of subjects to correspond with the class time available for students in civil engineering, other engineering curricula, architecture, geology, and forestry. The easy-reading qualities of the previous editions have been retained by keeping short lines for ready scanning and fewer lines per page.

Chapters are arranged in the order found most convenient at numerous colleges. Fundamental material is collected in the first sixteen chapters comprising Part I. Theory and use of the four fundamental surveying instruments—the tape, level, transit, and plane table—are described in detail, and new types of equipment noted. Any chapter following Chapter 11 can be omitted without loss of continuity, although many of them are short enough to be suitable for a single assignment.

Limited coverage of such subjects as photogrammetry, field astronomy, boundary surveys, and industrial applications of surveying methods is given in Part II to fit various programs offered. For example, the brief chapter on boundary surveys is intended to make students aware of a few problems involved in the survey and transfer of property, and the legal requirements of professional registration. Some instructors give broad survey-type courses and want their students to get an over-all view of the many surveying functions. It is believed that the arrangement in scope of material presented herein will meet that need also.

Taping, leveling, and transit work are taken up in order because students find it easier to acquire some facility with the equipment in that sequence, and because this arrangement permits the start and continuation of field work with a minimum of lecture time. The suggested order of field assignments given in Appendix A makes it possible to begin effective computation and drafting-room problems after just a few periods in the field if bad weather is encountered.

The difficulty in getting through all of the preliminary material (basic concepts of the profession, history, theory of errors, and methods of notekeeping) before commencing field work during the first week is recognized. Nevertheless the author feels that these topics must precede the theory and use of instruments.

The subject of notes and noteforms—an important part of sur-

veying and engineering—is discussed in a separate chapter. Most of the sample notefoms are collected in Appendix A instead of being scattered throughout the text.

Suggestions and criticism will be greatly appreciated.

RUSSELL C. BRINKER

University Park, New Mexico  
January, 1969

# *Acknowledgments*

The author wishes to acknowledge the use of material from the late Professors A. S. Cutler, O. S. Zelner, and L. F. Boon (University of Minnesota); Professor Emeritus C. B. Andrews (University of Hawaii); Professor (Retired) P. P. Rice (Rutgers University); and Mr. D. F. Griffin (formerly of the University of Southern California). Helpful suggestions, assistance, or pertinent material for this and/or previous editions were offered by Professor A. S. Chase (Auburn University); Professor L. Perez (Pennsylvania State University); Lt. Col. W. L. Baxter (formerly at the United States Military Academy); Professors L. G. Rich and J. P. Rastron (Clemson College); Professor D. V. Smith (Virginia Polytechnic Institute); Professor E. C. Wagner (University of Wisconsin); Professor H. E. Kallsen (formerly at Louisiana Polytechnic Institute); Professor G. B. Lyon (Cornell University); Professors W. Wintz, Jr., D. C. McKee, and J. M. DeMarche (Louisiana State University); W. Blakney (Auburn University); C. F. Meyer (Worcester Polytechnic Institute); Professor C. H. Drown (Sacramento State College); Professor J. R. Coltharp (University of Texas at El Paso); Professor Porter W. McDonnell, Jr. (Pennsylvania State University, Mont Alto Campus); Professor John O. Eichler (Georgia Institute of Technology); Professor J. L. Clapp (University of Wisconsin); Mr. W. C. Wattles of Glendale, California; Mr. R. B. Irwin of Los Angeles, and others.

Chapter 2 was prepared by Professor D. C. McNeese of the University of Washington; Chapter 18 and the Chapter on State Plane Coordinates in Appendix A by Professor Paul R. Wolf (University of California) who also provided many helpful suggestions throughout the entire book.

Illustrative material and other help has been freely supplied by the U. S. Bureau of Land Management, the U. S. Geological Survey,

the U. S. Coast and Geodetic Survey, and the Army Map Service. Manufacturers of surveying equipment who furnished illustrations include the Keuffel and Esser Company, W. and L. E. Gurley, Kern Instruments, Inc., Wild Heerbrugg Instruments, Inc., Abrams Aerial Survey Corporation, Wallace and Tiernan, and Bausch and Lomb.

# ***Contents***

## ***Part I***

### ***Chapter 1. Introduction . . . 1***

Definition of surveying. Importance of surveying. Training for all engineers. History of surveying. Types of surveys. Present status of surveying. The surveying profession. Problems.

### ***Chapter 2. Theory of Measurements and Errors . . . 12***

Measurements in general. Types of measurements made in surveying. Units of measurement. Significant figures. Rounding off numbers. Direct and indirect measurements. Errors in measurements. Sources of errors in making measurements. Types of errors. Magnitude of errors. Minimizing errors. Scope of probability. Occurrence of accidental errors. General laws of probability. The probability equation. The most probable value; the mean. The standard deviation or error. Interpretation of standard error. Probable error. General probability. The error of a sum. The error of a series. The error of the mean. Applications. Adjustments. Methods of computation. Problems.

### ***Chapter 3. Surveying Field Notes . . . 42***

General. Requirements of good notes. Types of field books. Kinds of notes. Arrangement of notes. Suggestions on recording notes. Problems.

### ***Chapter 4. Linear Measurements . . . 50***

General. Methods of making linear measurements. Odometer readings. Pacing. Taping. Tachymetry. Subtense bar. Electronic devices. Care of taping equipment. Taping on level ground. Horizontal measurements on uneven ground. Slope measurements. Stationing. Sources of error in taping. Incorrect length of tape. Temperature. Pull. Sag. Alignment. Tape not horizontal. Plumbing. Incorrect marking. Interpolation. Summary of effects of taping errors. Mistakes or blunders. Tape problems. Laying out a

right angle with a tape. Measuring an angle with a tape by the chord method. Measuring an angle with a tape by the tangent method. Laying off angles. Tape survey of a field. Solution of a taping problem. Problems.

### **Chapter 5. Leveling · · · 95**

General. Definitions. Curvature and refraction. Methods of determining differences in elevation. Types of leveling instruments. Level vials. Telescopes. Optics. Level bar and supports. Leveling head. Wye level. Dumpy level. Tripods. Tilting level. European instruments. Hand level. Leveling rods. Philadelphia rod. Verniers. Setting up the level. Holding the rod. Theory of leveling. Types of leveling. Differential leveling. Reciprocal leveling. Profile leveling. Airborne profile recorder. Drawing and use of the profile. Barometric leveling. Borrow-pit or cross-section leveling. Use of the hand level. Size of field party. Signals. Precision. Adjustment of simple level circuits. Sources of error in leveling. Mistakes. Reduction of errors and elimination of mistakes. Problems.

### **Chapter 6. Angles, Bearings, and Azimuths · · · 148**

General. Units of angle measurement. Measurement of angles. Measurement of direction. Bearings. Azimuths. Comparison of bearings and azimuths. Calculation of bearings. Sources of error. Mistakes. Problems.

### **Chapter 7. The Compass · · · 159**

General. Theory of the compass. Magnetic declination. Variations in magnetic declination. Local attraction. The surveyor's compass. The forester's and geologist's compass. Brunton compass. Typical problems. Sources of error in compass work. Mistakes. Problems.

### **Chapter 8. The Transit · · · 173**

General. The American transit. Upper plate. Lower plate. Leveling head. Scales. Verniers. Method of reading verniers. Properties of an American-type engineer's transit. Other American instruments. Setting up and handling the transit. Operation of the transit. Measuring direct angles by repetition. Closing the horizon. Laying off an angle. Deflection angles. Azimuths. Sights and marks. Prolonging a straight line. Prolonging a line past an obstacle. Balancing in. Random line. Measurement of a vertical angle. European theodolites. Sources of error in transit work. Mistakes. Problems.

### **Chapter 9. Traversing · · · 211**

Definition and uses. Methods of running a traverse. Traversing by compass bearings. Traversing by direct angles. Traversing by deflec-

tion angles. Angles to the right. Traversing by azimuths. Measurement of lengths. Selection of traverse hubs. Organization of field party. Traverse notes. Angle closure. Sources of error. Mistakes. Problems.

### **Chapter 10. Traverse Computations . . . 222**

Purpose. Balancing angles. Computation of bearings. Latitudes and departures. Methods for traverse adjustments. Traverse computation using electronic computers. Other methods of computing latitudes and departures. Coordinates. Lengths and bearings from latitudes and departures, or coordinates. Coordinate computations in boundary measurements. Traverse orientation by coordinates. State plane coordinate systems. Sources of error in traverse computations. Mistakes. Problems.

### **Chapter 11. Area . . . 242**

General. Methods of measuring area. Area by division into triangles. Area by offsets from straight lines. Area by double-meridian-distance method. Area by coordinates. Area from a map by triangles. Area by coordinate squares. Measurement of area by planimeter. Sources of error. Mistakes. Problems.

### **Chapter 12. Stadia . . . 257**

General. Measurement by stadia for horizontal sights. Measurement by stadia for inclined sights. Stadia rods. Beamman arc. Instruments with movable stadia lines. Field notes. Field procedure. Stadia traverses. Topography. Stadia leveling. Precision. Sources of error in stadia work. Mistakes. Problems.

### **Chapter 13. Topographic Surveys . . . 274**

General. Control for topographic surveys. Topographic details. Methods of locating points in the field. Location of lines. Location of lines from a single point. Contours. Characteristics of contours. Methods of obtaining topography. Transit-tape method. Transit-stadia method. Plane-table method. Coordinate squares. Offsets from the center line. Photogrammetry. Selection of field method. Specifications for topographic surveys. Sources of error in topographic surveys. Mistakes. Problems.

### **Chapter 14. Mapping . . . 290**

General. Mapping agencies. Map drafting. Plotting the traverse. Advantages and disadvantages of the different methods. Plotting details. Plotting contours. Topographic symbols. Locating the traverse on a map sheet. Meridian arrow. Title. Notes. Paper. Sources of error in mapping. Mistakes. Problems.

**Chapter 15. The Plane Table . . . 306**

General. Description of the plane table. Use of the plane table. Setting up and orienting the plane table. Traversing. Radiation method. Intersection, or graphical-triangulation, method. Resection. The two-point problem. The three-point problem. Leveling. Advantages and disadvantages of the plane table. Plane-table pointers. Sources of error in plane-table work. Mistakes. Problems.

**Chapter 16. Adjustment of Instruments . . . 326**

General. Tapes. Principle of reversion. Adjustment of the wye level. Adjustment of the dumpy level. Adjustment of the transit. Adjustment of the plane-table alidade. Adjustment of the Beaman stadia arc. Adjustment of the hand level. Other instruments. Sources of error in adjustment of instruments. Mistakes. Problems.

**Part II****Chapter 17. Determination of Meridian . . . 344**

General. Methods of determining azimuth. Shadow method. Meridian by equal altitudes of the sun. Meridian from Polaris at culmination. Definitions. Time. Star positions. Observation on Polaris at culmination. Computations for time of culmination. Observation on Polaris at elongation. Computations for an observation at elongation. Observation on Polaris at any hour angle. Practical suggestions on Polaris observations. Comparison of solar and Polaris observations. Methods of observing the sun. Required quantities in determining azimuth by direct solar observation. Notes and computations for a solar observation. Sources of error in meridian observations. Mistakes. Problems.

**Chapter 18. Photogrammetry . . . 368**

General. Aerial cameras. Vertical aerial photographs. Scale of a vertical photograph. Ground coordinates from a vertical photograph. Relief displacement on a vertical photograph. Flying height of a vertical photograph. Ground control for photogrammetry. Radial triangulation. Mosaics. Parallax. Stereoscopic viewing and measuring. Stereoscopic plotters. Analytical photogrammetry. Flight planning. Sources of error in photogrammetry. Mistakes. Problems.

**Chapter 19. Boundary Surveys . . . 408**

General. Basis of land titles. Property description by metes and bounds. Property description by block-and-lot system. Property description by coordinates. Field work. Registration of title. Sources of error. Mistakes. Problems.

**Chapter 20. Surveys of the Public Lands . . . 421**

General. Instructions for survey of the public lands. Initial point. Principal meridian. Base line. Standard parallels (correction lines). Guide meridians. Township exteriors; meridional (range) lines and latitudinal (township) lines. Designation of townships. Subdivision of a quadrangle into townships. Subdivision of a township into sections. Subdivision of sections. Fractional sections. Notes. Outline of subdivision steps. Marking corners. Witness corners. Meander corners. Lost and obliterated corners. Accuracy of public-lands surveys. Descriptions by township, section, and smaller subdivision. Sources of error. Mistakes. Problems.

**Chapter 21. Construction Surveys . . . 444**

General. Staking out a pipeline. Staking out grades. Staking out a building. Staking out a highway. Sources of error. Mistakes. Problems.

**Chapter 22. Circular Curves . . . 453**

General. Degree of curve. Derivation of formulas. Sample computation. Curve layout. Curve layout by offsets. Setups on the curve. Sight distance on horizontal curves. Compound and reverse curves; special problems. Sources of error. Mistakes. Problems.

**Chapter 23. Parabolic Curves . . . 468**

General. Computations for an equal-tangent curve. Computations for an unequal-tangent curve. High or low point on a vertical curve. Sight distance. Sources of error. Mistakes. Problems.

**Chapter 24. Volumes . . . 475**

General. Methods of measurement. The cross-section method. Types of cross sections. End-area formulas. Prismoidal formula. Unit area, or borrow-pit, method. Contour-area method. Sources of error. Mistakes. Problems.

**Chapter 25. Industrial Applications . . . 484**

General. Basic equipment. Sighting telescope. Alignment telescope. Use of alignment telescope. Positioning a part. The jig transit. Use of the jig transit. The tilting level. Alignment Laser. Optical micrometers. Use of the optical micrometer. Other equipment. Practical applications. Sources of error in optical alignment. Mistakes. Problems.

**Appendix A . . . 501**

Suggested order of field assignments. State plane coordinates. Note-forms.

**Appendix B . . . 543**

Tables: I. Sample pages from traverse table. II. Stadia reductions. III. Table of distances for subtense bar. IV. Convergency of range lines. V. Azimuths of the secant. VI. Offsets, in links, from the secant to the parallel. VII. Functions of circular curves. VIII. Lengths of circular arcs for radius = 1. IX. Trigonometric formulas for the solution of right angles. X. Trigonometric formulas for the solution of oblique triangles. XI. Relations between linear and angular errors. XII. Precision of computed values. XIII. Natural sines and cosines. XIV. Natural tangents and cotangents.

**References . . . 601****Index . . . 605**