DOCUMENT RESUME

ED 317 816 CE 054 654

AUTHOR	Olson, David A.; Kellum, Mary, Ed.
TITLE	Basic Surveying Technology.
INSTITUTION	Mid-America Vocational Curriculum Consortium, Stillwater, Okla.
PUB DATE	87
NOTE	590p.; Document contains colored paper.
AVAILABLE FROM	Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074 (order no. 301101: $20.50).
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF03 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Behavioral Objectives; Career Exploration; Competency Based Education; Curriculum Guides; *Electronics; *Measurement Equipment; Occupational Information; *Occupational Safety and Health; Optics; Problem Solving; Secondary Education; Technological Literacy; Trade and Industrial Education
IDENTIFIERS	*Surveying (Construction); Surveying (Geography); *Surveyors

ABSTRACT

This document is intended to help teachers prepare students to perform the duties of any member of a surveying party, including those of party chief, in the field and in the office. It contains instructional units on introduction to surveying, safety, horizontal measurements, vertical measurements, angles and directions, angular measurements, traversing and related calculations, topographical surveying, construction surveying, legal aspects, boundary surveying, control surveys, and electro-optical instruments and computer integration. The first section is designed to teach teachers how to use the materials and includes an explanation of instructional elements and an instructional-task analysis for each unit. The instructional elements for the units include objectives, suggested activities, information sheets, transparency masters, assignment sheets, job sheets, tests, test answers, references, and lists of supplemental materials. Some elements, such as the information sheets, include photographs, diagrams, and line drawings. (CML)

BASIC SURVEYING TECHNOLOGY

Written by

David A. Olson

Edited by

Mary Kellum

Developed by

The Mid-America Vocational Curriculum Consortium, Inc.

Printed in the United States of America by the
Oklahoma State Department of Vocational-Technical Education
Stillwater, Oklahoma 74074

Mid-America Vocational Curriculum Consortium, Inc.
1500 West Seventh
Stillwater, Oklahoma 74074-4364

FOREWORD

The material presented in *Basic Surveying Technology* forms a competency-based curriculum suitable for most vocational surveying programs. This publication prepares the student to perform the duties of any member of a surveying party, including party chief, both in the field and in the office. The publication also serves as a foundation for future studies in advanced surveying and other related fields such as civil drafting.

Basic Surveying Technology is designed to assist teachers in improving instruction. As this publication is used, it is hoped that the student performance will improve so the students will be better able to assume a role in a surveying occupation. Every effort has been made to make this publication readable and by all means usable. Every instructor using the publication for the first time should study the "Use of this Publication" section of this book prior to teaching. Three vital parts of instruction have been intentionally omitted (motivation, personalization, and leadership). These areas are left to the individual instructors who should capitalize on them. Only then will the publication become a vital part of the teaching-learning process.

Greg Pierce
Executive Director
Mid-America Vocational
Curriculum Consortium

Bob Patton
Chairman, Board of Directors
Mid-America Vocational
Curriculum Consortium

ACKNOWLEDGEMENTS

Appreciation is extended to those individuals who contributed their time and talents in the development of *Basic Surveying Technology*.

The contents of this publication were planned and reviewed by the following members of the Mid-America Vocational Curriculum Consortium civil drafting/surveying committee:

Jerry Baxter	Many, Louisiana
Roland Covert	Milford, Nebraska
Gary Flory	Morrilton, Arkansas
James Hrouda	Flat River, Missouri
Russell Kastelle	Wahpeton, North Dakota
Dave Olson	Sioux Falls, South Dakota
Rick Roman	Austin, Texas
Mark Saunders	Muskogee, Oklahoma
Karen Schertz	Boulder, Colorado
Tom Schoellen	Waterloo, Iowa
Charlie Theis	Topeka, Kansas

Special appreciation is extended to the following members for their valuable input and technical expertise as industry representatives on this surveying committee:

Monty Karns
City Engineer
Stillwater, Oklahoma

Billie Swenson
Jefferson County Mapping Department Director
Golden, Colorado

Pete VanWyhe
Bureau of Land Management
Denver, Colorado

Appreciation is also extended to the following committee members for representing state level supervisors and curriculum specialists:

Bill Hill
Trade and Industrial District Supervisor
State Department of Vocational and Technical Education
Stillwater, Oklahoma

Mervin Birdwell
Assistant Director
Vocational Curriculum Development and Research Center
Natchitoches, Louisiana

Monty Karns deserves special recognition for developing much of the final artwork and photographs used in this publication. We would also like to thank the following individuals on his staff for their assistance: **John Waldo, Troy Lott, David Heaton,** and **Aaron Green.**

Gratitude is expressed to the employees of the Graphics Division of the Oklahoma State Department of Vocational-Technical Education for their assistance with the phototypesetting, artwork, pasteup, and printing of this text.

Thanks are also extended to **Mary Kellum,** MAVCC Publication Specialist, for her assistance with the editing and proofreading of this book, as well as the coordination of the entire project.

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BASIC SURVEYING TECHNOLOGY

TABLE OF CONTENTS

USE OF THIS PUBLICATION

Instructional Units

Basic Surveying Technology contains thirteen units. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the tests. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated

1. Supplies needed
2. Equipment needed
3. Amount of practice needed
4. Amount of class time needed for demonstrations

C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which is a necessary prerequisite to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

BASIC SURVEYING TECHNOLOGY

INSTRUCTIONAL/TASK ANALYSIS

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

UNIT I: INTRODUCTION TO SURVEYING

1. Terms and definitions
2. Definition of surveying
3. Two classifications of surveying
4. Types of surveys
5. Types of equipment and their uses in the surveying profession
6. Recent technical advancements in surveying instrumentation and equipment
7. Responsibilities of each survey crew member
8. Types of surveyors and their duties
9. Personal characteristics of a good surveyor
10. Advantages and disadvantages of being a surveying technician
11. Employment opportunities available in the surveying profession
12. Research employment opportunities
13. Interview a surveying technician
14. Take a math pre-test

UNIT II: SAFETY

1. Terms and definitions
2. Rules for general job safety
3. Personal safety rules involved in the surveying field

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

4. Proper clothing for both warm and cold weather surveying
5. Safety precautions to take while working in the field
6. Types of channeling devices used for traffic control
7. Techniques of proper placement of traffic control devices
8. Responsibilities of a flagger
9. Safety rules for flaggers on a survey crew
10. Types of communication used by a survey crew
11. Common hand signals used while surveying
12. Commonly found species of poisonous plants that can be encountered while surveying
13. Characteristic reactions to common poisonous plants
14. Basic first-aid procedures for care of poisonous plant reactions
15. Poisonous insects and spiders found while surveying
16. Basic first-aid procedures for poisonous insect bites
17. Commonly found poisonous snakes and the effects of each
18. Standard first aid procedures for snake bites
19. First aid procedures for injuries
20. Compile a survey of winter clothing needs
21. Construct a diagram of appropriate traffic control for a two-lane roadway

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
	22. Distinguish between correct and incorrect procedures for flaggers
	23. Control traffic with a flag
	24. Place emergency parking devices

UNIT III: HORIZONTAL MEASUREMENTS

1. Terms and definitions
2. Equivalencies for various surveying measurements
3. Types of equipment used in the past to make horizontal measurements
4. Horizontal measurements and their uses
5. Methods of measuring distances
6. Types of tapes or chains
7. Types of tape readouts
8. Taping accessories and their uses
9. Care and storage of taping equipment
10. Purpose of taping
11. Steps used in taping on level ground
12. Procedure for taping on uneven or sloping ground
13. Accuracy and precision
14. Accuracy ratio
15. Common types of errors
16. Taping corrections and their formulas
17. Recent advancements in horizontal measuring
18. Responsibilities of each survey crew member when making horizontal measurements

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
	19. Compute horizontal conversions
	20. Calculate taping corrections for slope errors
	21. Calculate taping corrections for erroneous tape lengths
	22. Calculate taping corrections for temperature
	23. Calculate taping corrections for all types of taping errors
	24. Determine average length of pace
	25. Measure and lay out horizontal distances with a steel tape

UNIT IV: VERTICAL MEASUREMENTS

1. Terms and definitions
2. Uses of leveling results
3. Theory of leveling procedures
4. Curvature and refraction
5. Major parts of a level
6. Adjusting parts of a level
7. Types of leveling equipment and their characteristics and uses
8. Types of level rods
9. Procedure for setting up a leveling instrument
10. Steps used to establish an e...ation of an unknown point
11. Standard rules for note keeping
12. Applications of level work
13. Duties of survey crew members
14. Common errors that occur in leveling

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RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
15. Common mistakes that occur while leveling	
16. Process of making minor field adjustments (peg test)	
	17. Read various types of level rods
	18. Enter field data in standard field book form
	19. Make minor field adjustments to a leveling instrument (peg test)
	20. Perform a completed level circuit using the differential leveling process

UNIT V: ANGLES AND DIRECTIONS

1. Terms and definitions	
2. Systems of angular measurement	
3. Types of reference meridians	
4. Types of vertical angles used in surveying	
5. Types of horizontal angles	
6. Common methods of giving direction to a line	
7. Converting bearings to azimuths and azimuths to bearings	
8. Converting back directions from either bearings or azimuths	
	9. Convert bearings and azimuths to their opposite forms
	10. Calculate bearings and azimuths from interior angles
	11. Calculate bearings and azimuths from deflection angles
	12. Convert bearings and azimuths into interior angles

RELATED INFORMATION: What the Worker Should Know (Cognitive)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

UNIT VI: ANGULAR MEASUREMENTS

1. Terms and definitions
2. Uses of transits and theodolites
3. Major parts of a transit
4. Characteristics of transits and theodolites
5. Major types of verniers
6. Reading different styles of verniers
7. Typical mistakes made in reading verniers
8. Major types of theodolites
9. Field procedure used to determine if minor instrument adjustments are necessary on plate-level vials and the vertical cross hair
10. Accurately read various types of verniers on transits
11. Set up a transit over a desired point
12. Measure and read angles in the field
13. Set up a theodolite over a desired point

UNIT VII: TRAVERSING AND RELATED CALCULATIONS

1. Terms and definitions
2. Types of traverses commonly used in surveying
3. Methods of measuring traverse angles or directions
4. Proper location of traverse station points
5. Major sources of error in traverse operations

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RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
6. Primary steps taken when computing a traverse closure	
7. Observations or assumptions that can be made when calculating areas by means of the D.M.D. method	
8. Rules to follow when calculating areas by means of the coordinate method	
	9. Compute traverse closure and adjustment by the compass rule
	10. Compute traverse closure and adjustment by the transit rule
	11. Calculate area of a closed traverse by the D.M.D. method
	12. Calculate area of a closed traverse by the coordinate method
	13. Perform a closed loop traverse
	14. Perform a closed connecting traverse

UNIT VIII: TOPOGRAPHIC SURVEYING

1. Terms and definitions	
2. Purposes of topographic surveys	
3. Classifications of topographic surveys	
4. Methods of locating topographic details	
5. Methods of topographic surveying	
6. Stadia principles	
7. Characteristics of contours	
8. Methods of locating contours	
9. Techniques for keeping good topographic field notes	
	10. Construct an accurate contour drawing

RELATED INFORMATION: What the Worker Should Know (Cognitive)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

11. Layout and plot contours from radial survey notes

12. Perform a radial topo survey

13. Perform a right-angle offset survey

UNIT IX: CONSTRUCTION SURVEYING

1. Terms and definitions
2. Purpose of construction surveys
3. Responsibilities of a construction surveyor
4. Purposes of horizontal and vertical control points
5. Laying out control points
6. Computation of grades or slopes
7. Offset stakes
8. Difference between a baseline and an offset stake
9. Types of stake markings and their descriptions
10. Steps in laying out a building location
11. Typical roadway sections
12. Slope staking
13. Equations used in locating slope stakes
14. Types of horizontal curves
15. Elements of a simple horizontal circular curve
16. Steps for computing and laying out a simple horizontal curve
17. Elements of a simple vertical curve

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RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
18. Steps for computing a vertical curve	
	19. Calculate a simple horizontal curve
	20. Calculate a simple vertical curve
	21. Stake a horizontal curve
	22. Stake a centerline profile with a vertical curve
	23. Stake a sewer profile with offsets

UNIT X: LEGAL ASPECTS

1. Terms and definitions	
2. Purposes of legal land surveys	
3. Principles affecting laws on boundary positions	
4. Types of laws regulating land surveying	
5. Methods of transferring property titles	
6. Properly prepared deeds	
7. Types of information contained in land descriptions	
8. Legal terms affecting property possession	
9. Types of boundary evidence	
10. Riparian rights	
11. Terms related to riparian rights and changes in water boundaries	
12. Deed descriptions	
13. Methods of legal land descriptions	
	14. Write a metes and bounds description
	15. Plot or layout a legal land description
	16. Write a lot and block description
	17. Research and record existing property records

RELATED INFORMATION: What the Worker Should Know (Cognitive) | JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

UNIT XI: BOUNDARY SURVEYING

1. Terms and definitions
2. Purposes of a boundary survey
3. Types of boundary surveys
4. Basic rules for each of the principles involved with legal interpretation of evidence
5. Common types of monumentation found when setting boundary lines
6. Abbreviations used for marking monuments
7. Establishment of the U.S. public land survey system
8. States not subdivided under the U.S. public land survey system
9. Subdivision of a section
10. Procedures for performing a boundary survey
11. Answer questions based on the U.S. system of rectangular surveys
12. Write and locate descriptions for the subdivision of a section
13. Research and obtain deed descriptions of an assigned tract of land
14. Retrace boundaries from a deed description

UNIT XII: CONTROL SURVEYS

1. Terms and definitions
2. Purpose of control surveys
3. Items provided by established horizontal and vertical reference monuments
4. Types of control surveys
5. Types of reference datums

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RELATED INFORMATION: What the Worker Should Know (Cognitive)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

6. FGCC accuracy standards used in control surveys

7. Global positioning systems

8. Techniques used in making doppler observations

9. Inertial surveying systems

10. State plane coordinates

11. Celestial observations

12. Calculate the azimuth of a line

13. Determine the direction of a line by polar observation

UNIT XIII: ELECTRO-OPTICAL INSTRUMENTS AND COMPUTER INTEGRATION

1. Terms and definitions

2. Early electronic surveying instruments

3. Major classifications of E.D.M. instruments

4. Principles of E.D.M. measurement

5. Environmental conditions that affect E.D.M. wavelengths

6. Types of E.D.M.s

7. Use of laser energy for leveling and alignment

8. Data collection

9. Types of computer hardware that make up a complete system

10. Types of software programs that are available for engineering design systems

11. Make E.D.M. measurements

INTRODUCTION TO BASIC SURVEYING
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to list the possible employment opportunities available, match the various types of surveys with their descriptions, and identify the different members of a survey crew and their duties and responsibilities. Competencies will be demonstrated by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to basic surveying with the correct definitions.
2. Define the term "surveying."
3. Distinguish between the two classifications of surveying.
4. Match the different types of surveys with their appropriate descriptions.
5. Match types of equipment with their correct uses in the surveying profession.
6. Distinguish between recent technical advancements in surveying instrumentation and equipment.
7. Distinguish between the responsibilities of each survey crew member.
8. Match the various types of surveyors with their correct duties.
9. List personal characteristics of a good surveyor.
10. Distinguish between advantages and disadvantages of being a surveying technician.

OBJECTIVE SHEET

11. List employment opportunities available in the surveying profession.

12. Research employment opportunities. (Assignment Sheet #1)

13. Interview a surveying technician. (Assignment Sheet #2)

14. Take a math pre-test. (Assignment Sheet #3)

INTRODUCTION TO BASIC SURVEYING
UNIT I

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Integrate the following activities throughout the teaching of this unit:

1. Upon completion of Assignment Sheet #1, the students should compile a list of local job contacts, possible future openings, etc. to be referred to when seeking full-time employment.

2. Prior to Assignment Sheet #2, the instructor may want to assign groups of 2-3 students to interview a surveying technician depending on the number of firms in your local area.

3. Show actual examples of equipment used in surveying while discussing types of equipment included in the information sheet.

4. Invite a surveying technician, possibly a past graduate, to speak to the class about their job and educational requirements.

5. Invite a professional surveyor to speak to the class about employer requirements, job duties and skills of a surveying technician, and the importance of attitude on the job.

6. Upon each student's completion of the math pre-test, evaluate the results to identify any areas that need further development and provide additional work sheets that the student may complete.

7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

H. Give test.

I. Evaluate test.

J. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1 — Types of Surveys
2. TM 2 — Surveying Equipment
3. TM 3 — Surveying Equipment (Continued)

D. Assignment sheets

1. Assignment Sheet #1 — Research Employment Opportunities
2. Assignment Sheet #2 — Interview a Surveying Technician
3. Assignment Sheet #3 — Take a Math Pre-Test

E. Answers to assignment sheets

F. Test

G. Answers to test

REFERENCES USED IN WRITING THIS UNIT

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SUGGESTED SUPPLEMENTAL MATERIALS

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150 White Plains Road
Tarrytown, NY 10592

INTRODUCTION TO BASIC SURVEYING
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Accuracy — Denotes the absolute "nearness" of the measured value to the true value

B. Boundary line — A line along which two areas meet

(NOTE: A line between private parcels is usually termed a *property line*.)

C. Contour — An imaginary line along the ground where all points are of the same elevation above or below a specified datum surface

D. Evidence — Testimony, physical objects, marks, traces of former objects, or any relationship of these items that may furnish proof or partial proof of a lost corner or boundary line

E. Photogrammetry — The method of obtaining reliable measurements by means of photographs

F. Precision — The degree of refinement used in measuring a value, either by the number of times it is measured or by the degree of graduations it was measured in

Example: A value measured in feet is not as precise as the same value measured in hundredths of a foot.

G. Property — Used commonly to denote everything which is the subject of ownership

H. Property line — A line indicating ownership boundaries by land descriptions, surveyor's drawing, or physical markings such as fences, stone monuments, or iron pins

I. Terrain — The physical features of a tract of land

J. Theodolite — A precision instrument used for measuring horizontal and vertical angles

(NOTE: The graduated circles are normally more precisely graduated than that of a transit.)

K. Title line — A line indicating ownership as described by the legal description or the platted drawing

L. Topography — The configuration of a surface, including its relief and the position of its existing and man-made features

M. Transit — A repeating surveying instrument for measuring horizontal and vertical angles

INFORMATION SHEET

II. **Definition of surveying**

A. The art and science of making measurements to determine the relative position of *known* points

B. The process used to lay out or establish *new* points by making calculated field measurements

III. **Classifications of surveying**

A. Plane surveying — Any type of surveying in which the surface of the earth is considered a flat (plane) surface

(NOTE: Plane surveying is normally confined to small or limited areas of land such as construction projects and property surveys.)

B. Geodetic surveying — Any type of surveying in which the surface of the earth is considered spherical

(NOTE: Geodetic surveying includes very precise surveying involving large areas of land such as national or state boundaries and control survey networks.)

IV. **Types of surveys (Transparency 1)**

A. Cadastral surveys — Consist of the establishment of land corners and boundaries, and the areas of a given land parcel

B. Topographic surveys — Consist of the location of all ground contours and existing features that are found within the survey limits

C. Route surveys — Consist of the preliminary layout and control work required to survey a narrow but long strip of land

D. Construction surveys — Consist of the layout work required on sites where construction of an engineering nature is to be undertaken

E. Aerial surveys — Consist of the preliminary surveys utilizing photographs taken from an airplane; these photos are scaled and sometimes are viewed in three-dimensional format

F. Underground surveys — Consist of work done to locate points or objects that are below the earth's surface, as in mines, tunnels, and aqueducts

G. Hydrographic surveys — Consist of those made to determine the actual shape of the bottom of lakes, rivers, harbors, and oceans; also include the location of shorelines, measurement of flow, and estimation of resources

INFORMATION SHEET

V. **Types of equipment used in surveying** (Transparencies 2 and 3)

A. Transit or engineer's theodolite — Used to establish straight lines and to measure horizontal and vertical angles

B. Levels and level rods — Used to measure vertical differences in elevation

C. Tapes or chains — Used to measure horizontal and slope distances

D. Miscellaneous equipment

1. Chaining pins — Used to mark chain lengths when measuring distances

   (NOTE: These are also referred to as tally pins or taping arrows.)

2. Range pole — Used to establish a line of sight toward a point

3. Plumb bob — Used to extend a true vertical line up from a point

VI. **Technical advances in surveying**

(NOTE: All of the equipment discussed in this section is very expensive due to the electronics involved. Therefore, they should be handled with great care and under direct supervision until full operation skills have been developed. These technical advances have been incorporated into the surveying profession within the last ten years and are constantly being improved to perform with higher accuracy and user ease.)

A. Digital (read-out) theodolite

1. Electronic display screen that displays horizontal and vertical angles to a specified accuracy

2. Replaces the older "open-face" vernier found on the transit and the micrometer scale used on most theodolites

B. Electronic distance measuring device

1. Electronic device that measures the number of wave lengths (either microwave or light wave) and calculates an actual distance (feet or meters) from the instrument to the point sighted

2. Replaces the many methods of measuring distances, either horizontal, slope, or vertical, but these standard methods will always be used in surveying

INFORMATION SHEET

C. Electronic data collector

1. Electronic device (usually hand-held) that has the capacity to store field data, distances, angles, etc. either by hand entry (push button) or by automatic entry (instrument to data collector which completely bypasses the operator)

2. Enhances the surveyor's field book, notations, and sketches that normally would be kept when surveying

D. Surveying computers and plotting devices

1. Various types that can reduce notes, adjust surveys, calculate areas, assign coordinates, and actually draw the surveyed area simply by entering field data

2. When fully incorporated into a business, it can possibly replace the present duties of civil drafters, and change their roles

E. Global positioning system (GPS)

1. Uses satellites orbiting the earth to measure the location of points remote from each other

2. Anticipated to be in total operation by 1987

3. Expected to yield accuracies up to 2-3 centimeters

4. Will utilize a minimum of 18 satellites in 20,000-km altitude orbits

VII. **Responsibilities and required skills of survey crew**

A. Party chief or recorder

1. Responsible for total operation of the crew including the accuracy of the work completed

2. Must have good organizational skills

3. Should show leadership qualities

4. Should have good educational background and field experience in surveying

B. Instrument person or observer

1. Responsible for the care and operation of the surveying instruments

2. Must exhibit good surveying skills

3. Should have confidence in the total operation of all surveying instruments

4. Should have good educational background in surveying with preferably 1 year field experience

INFORMATION SHEET

C. Chain person or rod person

1. Assists in taking all actual surveying measurements in the field, and is responsible for the care and cleaning of all surveying tapes and miscellaneous equipment

2. Should have basic surveying skills

3. Must exhibit a strong willingness to learn

4. Should have a basic educational background in surveying with 0 to 1 year field experience

(NOTE: In all cases, each member of a survey crew should portray a sense of professionalism, be assertive, and do the best possible job in the least amount of time.)

VIII. **Duties of surveyors**

A. Land surveyor should be an expert in

1. Subdividing lands

2. Retracing old boundary lines

3. Analyzing evidence of the legality of a boundary

4. Writing accurate descriptions of land parcels

(NOTE: The educational requirements to become a registered land surveyor [R.L.S.] will vary from state to state. An average figure across the region would be 2-4 years educational requirements and 4-6 years experience working directly with a registered land surveyor. Check with your instructor to verify the requirements in your state.)

B. Topographic surveyor is responsible for

1. Locating all existing features of a site

2. Determining any elevation contours on a site

(NOTE: A large percentage of topographic information is obtained by photogrammetric methods, especially aerial photographs. Suggested educational background for a topographical surveyor would be completion of a 1 to 2 year surveying program, and 0-2 years of surveying experience.)

INFORMATION SHEET

C. Construction surveyor is responsible for

1. Accurately determining terrain where engineering projects are to be constructed

2. The actual laying out or staking procedures required to accurately locate the future construction

3. Measuring and/or computating construction quantities that would be used for final payments on work completed

(NOTE: Educational background and experience are extremely important in an area of daily construction of engineering projects, with a minimum suggested educational background of 2 years and 2-4 years of previous construction surveying background.)

D. Geodetic surveyor duties lie in

1. Locating, with great precision, surveyed station points used for horizontal control

2. Establishing vertical reference points used for vertical control

(NOTE: Geodetic survey work is normally performed to first-order accuracy and usually involves large areas of land. Educational background and experience, because of the accuracy required, is therefore quite stringent. You may want to visit with a local company that does geodetic work to see what their requirements are.)

IX. **Personal characteristics of a good surveyor**

A. Checks all equipment before starting work

B. Operates all equipment correctly

C. Is safety conscious and follows safety regulations

D. Takes instructions readily and follows company rules

E. Practices conservation of materials, equipment, and time

F. Displays enthusiasm about work

G. Exhibits pride in the trade

H. Controls temper at all times

I. Is punctual

J. Is cooperative with all involved parties

K. Keeps accurate field notes and log reports

INFORMATION SHEET

X. Advantages and disadvantages of being a surveying technician

A. Advantages

1. Good pay

2. Outdoor work

3. Job variety

4. Opportunity to improve skills

5. Job mobility

   (NOTE: A surveyor with several skills has an opportunity to work in all geographic locations.)

6. Comfortable dress

7. Sense of accomplishment

8. Involvement with many professional organizations

B. Disadvantages

1. Possibly dirty work

2. Possibly hazardous work

   Examples: Dangerous areas — Blasting, steep slopes, swamps
   Working near heavy construction equipment
   Possibility of accidents and injuries

3. Exposure to weather conditions

4. Work may require travel away from home

5. Work could require long or awkward hours at times

XI. Employment opportunities in the surveying profession

A. Registered land surveyors

B. Consulting engineers

C. Civil engineering companies

D. Contractors/Construction companies

INFORMATION SHEET

E. Material testing companies

F. Land title and mortgage companies

G. Local government agencies

   1. City engineering division

   2. City planning division

   3. Transportation division

   4. Municipal utilities division

H. Federal government agencies

   1. USGS — United States Geological Survey

   2. DMA — Defense Mapping Agency

   3. BLM — Bureau of Land Management

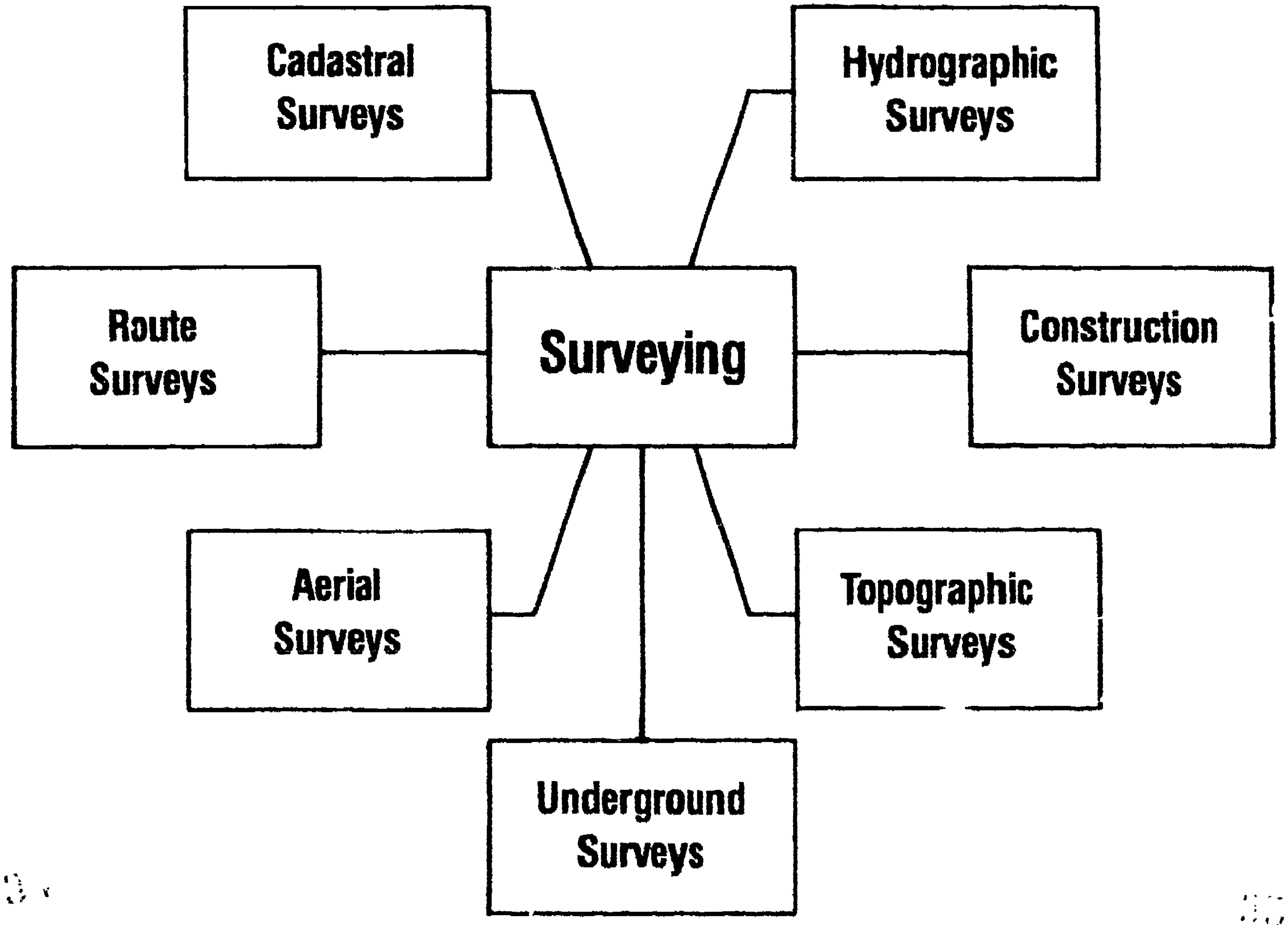
   4. USFS — United States Forestry Service

   5. SCS — Soil Conservation Service

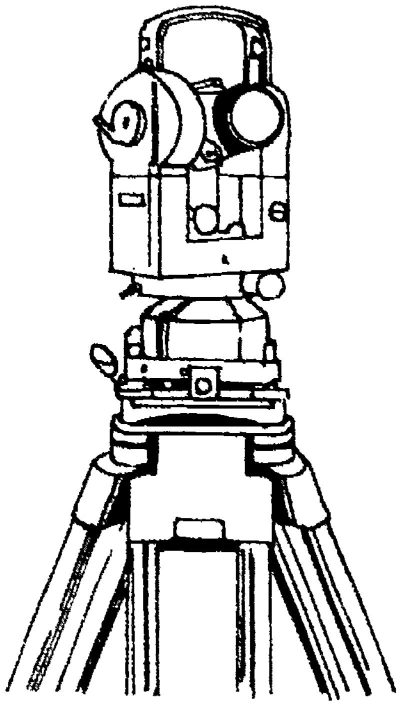
   6. Corps of Engineers, Dept. of the Army

   7. NGS — National Geodetic Survey

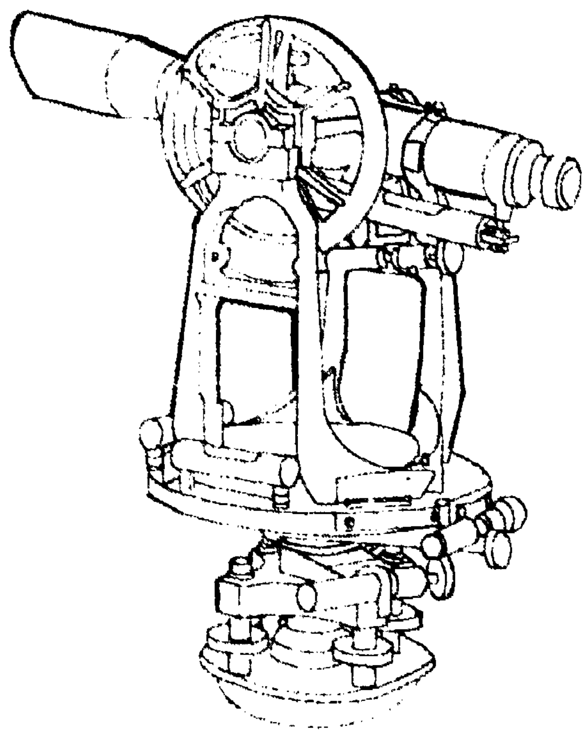
Types of Surveys



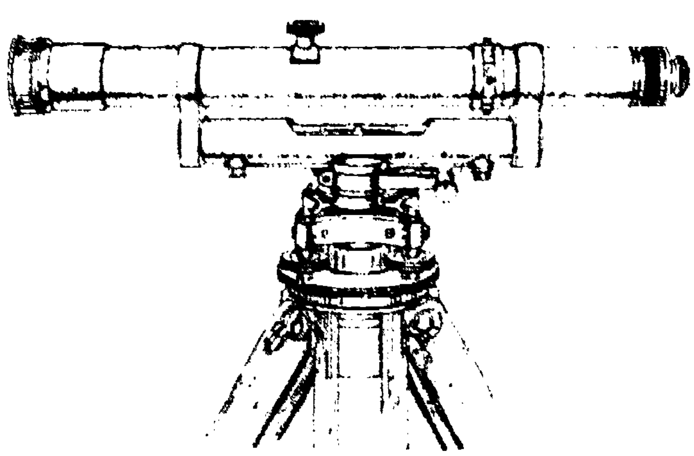
Surveying Equipment



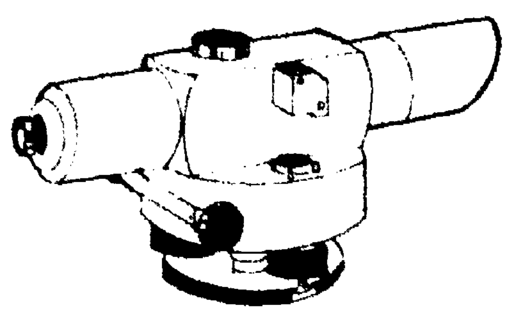
Theodolite



Transit

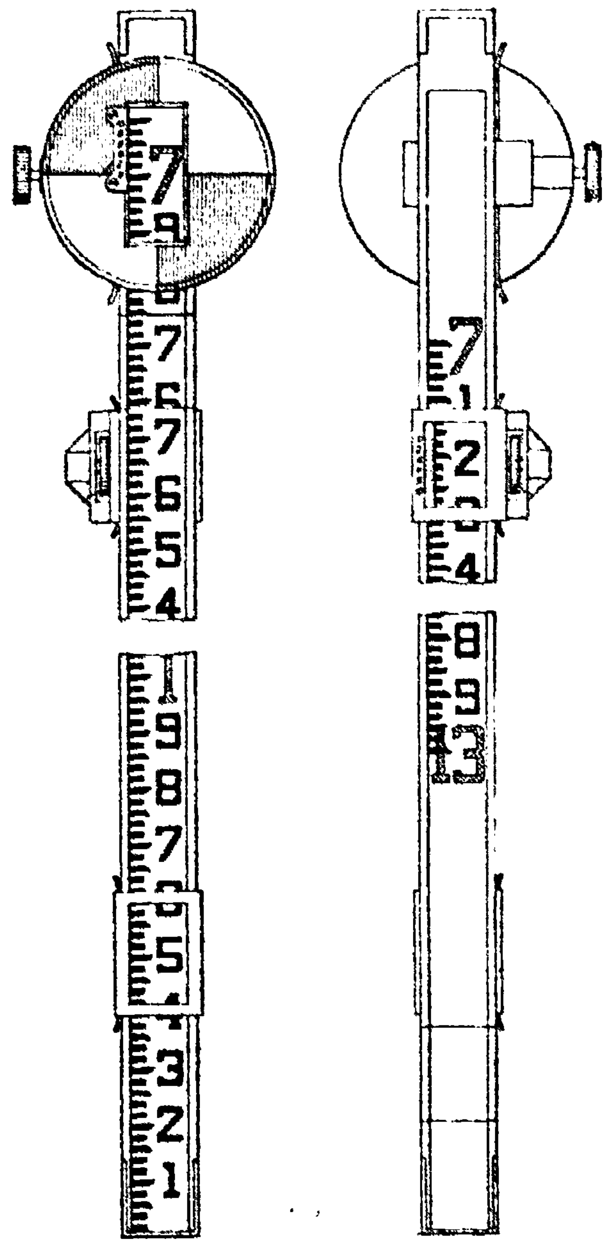


Dumpy Level



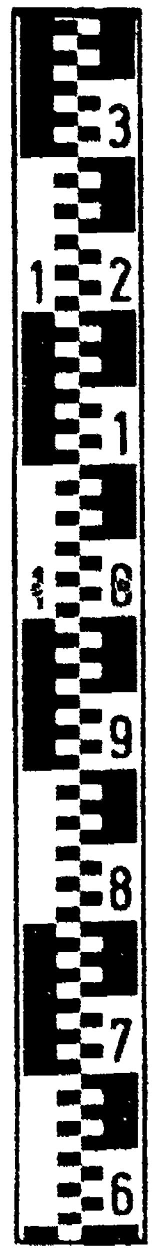
Automatic Level

Surveying Equipment
(Continued)



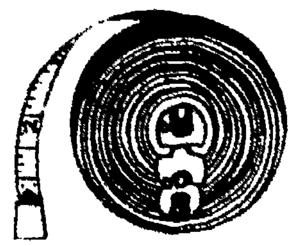
Philadelphia Rod

(Front) (Back)

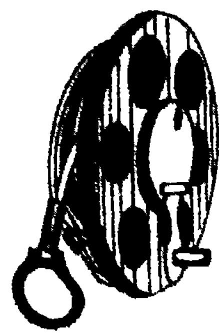


Metric Rod

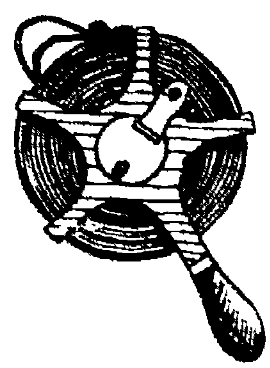
Level Rods



Woven/Cloth Tape



Steel Tape



Chain

Tapes

INTRODUCTION TO BASIC SURVEYING
UNIT I

ASSIGNMENT SHEET #1 — RESEARCH EMPLOYMENT OPPORTUNITIES

Directions: Research your local area for all possible employment opportunities for surveying technicians. Ask the following questions and record the answers in the blanks provided.

1. Are there any local private firms that currently employ surveying technicians? ____________ If so, list the names of each.

   ____

   ____

   ____

   ____

2. What local government agencies currently employ surveying technicians?

   ____

   ____

   ____

   ____

3. Are there any federal government agencies within your area that currently employ surveying technicians? ____________ If so, list the agencies.

   ____

   ____

   ____

   If not, where is the closest federal agency that does?

   ____

ASSIGNMENT SHEET #1

4. Do any of the private firms listed on the preceding page have openings for surveying technicians presently? ____________ If so, list each.

____

____

____

If not, how do they find new employees when openings occur? (classified ad, employment agency, etc.)

____

5. Are there any local, state, or federal agencies that currently have an opening for a surveying technician? ____________ If so, list the agency.

____

____

____

If not, what is their procedure for filling openings when they occur?

____

____

____

6. What is the employment outlook for the future for surveying technicians in:

Private industry ____

____

Local/state government ____

____

Federal government agencies ____

____

INTRODUCTION TO BASIC SURVEYING
UNIT I

ASSIGNMENT SHEET #2 — INTERVIEW A SURVEYING TECHNICIAN

Directions: Make an appointment with a surveying technician presently employed in that capacity. Ask the following questions and record the answers in the blanks provided

1. What is your career title? ______________________________

2. What tasks do you perform on the job? ______________________________

3. What educational training and occupational experience is required for this job?

4. What personality traits are most important in your field? ______________________________

5. What skills and knowledge are required in this occupation? ______________________________

6. What is the approximate starting salary of workers in your occupation? ______________________________

7. What is the employment outlook for the future in this career? ______________________________

ASSIGNMENT SHEET #2

8. What are the possibilities for advancement in this field? ________________________________

____

____

9. What is your favorite part of this job? ________________________________

____

____

10. What is your least favorite part of the job? ________________________________

____

____

INTRODUCTION TO BASIC SURVEYING
UNIT I

ASSIGNMENT SHEET #3 — TAKE BASIC MATH PRETEST

Directions: The following problems are designed to assess your basic math skills in various areas. Solve each problem and place your answer in the blank or space allowed.

PART A: Addition

1. 9 + 8

2. 8 + 8

3. 92, 38, + 77

4. 87, 26, + 44

5. 44, 57, + 63

6. 923, 934, 966, + 123

7. 327, 240, 136, + 238

8. 270, 368, 609, + 224

9. If a construction crew works 320 hours one week, 416 hours the next week, 345 hours in the third week, and 218 hours the fourth week, how many hours did the crew work in that month?

   ______________ hours

10. While repairing surface failures, a crew laid 528 sq ft of aggregate on the first job, 640 sq ft on the second job, and 580 sq ft on the third job. How many square feet did the crew cover?

    ______________ sq ft

PART B: Subtraction

1. 84 − 57

2. 4635 − 3187

3. 4178 − 1539

4. 983 − 656

5. 771 − 289

6. 53 − 39

7. 356 − 178

8. 378 − 179

ASSIGNMENT SHEET #3

9. If the boom on a side boom is 18 ft and you need 25 ft to do a particular job, how much boom would have to be added?

   ____________________ ft

10. If guardrails were placed along 2,488 linear ft of roadway the first day, and the operator needed to place them along 8,562 linear ft that week, how much more distance would have to be covered in the remaining four days?

   ____________________ linear ft

PART C: Multiplication

1. 63×38	2. 85×76	3. 32×59	4. 42×96
5. 73×64	6. 54×83	7. 567×485	8. 879×729

9. If a load of rock weighs 18,796 lb, how much would 78 loads weigh?

   ____________________ pounds

10. If a dragline could stockpile 676 cubic yd of dirt in two days, how much could be stockpiled in 14 days?

   ____________________ cubic yards

PART D: Division

1. $8\overline{)96}$	2. $12\overline{)24}$	3. $30\overline{)90}$	4. $66\overline{)198}$

ASSIGNMENT SHEET #3

5. $15\overline{)60}$ 6. $23\overline{)276}$ 7. $19\overline{)152}$ 8. $62\overline{)7739}$

9. If a survey crew's vehicle travels 4,572 miles a year, how far would it travel in one month?

______________________ miles

10. If the distance across a ravine is 13,608 ft, and the excavation crew can move only 90 ft. per day, how long would it take for the crew to cross the ravine?

______________________ days

PART E: Converting fractions

1. Convert each of the following mixed numbers to improper fractions (where the numerator is the same or larger than the denominator such as 4/4, 5/3, and 10/9.) **Do not** reduce answers to lowest terms at this time.

a. $3\frac{1}{4}$ = _____ f. $2\frac{1}{2}$ = _____

b. $4\frac{1}{2}$ = _____ g. $3\frac{2}{4}$ = _____

c. $7\frac{1}{3}$ = _____ h. $7\frac{3}{4}$ = _____

d. $8\frac{1}{2}$ = _____ i. $9\frac{2}{3}$ = _____

e. $6\frac{2}{3}$ = _____ j. $5\frac{2}{3}$ = _____

ASSIGNMENT SHEET #3

2. Convert each of the following improper fractions to mixed numbers. **Do not** reduce answers to lowest terms at this time.

a. $\frac{16}{5} =$ ____ f. $\frac{19}{13} =$ ____

b. $\frac{12}{5} =$ ____ g. $\frac{8}{7} =$ ____

c. $\frac{17}{3} =$ ____ h. $\frac{75}{32} =$ ____

d. $\frac{8}{3} =$ ____ i. $\frac{24}{17} =$ ____

e. $\frac{9}{2} =$ ____ j. $\frac{13}{9} =$ ____

PART F: Reducing fractions to lowest terms

Reduce the following fractions to the lowest terms.

1. $\frac{3}{9} =$ ____ 6. $\frac{5}{5} =$ ____

2. $\frac{8}{24} =$ ____ 7. $\frac{8}{12} =$ ____

3. $\frac{10}{15} =$ ____ 8. $\frac{7}{21} =$ ____

4. $\frac{15}{25} =$ ____ 9. $\frac{4}{8} =$ ____

5. $\frac{12}{48} =$ ____ 10. $\frac{10}{12} =$ ____

ASSIGNMENT SHEET #3

PART G: Finding lowest common denominators (LCD)

Find the lowest common denominator and convert each fraction to its LCD equiv lent.

1. a. $\frac{2}{3}, \frac{7}{9}$ LCD = ______

   b. $\frac{2}{3}$ = ______

   c. $\frac{7}{9}$ = ______

2. a. $\frac{7}{8}, \frac{5}{6}$ LCD = ______

   b. $\frac{7}{8}$ = ______

   c. $\frac{5}{6}$ = ______

3. a. $\frac{1}{3}, \frac{11}{12}, \frac{3}{8}$ LCD = ______

   b. $\frac{1}{3}$ = ______

   c. $\frac{11}{12}$ = ______

   d. $\frac{3}{8}$ = ______

4. a. $\frac{1}{7}, \frac{5}{8}$ LCD = ______

   b. $\frac{1}{7}$ = ______

   c. $\frac{5}{8}$ = ______

5. a. $\frac{1}{16}, \frac{3}{8}, \frac{3}{4}$ LCD = ______

   b. $\frac{1}{16}$ = ______

   c. $\frac{3}{8}$ = ______

   d. $\frac{3}{4}$ = ______

ASSIGNMENT SHEET #3

PART H: Adding, subtracting, multiplying, and dividing fractions

1. $\frac{7}{12} + \frac{5}{8} =$ ______

2. $\frac{3}{5} + \frac{2}{3} =$ ______

3. $\frac{1}{16} + \frac{3}{8} + \frac{3}{4} =$ ______

4. $\frac{3}{20} + \frac{3}{4} + \frac{7}{10} + \frac{4}{5} =$ ______

5. $\frac{7}{8} - \frac{2}{3} =$ ______

6. $\frac{4}{5} - \frac{3}{8} =$ ______

7. $\frac{5}{9} - \frac{3}{8} =$ ______

8. $\frac{1}{3} - \frac{5}{16} =$ ______

9. $1\frac{1}{2} \times 2\frac{1}{4} =$ ______

10. $\frac{1}{2} \times 6\frac{1}{2} =$ ______

11. $\frac{7}{8} \times \frac{2}{3} =$ ______

12. $\frac{1}{4} \times \frac{1}{3} \times \frac{1}{2} =$ ______

13. $\frac{3}{8} \div \frac{1}{2} =$ ______

14. $8 \div \frac{3}{5} =$ ______

15. $12\frac{3}{8} \div 1\frac{1}{2} =$ ______

ASSIGNMENT SHEET #3

PART I: Converting fractions to decimals

1. $5\frac{6}{10}$ = ______
2. $1\frac{2}{100}$ = ______
3. $\frac{87}{1000}$ = ______
4. $7\frac{83}{1000}$ = ______
5. $5\frac{6}{100}$ = ______
6. $3\frac{3}{4}$ = ______
7. $55\frac{1}{2}$ = ______
8. $110\frac{5}{8}$ = ______
9. $77\frac{1}{50}$ = ______
10. $12\frac{2}{3}$ = ______

PART J: Adding, subtracting, multiplying, and dividing decimals

1.
$$\begin{array}{r} 5.29 \\ 4.38 \\ +\ 9.62 \\ \hline \end{array}$$

2.
$$\begin{array}{r} 72.24 \\ 16.38 \\ +\ 92.37 \\ \hline \end{array}$$

3. 868.87 − 516.89 = ______

4. $15 − $12.53 = ______

5. 2.54 × 3.1 = ______

6. 35 × 8.5 = ______

7. 120 × 0.33 = ______

8. 26.4 × 3.8 = ______

9. 10.71 − 0.07 = ______

10. 0.225 ÷ 0.15 = ______

ASSIGNMENT SHEET #3

PART K: Converting fractions to percentages

1. $\frac{1}{4}$ = ______
2. $\frac{2}{9}$ = ______
3. $\frac{7}{10}$ = ______
4. $\frac{3}{4}$ = ______
5. $\frac{2}{2}$ = ______

PART L: Percentage problems

1. There are 100 bolts in a box. Twenty-five bolts are what percent of the bolts in the box?

   ____

2. If 11% of the students in a school are absent, what percent are present? ______

3. There are 20 students in a class. Sixty percent of the students are boys. How many are boys? ______________________________

4. One day 5% of the 20 operators in Mr. Moore's group made perfect time completing a job. How many operators made perfect time? ______________________________

5. Contractor McGill bought a new compressor, regularly selling for $120, at a sale and saved 20%. What was the sale price? ______________________________

PART M: Mix ratio problems

1. Given 90 cu yd of aggregate, how much sand will you need to mix a 3:2 ratio of sand and aggregate?

   ______________________ cu yd of sand

2. You are to mix ¼" aggregate and ½" aggregate to a ratio of 3:2. How much ¼" aggregate will you need if you have 150 cu yd of ½" aggregate?

   ______________________ cu yd of ¼" aggregate

3. Given 300 tons of asphalt concrete, mix asphalt concrete and solvent to a ratio of 75:25. How much solvent will you need?

   ______________________ gal of solvent

ASSIGNMENT SHEET #3

4. The fuel mixture ratio of gasoline to two-cycle engine oil is 20:1 for your chain saw. How much oil will you add to 5 gal of gas?

   ________________ qt of oil

5. The ratio of an industrial strength cleaner in water is 6 parts cleaner to 100 parts water. You estimate the job will take 15 gallons of water. How much cleaner will you add?

   ________________ gal cleaner

PART N: Slope ratio problems

1. Find the slope ratio in feet and hundredths. Convert distances to like terms where needed. Round off to the nearest hundredth. Round the slope ratio to whole numbers.

   V = vertical distance

   H = horizontal distance

DISTANCES	RATIO (FEET)	RATIO (HUNDREDTHS/FT)	SLOPE RATIO
a. V = 12 ft, H = 24 ft	________	________	________
b. H = 15 in, V = 5 in	________	________	________
c. H = 5 ft, V = 0.05 ft	________	________	________
d. V = 1 in, H = 3 ft	________	________	________
e. H = 12 ft, V = 4 in	________	________	________

2. Find the vertical distance.

	SLOPE RATIO	HORIZONTAL DISTANCE	VERTICAL DISTANCE
a.	3:1	24 ft	________ ft
b.	14:1	224 in	________ in

3. Find the horizontal distance.

	SLOPE RATIO	VERTICAL DISTANCE	HORIZONTAL DISTANCE
a.	25:1	0.5 ft	________ ft
b	16:3	9 in	________ ft
c.	40:1	4 ft	________ ft

ASSIGNMENT SHEET #3

PART O: Measure and volume

1. Conversions. Round answers to nearest tenth.

   a. 48 in = __________ ft

   b. 312 ft = __________ yd

   c. 8 cu yd = __________ cu ft

   d. 7 sq yd = __________ sq ft

   e. 11 gal = __________ qt

2. Basic formulas for areas and volumes.

   a. 24' long, 18' wide -- Surface area = __________

   b. 13" wide, 2 ½" long -- Surface area = __________

   c. 7' long, 2' wide, 1' high -- Volume = __________

   d. ½' wide, 3" high, 2' long -- Volume = __________

   e. 4" long, 2" wide, ½" high — Volume = __________

3. Word problems. Round off answers to the nearest tenth. Show your work.

   a. One cubic yard of aggregate weighs 2,550 lb. How many tons would 10 cubic yards weigh?

      (NOTE: 1 ton = 2,000 lb)

      __________ tons

   b. What is the surface area of a failure 2'8" × 1'6"?

      __________ sq ft

ASSIGNMENT SHEET #3

c. How many cubic feet of concrete will be required to make a pavement patch 8 feet long, 7 feet wide and 6 inches deep?

_______________ cu ft

d. How many square feet have to be painted on a building 20 feet long on each side and 14 feet high if you paint all four sides? If a gallon of paint covers 350 square feet, how many gallons are required?

_______________ sq ft _______________ gal of paint

INTRODUCTION TO BASIC SURVEYING
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheets #1 and #2 — Evaluated to the satisfaction of the instructor

Assignment Sheet #3

PART A

1. 17
2. 16
3. 207
4. 157
5. 164
6. 2946
7. 941
8. 1471
9. 1,299 hours
10. 1,748 sq ft

PART B

1. 27
2. 1448
3. 2639
4. 327
5. 482
6. 14
7. 178
8. 199
9. 7 feet
10. 6,084 linear feet

PART C

1. 2394
2. 6460
3. 1888
4. 4032
5. 4672
6. 4482
7. 274,995
8. 640,791
9. 1,466,088 pounds
10. 4,732 cubic yards

ANSWERS TO ASSIGNMENT SHEETS

PART D

1. 12
2. 2
3. 3
4. 3
5. 4
6. 12
7. 8
8. 124, R51
9. 381 miles
10. 151.2 days

PART E

1. a. 13/4 f. 5/2
   b. 9/2 g. 14/4
   c. 22/3 h. 11/4
   d. 17/2 i. 29/3
   e. 20/3 j. 17/3

2. a. 3 1/6 f. 1 9/13
   b. 2 2/5 g. 1 1/7
   c. 5 2/3 h. 2 11/32
   d. 2 2/3 i. 1 7/17
   e. 4 1/2 j. 1 4/9

PART F

1. 1/3
2. 1/3
3. 2/3
4. 3/5
5. 1/4
6. 1
7. 2/3
8. 1/4
9. 1/2
10 5/6

PART G

1. a. 9
   b. 6/9
   c. 7/9

2. a. 24
   b. 21/24
   c. 20/24

3. a. 24
   b. 8/24
   c. 22/24
   d. 9/24

4. a. 56
   b. 8/56
   c. 49/56

5. a. 16
   b. 1/16
   c. 6/16
   d. 12/16

ANSWERS TO ASSIGNMENT SHEETS

PART H

1. 1 5/24
2. 1 4/15
3. 1 3/16
4. 2 3/8
5. 5/24
6. 17/40
7. 13/72
8. 1/48
9. 3 3/8
10. 3 1/4
11. 7/12
12. 1/24
13. 3/4
14. 13 1/3
15. 8 1/4

PART I

1. 5.6
2. 1.02
3. .037
4. 7.083
5. 5.06
6. 3.75
7. 55.5
8. 110.625
9. 77.02
10. 12.667

PART J

1. 19.29
2. 180.99
3. 351.98
4. $2.47
5. 7.874
6. 297.5
7. 39.6
8. 100.32
9. 153
10. 1.5

PART K

1. 25%
2. 22.2%
3. 70%
4. 75%
5. 100%

PART L

1. 25%
2. 89%
3. 12
4. 1
5. $96.00

PART M

1. 135 cu yd of sand
2. 225 cu yd of 1/4" aggregate
3. 100 gal of solvent
4. 1 qt of oil
5. 0.9 gal cleaner

ANSWERS TO ASSIGNMENT SHEETS

PART N

1.

		RATIO (FEET)	RATIO (HUNDREDTHS/FT)	SLOPE RATIO
	a.	24:12	-- --	2:1
	b.	-- --	15:5	3:1
	c.	5:0.05	60:0.6	100:1
	d.	3:0.08	36:1	36:1
	e.	12:0.33	144:4	36:1

2. a. 8 ft
   b. 16 in

3. a. 12.5 ft
   b. 4 ft
   c. 160 ft

PART O

1. a. 4 ft
   b. 104 yd
   c. 216 cu ft
   d. 63 sq ft
   e. 44 qt

2. a. 432 sq ft
   b. 390 sq in
   c. 14 cu ft
   d. 432 cu in
   e. 4 cu in

3. a. 12.8 tons
   b. 4 sq ft
   c. 28 cu ft
   d. 1120 sq ft, 3.2 gal of paint

INTRODUCTION TO BASIC SURVEYING
UNIT I

NAME ______________________

TEST

1. Match the terms on the right with the correct definitions.

______a. Testimony, physical objects, marks, traces of former objects, or any relationship of these items that may furnish proof or partial proof of a lost corner or boundary line		1. Accuracy
		2. Boundary line
______b. Used commonly to denote everything which is the subject of ownership		3. Contour
		4. Evidence
______c. An imaginary line along the ground where all points are of the same elevation above or below a specified datum surface		5. Photogrammetry
		6. Precision
______d. The configuration of a surface, including its relief and the position of its existing and man-made features		7. Property
		8. Property line
______e. The physical features of a tract of land		9. Terrain
______f. A precision instrument used for measuring horizontal and vertical angles		10. Theodolite
		11. Title line
______g. The method of obtaining reliable measurements by means of photographs		12. Topography
______h. A line along which two areas meet		13. Transit
______i. A line indicating ownership as described by the legal description or the platted drawing		
______j. A repeating surveying instrument for measuring horizontal and vertical angles		
______k. The degree of refinement used in measuring a value, either by the number of times it is measured or by the degree of graduations it was measured in		
______l. Denotes the absolute "nearness" of the measured value to the true value		
______m. A line indicating ownership boundaries by land descriptions, surveyor's drawing, or physical markings such as fences, stone monuments, or iron pins		

TEST

2. Define the term "surveying." ____

____

3. Distinguish between the two classifications of surveying by placing a "P" next to the description of plane surveying and a "G" next to geodetic surveying.

_____a. Any type of surveying in which the surface of the earth is considered spherical

_____b. Any type of surveying in which the surface of the earth is considered a flat surface

4. Match the different types of surveys on the right with their appropriate descriptions.

_____a.	Consist of the establishment of land corners and boundaries, and the areas of a given land parcel	1. Aerial surveys
		2. Cadastral surveys
_____b.	Consist of the location of all ground contours and existing features that are found within the survey limits	3. Construction surveys
		4. Hydrographic surveys
_____c.	Consist of the preliminary layout and control work required to survey a narrow but long strip of land	5. Route surveys
		6. Topographic surveys
_____d.	Consist of the layout work required on sites where construction of an engineering nature is to be undertaken	7. Underground surveys
_____e.	Consist of the preliminary surveys utilizing photographs taken from an airplane; these photos are scaled and sometimes are viewed in three-dimensional format	
_____f.	Consist of work done to locate points or objects that are below the earth's surface, as in mines, tunnels, and aqueducts	
_____g.	Consist of those made to determine the actual shape of the bottom of lakes, rivers, harbors, and oceans; also include the location of shorelines, measurement of flow, and estimation of resources	

TEST

5. Match types of equipment on the right with their correct uses in the surveying profession.

_____a. Used to measure horizontal and slope distances

_____b. Used to mark chain lengths when measuring distances

_____c. Used to establish straight lines and to measure horizontal and vertical angles

_____d. Used to establish a line of sight toward a point

_____e. Used to extend a true vertical line up from a point

_____f. Used to measure vertical differences in elevation

1. Chaining pins
2. Levels and level rods
3. Plumb bob
4. Range pole
5. Tapes or chains
6. Transit or engineer's theodolite

6. Distinguish between recent technical advancements in surveying instrumentation and equipment by placing the following letters in the appropriate blanks.

- DT -- Digital theodolite
- EDMD -- Electronic distance measuring device
- EDC -- Electronic data collector
- SC & PD -- Surveying computers and plotting devices
- GPS -- Global positioning system

_____a. Various types that can reduce notes, adjust surveys, calculate areas, assign coordinates, and actually draw the surveyed area simply by entering field data

_____b. Replaces the older "open-face" vernier found on the transit and the micrometer scale used on most theodolites

_____c. Enhances the surveyor's field book, notations, and sketches that normally would be kept when surveying

_____d. Electronic display screen that displays horizontal and vertical angles to a specified accuracy

_____e. Uses satellites orbiting the earth to measure the location of points remote from each other

_____f. Electronic device that measures the number of wave lengths (either microwave or light wave) and calculates an actual distance (feet or meters) from the instrument to the point sighted

_____g. When fully incorporated into a business, it can possibly replace the present duties of civil drafters, and change their roles

TFST

_____h. Replaces the many methods of measuring distances, either horizontal, slope, or vertical

_____i. Electronic device (usually hand-held) that has the capacity to store field data, distances, angles, etc. either by hand entry (push button) or by automatic entry (instrument to data collector which completely bypasses the operator)

7. Distinguish between the responsibilities of each survey crew member by placing the following letters in the appropriate blanks:

- I — Instrument person or observer
- C — Chain person or rod person
- PC — Party chief or recorder

_____a. Responsible for total operation of the crew including the accuracy of the work completed

_____b. Assists in taking all actual surveying measurements in the field, and is responsible for the care and cleaning of all surveying tapes and miscellaneous equipment

_____c. Responsible for the care and operation of the surveying instruments

8. Match the various types of surveyors on the right with their correct duties.

_____a. Should be an expert in subdividing lands, retracing old boundary lines, analyzing evidence of the legality of a boundary, and writing accurate descriptions of land parcels

_____b. Responsible for locating all existing features of a site and determining any elevation contours on a site

_____c. Responsible for accurately determining terrain where engineering projects are to be constructed, the actual laying out or staking procedures required to accurately locate the future construction, and measuring and/or computing construction quantities that would be used for final payments on work completed

_____d. Duties lie in locating, with great precision, surveyed station points used for horizontal control, and in establishing vertical reference points used for vertical control

1. Construction surveyor
2. Geodetic surveyor
3. Land surveyor
4. Topographic surveyor

TEST

9. List five personal characteristics of a good surveyor.

   a. ______________________
   b. ______________________
   c. ______________________
   d. ______________________
   e. ______________________

10. Distinguish between advantages and disadvantages of being a surveying technician by placing an "A" next to the advantages and a "D" next to the disadvantages in the blanks provided.

   _____a. Sense of accomplishment
   _____b. Long or awkward hours at times
   _____c. Possibly hazardous work
   _____d. Involvement with many professional organizations
   _____e. Opportunity to improve skills
   _____f. Comfortable dress
   _____g. Possibly dirty work
   _____h. Job variety

11. List seven employment opportunities available in the surveying profession.

   a. ______________________
   b. ______________________
   c. ______________________
   d. ______________________
   e. ______________________
   f. ______________________
   g. ______________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

12. Research employment opportunities. (Assignment Sheet #1)

13. Interview a surveying technician. (Assignment Sheet #2)

14. Take a math pre-test. (Assignment Sheet #3)

INTRODUCTION TO BASIC SURVEYING
UNIT I

ANSWERS TO TEST

1. a. 4 — h. 2
   b. 7 — i. 11
   c. 3 — j. 13
   d. 12 — k. 6
   e. 9 — l. 1
   f. 10 — m. 8
   g. 5

2. Either or both of the following:
   a. The art and science of making measurements to determine the relative position of *known* points
   b. The process used to lay out or establish *new* points by making calculated field measurements

3. a. G
   b. P

4. a. 2 — e. 1
   b. 6 — f. 7
   c. 5 — g. 4
   d. 3

5. a. 5 — d. 4
   b. 1 — e. 3
   c. 6 — f. 2

6. a. SC & PD
   b. DT
   c. EDC
   d. DT
   e. GPS
   f. EDM
   g. SC & PD
   h. EDM
   i. EDC

7. a. PC
   b. C
   c. I

8. a. 3
   b. 4
   c. 1
   d. 2

ANSWERS TO TEST

9. Any five of the following:
    a. Checks all equipment before starting work
    b. Operates all equipment correctly
    c. Is safety conscious and follows safety regulations
    d. Takes instructions readily and follows company rules
    e. Practices conservation of materials, equipment, and time
    f. Displays enthusiasm about work
    g. Exhibits pride in the trade
    h. Controls temper at all times
    i. Is punctual
    j. Is cooperative with all involved parties
    k. Keeps accurate field notes and log reports

10.

a.	A	e.	A
b.	D	f.	A
c.	D	g.	D
d.	A	h.	A

11. Any seven of the following:
    a. Registered land surveyors
    b. Consulting engineers
    c. Civil engineering companies
    d. Contractors/Construction companies
    e. Material testing companies
    f. Land title and mortgage companies
    g. Local government agencies
        1) City engineering division
        2) City planning division
        3) Transportation division
        4) Municipal utilities division
    h. Federal government agencies
        1) USGS — United States Geological Survey
        2) DMA — Defense Mapping Agency
        3) BLM — Bureau of Land Management
        4) USFS — United States Forestry Service
        5) SCS — Soil Conservation Service
        6) Corps of Engineers, Dept. of the Army
        7) NGS — National Geodetic Survey

12.-14. Evaluated to the satisfaction of the instructor

SAFETY
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to recognize common safety terms, practice both personal and general job safety while performing duties, identify potential dangers that may exist, as well as discuss some basic first-aid skills that are commonly practiced in the construction field. Competencies will be demonstrated by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to safety with the correct definitions.
2. Select true statements concerning rules for general job safety.
3. State personal safety rules involved in the surveying field.
4. Select from a list the proper clothing for both warm and cold weather surveying.
5. Select true statements concerning safety precautions to take while working in the field.
6. Label different types of channeling devices used for traffic control.
7. List the techniques of proper placement of traffic control devices.
8. Select responsibilities of a flagger.
9. Complete statements concerning safety rules for flaggers on a survey crew.
10. Distinguish between types of communication used by a survey crew.

OBJECTIVE SHEET

11. Identify common hand signals used while surveying.

12. Identify the commonly found species of poisonous plants that can be encountered while surveying.

13. List characteristic reactions to common poisonous plants.

14. Arrange in order the basic first-aid procedures for care of poisonous plant reactions.

15. List numerous poisonous insects and spiders found while surveying.

16. Discuss basic first-aid procedures for poisonous insect bites.

17. List the four types of commonly found poisonous snakes and the effects of each.

18. Describe the standard first aid procedures for snake bites.

19. Match the different first aid procedures to the proper type of injury that the victim is suffering.

20. Compile a survey of winter clothing needs. (Assignment Sheet #1)

21. Construct a diagram of appropriate traffic control for a two-lane roadway. (Assignment Sheet #2)

22. Distinguish between correct and incorrect procedures for flaggers. (Assignment Sheet #3)

23. Demonstrate the ability to:

    a. Control traffic with a flag. (Job Sheet #1)

    b. Place emergency parking devices. (Job Sheet #2)

SAFETY
UNIT II

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Have students demonstrate correct procedures of using hand signals to communicate in the surveying profession.
2. Have a registered nurse or a safety engineer speak to the class on safety procedures and techniques to prevent accidents.
3. Have students complete a first aid course and earn certification according to OSHA regulations.
4. Visit a construction site and have students observe and analyze safety equipment, procedures, and methods of traffic control.
5. Demonstrate and discuss precaution and first-aid techniques for dangers in your area such as snake bites, poisonous plants, biting insects, ticks, etc.
6. Ask students if they have ever had a severe allergic reaction to poisonous plants, insects, or spiders. Emphasize precautions these students should follow. Discuss emergency treatment with school nurse or local physician.
7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

   1. TM 1 – Standard Types of Emergency Parking Devices

   2. TM 2 – Placement of Traffic Control Devices

D. Assignment sheets

   1. Assignment Sheet #1 — Compile a Survey of Winter Clothing Needs

   2. Assignment Sheet #2 — Construct a Diagram of Appropriate Traffic Control for a Two-Lane Roadway

   3. Assignment Sheet #3 — Distinguish Between Correct and Incorrect Procedures for Flaggers

E. Answers to assignment sheets

F. Job sheets

   1. Job Sheet #1 — Control Traffic with a Flag

   2. Job Sheet #2 — Place Emergency Parking Devices

G. Test

H. Answers to test

REFERENCES USED IN WRITING THIS UNIT

A. Perky, Sandra. *Highway Maintenance Equipment Operator.* Stillwater, OK: CIMC/Oklahoma State Department of Vocational Technical Education, 1983.

B. American Red Cross. *Standard First Aid and Personal Safety,* 2nd ed., 1979.

C. Kavanagh, Barry and S. J. Glenn Bird. *Surveying: Principles and Applications.* Reston, VA: Reston Publishing Co., Inc., 1984.

D. *Manual on Uniform Traffic Control Devices for Streets and Highways.* "Part VI: Traffic Controls for Street and Highway Construction and Maintenance Operations." Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 1984.

SUPPLEMENTAL REFERENCE MATERIALS

Texts...

A. *Accident Prevention Manual for Industrial Operations*, 7th ed. National Safety Council. 444 North Michigan Avenue. Chicago. Illinois. 1974.

B. *First Aid*. Washington, D.C.: United States Department of Labor. Bureau of Mines, 1978.

Filmstrips...

A. *Night Safety at Work Site.*
American Traffic Services Association.

(NOTE: This film should be available through your state department of transportation. The program deals with the safety of maintenance and construction crews, and traffic controls through night work areas.)

B. *Shake Hands With Danger.*
Calvin Productions
1105 Truman Road
Kansas City, Missouri 64106

(NOTE: This safety film stresses the importance of safety procedures and the consequences that will result if ignored or overlooked.)

C. *The Flagman*
Utah State Department of Highways

(NOTE: This film should be available through your state department of transportation. It shows the flagger's requirements, duties, responsibilities, techniques, and how important these duties are.)

SAFETY
UNIT II

INFORMATION SHEET

I. **Terms and definitions**

A. Channelize — To divert traffic flow from one lane into another lane

B. First aid — Immediate, temporary care given the victim of an accident or sudden illness until the services of a physician can be obtained

C. Frostbite — Tissue damage due to freezing of tissue fluids

D. Heat cramps — Muscular pains and spasms due to loss of salt through sweating or to inadequate intake of salt

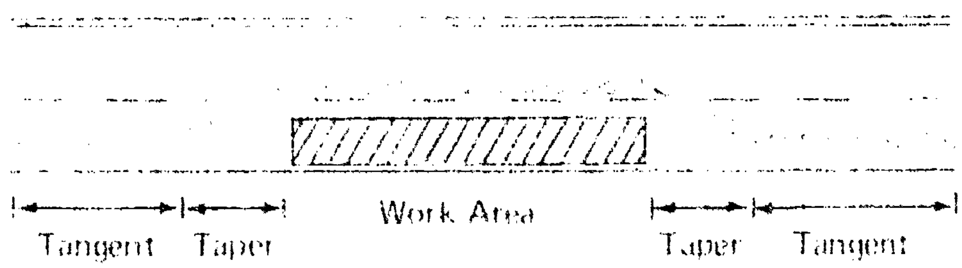
E. Heat exhaustion — Fatigue, weakness, and sometimes collapse due to loss of body fluids through sweating and inadequate water intake

F. Heat stroke — Immediate life-threatening emergency characterized by extremely high body temperature and disturbance of sweating mechanism

G. Hypothermia — Below normal body temperature usually due to overexposure to low temperatures

H. Occupational Safety and Health Act (OSHA) — Federal legislation designed to ensure safe and sanitary working conditions for employees

I. Tangent — Sections of sign-posted roadway preceding and following taper



J. Taper — Angle at which traffic is diverted from regular lane into new lane

II. **Rules for general job safety**

A. Be conscious of the effects of your own, as well as other people's, actions.

B. Use the proper tool for the proper application at all times.

C. Report all defects in tools, supplies, and equipment to your immediate supervisor.

D. Properly use traffic control devices whenever conditions require them.

E. Follow standard company procedures at all times — Safety is organization.

F. Be constantly alert to all potential dangers.

INFORMATION SHEET

III. **Personal safety rules**

A. Wear close-fitting clothes that are appropriate for the activities being performed.

B. Wear safety glasses, hard hats, and traffic vests in areas where required.

C. Remove rings and other jewelry when working.

D. Be alert and conduct yourself in a manner that will ensure safe practices.

E. Know locations of first-aid equipment and fire extinguishers.

IV. **Appropriate clothing while surveying** (Assignment Sheet #1)

A. Warm weather dress

1. Long sleeve shirts in brush cover

2. Short sleeve shirts are acceptable, although one should constantly be aware of the dangers of sunburn, wind burn, insect bites, scratches, and skin reactions, allergies, etc.

3. Long leg trousers should always be worn. Shorts or cut-off pants are always avoided.

4. Safety shoes are suggested or high-lace field boots with steel-toe protection if possible.

5. Head protection can be used for protection against heat stroke and sunburn, and hard hats are worn in areas of construction equipment.

B. Cold weather dress

1. Wear layers of clothing (undershirt, long-sleeve shirt, and appropriate jacket) whenever possible so layers can be removed or added as one desires.

2. Thermal underwear, trousers, and insulated coveralls are suggested for winter time wear.

3. Foot-wear is very important in cold weather work, not only insulated, water-proof boots, but also 2 pairs of socks with a spare pair suggested.

4. Gloves or mittens should be neither too bulky so that they interfere with the ability of the worker nor too tight to make circulation difficult.

5. Head gear is mandatory in cold weather to help prevent hypothermia and frostbite of the ears and face.

INFORMATION SHEET

V. **Safety precautions while in the field**

A. Route selection to the site

1. Should be chosen in advance whenever possible

2. While in rough terrain, the safest route to the site may not always be the shortest.

3. Care should be taken when traveling in heavy ground cover, drainage ditches, and along high points or steep embankments.

4. Always be aware of where you are and the route that you have taken.

B. Parking of surveying vehicles at site location (Transparency 1)

1. Select a place where backing up will not be required if possible.

2. Park in the direction of traffic, and well along the shoulder, or near curb if working on streets or highways.

3. It may be necessary to park the vehicle out in the roadway as to protect the survey site, but this should be up to the discretion of the party chief and strict precautions should then be taken.

4. Upon arriving at site location, have a "tailgate" conference discussing the project and what information you are trying to obtain, and any dangers or traffic hazards that may affect the safety of the survey crew.

C. Using hand tools and miscellaneous surveying equipment

1. Do not hold pencils, chaining pins, or other objects in your hands when driving stakes.

2. Keep eyes and mind on the job task.

   Example: Pounding stakes, cutting brush, using axe or hatchets, etc.

3. Give crew members room to work with tools.

4. Watch for overhead power lines when using level rods or range poles. (Always look up.)

5. Keep a safe distance away from instruments and vehicles during an electrical storm. Seek shelter.

6. When taping, watch for electric fences, passing vehicles, electric cables, etc.

7. The proper location for instrument setups should be chosen keeping safety considerations in mind as well as any advantages for completing the work required.

INFORMATION SHEET

8. Do not allow other workers or passersby within a 30' radius during operation of chain saws, brush saws, or other clearing equipment.

9. When not in use, equipment and all hand tools should have their protective guards in place and stored back in their original compartments.

10. Prior to leaving the job site, a 360° equipment and tool check must be performed and a conformation by all crew members should be made.

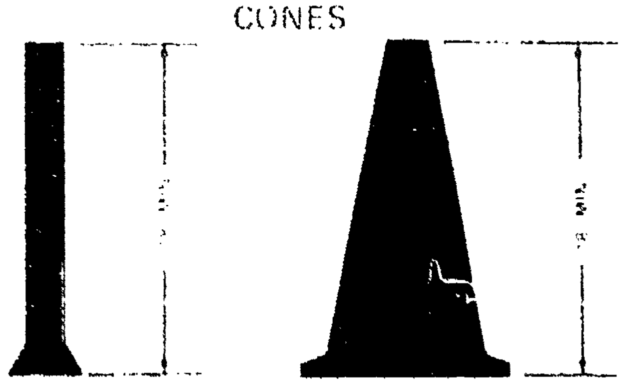
VI. Common types of traffic control devices

A. Channeling devices and their uses

. Cones — Used to guide traffic along a regular channel

(NOTE: Cones may become displaced by traffic. They should be patrolled and replaced as necessary.)

CONES

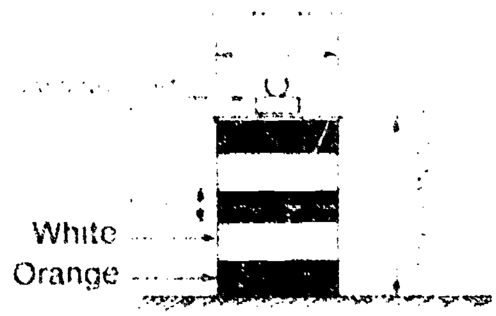


(NOTE: Orange must be the predominant color for cones. For nighttime use, they must be reflectorized or equipped with lighting devices for maximum visibility.)

INFORMATION SHEET

2. Drums — Used to mark an unusual vehicle path

   Examples: Mark the edge of pavement; channel traffic away from an open trench; provide working room for survey crew and their equipment

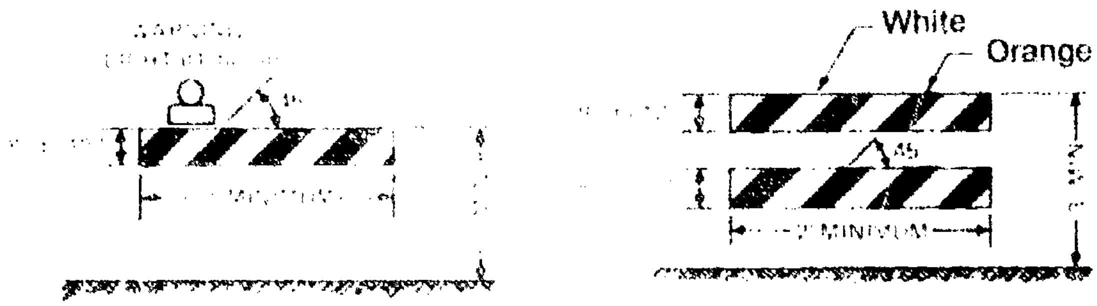


DRUM

(NOTE: At least two orange and two white stripes are required on each drum.)

3. Barricades — Used to close, restrict, or delineate all or a portion of the right-of-way

   a. Types I and II — Used where traffic is maintained to mark a specific hazard or in a series for channelizing traffic

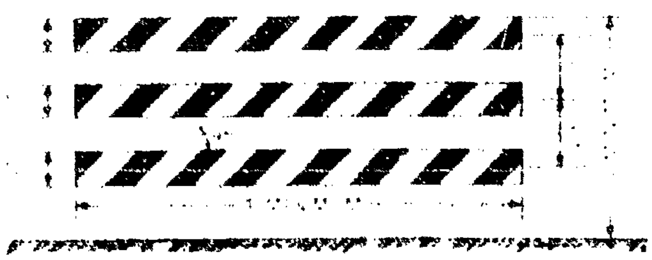


TYPE I BARRICADE

TYPE II BARRICADE

   (NOTE: Type I barricades are normally used on conventional roads or urban streets, and Type II barricades are intended for use on expressways and other high speed roadways.)

   b. Type III — Used to mark a road section closed to traffic



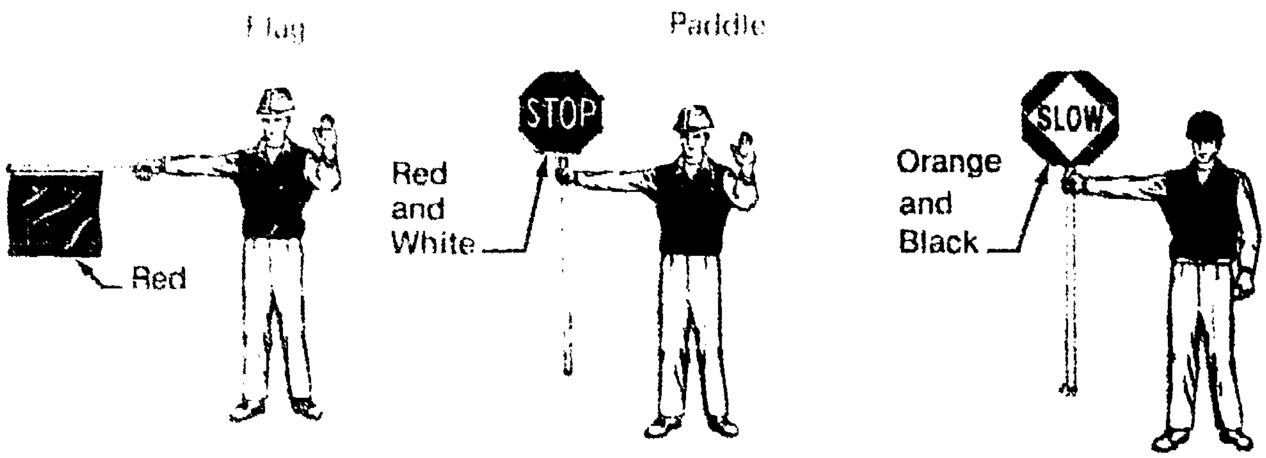
TYPE III BARRICADE

   (NOTE: The Type III barricade is primarily used for extended construction projects.)

INFORMATION SHEET

B Survey crew flagger — Should always be used in areas of heavy traffic while working in the driving lanes

(NOTE: Two flaggers may be used in extremely heavy traffic.)



VII. **Proper placement of traffic control devices** (Transparency 2 and Assignment Sheet #2)

A. Place all devices before survey operations begin.

(NOTE: Allow devices to remain in place only as long as needed; remove immediately thereafter.)

B. Place signs and barricades in areas free from visual obstructions.

C. Place where they will convey messages most effectively according to highway design, alignment, and speed.

D. Place at a distance that allows driver adequate time to respond.

E. Place on right side of street or roadway.

(NOTE: Where special emphasis is needed, install duplicate signs opposite each other on right and left sides.)

F. Place in traffic lane when appropriate.

G. Place advance warning signs approximately 1,500 feet in advance of work area at 500 ft interval where open highway conditions prevail.

VIII. **Responsibilities of a flagger**

A. Protecting public, other workers, and self

B. Stopping and slowing traffic

C. Releasing traffic when it is safe to proceed

INFORMATION SHEE

D. Alerting drivers to traffic conditions

E. Promoting good public relations

(NOTE: The flagger has the most public contact. When practical, the flagger should tell motorists the reason and approximate length of delay.)

IX. **Safety rules for flaggers** (Assignment Sheet #3)

A. Wear orange vest, shirt, or jacket and hard hat if required. Garments must be reflectorized for nighttime conditions.

B. Stand where you can be seen by oncoming traffic for 500 feet or more.

C. Stand 100-200 feet from work area

D. Stand in safe position on shoulder, never in path of approaching vehicles.

E. Stand sideways to traffic.

(NOTE: Stand in such a way that you can watch the cars and the signal person to your rear. Never turn full back to traffic.)

F. Use either a STOP/SLOW paddle or a 24-inch, square, red flag for daylight flagging.

G. Always stand alone; never ming workers or passersby.

H. When communicating with other rs, use verbal or hand signals which will not be confused with traffic or gging signals.

I. Remain at your station until work has been completed.

J. Remove all traffic control signs when work has ended.

K. Always plan an escape route to safety in case of a dangerous situation.

X. **Types of communications used by a survey crew**

A. Verbal communications

1. Are used to clarify the job task prior to the actual surveying operation

2. Are used to explain responsibilities of each crew member when new tasks or methods are to be used

3. Are used whenever possible to eliminate misunderstandings of operations being used and misinterpretation of field data

INFORMATION SHEET

B. Hand signals

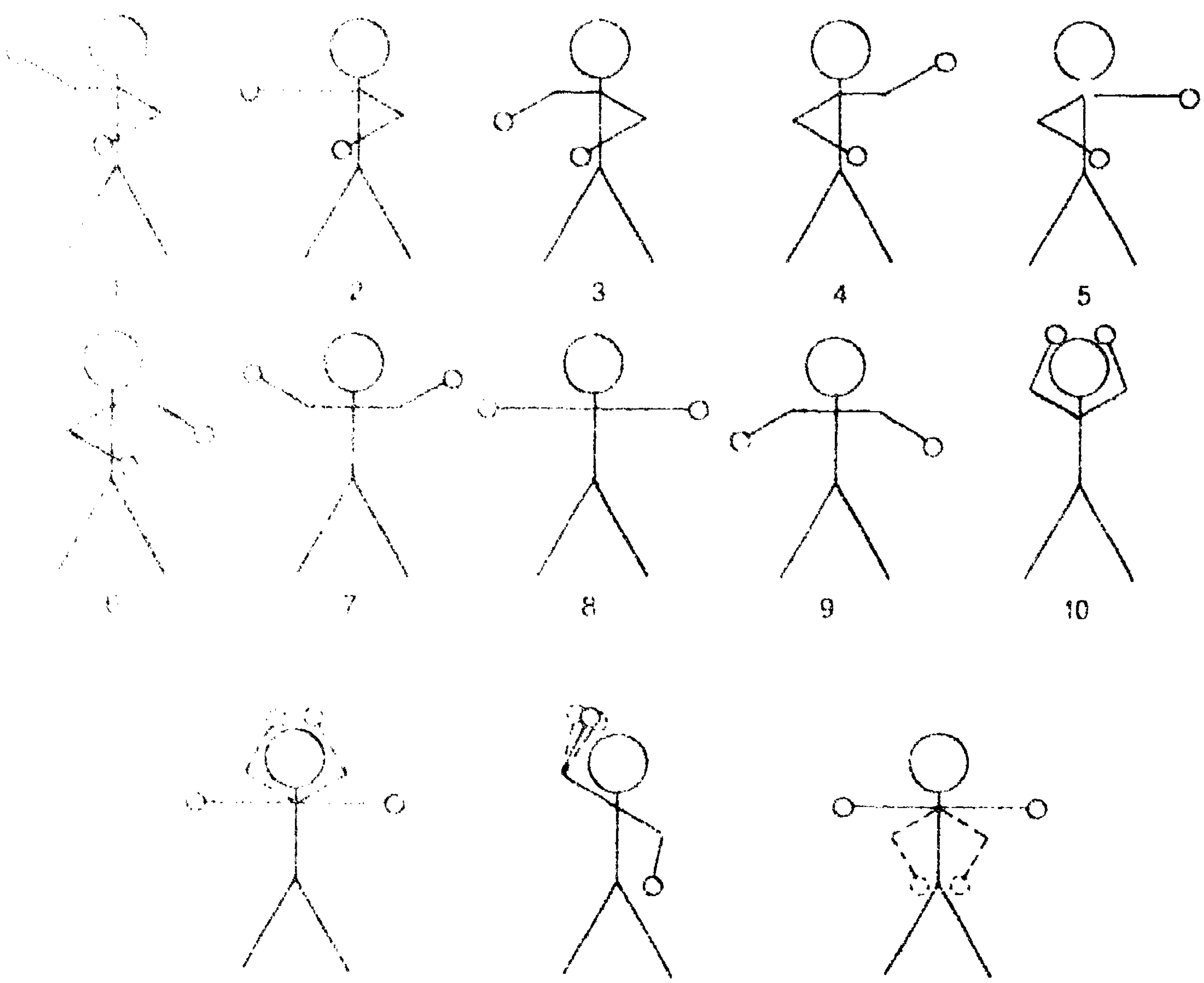
1. Are commonly used in the field for nonverbal communication
2. Should be made with slow and definite motions

C. Radio communications

1. Follow F.A.A. rules and regulations
2. Use call letters or registration number if possible
3. Should be spoken into clearly and used with a sense of professionalism

   Example: Do not cut in or "break" on other parties' conversations.

XI. Common hand signals used while surveying



1 2 3 4 5

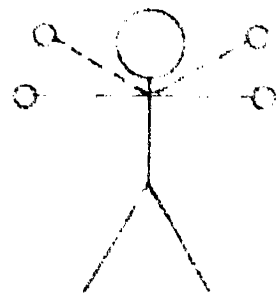
6 7 8 9 10

O.K. or All right

Can't see or No

Turning point or T.P.

INFORMATION SHEET



Pick up
or
move instrument

Plumb the rod
or
straighten

XII. **Common species of poisonous plants**

(NOTE: Distinguishing features of poison ivy and poison oak are their leaves which are composed of three leaflets each. Both plants also have greenish-white flowers and berries that grow in clusters. These poisonous plants can be contacted **year-round.**)

A. Common poison ivy (*rhus radicans*)

1. Grows as a small plant, a vine, and a shrub.

2. Grows everywhere in the United States except California and parts of adjacent states. Eastern oak leaf poison ivy is one of its varieties.

3. Leaves always consist of three glossy leaflets.

4. Also known as three leaf ivy, poison creeper, climbing sumac, poison oak, milkweed, picry, and mercury.

INFORMATION SHEET

B. Western poison oak (*rhus diversiloba*)

1. Grows in shrub and sometimes vine form.
2. Grows in California and parts of adjacent states.
3. Sometimes called poison ivy, or yeara
4. Leaves always consist of three leaflets.

C. Poison sumac (*rhus vernix*)

1. Grows as a woody shrub or small tree from 5 to 25 feet tall.
2. Grows in most of eastern third of United States.
3. Also known as swamp sumac, poison elder, poison ash, poison dogwood, and thunderwood.

XIII. **Characteristic reactions to common poisonous plants**

A. Headache

B. Fever

C. Itching

D. Redness

E. Rash

XIV. **Basic first-aid for poisonous plant reactions**

A. Remove contaminated clothing.

B. Wash all exposed areas with soap and water.

C. Rinse with rubbing alcohol.

D. Apply calamine or other skin lotion.

(NOTE: Fels Naphtha lotion is an excellent non irritating lotion for this use.)

E. Seek medical advice if reaction is severe.

(NOTE: The best prevention of poisoning from plants is to learn to identify the plant species, avoid any contact on skin or clothing, and immediately remove contaminated clothes if contact is unavoidable.)

INFORMATION SHEET

XV. **Common poisonous insects and spiders**

A. Stings from ants, bees, wasps, hornets, and yellow jackets

(NOTE: Occasionally death may occur, but this is almost always due to an acute allergic reaction.)

B. Bites or stings from fleas, mosquitoes, gnats, chiggers, and other insects produce local pain and irritations but are not likely to be severe.

C. Ticks can carry several diseases, including Rocky Mountain Spotted Fever.

D. Spiders in the United States are generally harmless, with two notable exceptions:

1. Black widow spider (*latrodectus mactans*)

(NOTE: Symptoms resulting from a black widow spider bite are a slight local reaction, severe pain caused by nerve toxin, profuse sweating, nausea, cramps, and difficulty in breathing and speaking.)

2. Brown recluse (*loxosceles reclusa*) (also called violin spider or fiddle-back)

(NOTE: Symptoms resulting from a brown recluse bite are a severe local reaction produced by venom, which will form an open ulcer within 1 to 2 weeks, destruction of red blood cells, development of chills, fever, nausea, and vomiting, and possible development of a generalized rash within 24 to 48 hours.)

XVI. **Basic first-aid for poisonous insect bites**

A. Minor bites

1. Use cold applications.

2. Apply soothing lotions, such as calamine.

3. Avoid scratching the infected area.

B. Tick bites

1. Cover the tick with a heavy oil (mineral, salad, or machine) to close its breathing pores.

INFORMATION SHEET

2. If the tick doesn't disengage, allow oil to remain for up to ½ hour. Then carefully remove tick with tweezers, taking care to remove all parts

3. With soap and water thoroughly but gently scrub the area from which the tick was removed.

   (NOTE: Although other methods are often used (example: heat such as a hot match or lit cigarette), they will often leave parts of the tick in the wound and may also injure the surrounding skin. Therefore, great care should be used to be certain all parts are removed.)

C. **Severe** reactions to insect bites

1. Seek medical attention immediately

2. Give artificial respiration if required.

3. Apply a constrictive band above the injection site on victim's arm or leg. Do not apply tightly and remove after 30 minutes.

4. Keep affected part down, below the level of the victim's heart.

5. Apply ice contained in towel or plastic bag.

6. Give aspirin for pain

7. In case of bee sting, remove and discard the stinging apparatus and venom sac.

XVII. Common poisonous snakes and effects of each (Table 1)

A. Rattlesnakes — 13 species, venom affects the circulatory system

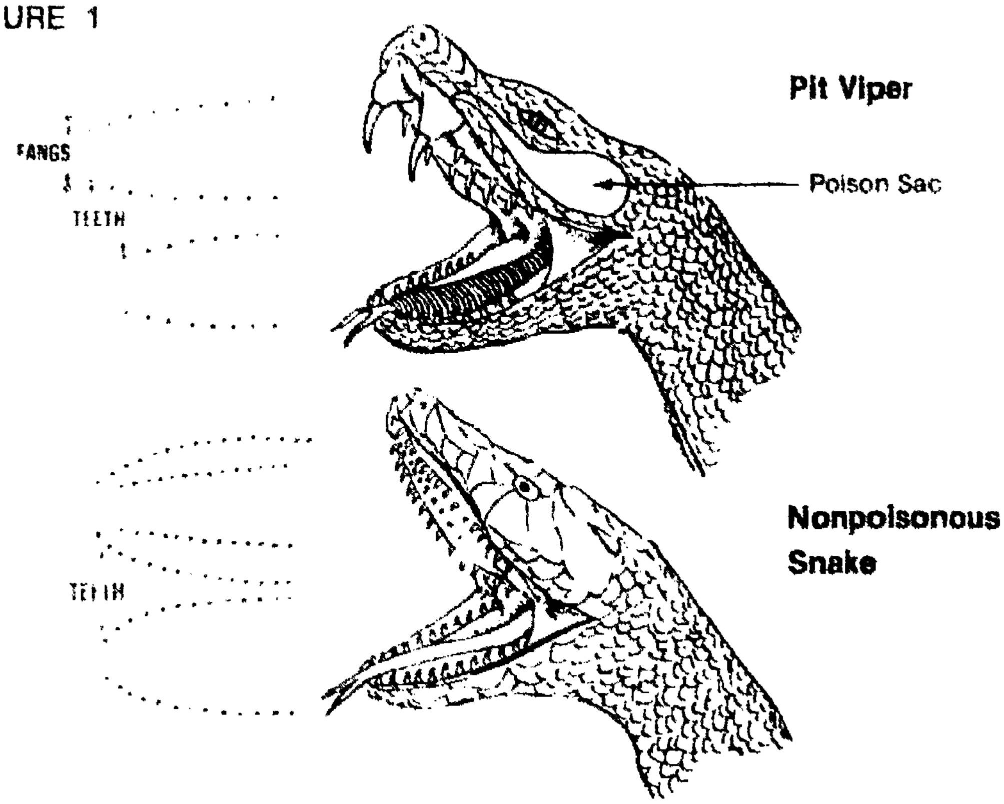
B. Copperheads — Venom affects the circulatory system

INFORMATION SHEET

C. Water moccasin — Venom affects the circulatory system

(NOTE: Rattlesnakes, copperheads and water moccasins belong to the family of pit vipers (*crotalinae*). They have a pit between the eye and nostril on each side, elliptical pupils, from one to six fangs but usually two well-developed fangs, and one row of plates beneath the tail. See Figure 1)

FIGURE 1



D. Coral snake — Venom affects the nervous system and is very toxic

(NOTE: The coral snake is normally small in size, has tubular fangs, round pupils, and a double row of plates beneath the tail. It is characterized by red, yellow, and black rings around the body and always has a black nose.)

INFORMATION SHEET

TABLE 1 — POISONOUS SNAKES

RATTLESNAKES

TIMBER (*Crotalus Horridus*)
Also called Banded rattlesnake, mountain rattler, and black rattler.
Found: In uplands and mountains from southwestern Maine to northern Florida; westward to central Texas, eastern Oklahoma, and Kansas; and northerly to southeastern Minnesota and southwestern Wisconsin.

Size: 36-60 inches.

EASTERN DIAMONDBACK (*Crotalus Adamanteus*)
Found: From central coast region of North Carolina; along lower coastal plain through Florida, westward to eastern Louisiana.

Size: 33-72 inches

WESTERN DIAMONDBACK (*Crotalus Atrox*)
Found: Central Arkansas and eastern Texas to southeastern California, and northward to central Arizona and New Mexico.

Size: 30-72 inches

PACIFIC (*Crotalus Viridis Oreganus*)
Found: British Columbia to southern California and lower California, east to Idaho, Nevada, and Arizona.

Size: 30-60 inches.

PRAIRIE (*Crotalus Viridis Viridis*)
Found: Extreme western Iowa to the Rockies, and beyond from southern Canada to northern Mexico.

Size: 35-45 inches.

MASSASAUGA (*Sistrurus Catenatus*)
Also called: Pygmy rattlesnake.
Found: Western New York and northern Pennsylvania, westward to southeastern Colorado, and southward through western Oklahoma into Texas, southern New Mexico, and Arizona.

Size: 15-26 inches

COPPERHEADS

(*Agkistrodon Contortrix*)
Also called: Highland moccasin, pilot, copperhead, chunkhead and adder.
Found: Massachusetts to northern Florida; westward to Mississippi River in Illinois; eastern Kansas and Oklahoma; and across to Texas.

Size: 24-36 inches.

WATER MOCCASIN

(*Agkistrodon Piscivorus*)
Also called: Cottonmouth and water pilot.
Found: From southeastern Virginia along coastal plains through Florida, westward to Texas and eastern Oklahoma; and up the Mississippi Valley to southern Missouri and Indiana.

Size: 30-48 inches.

CORAL SNAKES

(*Micrurus Fulvius* — *Eastern Coral*)
(*Micruroides Euryxanthus* — *Western Coral*)
Also called: Harlequin and bead snake.
Found: Along the coastal plains from central North Carolina through Florida and the Gulf States; westward to Texas, and up the Mississippi Valley to Arkansas.

Size: 20-30 inches.

XVIII. **Basic first-aid procedures for snake bites**

A. Keep the victim from moving around.

B. Keep the victim in a lying position and as calm as possible.

C. Immobilize the bitten extremity and keep it at or below heart level.

D. Apply a constricting band 2 to 4 inches above the bite. This should be snug but *not* tight. It should be used to *slow* the blood circulation.

E. If severe symptoms develop, make an incision and apply suction immediately with mechanical device available in snake bite kit.

(NOTE: A snake bite kit should be kept in all survey vehicles.)

INFORMATION SHEET

F. Try to identify the species of snake. If you can kill it without risk or delay, bring it to hospital for identification using great care in handling.

(**CAUTION:** A poisonous dead snake is still dangerous because its venom is still poisonous and the snake's reflexes are present for some time.)

XIX. **Basic first-aid in the field**

(NOTE: Sometime while surveying you may be faced with providing aid in an accident situation. When this happens, your objective is to provide immediate and temporary care to the victim until services of a physician can be obtained.)

A. Wounds and hemorrhage

1. Apply direct pressure to the wound.
2. Immediately apply a sterile dressing to the wound.
3. Cover with a clean, bulky cloth and apply pressure for 10 to 15 minutes.
4. If bleeding *cannot* be stopped, a tourniquet may be applied but *only* as a last resort.

B. Shock

1. Apply warm coverings to retain body heat.
2. Keep victim lying down.
3. Elevate the victim's legs if there are no broken bones.
4. If unconscious, be sure air passage is kept clear.
5. If conscious, give victim lots of liquids.

C. Heat stroke

1. Cool the body with water or othe[illegible]s.
2. If conscious, give victim salt water.
3. Call physician.

D. Heat exhaustion

1. Lay victim down with head lower than body.
2. Preferrably relocate victim to a shaded area.
3. Give victim salt water.
4. Call physician.

INFORMATION SHEET

E. Hypothermia (exposure to cold)

1. Remove any wet clothing and replace with dry, warm clothes.
2. Keep victim warm with sleeping bags, coats, or blankets.
3. Place victim inside vehicle or a warm shelter.
4. Replace body fluids with warm drinks.

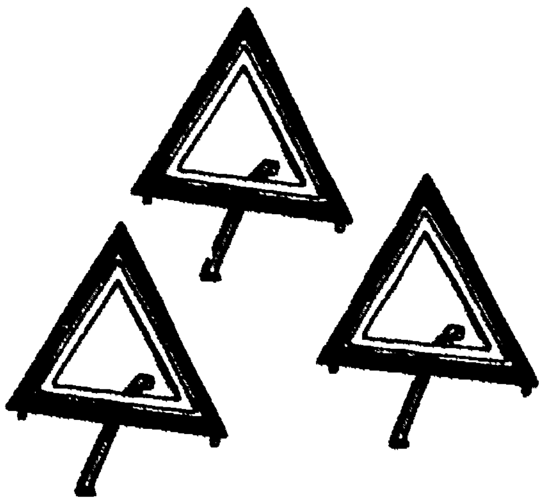
F. Frostbite

1. Move victim indoors as soon as possible.
2. Give plenty of warm liquids to drink.
3. Quickly rewarm frostbitten areas by immersing them in warm water heated to 104°F. for 20-30 minutes.
4. Do **not** rub the frostbitten parts.

G. Fractures, dislocations, and sprains

1. Do **not** try to "set" or relocate the injured limb.
2. Immobilize the injured area by using splints or padding.
3. Generally one should splint both the joint above and below the injury.
4. Consult a physician as soon as possible.

Standard Types of Emergency Parking Devices



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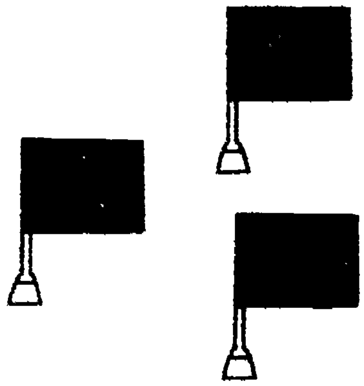
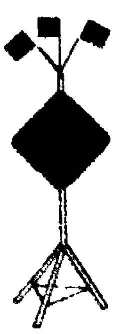
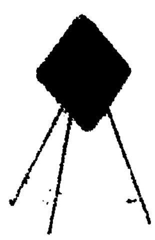


Three Red Reflectors

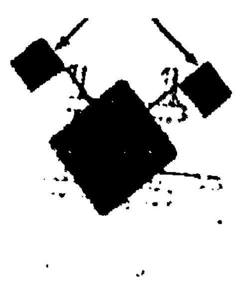
Three Red Flags and Stands

Portable and Temporary Mountings

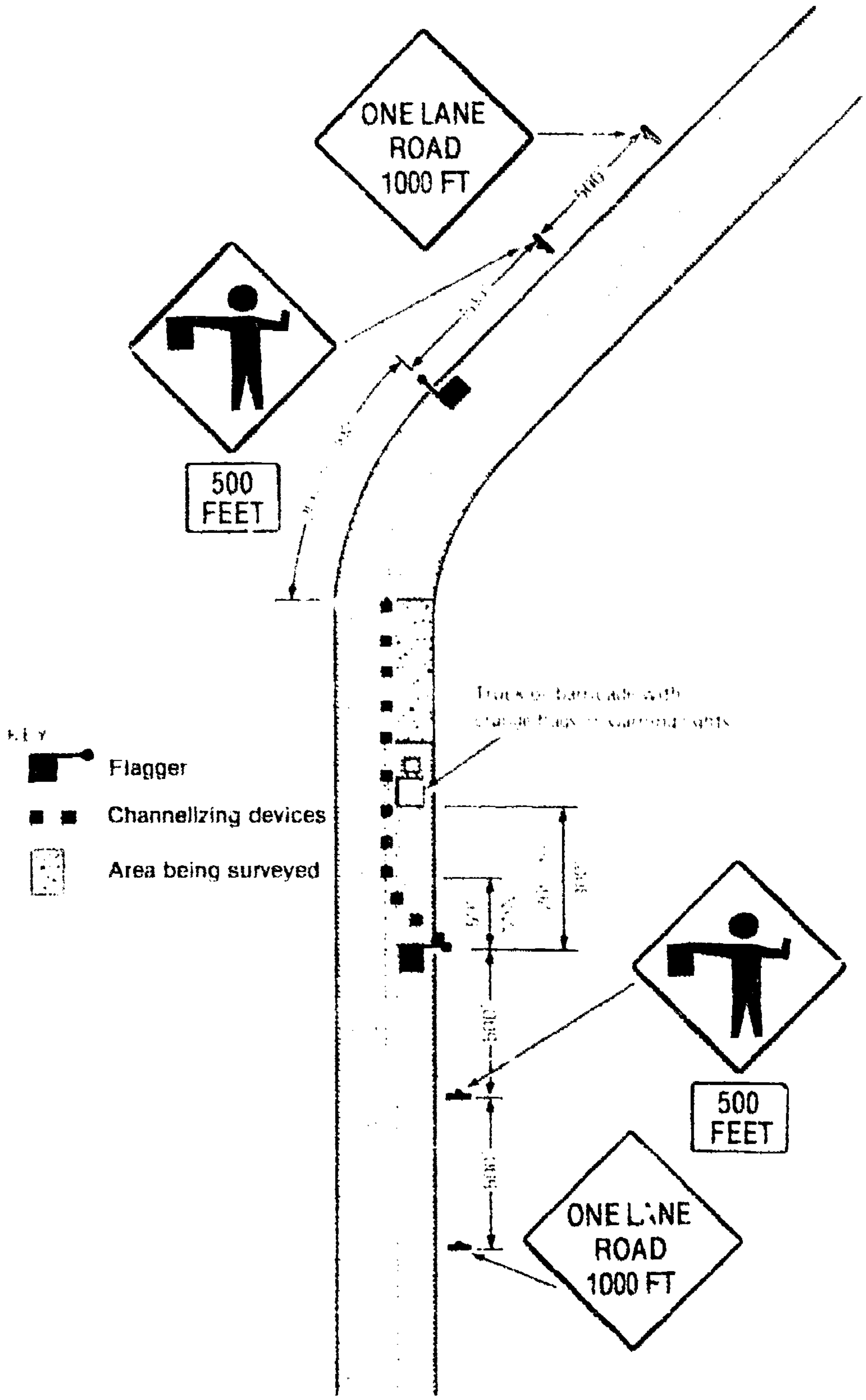




Orange Flags (Optional)



Placement of Traffic Control Devices



Typical Application — Daytime Maintenance Operations of Short Duration on a Two-Lane Roadway and Flagging is Provided

SAFETY
UNIT II

ASSIGNMENT SHEET #1 — COMPILE A SURVEY OF WINTER CLOTHING NEEDS

Surveying may require you to work in extreme weather conditions. It is essential for the surveyor to be well-prepared and protected against exposure to cold and frostbite.

Survey your own clothing. Make a list of the winter gear you already have. Make another list of the items you need to ensure proper protection.

A. Clothing you have — ______________________________

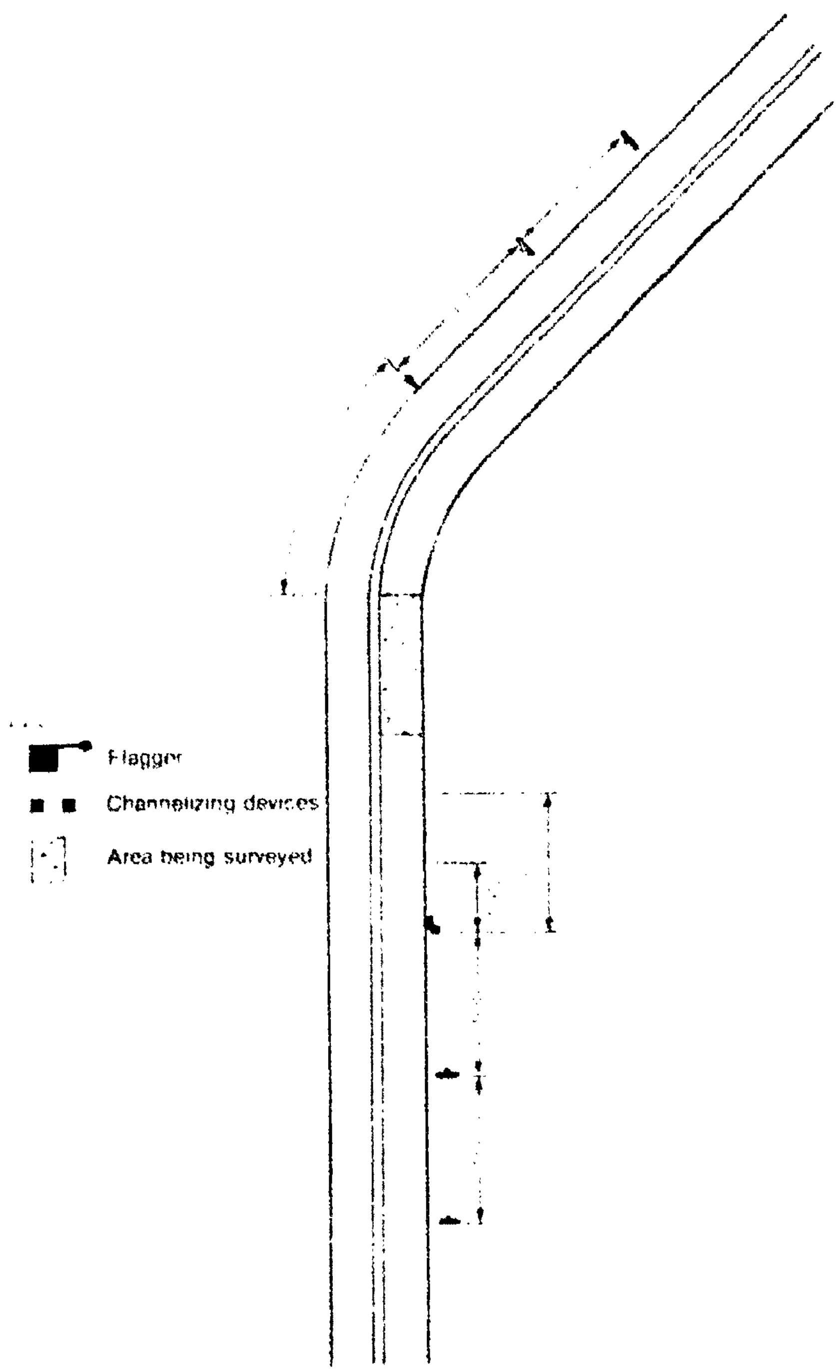
B. Clothing you need — ______________________________

SAFETY
UNIT II

ASSIGNMENT SHEET #2 — CONSTRUCT A DIAGRAM OF APPROPRIATE TRAFFIC CONTROL FOR A TWO-LANE ROADWAY

Channeling is the most important element in traffic control and safety, both for the survey crew and the public. Every operation will include installation of traffic control devices.

On the stretch of highway below, draw in the appropriate signs, cones, barricades, or flaggers for effective traffic control. Assume that you have available any of the devices you have studied.



SAFETY
UNIT II

ASSIGNMENT SHEET #3 — DISTINGUISH BETWEEN CORRECT AND INCORRECT PROCEDURES FOR FLAGGERS

Correct safety procedures for flagging are necessary to protect the flagger, fellow workers, and the public.

The following is a description of Janice Wilson channeling traffic into a single lane on a bridge. After each statement, mark whether Janice's actions were correct or incorrect by writing an "X" in the appropriate blank.

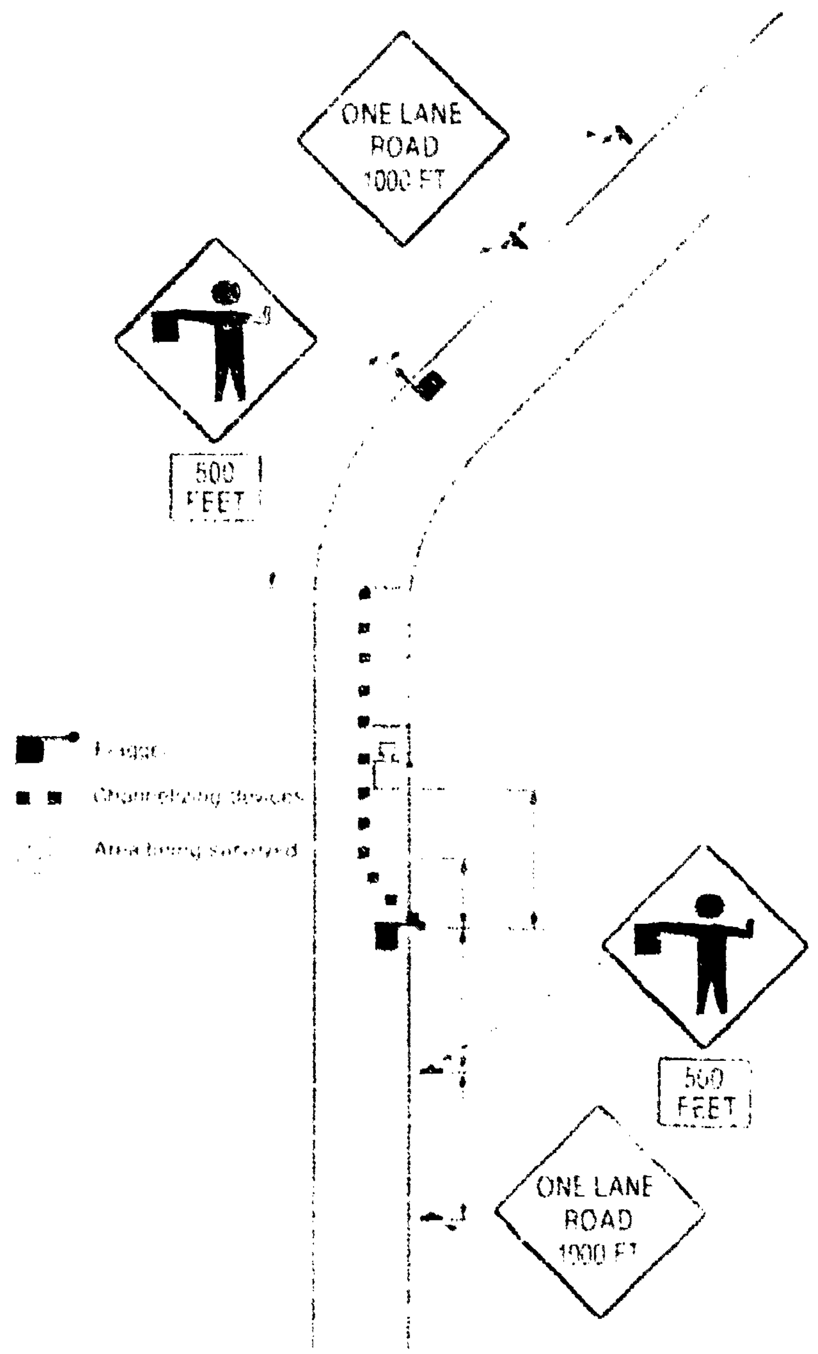
	CORRECT	INCORRECT
A. Janice wears a hard hat and a black vest.	______	______
B. She stands in the traffic lane to move the cars into the changed lane.	______	______
C. She uses a 24-inch STOP/SLOW paddle.	______	______
D. Janice can be seen by oncoming traffic 500 feet before the bridge.	______	______
E. She stands about 250 feet from the bridge.	______	______
F. While she is waiting for cars to come from the other end of the bridge, she turns and watches the bridge operation.	______	______
G. After her traffic is stopped, she takes a quick look at the other flagger for a signal.	______	______
H. She takes her breaks promptly at 10:15 and 3:15, at which time her relief is supposed to cover for her.	______	______
I. At 4:30 when the crew stops for the day, Janice puts the signs out of view of motorists.	______	______
J. Andy came over to Janice's station to ask her for a date. Janice told him to keep clear of her station, and that she would talk to him on her break.	______	______

SAFETY
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1 — Evaluated to the satisfaction of the instructor

Assignm ' Sheet #2



ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3

A. Incorrect

B. Incorrect

C. Correct

D. Correct

E. Incorrect

F. Incorrect

G. Correct

H. Incorrect

I. Correct

J. Correct

SAFETY
UNIT II

JOB SHEET #1 — CONTROL TRAFFIC WITH A FLAG

(NOTE: Flags are to be used for daytime flagging only.)

A. Equipment and materials

1. One 24-inch, square, red flag on a staff approximately 3 feet long
2. Orange vest, shirt, or jacket (may be reflective)

B. Procedure

1. Stopping traffic (Figure 1)

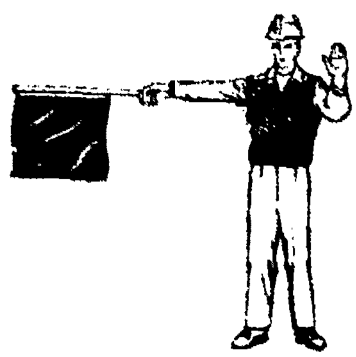
   a. Stand in safe position on shoulder or in barricaded area.

   b. Hold flag in RIGHT hand.

   c. Extend flag horizontally across traffic lane.

   d. Raise free arm, with palm toward driver.

   FIGURE 1



   e. Look driver in eye; maintain eye contact until driver comes to a full stop.

   f. After first vehicle has been stopped, move to a conspicuous position near centerline in order to be readily seen by drivers approaching from rear.

JOB SHEET #1

2. Releasing traffic when it is safe to proceed (Figure 2)

   a. Move to side of traffic lane, and stand parallel to flow of traffic.

   b. Lower flag to your side.

   c. With free arm, motion traffic to proceed.

   FIGURE 2

   (NOTE: *Do not* wave traffic through with flag. Use slow motions. Rapid gestures may be seen as impatience or as a signal to hurry.)

3. Alerting or slowing traffic (Figure 3)

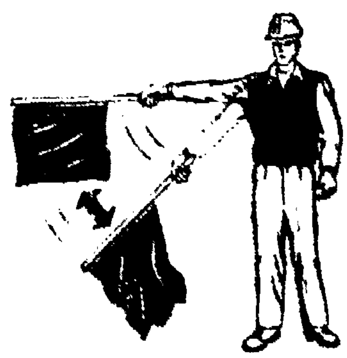
   (NOTE: This is used when slowing traffic or channeling traffic into other lanes.)

   a. Face traffic.

   b. Wave flag slowly up and down in sweeping motion.

   (NOTE: Keep flag at shoulder level; don't raise it above the horizontal.)

   FIGURE 3



   c. When vehicle has slowed, lower flag, and with free arm, motion driver to proceed.

   (NOTE: Never wave traffic through with the flag.)

SAFETY
UNIT II

JOB SHEET #2 — PLACE EMERGENCY PARKING DEVICES

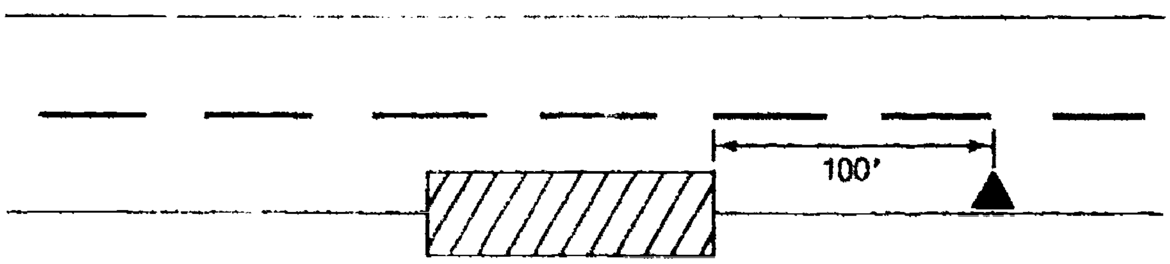
A. Materials — 3 red flags or reflectors (see Transparency 1)

B. Procedure

1. Pull off the road.

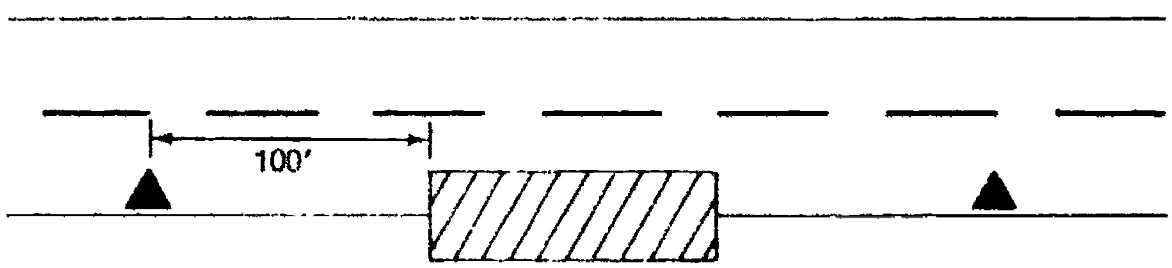
2. Place one signal 100 feet (40 paces) ahead of the equipment. (Figure 1)

FIGURE 1



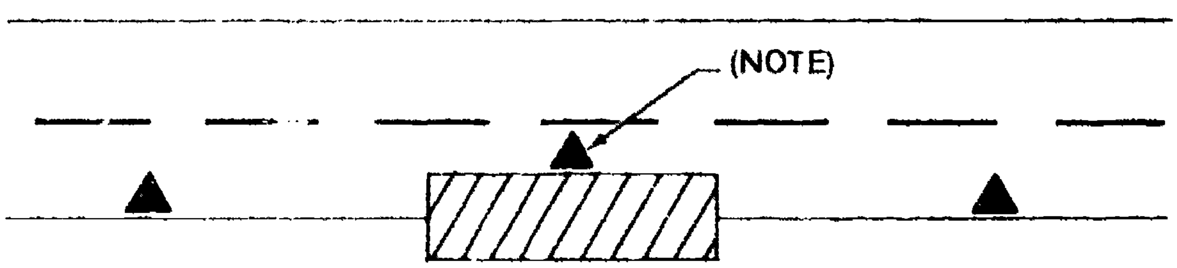
3. Place second signal 100 feet (40 paces) to rear of equipment. (Figure 2)

FIGURE 2



4. Place third signal as near as practical to side of equipment near traffic. (Figure 3)

FIGURE 3



(NOTE: If disabled on a divided highway, place rear signal 200 feet [80 paces] from equipment. If disabled on a curve or hill crest or other such obstruction, place signal where it will give ample warning, but not more than 500 feet or less than 100 feet from equipment.)

SAFETY
UNIT II

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a.	Fatigue, weakness, and sometimes collapse due to loss of body fluids through sweating and inadequate water intake	1.	Channelize
_____b.	Angle at which traffic is diverted from regular lane into new lane	2.	First aid
_____c.	Sections of sign-posted roadway preceding and following taper	3.	Frostbite
_____d.	Muscular pains and spasms due to loss of salt through sweating or to inadequate intake of salt	4.	Heat cramps
_____e.	Immediate, temporary care given the victim of an accident or sudden illness until the services of a physician can be obtained	5.	Heat exhaustion
_____f.	To divert traffic flow from one lane into another lane	6.	Heat stroke
_____g.	Immediate life-threatening emergency characterized by extremely high body temperature and disturbance of sweating mechanisms	7.	Hypothermia
_____h.	Federal legislation designed to ensure safe and sanitary working conditions for employees	8.	Occupational Safety and Health Act
_____i.	Tissue damage due to freezing of tissue fluids	9.	Tangent
_____j.	Below normal body temperature usually due to overexposure to low temperatures	10.	Taper

2. Select true statements concerning rules for general job safety by placing an "X" in the appropriate blanks.

_____a. Be conscious of the effects of your own, as well as other people's, actions.

_____b. Use any available tool for various applications.

TEST

_____c. Defects in tools, supplies and equipment are very common, and do not need to be reported.

_____d. Properly use traffic control whenever conditions require them.

_____e. Follow standard company procedures at all times.

_____f. Be alert for potential dangers when you are tired; very few dangers exist at other times so you don't have to watch then.

3. State three personal safety rules involved in the surveying field.

   a. ____

   b. ____

   c. ____

4. Select from the following list proper clothing for both warm and cold weather surveying by placing a "W" next to those for warm weather and a "C" next to those for cold.

   (NOTE: Some may be used in both warm and cold weather. Mark these "CW".)

_____a. insulated, water-proof boots, and 2 pairs of socks with a spare pair suggested

_____b Thermal underwear, trousers, and insulated coveralls

_____c. Short sleeve shirts are acceptable, although one should constantly be aware of the dangers of sunburn, wind burn, insect bites, scratches, and allergies. Long sleeve shirts should be worn in brush cover.

_____d. Safety shoes are suggested or high-lace field boots with steel-toe protection if possible.

_____e. Head gear is mandatory to help prevent hypothermia and frostbite of the surveyor's ears and face.

_____f. Head-protection can be used for protection against heat stroke and sunburn.

_____g. Gloves or mittens that do not interfere with the ability of the worker or interfere with circulation.

5. Select true statements concerning safety precautions to take while working in the field by placing an "X" next to the true statements.

_____a. While in rough terrain, the safest route to the site is always the shortest.

_____b. Care should be taken when traveling in heavy ground cover, drainage ditches, along high points, or steep embankments.

TEST

_____c. Select a place where backing up will not be required if possible.

_____d. Park against the direction of traffic, and well along the shoulder, or in the center if working on streets or highways.

_____e. It may be necessary to park the vehicle out in the roadway as to protect the survey site, but this should be up to the discretion of the flagger.

_____f. Hold pencils and chaining pins in your hands when driving stakes so you won't lose them.

_____g. Keep your eye and mind on the job task.

_____h. Give crew members room to work with tools.

_____i. Watch for underground power lines when using level rod or range poles.

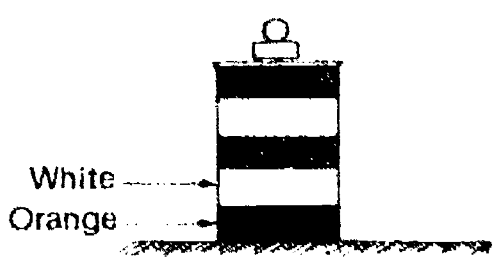
_____j. When taping, watch for electric fences, passing vehicles, and electric cables.

_____k. Do not allow other workers or passersby within a 5′ radius during operation of chainsaws, brush saws, or other clearing equipment.

_____l. Protective guards do not need to be used on equipment and hand tools except at the end of the day.

_____m. Prior to leaving the job site, a 360° equipment and tool check must be performed and a conformation by all crew members should be made.

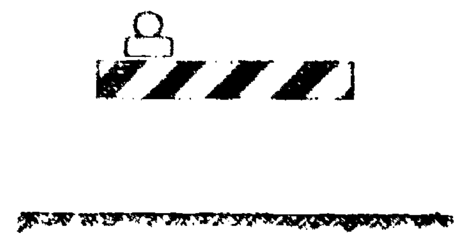
6. Label the following types of channeling devices used for traffic control.



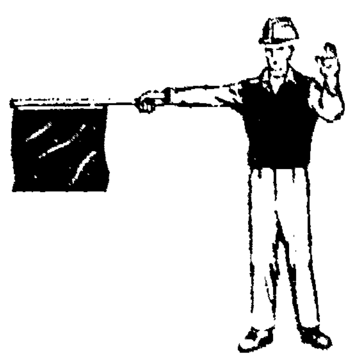
a. ______________________

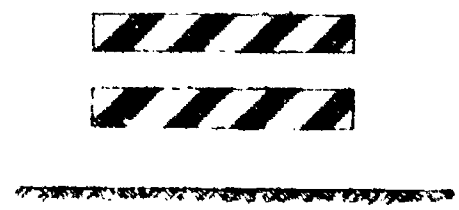
b. ______________________

TEST



c. ______________________ d. ______________________





e. ______________________ f. ______________________

7. List four techniques of proper placement of traffic control devices.

   a. ____

   b. ____

   c. ____

   d. ____

8. Select from the following list the responsibilities of a flagger by placing an "X" in the appropriate blanks.

   _____a. Protecting public, other workers, and self

   _____b. Inspecting survey site

   _____c. Stopping and slowing traffic

   _____d. Releasing traffic when it is safe to proceed

TEST

_____e. Setting up survey equipment

_____f. Surveying site

_____g. Alerting drivers to traffic conditions

_____h. Promoting good public relations

9. Complete the following statements concerning safety rules for flaggers on a survey crew by circling the correct words.

   a. Wear orange or reflective (**pants, vest**) and hard hat if required.

   b. Stand where you can be seen by oncoming traffic for (**100, 500**) feet.

   c. Stand (**100-200, 500-600**) feet from work area.

   d. Stand (**in safe position on shoulder, in path of approaching vehicles**).

   e. Stand (**full front, sideways, full back**) to traffic.

   f. Use either a STOP/SLOW paddle or a 24 inch square (**red, white**) flag for daylight flagging.

   g. Always stand (**alone, with workers**).

   h. Remain at your station until work has been (**started, completed**).

   i. Remove all traffic control signs (**when work has ended, one day later**).

10. Distinguish between the following types of communication used by a survey crew by placing the following letters next to the correct descriptions: "V" for verbal communication, "H" for hand signals, and "R" for radio communication.

_____a. Are commonly used in the field for nonverbal communication

_____b. Use call letters or registration number

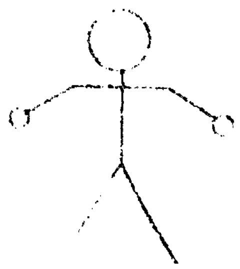
_____c. Are used to clarify the job task prior to the actual surveying operation

_____d. Follow F.A.A. rules and regulations

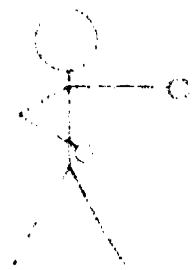
_____e. Should be made with slow and definite motions

TEST

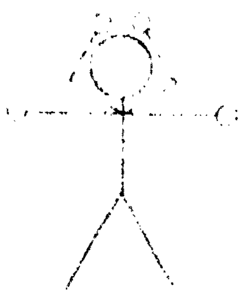
11. Identify the following common hand signals used while surveying. Select your answers from the following list: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, ok, can't see or no, turning point, pick up or move instrument, and plumb the rod or straighten



a. ____________________ b. ____________________ c. ____________________



d. ____________________ e. ____________________ f. ____________________



g. ____________________ h. ____________________ i. ____________________

TEST

j. ______________ k. ______________ l. ______________

m. ______________ n. ______________ o. ______________

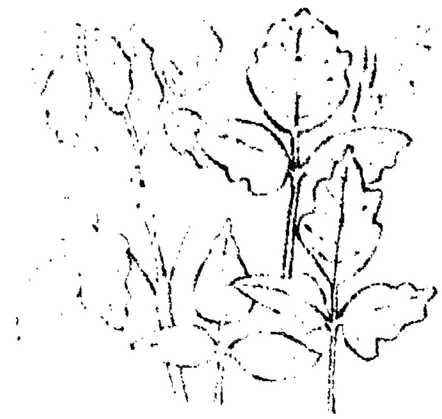
12. Identify the following commonly found species of poisonous plants that can be encountered while surveying.

    a. ______________________________

        1) Grows as a woody shrub or small tree from 5 to 25 feet tall

        2) Grows in most of eastern third of United States

TEST



[illegible] small plant, a vine, and [illegible]

[illegible] everywhere in the United States except California and parts of adjacent states

[illegible] consist of three [illegible]

[illegible] sometimes [illegible]

[illegible] California and parts of [illegible]

[illegible] consist of three [illegible]

13 [illegible] reactions to common poisonous plants.

____

____

____

14. [illegible] following basic first-aid procedures for care of poisonous plant [illegible] correct sequence numbers (1-5) in the appropriate blanks.

[illegible] or other skin lotion.

[illegible] areas with soap and water.

[illegible] contaminated clothing

[illegible] Seek medical advice if reaction is severe.

[illegible] rubbing alcohol

TEST

15. List six poisonous insects and spiders found while surveying.

    a. ______________________

    b. ______________________

    c. ______________________

    d. ______________________

    e. ______________________

    f. ______________________

16. Discuss the basic first aid procedures for the following poisonous insect bites.

    a. For minor bites — ______________________

    ____

    ____

    b. For tick bites — ______________________

    ____

    ____

    c. For **severe** reactions to insect bites — ______________________

    ____

    ____

    ____

17. List four types of commonly found poisonous snakes and the effects of each.

    a ______________________

    b ______________________

    c ______________________

    d. ______________________

TEST

18 Describe the standard first aid procedures for snake bites.

____

____

____

____

____

____

19. Match the type of injury on the right with the correct first-aid procedure.

_____a.
1) Move victim indoors as soon as possible.
2) Give plenty of warm liquids to drink
3) Quickly rewarm affected areas by immersing them in warm water heated to 104°F for 20-30 minutes.
4) Do *not* rub the affected parts

_____b.
1) Lay victim down with head lower than body
2) Preferably relocate victim to a shaded area
3) Give victim salt water
4) Call physician

_____c.
1) Cool the body with water or other cool applications
2) If conscious, give victim salt water
3) Call physician

_____d.
1) Apply warm coverings to retain body heat.
2) Keep victim lying down.
3) Elevate the victim's legs if there are no broken bones.
4) If unconscious, be sure air passage is kept clear.
5) If conscious, give victim lots of liquids.

_____e.
1) Do *not* try to "set" or relocate the injured limb.
2) Immobilize the injured area by using splints or padding.
3) Generally one should splint both the joint above and below the injury.
4) Consult a physician as soon as possible.

1. Wounds and hemorrhage
2. Shock
3. Heat stroke
4. Heat exhaustion
5. Hypothermia
6. Frostbite
7. Fractures, dislocations, and sprains

TEST

_____f. 1) Apply direct pressure to the wound.
2) Immediately apply a sterile dressing to the wound.
3) Cover with a clean, bulky cloth and apply pressure for 10 to 15 minutes.
4) If bleeding *cannot* be stopped a tourniquet may be applied but *only* as a last resort.

_____g. 1) Remove any wet clothing and replace with dry, warm clothes.
2) Keep victim warm with sleeping bags, coats, or blankets.
3) Place victim inside vehicle or a warm shelter.
4) Replace body fluids with warm drinks.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

20. Compile a survey of winter clothing needs. (Assignment Sheet #1)

21. Construct a diagram of appropriate traffic control for a two lane roadway. (Assignment Sheet #2)

22. Distinguish between correct and incorrect procedures for flaggers. (Assignment Sheet #3)

23. Demonstrate the ability to:

    a. Control traffic with a flag. (Job Sheet #1)

    b. Place emergency parking devices. (Job Sheet #2)

SAFETY
UNIT II

ANSWERS TO TEST

1.

a.	5	f.	1
b.	10	g.	6
c.	9	h.	8
d.	4	i.	3
e.	2	j.	7

2. a,d,e

3. Any three of the following:
   a. Wear close-fitting clothes that are appropriate for the activities being performed.
   b. Wear safety glasses, hard hats, traffic vests, etc. in areas where required.
   c. Remove rings and other jewelry when working.
   d. Be alert and conduct yourself in a manner that will ensure safe practices.
   e. Know locations of first-aid equipment and fire extinguishers.

4. a. C
   b. C
   c. W
   d. W (or CW)
   e. C
   f. W
   g. C

5. b,c,g,h,j,m

6. a. Drum
   b. Cones
   c. Survey crew flagger with sign paddle
   d. Type I barricade
   e. Survey crew flagger with flag
   f. Type II barricades

7. Any four of the following:
   a. Place all devices before survey operations begin.
   b. Place signs and barricades in areas free from visual obstructions.
   c. Place where they will convey messages most effectively according to highway design, alignment, and speed.
   d. Place at a distance that allows driver adequate time to respond.
   e. Place on right side of street or roadway.
   f. Place in traffic lane when appropriate.
   g. Place advance warnings signs approximately 1,500 feet in advance work area at 500 ft interval where open highway conditions prevail.

8. a,c,d,g,h

ANSWERS TO TEST

9. a. Vest
   b. 500
   c. 100-200
   d. In safe position on shoulder
   e. Sideways
   f. Red
   g. Alone
   h. Completed
   When work has ended

10. a. H
    b. R
    c. V
    d. R
    e. H

11. a. 9
    b. 2
    c. Plumb the bob or straighten
    d. Turning point
    e. 10
    f. 5
    g. ok
    h. 4
    i. 3
    j. Can't see or no
    k. 5
    l. 7
    m. 1
    n. 8
    o. Pick up or move instrument

12. a. Poison sumac
    b. Common poison ivy
    c. Western poison oak

13. Any three of the following.
    a. Headaches
    b. Fever
    c. Itching
    d. Redness
    e. Rash

14. a. 4
    b. 2
    c. 1
    d. 5
    e. 3

ANSWERS TO TEST

15. Any six of the following.
    a. Ants
    b. Bees
    c. Wasps
    d. Hornets
    e. Yellow jackets
    f. Fleas
    g. Mosquitoes
    h. Gnats
    i. Chiggers
    j. Ticks
    k. Spiders
        1) Black widow
        2) Brown recluse

16. Discussions should include:
    a. For minor bites — Use cold applications, soothing lotions, such as calamine, and avoid scratching the infected area
    b. For tick bites
        1) Cover the tick with a heavy oil (mineral, salad, or mact [illegible]) to close its breathing pores.
        2) If the tick doesn't disengage, allow oil to remain for up to ½ hour, then carefully remove tick with tweezers, taking care to remove all parts.
        3) With soap and water thoroughly but gently scrub the area from which the tick was removed
    c. For severe reactions to insect bites
        1) Seek medical attention immediately
        2) Give artificial respiration if required
        3) Apply a constrictive band above the injection site on victim's arm or leg. Do not apply tightly and remove after 30 minutes.
        4) Keep affected part down, below the level of the victim's heart.
        5) Apply ice contained in towel or plastic bag.
        6) Give aspirin for pain.
        7) In case of bee sting, remove and discard the stinging apparatus and venom sac.

17. a. Rattlesnakes — Venom affects the circulatory system
    b. Copperheads — Venom affects the circulatory system
    c. Water moccasins — Venom affects the circulatory system
    d. Coral snakes — Venom affects the nervous system and is very toxic

18. Description should include:
    a. Keep the victim from moving around.
    b. Keep the victim in a lying position and as calm as possible.
    c. Immobilize the bitten extremity and keep it at or below heart level.
    d. Apply a constricting band 2 to 4 inches above the bite. This should be snug but *not* tight. It should be used to *slow* the blood circulation.
    e. If severe symptoms develop, make an incision and apply suction immediately with mechanical device available in snake bit kit.
    f. Try to identify the species of snake. If you can kill it without risk or delay, bring it to hospital for identification using great care in handling.

ANSWERS TO TEST

19. a. 6
    b. 4
    c. 3
    d. 2
    e. 7
    f. 1
    g. 5

20.-22. Evaluated to the satisfaction of the instructor

23. Performance skills evaluated to the satisfaction of the instructor

HORIZONTAL MEASUREMENTS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to list methods of making horizontal measurements, recognize the various types of surveying tapes and taping accessories, demonstrate the basic procedure for taping horizontal measurements, perform accurate taping skills utilizing various taping accessories, and identify and solve common types of taping errors. Competencies will be demonstrated by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to horizontal measurements with the correct definitions.
2. State equivalencies for various surveying measurements.
3. List types of equipment used in the past to make horizontal measurements.
4. Match ' orizontal measurements with their correct uses.
5. Distinguish between tl e methods of meast ring distances.
6. Complete statements concerning types of tapes or chains.
7. Identify types of tape readouts.
8. Match taping accessories with their correct uses.
9. Complete statements concerning the care and storage of taping equipment.
10. State the purpose of taping.

OBJECTIVE SHEET

11. Arrange in order the steps used in taping on level ground.

12. Select true statements concerning the procedure for taping on uneven or sloping ground.

13. Distinguish between accuracy and precision related to surveying technology.

14. Calculate an accuracy ratio in relation to the amount of error within a survey problem.

15. List three examples of each common type of error that may occur while surveying.

16. Match taping corrections with the correct formulas.

17. Complete statements concerning recent advancements in horizontal measuring.

18. Distinguish between the responsibilities of each survey crew member when making horizontal measurements.

19. Compute horizontal conversions. (Assignment Sheet #1)

20. Calculate taping corrections for slope errors. (Assignment Sheet #2)

21. Calculate taping corrections for erroneous tape lengths. (Assignment Sheet #3)

22. Calculate taping corrections for temperature. (Assignment Sheet #4)

23. Calculate taping corrections for all types of taping errors. (Assignment Sheet #5)

24. Demonstrate the ability to:

    a. Determine average length of pace. (Job Sheet #1)

    b. Measure and lay out horizontal distances with a steel tape. (Job Sheet #2)

HORIZONTAL MEASUREMENTS
UNIT III

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

   (NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

   (NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

   1. Try to obtain any older surveying equipment that is available to exhibit to the students during instruction.

   2. Demonstrate some technical advancements that have become available to the surveying industry.

      Example: EDM's, digital theodolites, etc.

   3. Demonstrate the procedure of "throwing a chain" to the students and let them practice the technique on an old chain.

   4. Have the students calibrate some tapes and determine their actual lengths and retain a list for future reference.

   5. Have each of the students frequently reestablish their pacing increment and continually update them.

   6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1 — Styles of Tape Read-Outs
2. TM 2 — Taping Accessories
3. TM 3 — Principles of EDM

D. Assignment sheets

1. Assignment Sheet #1 — Compute Horizontal Conversions
2. Assignment Sheet #2 — Calculate Taping Corrections for Slope Errors
3. Assignment Sheet #3 — Calculate Taping Corrections for Erroneous Tape Lengths
4. Assignment Sheet #4 — Calculate Taping Corrections for Temperature
5. Assignment Sheet #5 — Calculate Taping Corrections for All Types of Taping Errors

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1 — Determine Average Length of Pace
2. Job Sheet #2 — Measure and Lay Out Horizontal Distances With a Steel Tape

G. Test

H. Answers to test

REFERENCES USED IN WRITING THIS UNIT

A. Kavanagh, Barry and S.J. Glenn Bird. *Surveying: Principles and Applications.* Reston, VA: Reston Publishing Co., Inc., 1984.

B. Brinker, R.C. and P. R. Wolf. *Elementary Surveying.* 7th ed. New York: Harper & Row. 1984.

SUGGESTED SUPPLEMENTAL MATERIAL

Texts...

A. Davis, R. E., F. S. Foote, and J. H. Kelly. *Surveying.* 5th ed. New York: McGraw-Hill Book Company. 1966.

B. Kissam, P. *Surveying for Civil Engineers.* New York: McGraw-Hill, 1976.

Filmstrip...

(Measuring Horizontal Distances.) "Surveying". Prentice-Hall Media
150 White Plains Road, Tarrytown, NY 10591

HORIZONTAL MEASUREMENTS
UNIT III

INFORMATION SHEET

I. **Terms and definitions**

A. Baseline — A surveyed line, normally straight, with measured increments called stations; often used for control work on engineering projects and as a method of collecting existing ground features

B. Blunder — A mistake due to human error that can be discovered unless negligible

Example: Transposing figures while recording

C. Circumference — The calculated or measured distance around a circular object

D. Field book — The common term for the collection base of all field data; usually either a bound booklet or a loose-leaf binder-type book.

(NOTE: Various styles and sheet types will be discussed later in the text.)

E. Parameter — A set of physical properties whose values determine the characteristics of a system

F. Point — A common surveying abbreviation which represents an accurate position of a surveyed station

G. Reconnaissance — A normal preliminary stage of a project used to evaluate approaches to surveying projects, collect preliminary data, and familiarize oneself with the site

H. Recorded — A surveying term used to signify writing down or transcribing field data into a field book

I. Theodolite — A surveying device developed after the transit for both vertical and horizontal angular measurements; normally has greater precision than standard transits

J. Tripod — A piece of surveying equipment, normally three-legged, of wood or aluminum on which the surveying instruments can be mounted

INFORMATION SHEET

II. Measurements and equivalencies

Linear Measurements			*English Units*		
1 mile	=	5280 feet	1 foot =	12	inches
	=	1760 yards	1 yard =	3	feet
	=	320 rods	1 rod =	16½	feet
	=	80 chains	1 chain =	66	feet
1 acre	=	43560 ft²	1 chain =	100	links
	=	10 square chains			

Linear Measurement		*Metric (SI) Units*	
1 kilometer	=	1000	meters
1 meter	=	100	centimeters
1 centimeter	=	10	millimeters
1 decimeter	=	10	centimeters
1 hectare (ha)	=	10,000	m²
1 square kilometer	=	1,000,000	m²
	=	100	hectares

English to Metric Conversion	
1 ft = 0.3048 m (exactly)	1 inch = 25.4 mm (exactly)
1 km = 0.62137 miles	1 meter = 3.280833 ft.
1 hectare (ha) = 2.471 acres	(ASCM Standard Metric Conversion)
1 km² = 247.1 acres	

(NOTE: Prior to 1959, the United States used the relationship 1 m = 39.37 in. This resulted in a U.S. survey foot of .3048006 m.)

III. Common types of equipment used in the past

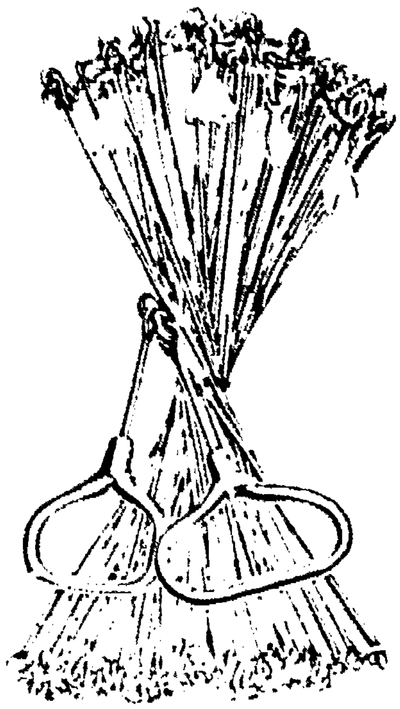
A. Rod or pole — Early surveyors struggled with braced timbers, wood and metal poles. These devices resulted in the term "pole" as a unit of measurement. Its length was 16 ½ ft, the same as a "rod."

INFORMATION SHEET

B. Gunter's chain — Was in popular use during the time of the settlement of North America. It was 66 ft long (4 rods) and had 100 links, each link equal to 0.66 ft or 7.92 inches. The links were made of heavy wire, had a loop at each end, and were joined by 3 rings. (See Figure 1 below.) The length of 66 ft was chosen because of its relationship to other English units of measure.

(NOTE: Measurements made for the Bureau of Land Management (BLM) must be recorded in gunter's chain. Measurements can be taken by conventional methods [feet or meters], but they must be converted when recorded.)

FIGURE 1



Gunter's Chain

C. Engineer's chain — This had the same basic construction as a gunter's chain but was 100 ft long with links every 1 foot, therefore 100 links. Chains are seldom used today, although steel tapes graduated like the "gunter's" or "engineer's" chain are manufactured and are commonly used in modern surveying methods. The term "chaining" continues to be used interchangeably with "taping," even though tapes are employed exclusively.

D. Wires — Before the thin, flat steel tapes now being used could be manufactured, wires were utilized for measuring lengths. They still are practical in special applications such as in hydrographic surveys.

IV. Horizontal measurements and their uses

A. Horizontal ties — Used to relocate points set from existing features that can be readily found later

INFORMATION SHEET

B. Linear stationing — Used to provide a method of control along a base ine for construction purposes

C. Traversing — Used to measure the distance between control points along with the angular measurements

D. Trilateration — Used to establish a series of control points and their positions by horizontal distances only

E. Triangulation — Used to establish an accurate baseline from which angles are measured to numerous points

F. Construction — Used to establish proposed location of all engineering works

G. Topographical — Used to establish location of all existing features within a survey limit

V. **Methods of measuring distances**

A. Pacing

1. Consists of counting the number of steps in a required distance. Best done by walking with natural steps a measured distance, at least 200 feet long, and dividing the known distance into the number of steps taken, therefore determining an average length of each step or "pace"

2. Particularly useful when looking for survey markers, marking rough measurements, detecting blunders, and checking measurements on construction layouts

3. Pacing can be performed, with practice, to an accuracy of 1/100, but one must remember that the length of a pace will vary when going uphill or downhill, and various types of ground cover can have an effect in the overall accuracy of the measured distance.

B. Odometer

1. Consists of the number of revolutions of a wheel of known circumference converted to a linear distance

2. Useful to collect preliminary data when beginning a survey, to serve as a rough check of measurements made by other methods, and to aid in differentiating fencelines for determining property ownerships

3. Odometer readings have an accuracy of approximately 1/200, but one should note that using an odometer gives surface measurements and should be corrected if severe ground slopes occur.

INFORMATION SHEET

C. Electronic distance measuring (EDM) devices

1. EDM instruments function by sending a lightwave or microwave signal along the path to be measured, and measuring the time involved in traveling that distance.

   (NOTE: Types and basic principles involved will be discussed later in this unit.)

2. Very useful when measuring over long distances, bodies of water, rough terrain, etc.

3. This method of measurement is highly accurate if proper operating procedures are utilized. Advancements in this technology have rapidly increased the accuracy and range of this type of equipment.

D. Tacheometry

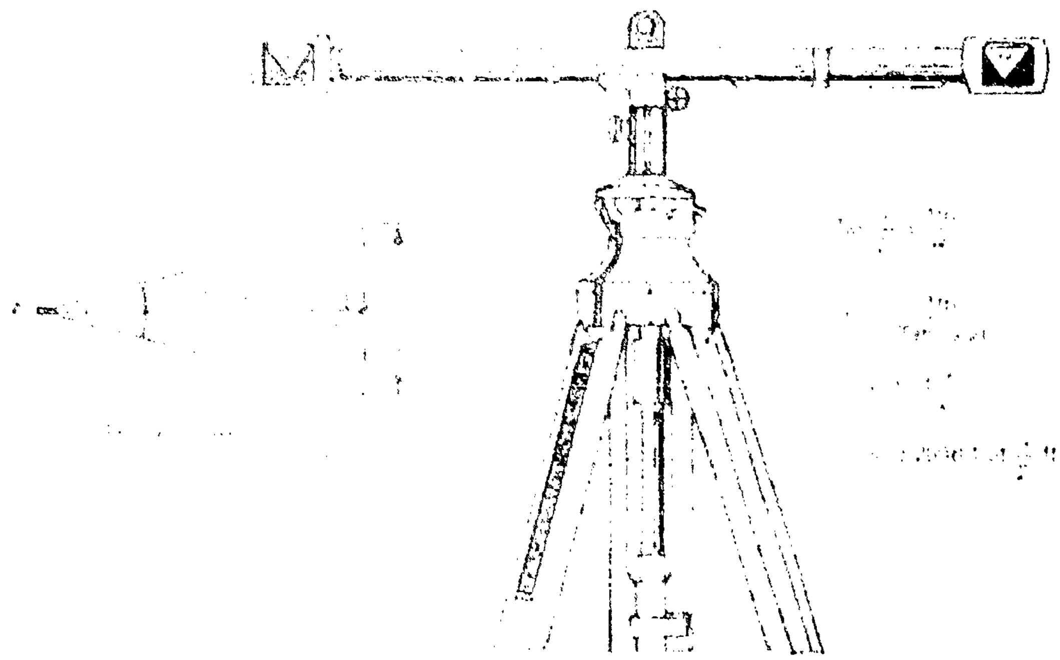
1. Involves the measurement of a related distance parameter either by means of a fixed angle intercept (example — stadia) or by means of a measured angle to a fixed base (example — subtense bar)

2. Stadia is a form of tacheometry that utilizes a telescope cross-hair configuration to assist in determining distances.

   (NOTE: This technique will be discussed further in Unit VIII, "Topographic Surveying.")

3. A subtense bar consists of a bar with 2 targets held in place with "invar" wires precisely at 2.000 meters. It is then mounted on a tripod over Pt. B (see Figure 2). A theodolite is set up over Pt. A. The horizontal angle between targets is then measured and a distance from Pt. A to B can then be computed for distances up to 500' (150 m.). When using a one-second theodolite, an accuracy of 1/3000 can be obtained, comparable to conventional chaining methods. (Figure 2)

FIGURE 2



Subtense bar

INFORMATION SHEET

E. Optical range finders

1. These instruments operate on the same principles as range finders on a single-lens camera. Basically, when focused, they solve for object distance. The operator views the object, focuses the image, and a distance reading can be obtained.

2. Particularly useful in reconnaissance, sketching, or checking a more accurate measurement for mistakes

3. These instruments are normally capable of accuracies of 1/50 at distances up to 200 ft with accuracy diminishing as distance increases.

VI. **Types of tapes or chains**

A. Available in many lengths, marked in either English or metric units and different unit weights

B. Common lengths are 100, 200, and 300 foot tapes with 100 ft being the most commonly used

C. Steel tapes or chains come in two prevalent cross sections:

1. Heavy duty — 8 mm. x 0.45 mm. (5/16" x 0.018") — Used in route surveying (e.g. highways, railways)

2. Lightweight — 6 mm. x 0.30 mm. (1/4" x 0.012") — Used in most surveying operations (e.g. structural, municipal)

(NOTE: Invar tapes are composed of 35% nickel and 65% steel which has a very low coefficient of expansion, making it very useful in precise work.)

VII. **Types of tape readouts** (Transparency 1)

A. Fully graduated — Marked throughout the entire length in either feet and hundreds of a foot or meters and millimeters

B. Cut tape — Marked throughout the total length in feet or meters, with the first and possibly last foot (or meter) graduated in tenths and hundredths of a foot (or millimeters). A measurement is made by one chain person holding an even foot over the first mark or point and the other chain person reading the distance on the first foot graduated in hundredths, being held over the second point, then subtracting the reading over point #2 from the even foot mark chain person #1 was holding.

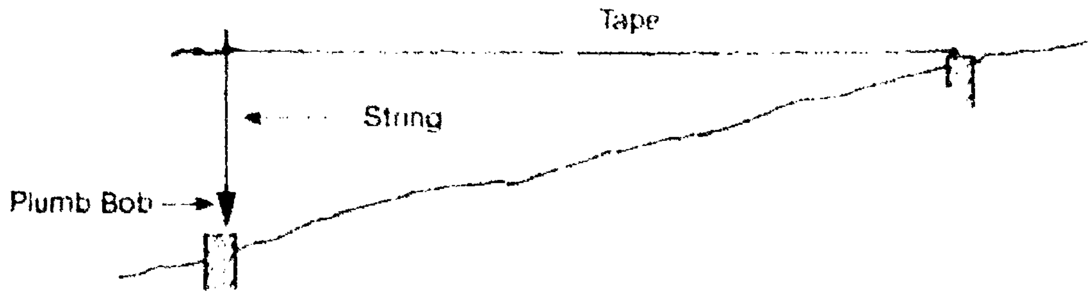
INFORMATION SHEET

C. Add tape — Marked throughout in feet or meters with the last foot or meter being graduated to tenths and hundredths or cm. and mm. An additional graduated foot (meter) is included prior to the zero mark on the tape. A measurement is made by holding an even foot mark at one point and reading the graduated measurement at the second point, then adding the latter measurement to the even foot mark read at the first point.

VIII. **Taping accessories** (Transparency 2)

A. Plumb bobs — Normally made of solid brass with a weight of 8 oz. to 18 oz. used in taping to transfer from tape to ground (and vice versa) when above ground (e.g. heavy ground cover) and to maintain horizontal alignment when measuring distances (e.g. hilly or sloping grades and rough terrain). (Figure 3)

FIGURE 3



B. Hand levels — Used to keep tape ends at same elevation while taping along uneven terrain

C. Tension handles — Used in precise work to ensure proper tension is being applied to the tape when measuring a distance between two points

D. Clamp handles — Aid in gripping the tape at any intermediate point without bending or damaging the tape and in eliminating any injury to hands while measuring

E. Chaining pins — Used to mark out tape lengths or intermediate distances while measuring a longer distance: sometimes referred to as surveyor's arrows, tally pins, or taping pins

(NOTE: Chaining pins are usually painted alternately red and white, 14 to 18 inches long, and sharpened to a point at one end with a loop at the other. Sets of 11 pins and a steel ring are standard.)

F. Pocket thermometers — Used to determine the temperature of the tape while being used so the surveyor can make corrections for expansion or contraction of the tape to calculate the "actual" distance between the points measured

INFORMATION SHEET

G. Range poles -- Used to mark alignment while sighting a point; typically made in 4 ft sections of wood, steel, or aluminum with threaded ends which can be connected together if needed, and painted red and white alternately, usually at 1 foot intervals

H. Tape repair kits -- Available so that broken tapes can be put back in service. Great care should be taken to ensure that the repair is precisely accomplished and the integrity of the tape is maintained.

I. Woven tapes -- Used for measuring ties to survey points, cross sections, and rough measurements or "checks" of actual survey line measurements; commonly called cloth (or metallic) tapes

(NOTE: You should realize that the accuracy of woven tapes is quite limited due to the possibility of stretching the tape over longer measurements. Therefore, these are not suitable for precise work, yet are convenient for many practical purposes. Woven tapes should be calibrated or checked with a steel tape often to verify any stretching that might occur with use.)

IX. **Care and storage of taping equipment**

A. When considering the cross-sectional area of a surveyor's tape and its permissible stress, a pull of 100 lbs. will do no damage. However, if the tape is kinked or looped, a pull of 1 pound will usually break it. Therefore, be certain to check for any loops or kinks in the tape prior to applying tension.

B. All tapes should be kept on their reel or "thrown" into a circular loop at all times when not being used by the surveyor.

(NOTE: The term "throwing chain" is a common term known by any experienced surveyor. The procedure is quite lengthy and difficult to explain in textbook form, but should be demonstrated by the instructor and practiced by all surveying students.)

C. If a tape gets wet, wipe it first with a dry cloth, then an oily rag, taking care to remove all mud areas and inspect for any deformities in the tape prior to storage on reel

D. Broken tapes can be mended by riveting and/or applying a sleeve device, but should then be recalibrated prior to any precise field work.

E. Chaining pins should be placed back on the steel ring after use and a count taken to determine that all eleven pins are retrieved before leaving the job site

F. While taping distances, the rear tape person should never hold on to the end of the tape while moving up the measured line. Only the head tape person should be dragging the tape to the next segment.

INFORMATION SHEET

X. **Purposes of taping**

A. To determine the actual distance between two existing points in the field

B. To establish points in the field at prescribed distances determined by survey calculations or for proposed engineering works

(NOTE: In either case, the procedures to follow are similar and should be carried out with the utmost care to ensure that the greatest accuracy can be obtained at all times.)

XI. **Procedure for taping on level ground**

A. Lining in

(NOTE: The line to be measured should be definitely marked on both ends, and at intermediate points when necessary. Range poles are commonly used for this purpose.)

1. The forward or "head" tape person is either lined in by the instrument or by the rear tape person (depending on the accuracy required.)

2. Direction is given by vocal or hand signals.

B. Applying tension

1. After proceeding with the zero end of the tape and establishing a line, the head tape person waits for the rear tape person to position the 100 ft end of the tape over the first point.

2. Head tape person then gradually adds tension to the tape taking care not to jerk or pull the rear tape person out of position.

(NOTE: Good communication between the two will bring better results and save considerable time in initial set up.)

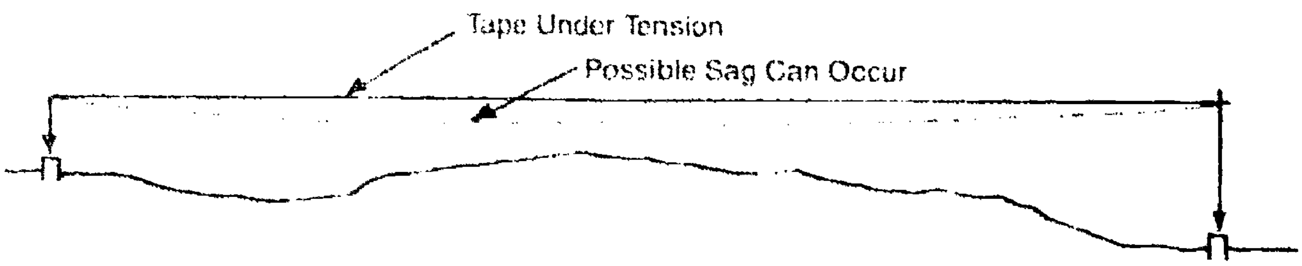
C. Plumbing

1. Since accurate measurements can only be accomplished when the tape is in a horizontal position, plumb bobs are used when taping in weeds, brush, and when surface irregularities make it undesirable to lay tape along the ground.

INFORMATION SHEET

2. Care should be taken to maintain required tension along tape when taping above grade. (Figure 4)

FIGURE 4



D. Marking tape lengths

1. After the tape has been lined in, proper tension has been applied, and the rear tape person is over the point, the rear tape person calls out "stick" or "mark" aloud to let the head tape person know he is ready.

2. The head tape person places the chaining pin exactly opposite the zero mark of the tape and calls out "stuck" or "marked." The point where the pin enters the ground is checked repeatedly until certainty of its location is assured.

3. After its location has been checked, the head tape person calls out "O.K.", the rear tape person drops his end of the tape, and both crew members advance forward pacing approximately 100 ft.

4. The head tape person "drags" the tape forward until the rear tape person calls out "tape" or "chain" notifying the head tape person that he has reached the pin that was previously set.

5. The process is then repeated until a partial tape length is needed at the end of the line.

E. Reading the tape (procedure depends on style of tape being used.)

1. *Fully graduated tape*

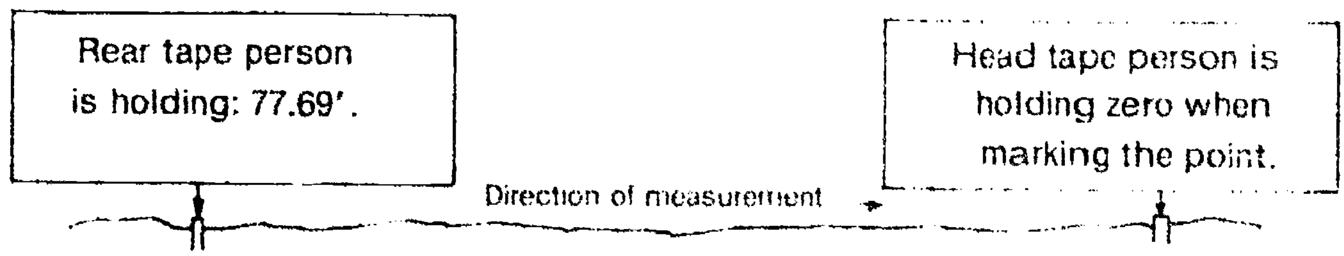
a. The head tape person always marks zero.

INFORMATION SHEET

b. The rear tape person holds the desired measurement.

Example: Required measurement: 77.69'

FIGURE 5



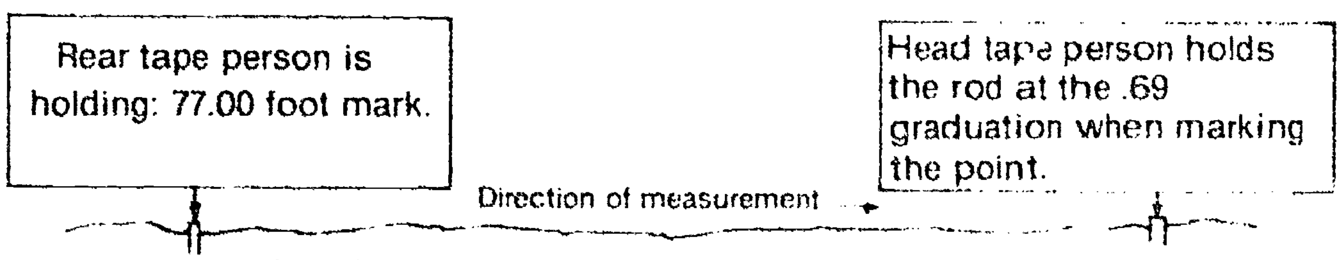
2. *Add tape*

a. The rear tape person should always hold the desired even foot mark required for the measurement.

b. The head tape person always marks the point on ground where the correct graduation of tenths and hundredths is found.

Example: Required measurement: 77.69'

FIGURE 6



3. *Cut tape*

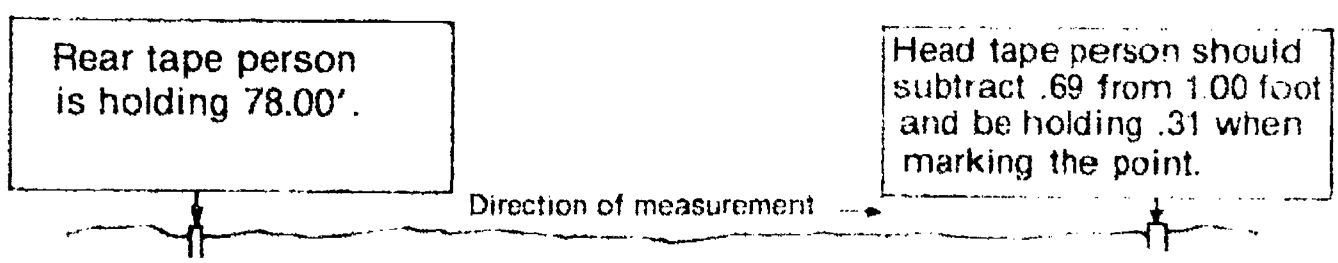
(NOTE: When a "cut" tape is being used, subtraction is necessary; therefore, error in measurement calculations can easily occur.)

a. The rear tape person holds the next even 1 foot mark over the point. (e.g. 77.69 desired, he holds the 78 foot mark)

b. The head tape person calculates the correct amount to "cut" from the 0 to 1 foot mark he is holding. (e.g. 77.69 desired. 1.00 minus .69 = .31. He should be holding .31 or "cut" 0.31 when marking the desired distance.)

Example: Required measurement: 77.69'

FIGURE 7



INFORMATION SHEET

F. Recording the distance

1. After the [illegible] at the end of the total measurement [illegible] the number of full tape lengths [illegible] the number of pins collected from the beginning of the [illegible]

2. [illegible] measurement are recorded in the field book [illegible]

(NOTE: [illegible] by careless recording. Taping is a skill [illegible] and learned by field demonstration and practice.)

XII. Procedure for taping on uneven or sloping ground

(NOTE: Taping [illegible] on uneven or sloping ground are very similar to the [illegible] there are some basic rules to remember.)

A. Hold the tape [illegible] estimation or by the use of a hand level.

B. Both tape [illegible] to the ends of the tape.

C. When [illegible] ground, try to use even foot increments [illegible] tape length, thereby aiding in [illegible]

Example:

D. Common [illegible] important during this operation.

E. Always double [illegible] measurements chained to be sure of the total [illegible]

INFORMATION SHEET

XIII. Accuracy and precision

(NOTE: In surveying, the terms accuracy and precision can easily be confused if their meanings are not thoroughly understood.)

A. Accuracy — Denotes the absolute "nearness" of the measured value to the true value.

Example: A wall is measured with a tape and found to be 89.24'. The actual wall was constructed at 89.25'. Consider this an "accurate" measurement.

B. Precision — Refers to the degree of refinement used in measuring a value, either by the number of times measured or by the degree of graduation it was measured in.

Example: The same wall was measured 3 times and the distances recorded: 89.25, 89.24, and 89.25 which were then averaged with the result being 89.247'. This is a more "precise" measurement than the previous one.

(NOTE: On good surveys, precision and accuracy are consistent throughout all stages of work.)

XIV. Accuracy ratio

A. The accuracy of a measurement or series of measurements is the ratio of error in the measurement to the distance measured.

B. Error of closure is the difference between the measured location and the theoretically correct location of the same point.

Example: A distance was measured and found to be 250.56 ft. The distance was previously known to be 250.50. This is an error of 0.06 ft in 250.50 ft.

$$\text{Accuracy ratio} = \frac{0.06}{250.50} \div \frac{0.06}{0.06} = \frac{1}{4175} = \frac{1}{4200} \leftarrow \text{rounded}$$

C. Used to determine the order of accuracy of the work that was performed.

(NOTE: Orders of accuracy will be discussed in more detail in Unit XII, "Control Surveys.")

INFORMATION SHEET

XV. **Types of errors**

A. Systematic errors also known as "cumulative errors" are defined as errors whose magnitude and algebraic sign can be determined. The fact that these errors can be determined allows the surveyor to eliminate them either by calculation or adjustment.

Examples of systematic errors in surveying:

1. Slope in measurement
2. Erroneous tape length
3. Temperature variations
4. Improper tension

B. Random errors are beyond the control of the surveyor and are associated with the skill and vigilance of the surveyor. They follow the laws of probability and are often called "accidental or compensating errors."

Examples of random errors in surveying:

1. Improper plumbing
2. Faulty marking
3. Incorrect reading or interpolation
4. Misalignment

C. Mistakes or blunders — Consist of errors or mistakes made by survey personnel. Mistakes will occur but should be discovered and eliminated.

Examples of common mistakes made by personnel:

1. Transposing figures (e.g. writing 68 instead of 86)
2. Miscounting full tape lengths
3. Measuring to or from the wrong point
4. Arithmetic mistakes

XVI. **Taping corrections**

A. Slope corrections

(NOTE: Survey distances can be measured either horizontally or on a slope. Since most survey distances are normally shown on a plan view, any slope distances must be converted to their horizontal equivalents.)

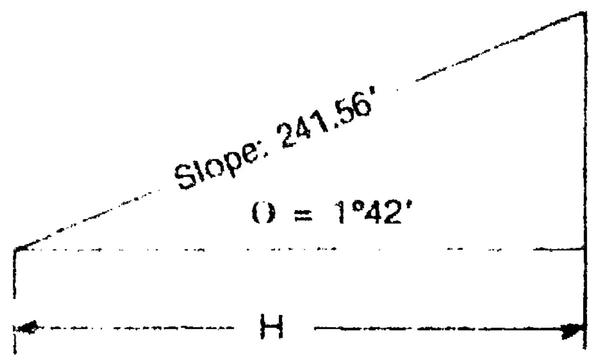
1. To convert slope distances, either the slope angle or the vertical distance must be known:

INFORMATION SHEET

2. When slope angle is known.

$$\frac{H \text{ (Horizontal)}}{S \text{ (Slope)}} = \cos\theta \quad \text{or} \quad H = S\cos\theta$$

Where θ is the angle of inclination

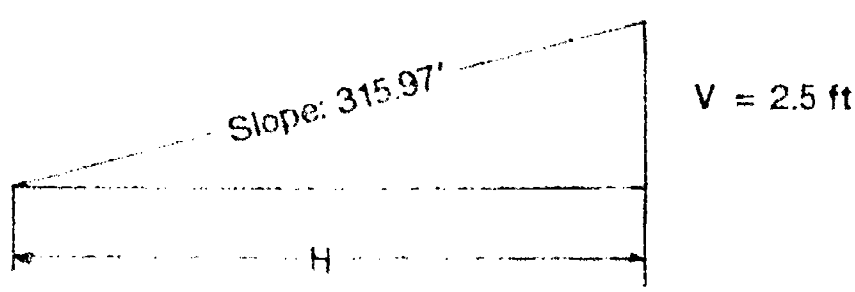


$$\begin{aligned} H &= S \cos \\ &= 241.56 \cos 1°42' \\ &= 241.454 \end{aligned}$$

3. When vertical distance is known,

$$H^2 = S^2 - V^2 \quad \text{or} \quad H = \sqrt{S^2 - V^2}$$

Where V is the difference in elevation.



$$H = \sqrt{(S^2 - V^2)}$$

$$\begin{aligned} &= \sqrt{315.97^2 - 2.5^2} \\ &= 315.96 \end{aligned}$$

B. Erroneous tape length corrections

(NOTE: Through extensive use, tapes do become kinked, stretched, and repaired. The length can become something other than that specified. When this occurs, the tape must be corrected or the measurements taken with it must be corrected.)

1. The error in the tape must be known.

INFORMATION SHEET

2. The number of times it was used in that measurement must be determined.

3. The following formula should be followed:

$$C_l = \left(\frac{l - l'}{l'}\right) L$$

and $\bar{L} = L + C_l$

Where: C_l is the correction to be applied to the measured distance.
l is the actual tape length.
l' is the nominal tape length.
L is the measured (recorded) length of the line.
$\bar{L}$ is the corrected or adjusted length of the line.

Example: A 100 ft steel tape when compared with a standard is actually 100.02 ft long. What is the corrected length of the line measured with this tape and found to be 565.75 ft?

$$C_l = \left(\frac{100.02 - 100.00}{100.00}\right) 565.75 = +0.11 \text{ ft.}$$

then $\bar{L} = 565.75 + 0.11 = 565.86$ ft.

(NOTE: This example illustrates that in measuring unknown distances with a tape that is too long, a correction must be added. Conversely, if the tape is too short, the correction will be minus, therefore resulting in a decrease. Also when a problem involves "laying out" or "setting" a desired distance, the sign of the correction must be reversed before being applied to the layout measurement.)

C. Temperature corrections

(NOTE: Steel tapes are standardized for 68°F (20°C) in the United States. Therefore a temperature higher or lower than this value will cause a change in the length of the tape due to expansion or contraction. To eliminate this the following computations must be performed.)

1. The coefficient of thermal expansion and contraction of steel used in ordinary tapes is 0.00000645 per unit length per degree Fahrenheit (0.0000116 per unit length per degree Celsius)

INFORMATION SHEET

2. The following formula should be used:

$$C_t = \alpha (T - T_s) L \text{ (general formula)}$$

or

$$C_t = 0.00000645 (T - 68) L$$

Where: C_t is the correction due to temperature in feet
T is the temperature of the tape during measurement.
L is the distance measured in feet.

Example: A distance was recorded as being 471.37 ft at a temperature of 38°F.

$$C_t = 0.00000645 (38 - 68) 471.37$$
$$= -0.09$$
$$= 471.37 - 0.09 = 471.28 \quad \text{corrected distance}$$

(NOTE: Errors due to temperature change can be practically eliminated by either (1) measuring temperature and making corrections as shown, or by (2) using an "Invar" tape manufactured from a nickel-steel alloy. Thermal expansion of Invar tapes range from 0.0000002 to 0.00000055 making corrections to tapes nearly negligible. (3) Lovar tapes can also be used with coefficients approximately ⅓ that of steel tapes. Invar and Lovar tapes are fragile and lose calibration more readily than steel tapes.)

D. Tension and sag corrections

(NOTE: If a tape is not supported throughout and/or a tension other than 10 lb. is applied, a correction may be calculated and adjustments applied as follows.)

1. The formula for tension correction is:

$$C_p = (P_1 - P) \frac{L}{AE}$$

and $\bar{L} = L + C_p$

C_p = Total elongation in tape due to pull, in feet.
P_1 = The pull applied to the tape, in pounds.
P = The standard pull for the tape, in pounds.
A = The cross-sectional area, in square inches.
E = The modulus of elasticity of steel, in lbs. per sq. inch.
L = The measured (recorded) length at the line.
$\bar{L}$ = The corrected (adjusted) length of the line.

INFORMATION SHEET

(NOTE:
1) An average value of E is 29,000,000 lb./in^2 for the kind of steel used in tapes.
2) The cross-sectional value of a tape can be obtained from the manufacturer or by dividing the total tape weight by its length [in feet] times the unit weight of steel [490 lbs/ft^3] and multiplying by 144 to convert sq. ft. to sq. in.)

Example of tension correction:
Given a standard tension of 10 lb. force for a 100 ft tape that is being used with a 20 lb. force pull. If the cross-sectional area of the tape is 0.003, what is the tension error for each tape length used?

$$C_p = \frac{(20 - 10)\ 100}{29{,}000{,}000 \times 0.003} = +\ 0.011 \text{ ft}$$

If a distance of 421.22 has been recorded, the total correction would be 4.2122 × 0.011 = +0.05 ft. The corrected distance would be 421.27 ft.

2. The formula for sag correction is:

$$C_s = \frac{-W^2 L}{24\ P^2}$$

Where: C_s = Corrections due to sag per tape length
W^2 = Weight of the tape
L = Length of tape under consideration
P = Applied tension, in pounds

Example: A 100 ft tape weighs 1.6 lbs. and is supported only at the ends with a force of 10 lb. What is the sag correction?

$$C_s = \frac{-1.6^2 \times 100}{24 \times 10^2} = -0.11 \text{ ft.}$$

Therefore, the tape must be corrected -0.11 ft per tape length.

(NOTE: Tension and sag errors are normally quite small and are not used commonly on any surveying work other than precise work. These types of errors can best be compensated with a spring balance tension handle thus eliminating the necessity of calculating numerous corrections.)

INFORMATION SHEET

XVII. **Recent advancements in horizontal measuring**

A. Electronic distance-measuring instruments (EDMI's) (Transparency 3)

1. Determine lengths based on phase changes that occur as electromagnetic energy of known wavelength travels from one end of a line to the other and returns.

2. The first EDM instrument was introduced in the early 1950's (the geodimeter) and has undergone continual refinements.

3. Short range, lightweight EDM's have found wide acceptance in the engineering and surveying fields.

4. Two classifications of EDMI's are:

a. *Electro-optical* which transmit a modulating laser or infrared light having wavelength within or slightly beyond the visible spectrum

b. *Microwave* which transmit microwaves with frequencies in the common range 3 to 35 GHz corresponding to wavelengths of about 1.0 to 8.6 mm.

B. Global positioning systems (GPS) — Use satellites orbiting the earth to measure the locations of control points remote from each other.

(NOTE: This topic will be discussed further in Unit XII, "Control Surveys.")

C. Inertial systems — Use gyroscopes and accelerometers that are carried in helicopters and ground vehicles to determine the positions of points remote from each other.

XVIII. **Responsibilities of crew members**

A. Party chief or instrument person

1. Responsible for the total accuracy and integrity of the survey crew

2. Coordinates all work to be done by that crew

3. Verifies all measurements and checks for blunders

4. Aligns the head tape person when measuring toward a station

5. Records and reviews all field data that is obtained

INFORMATION SHEET

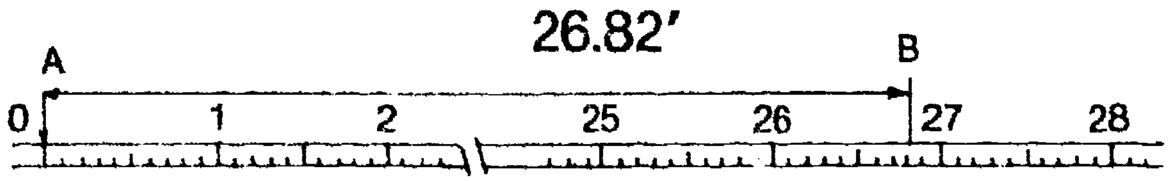
B. Rear tape person

1. Aligns the head tape person if an instrument is not used
2. Holds the tape precisely over the rear mark
3. Calls out "stick" or "mark" when in position
4. Calls out the station and tape reading for each measurement
5. Keeps count of all full tape lengths
6. Maintains care and storage of equipment

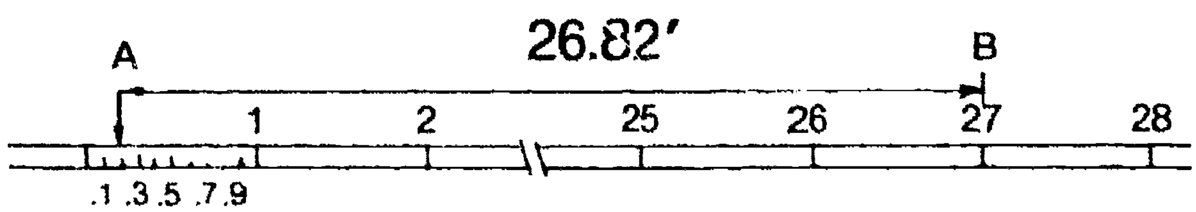
C. Head tape person

1. Carries the tape forward ensuring that there are no loops
2. Prepares the ground surface for the mark
3. Applies proper tension. checking that the tape is horizontal
4. Places all taping marks, calling out "stuck" or "marked"
5. Records measurements of distances
6. Supervises the taping work in progress

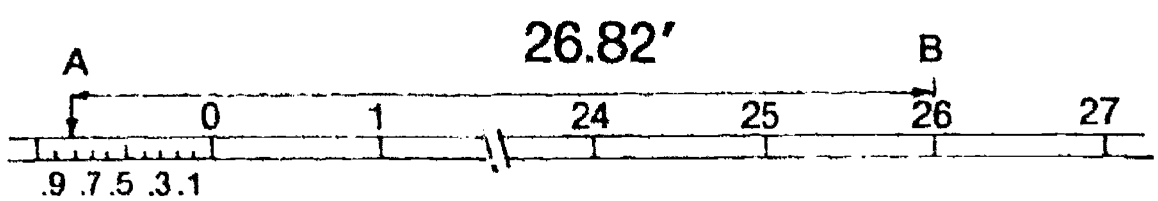
Styles of Tape Read Outs



Fully Graduated Tape

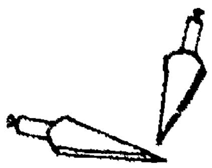


Cut Tape

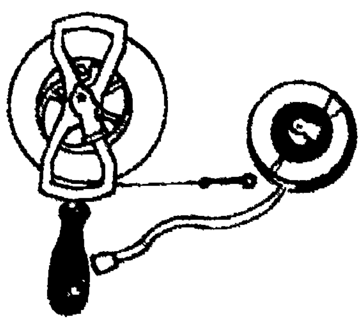


Add Tape

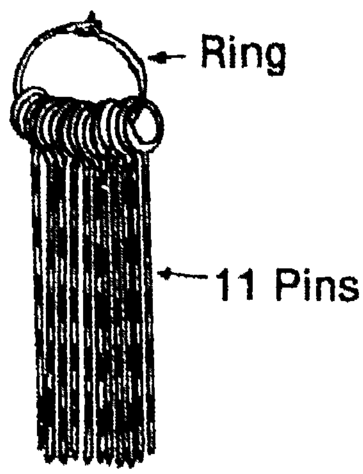
Taping Accessories



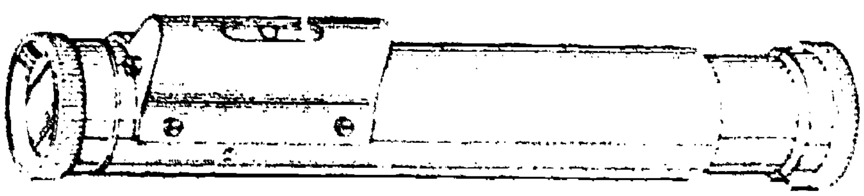
Plumb Bobs



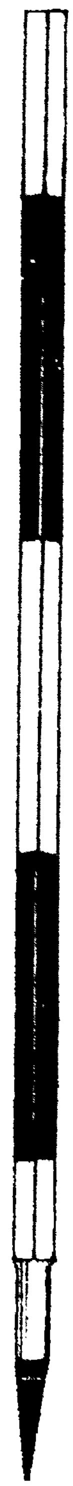
Tapes



Chaining Pins

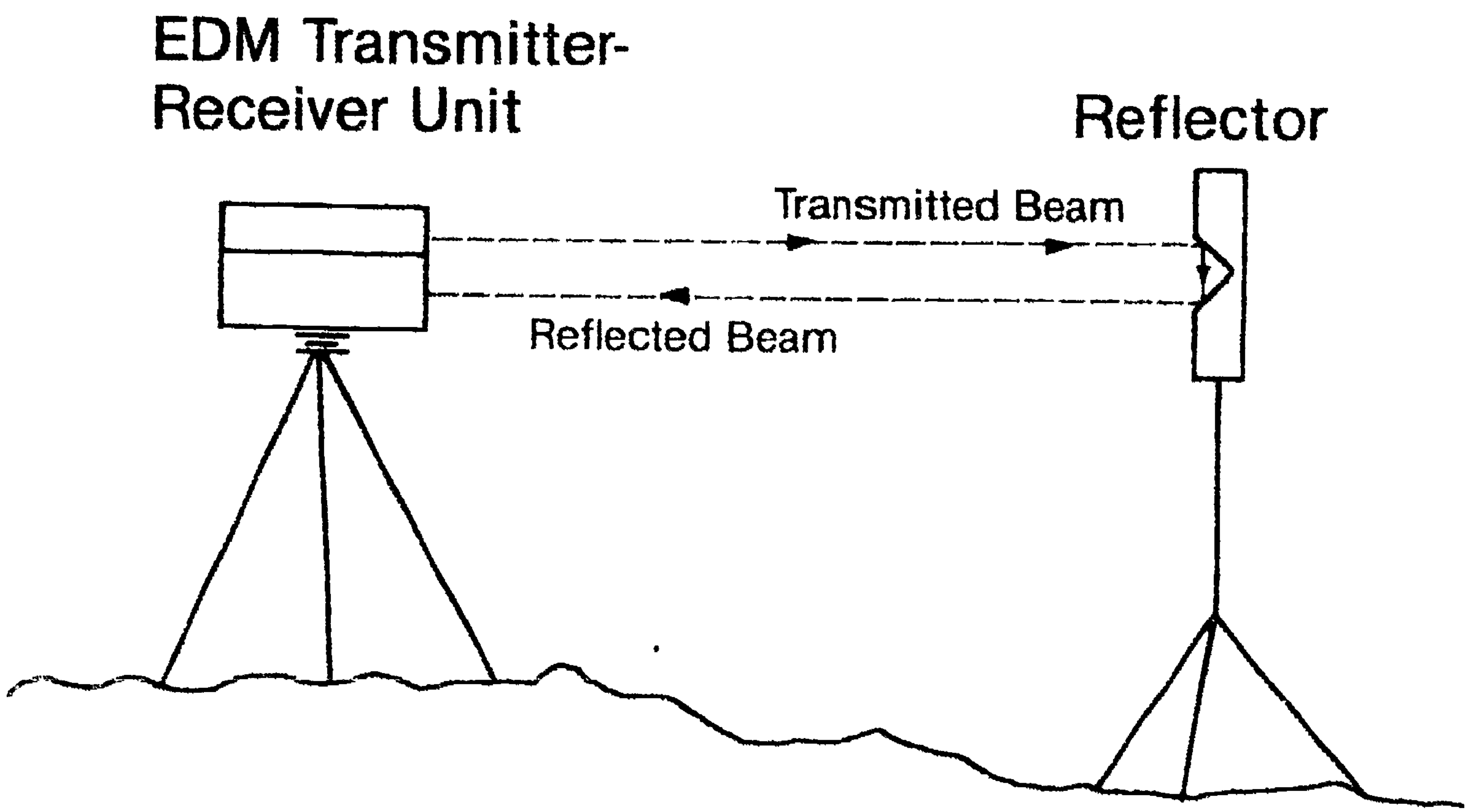


Hand Level



Range Pole

Basic Principles of E.D.M.



HORIZONTAL MEASUREMENTS
UNIT III

ASSIGNMENT SHEET #1 — COMPUTE HORIZONTAL CONVERSIONS

Directions: Accurately convert the linear measurement to its correct horizontal equivalent. Record that answer in the space provided.

Part One (English Units)

1. 1 foot = _______ inches
2. 1 yard = _______ feet
3. 1 rod = _______ feet
4. 1 chain = _______ feet
5. 1 chain = _______ links
6. 80 chains = _______ feet
7. 1 mile = _______ feet
8. 1 acre = _______ sq. feet
9. 1 mile = _______ rods
10. 1 acre = _______ sq. rods

Part Two (Metric Units)

1. 1 foot = _______ meter
2. 1 km = _______ miles
3. 1 inch = _______ mm
4. 1 meter = _______ inches
5. 1 mile = _______ meters
6. 30 meters = _______ feet
7. 7.6 hectares = _______ acres
8. 32,500 m = _______ hectares

Part Three (Fractional to Decimal)

1. 4' - 8" = _______ feet
2. 0' - 9" = _______ foot
3. 12' - 4" = _______ feet
4. 6.583' = _______ ft _______ inches
5. 26.944' = _______ ft _______ inches
6. 0.875' = _______ ft _______ inches

HORIZONTAL MEASUREMENTS
UNIT III

ASSIGNMENT SHEET #2 — CALCULATE TAPING CORRECTIONS FOR SLOPE ERRORS

Directions: Accurately calculate the correct horizontal measurements from the field data listed for each problem. Use the formulas listed below. Record your answers in the blanks provided.

Formulas:

1. When given the slope distance and slope angle (θ), use

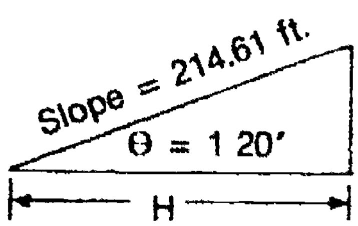
$$\frac{H\text{ (horizontal)}}{S\text{ (slope)}} = \text{Cos } \theta \text{ or } H = S \text{ Cos } \theta$$

2. When given the slope distance and difference in elevation (V), use

$$H^2 = S^2 - V^2 \text{ or } H = \sqrt{S^2 - V^2}$$

Examples:

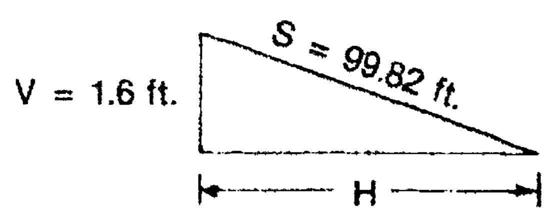
a. Given the slope distance and slope angle:



$H = S \text{ Cos } \theta$

H = 214.61 Cos 1°20'
= 214.552'
= 214.55' rounded

b. Given the slope distance and difference in elevation:



$H = \sqrt{(S^2 - V^2)}$

$H = \sqrt{99.82^2 - 1.6^2}$
= 99.807'
= 99.81' rounded

ASSIGNMENT SHEET #2

Problems:

PART I — Given slope distance and slope angle

1. Slope Distance = 419.65′ θ = 3°20′ Horizontal Distance = ______________
2. Slope Distance = 120.55′ θ = 6°45′ Horizontal Distance = ______________
3. Slope Distance = 644.20′ θ = 3°50′ Horizontal Distance = ______________
4. Slope Distance = 96.16′ θ = 8°40′ Horizontal Distance = ______________
5. Slope Distance = 251.32′ θ = 2°15′ Horizontal Distance = ______________
6. Slope Distance = 843.90′ θ = 6°25′ Horizontal Distance = ______________
7. Slope Distance = 1140.66′ θ = 9°09′ Horizontal Distance = ______________
8. Slope Distance = 551.15′ θ = 1°30′ Horizontal Distance = ______________
9. Slope Distance = 339.47′ θ = 2°12′ Horizontal Distance = ______________
10. Slope Distance = 768.14′ θ = 5°19′ Horizontal Distance = ______________

Part II — Given slope distance and difference in elevation

1. Slope Distance = 619.25, Elevation Difference = 6.91
   Horizontal Distance = ______________
2. Slope Distance = 204.19, Elevation Difference = 4.40
   Horizontal Distance = ______________
3. Slope Distance = 19.90, Elevation Difference = 12.20
   Horizontal Distance = ______________
4. Slope Distance = 1016.96, Elevation Difference = 18.94
   Horizontal Distance = ______________
5. Slope Distance = 416.46, Elevation Difference = 2.16
   Horizontal Distance = ______________
6. Slope Distance = 112.36, Elevation Difference = 3.45
   Horizontal Distance = ______________
7. Slope Distance = 79.13, Elevation Difference = 0.61
   Horizontal Distance = ______________
8. Slope Distance = 525.51, Elevation Difference = 1.24
   Horizontal Distance = ______________
9. Slope Distance = 902.34, Elevation Difference = 9.67
   Horizontal Distance = ______________
10. Slope Distance = 2612.18, Elevation Difference = 22.47
    Horizontal Distance = ______________

HORIZONTAL MEASUREMENTS
UNIT III

ASSIGNMENT SHEET #3 — CALCULATE TAPING CORRECTIONS FOR ERRONEOUS TAPE LENGTHS

Directions: Accurately calculate the correct horizontal measurements from the field data obtained in each problem. Use the formula listed below. Record your answers in the blanks provided.

Formula:

$$C_l = \left(\frac{l - l'}{l'}\right) L \text{ and } \bar{L} = L + C_l$$

C_l = Correction to be applied to the measured distance
l = Actual tape length
l' = Nominal tape length
L = Measured (recorded) length of the line
$\bar{L}$ = Corrected or adjusted length of the line

Example: A measurement was recorded as 171.94 with a 100.00 ft tape that was only 99.98 ft under standard conditions. What is the corrected measurement?

Solution: $l = 99.98$
$l' = 100.00$ (thus)
$L = 171.94$

$$C_l = \left(\frac{99.98 - 100.00}{100.00}\right) 171.94$$

$$C_l = -0.034$$

$C_l + L = \bar{L}$ so: $-0.034 + 171.94 = 171.906$

Problems:

Measurement Recorded	Actual Tape Length	Nominal Tape Length	Corrected Length
1. 693.41	100.03	100.00	________
2. 219.87	199.97	200.00	________
3. 885.43	200.04	200.00	________
4. 368.36	100.02	100.00	________
5. 565.64	99.97	100.00	________

ASSIGNMENT SHEET #3

Lay Out Distance Required	Actual Tape Length	Nominal Tape Length	Corrected Length
6. 450.00	100.02	100.00	______
7 275.50	99.96	100.00	______
8. 618.44	200.05	200.00	______
9. 775.00	200.04	200.00	______
10. 513.30	99.97	100.00	______

HORIZONTAL MEASUREMENTS
UNIT III

ASSIGNMENT SHEET #4 — CALCULATE TAPING CORRECTIONS FOR TEMPERATURE

Directions: Accurately calculate the correct horizontal measurement from the field data provided in each of the problems below. Use the formula given. Record all your answers in the blanks provided.

Formula:

$$C_t = \alpha (T - T_s)\ L$$

or

$$C_t = 0.00000645\ (T - 68)\ L$$

where: C_t = Correction due to temperature, in feet
T = Temperature of the tape during measurement
α = 0.00000645 (the coefficient of expansion of steel)
L = Distance measured in feet

Example: It is required to lay out 2 points that will be exactly 100.00 ft apart. The temperature of the tape is 107°F. What distance should be laid out? ____________________

$C_t = \alpha (T - T_s)\ L$
$C_t = 0.00000645\ (107\text{-}68)\ 100.00$
$C_t = +\ 0.025$

(NOTE: Since this is a "lay out" problem, the sign of the correction must be reversed. Therefore, lay out distance = 100.00 − 0.025 = 99.975.)

Problems:

			Corrected tape length
1.	Measured = 442.41′	Tape Temperature = 26°F	____________
2.	Lay out = 250.00′	Tape Temperature = 31°F	____________
3.	Lay out = 317.50′	Tape Temperature = 9[illegible]°F	____________
4.	Measured = 291.63′	Tape Temperature = 102°F	____________
5.	Lay out = 742.25′	Tape Temperature = 79°F	____________
6.	Measured = 819.61′	Tape Temperature = 52°F	____________
7.	Measured = 412.35′	Tape Temperature = 40°F	____________
8.	Lay out = 175.00′	Tape Temperature = 21°F	____________
9.	Measured = 216.37′	Tape Temperature = 116°F	____________
10.	Lay out = 525.75′	Tape Temperature = 87°F	____________

HORIZONTAL MEASUREMENTS
UNIT III

ASSIGNMENT SHEET #5 — CALCULATE TAPING CORRECTIONS FOR ALL TYPES OF ERRORS

Directions: Accurately calculate the correct horizontal measurements from the field data obtained in each problem. Using the formulas listed below, solve for each type of taping correction: slope, temperature, and erroneous tape lengths. Record your answers in the blanks provided.

FORMULAS:

Slope

$$\frac{H\ (\text{Horizontal})}{S\ (\text{Slope})} = \cos\theta \quad \text{or} \quad H = S \cdot \cos\theta$$

where: θ is the angle of inclination

$$H^2 = S^2 - V^2 \quad \text{or} \quad H = \sqrt{S^2 - V^2}$$

where: V is the difference in elevation

Temperature

$$C_t = \alpha\,(T - T_s)\,L \text{ (general formula)}$$

or

$$C_t = 0.00000645\,(T - 68)\,L$$

where: C_t = Correction due to temperature in feet
T = Temperature of the tape during measurement
L = Distance measured in feet

Erroneous tape length

$$C_l = \left(\frac{l - l'}{l'}\right) L$$

and $\bar{L} = L + C_l$

where: C_l = Correction to be applied to the measured distance
l = Actual tape length
l' = Nominal tape length
L = Measured (recorded) length of the line
$\bar{L}$ = Corrected or adjusted length of the line

ASSIGNMENT SHEET #5

Problems

	Temperature	Tape Length	Slope Data	Slope Distance	Horizontal Distance
1.	18°F	100.00 ft.	slope angle + 2°02′	321.68 ft.	________
2.	0°C	30.004 m.	slope @ 1.20%	172.193 m.	________
3.	-20°F	99.98 ft.	elev. diff.: 6.10 ft.	498.98 ft.	________
4.	28°C	29.990 m.	slope angle: -3°08′	359.071 m.	________
5.	92°F	100.03 ft.	slope @ -0.80%	610.29 ft.	________

	Temperature	Tape Length	Slope data	Required Horiz. Distance	Actual Layout Distance
6.	24°F	30.012 m.	slope angle + 4°30′	338.666 m.	______slope
7.	50°F	99.98 ft.	horizontal	300.00 ft.	______horiz.
8.	30°F	100.02 ft.	slope @ +1.5%	500.00 ft.	______slope
9.	11°C	29.990 m.	horizontal	260.000 m.	______horiz.
10.	92°F	100.04 ft.	horizontal	440.00 ft.	______horiz.

TAKE HORIZONTAL MEASUREMENTS
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

Part 1

1. 12
2. 3
3. 16 ½
4. 66
5. 100
6. 5280
7. 5280
8. 43,560
9. 320
10. 10

Part 2

1. 0.3048
2. 0.62137
3. 25.4
4. 39.37
5. 1609.347
6. 98.425
7. 18.7796
8. 3.25

Part 3

1. 4.667'
2. 0.75'
3. 12.333'
4. 6' - 7"
5. 26' - 11 [illegible]"
6. 0' - 10 ½"

Assignment Sheet #2

Part 1

1. 418.94
2. 119.71
3. 642.76
4. 95.06
5. 251.13
6. 838.61
7. 1126.15
8. 550.96
9. 339.22
10. 764.84

Part 2

1. 619.21
2. 204.14
3. 15.72
4. 1016.78
5. 416.45
6. 112.31
7. 79.13
8. 525.51
9. 902.29
10. 2612.08

Assignment Sheet #3

1. 693.62
2. 219.84
3. 885.61
4. 368.43
5. 565.47
6. 449.91
7. 275.61
8. 618.29
9. 774.85
10. 5[illegible]3.45

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #4

1. 442.29'
2. 250.06'
3. 317.44'
4. 291.69'
5. 742.20'
6. 819.53'
7. 412.28'
8. 175.05'
9. 216.44'
10. 525.69'

Assignment Sheet #5

1. 321.37 ft.
2. 172.164 m.
3. 498.56 ft.
4. 358.621 m.
5. 610.55 ft.
6. 339.561 m.
7. 300.09 ft.
8. 500.08 ft.
9. 260.114 m.
10. 439.76 ft.

HORIZONTAL MEASUREMENTS
UNIT III

JOB SHEET #1 — DETERMINE AVERAGE LENGTH OF PACE

A. Tools and equipment

1. Steel tape (either 100' or 200' length)
2. Chaining pins (or other method to mark points)
3. Field book and pencil

B. Procedure

1. Set initial starting point and set point #1.

   (NOTE: Try to pick out an area that is at least 200' to 250' long, clear of obstructions, and quite level for this pacing exercise)

2. Head tape person should reel out the tape toward point #2.
3. Set an intermediate point #2 at 100' from the initial starting point #1.
4. Continue in a straight line from point #2, set at 100', and set point #3 at 200' even from the initial starting point.
5. After points are set, reel up tape and store properly.
6. Begin pacing procedures by starting with the toe of your foot even and just to the side of point #1.
7. Begin a normal walking pace toward point #3.

   (NOTE: Not too fast, not too slow.)

8. Counting your paces as you go, you may want to make note of the number of paces when crossing Point #2.
9. Upon reaching point #3, make note of total number of paces that the 200.00' distance required including any partial step at the end.
10. Repeat this procedure back toward the beginning point, totaling up and recording the total each time.
11. After completing this exercise 6 to 8 times and determining a comfortable pace, add up the totals, keeping in mind that they should all be relatively similar.

JOB SHEET #1

12. Divide the total footage by the number of paces accumulated.

Example:

200.00	1st	=	64.0	
200.00	2nd	=	64.5	
200.00	3rd	=	64.0	
200.00	4th	=	64.5	
200.00	5th	=	64.0	
200.00	6th	=	64.0	
1200.00	Total Feet		385.00	Total Paces

1200 ÷ 385 = 3.12 ft per pace

13. This number, average feet per pace, can now be used for any required distance needed simply by dividing your average pace into the desired distance.

(NOTE: Again keep in mind that pacing downhill lengthens your stride, and pacing uphill can shorten each pace considerably. This exercise should be repeated frequently.)

HORIZONTAL MEASUREMENTS
UNIT III

JOB SHEET #2 — MEASURE AND LAY OUT HORIZONTAL DISTANCES WITH A STEEL TAPE

A. Tools and equipment

1. 100 foot tape
2. Full set of chaining pins
3. Plumb bobs
4. Spring balance tension handle
5. Range poles
6. 2 wooden stakes
7. Hand level
8. Field book and pencil

B. Procedure

1. Split up into groups of 2-3 students, depending on how many steel tapes and taping accessories are available.

   (NOTE: Each group should set out a pair of stakes approximately 450' to 475' apart on level ground, with a section of range pole behind each point for alignment.)

2. Rear tape person begins taping procedure by lining up the head tape person using vocal or hand signals. (Figure 1)

   FIGURE 1

JOB SHEET #2

3. Apply proper tension to tape.

4. Plumb tape as needed. (Figure 2)

FIGURE 2

5. Mark tape lengths, double check locations, and move on to second stake.

6. Continue marking until a partial tape length is needed.

7. Read the tape for the last measurement.

   (NOTE: The correct procedure depends on the type of tape being used.)

8. Record the distance (full lengths and partial) in the field book.

9. Repeat this entire procedure back and forth several times. Record each total horizontal measurement from point #1 to point #2.

10. Compare all of your results when finished, and calcu' ‹e an average horizontal measurement.

    (NOTE: Office calculations can also be done later to correct for slope, tension, and temperature.)

11. Practice the following variations as time allows.

    a. Use different styles of tapes.

    b. Set out other distances.

    c. Exchange roles of crew members

    d. Work on slightly sloping ground.

    e. Measure in weeded areas.

    f. Practice plumb bobbing steep slopes.

HORIZONTAL MEASUREMENTS
UNIT III

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a.	A common surveying abbreviation which represents an accurate position of a surveyed station	1.	Baseline
_____b.	A piece of surveying equipment, normally three-legged, of wood or aluminum on which the surveying instruments can be mounted	2.	Blunder
_____c.	A mistake due to human error that can be discovered unless negligible	3.	Circumference
_____d.	A surveying device developed after the transit for both vertical and horizontal angular measurements; normally has greater precision than standard transits	4.	Field book
_____e.	A set of physical properties whose values determine the characteristics of a system	5.	Parameter
_____f.	A surveyed line, normally straight, with measured increments called stations; often used for control work on engineering projects and as a method of collecting existing ground features	6.	Point
_____g.	A surveying term used to signify writing down or transcribing field data into a field book	7.	Reconnaissance
_____h.	A normal preliminary stage of a project used to evaluate approaches to surveying projects, collect preliminary data, and familiarize oneself with the site	8.	Recorded
_____i.	The calculated or measured distance around a circular object	9.	Theodolite
_____j.	The common term for the collection base of all field data; usually either a bound booklet or a loose-leaf binder-type book	10.	Tripod

TEST

2. State the equivalencies for the following surveying measurements.

   a. 1 mile = ____________ feet = ____________ chains

   b. 1 acre = ____________ square chains

   c. 1 chain = ____________ feet = ____________ links

   d. 1 rod = ____________ feet

   e. 1 kilometer = ____________ meters = ____________ miles

   f. 1 hectare = ____________ acres

   g. 1 square kilometer (km^2) = ____________ hectares

3. List three types of equipment used in the past to make horizontal measurements.

   a. ____

   b. ____

   c. ____

4. Match horizontal measurements on the right with their correct uses.

_____a.	Used to relocate points set from existing features that can be readily found later	1. Construction
_____b.	Used to provide a method of control along a baseline for construction purposes	2. Horizontal ties
_____c.	Used to measure the distance between control points along with the angular measurements	3. Linear stationing
_____d.	Used to establish a series of control points and their positions by horizontal distances only	4. Topographical
_____e.	Used to establish an accurate baseline from which angles are measured to numerous points	5. Traversing
_____f.	Used to establish proposed location of all engineering works	6. Triangulation
_____g.	Used to establish location of all existing features within a survey limit	7. Trilateration

TEST

5. Distinguish between the methods of measuring distances by placing the following letters next to the correct descriptions:

- EDM — Electronic distance measuring
- OD — Odometer
- OP — Optical range finders
- P — Pacing
- T — Tacheometry

_____a. Consists of counting the number of steps in a required distance. Particularly useful when looking for survey markers, marking rough measurements, detecting blunders, and checking measurements on construction layouts.

_____b. Consists of the number of revolutions of a wheel of known circumference converted to a linear distance. Used to collect preliminary data when beginning a survey, to serve as a rough check of measurements made by other methods, and to aid in differentiating fencelines for determining property ownerships

_____c. Operate on the same principles as similar equipment on a single-lens camera. Basically, when focused, they solve for object distance. The operator views the object, focuses the image, and a distance reading can be obtained. Particularly useful in reconnaissance, sketching, or checking a more accurate measurement for mistakes.

_____d. Involves the measurement of a related distance parameter either by means of a fixed angle intercept (example -- stadia) or by means of a measured angle to a fixed base (example -- subtense bar).

_____e. Function by sending a lightwave or microwave signal along the path to be measured, and measuring the time involved in traveling that distance. Very useful when measuring over long distances, bodies of water, rough terrain, etc.

6. Complete the following statements concerning types of tapes or chains by filling in the blanks with the appropriate words.

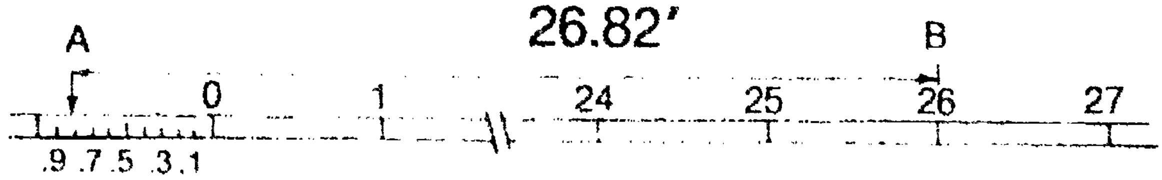
   a. Available in many lengths, marked in either __________ or metric units and different unit weights

   b. Common lengths are 100, 200, and 300 foot tapes with __________ being the most commonly used

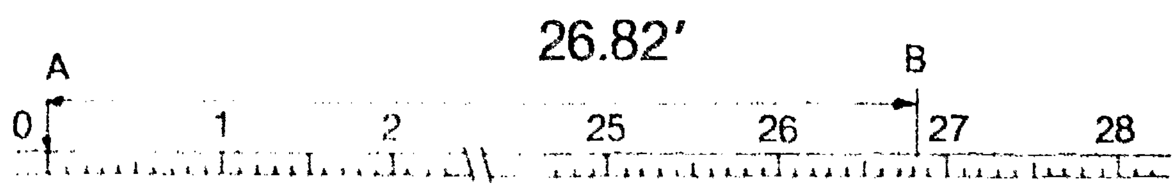
   c. Steel tapes or chains come in two prevalent cross sections, __________ and lightweight

TEST

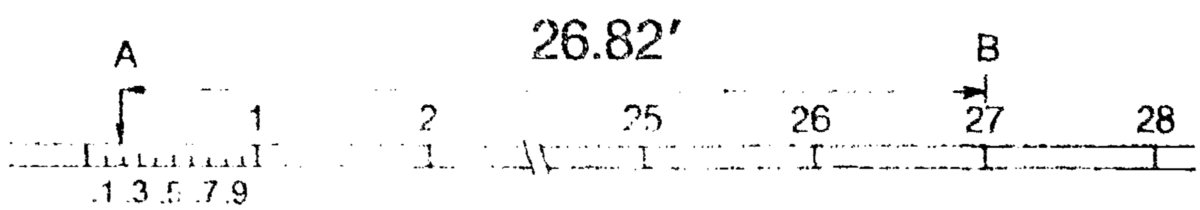
7. Identify the following types of tape readouts.



a. ______________________________



b. ______________________________



c. ______________________________

8. Match taping accessories on the right with their correct uses.

______	a.	Normally made of solid brass with a weight of 8 oz. to 18 oz. used in taping to transfer from tape to ground (and vice versa) when above ground and to maintain horizontal alignment when measuring distances	1. Hand levels 2. Chaining pins 3. Tape repair kits
______	b.	Used to keep tape ends at same elevation while taping along uneven terrain	
______	c.	Used in precise work to ensure proper tension is being applied to the tape when measuring a distance between two points	

TEST

_____d.	Aid in gripping the tape at any intermediate point without bending or damaging the tape and in eliminating any injury to hands while measuring	4. Clamp handles
_____e.	Used to mark out tape lengths or intermediate distances while measuring a longer distance; sometimes referred to as surveyor's arrows	5. Woven tapes
_____f.	Used to determine the temperature of the tape while being used so the surveyor can make corrections for expansion or contraction of the tape to calculate the "actual" distance between the points measured	6. Plumb bobs
_____g.	Used to mark alignment while sighting a point; typically made in 4 ft sections of wood, steel, or aluminum with threaded ends which can be connected together if needed, and painted red and white alternately, usually at 1 foot intervals	7. Range poles
_____h.	Available so that broken tapes can be put back in service	8. Tension handles
_____i.	Used for measuring ties to survey points, cross sections, and rough measurements of actual survey line measurements	9. Pocket thermometers

9. Complete the following statements concerning the care and storage of taping equipment by circling the correct words.

   a. If a surveyor's tape is kinked. a pull of 1 pound **(will, will not)** usually break it

   b. Tapes **(may, may not)** be "thrown" into a circular loop when not being used by the surveyor.

   c. Tapes should be kept **(loose in a box, on their reel)** for storage.

   d. If a tape gets wet, wipe it first with a dry cloth, then **(a water-saturated cleaning cloth, oily cloth)**, and inspect for any deformities prior to storage.

   e. While taping distances, only the **(head, rear)** tape person should hold on to the end of the tape while moving to the next segment.

10. State one purpose of taping.

____

TEST

11. Arrange in order the following steps used in taping on level ground by placing the correct sequence numbers (1-6) in the appropriate blanks.

    _____a. Plumbing

    _____b. Marking tape lengths

    _____c. Lining in

    _____d. Recording the distance

    _____e. Applying tension

    _____f. Reading the tape

12. Select true statements concerning the procedure for taping on uneven or sloping ground by placing an "X" next to the true statements.

    _____a. Hold the tape horizontal, either by accurate estimation or by the use of a hand level.

    _____b. Only the rear tape person should apply steady tension to the end of the tape.

    _____c. When "breaking tape" or plumbing on sloped ground, try to use foot increments that will add up to 66′ tape lengths, thereby aiding in reduction of calculating errors.

    _____d. Communication between tape persons is important during this operation.

    _____e. The addition of all increments chained does not have to be double checked since there are rarely errors.

13. Distingiush between accuracy and precision related to surveying technology by placing an "X" next to the description of accuracy.

    _____a. Refers to the degree of refinement used in measuring a value, either by the number of times measured or by the degree of graduation it was measured in.

    _____b. Denotes the absolute "nearness" of the measured value to the true value.

14. Calculate the accuracy ratio for the following survey problem.

    A distance was measured and found to be 300.78 ft. The distance was previously known to be 300.00 ft. What is the accuracy ratio? Round answer to nearest whole number.

    ____

TEST

15. List three examples of each common type of error that may occur while surveying.

a. Systematic errors

1) ____________________

2) ____________________

3) ____________________

b. Random errors

1) ____________________

2) ____________________

3) ____________________

c. Mistakes or blunders

1) ____________________

2) ____________________

3) ____________________

16. Match taping corrections on the right with the correct formulas.

_____a. $C_p = (P_1 - P)\frac{L}{AE}$ and $\bar{L} = L + C_p$

_____b. $H^2 = S^2 - V^2$ or $H = \sqrt{S^2 - V^2}$

_____c. $C_s = \frac{-W^2 L}{24 P^2}$

_____d. $\frac{H}{S} = \text{Cos } \theta$ or $H = S \text{ Cos } \theta$

_____e. $C_t = \alpha (T - T_s) L$ (general formula)

or

$C_t = 0.00000645 (T - 68) L$

_____f. $C_l = \left(\frac{l - l'}{l'}\right)L$ and

$\bar{L} = L + Cl$

1. Slope correction when slope angle is known
2. Slope correction when vertical distance is known
3. Tape length corrections
4. Temperature corrections
5. Tension correction
6. Sag correction

TEST

17. Complete the following statements concerning recent advancements in horizontal measuring by placing the correct answers in the blanks provided.

_____a. The first EDM instrument was introduced in the early

1) 1900's
2) 1940's
3) 1950's
4) 1960's

_____b. The type of EDMI which transmits a modulating laser or infrared light having wavelength within or slightly beyond the visible spectrum is the _____________.

1) Microwave EDMI
2) Magnetic EDMI
3) Laser EDMI
4) Electro-optical EDMI

_____c. EDMI's determine lengths based on phase changes that occur as _____________ energy of known wavelength travels from one end of a line to the other and returns.

1) Electromagnetic
2) Kinetic
3) Atomic
4) Electrical

_____d. Global positioning systems use _____________ to measure the locations of control points remote from each other.

1) EDMIs
2) Satellites
3) Gyroscopes
4) Altimeters

TEST

_____e. Inertial systems use _____ to ... points remote from each other.

1) EDMIs

2) Satellites

3) Gyroscopes

4) Altimeters

18. Distinguish between the responsibilities of each ... making horizontal measurements by placing the following ... blanks:

P — Party chief or instrument person
R — Rear tape person
H — Head tape person

_____a. Records and reviews all field data ...

_____b. Calls out the station and tape reading ...

_____c. Aligns the head tape person when measuring ...

_____d. Aligns the head tape person if an ...

_____e. Carries the tape forward ensuring that ...

_____f. Holds the tape precisely over the ...

_____g. Keeps count of all full tape lengths

_____h. Records measurements of distances

_____i. Responsible for the total accuracy ...

_____j. Calls out "stick" or "mark" when ...

_____k. Coordinates all work to be done by the ...

_____l. Verifies all measurements and ...

_____m. Places all taping marks, calling out ...

(NOTE: If the following activities have not been ... your instructor when they should be completed.)

19. Compute horizontal conversions. (Assignment Sheet # ...)

20. Calculate taping corrections for slope errors. (Assignment ...)

21. Calculate taping corrections for erroneous tape length ...

TEST

22. Calculate taping corrections for temperature. (Assignment Sheet #4)

23. Calculate taping corrections for all types of taping errors. (Assignment Sheet #5)

24. Demonstrate the ability to:

    a. Determine average length of pace. (Job Sheet #1)

    b. Measure and lay out horizontal distances with a steel tape. (Job Sheet #2)

HORIZONTAL MEASUREMENTS
UNIT III

ANSWERS TO TEST

1. a. 6   f. 1
   b. 10   g. 8
   c. 2   h. 7
   d. 9   i. 3
   e. 5   j. 4

2. a. 5280 feet, 80 chains
   b. 10 square chains
   c. 66 feet, 100 links
   d. 16 1/2 feet
   e. 1000 meters, 0.62137 miles
   f. 2.471 acres
   g. 100 hectares

3. Any three of the following:
   a. Rod or pole
   b. Gunter's chain
   c. Engineer's chain
   d. Wires

4. a. 2   e. 6
   b. 3   f. 1
   c. 5   g. 4
   d. 7

5. a. P
   b. OD
   c. OP
   d. T
   e. EDM

6. a. English
   b. 100 ft
   c. Heavy duty

7. a. Add tape
   b. Fully graduated tape
   c. Cut tape

8. a. 6   f. 9
   b. 1   g. 7
   c. 8   h. 3
   d. 4   i. 5
   e. 2

ANSWERS TO TEST

9. a. Will
   b. May
   c. On their reel
   d. Oily cloth
   e. Head

10. Either one of the following:
    a. To determine the actual distance between two existing points in the field
    b. To establish points in the field at prescribed distances determined by survey calculations or for proposed engineering works

11. a. 3
    b. 4
    c. 1
    d. 6
    e. 2
    f. 5

12. a,d

13. b

14. $\frac{0.78}{300} \div \frac{0.78}{0.78} = \frac{1}{384.6} = \frac{1}{385}$

15. a. Any three of the following systematic errors:
       1) Slope in measurement
       2) Erroneous tape length
       3) Temperature variations
       4) Improper tension
    b. Any three of the following random errors:
       1) Improper plumbing
       2) Faulty marking
       3) Incorrect reading or interpolation
       4) Misalignment
    c. Any three of the following mistakes or blunders:
       1) Transposing figures
       2) Miscounting full tape lengths
       3) Measuring to or from the wrong point
       4) Arithmetic mistakes

16. a. 5
    b. 2
    c. 6
    d. 1
    e. 4
    f. 3

ANSWERS TO TEST

17. a. 3
    b. 4
    c. 1
    d. 2
    e. 3

18.

a.	P	h.	H
b.	R	i.	P
c.	P	j.	R
d.	R	k.	P
e.	H	l.	P
f.	R	m.	H
g.	R		

19.-23. Evaluated to the satisfaction of the instructor

24. Performance skills evaluated to the satisfaction of the instructor

VERTICAL MEASUREMENTS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to enter field data in standard field book form, make minor field adjustments to a leveling instrument, and perform various leveling problems. Competencies will be demonstrated by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to vertical measurements with the correct definitions.
2. List uses of leveling results.
3. Complete statements concerning the theory of leveling procedures.
4. Distinguish between curvature and refraction.
5. Identify major parts of a level.
6. Complete statements concerning adjusting parts of a level.
7. Match types of leveling equipment with the correct characteristics and uses.
8. Complete statements concerning types of level rods.
9. Complete statements concerning the proper procedure for setting up a leveling instrument.
10. Arrange in order the steps used to establish an elevation of an unknown point.
11. Select true statements concerning standard rules for note keeping.

OBJECTIVE SHEET

12. Match various applications of level work with the correct characteristics and uses.

13. Distinguish between the duties of survey crew members.

14. Classify common errors that occur in leveling.

15. List common mistakes that occur while leveling.

16. Describe the process of making minor field adjustments (peg test).

17. Read various types of level rods. (Assignment Sheet #1)

18. Enter field data in standard field book form. (Assignment Sheet #2)

19. Demonstrate the ability to:

    a. Make minor field adjustments to a leveling instrument (peg test). (Job Sheet #1)

    b. Perform a completed level circuit using the differential leveling process. (Job Sheet #2)

VERTICAL MEASUREMENTS
UNIT IV

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Have students perform a leveling problem consisting of a profile and cross sections.
2. Have students perform a three wire level circuit to demonstrate the increase in accuracy that can be obtained.
3. Have students research locations of various types of local bench marks that can be found in your local area.
4. Have students perform a double-rod level circuit to demonstrate the increased accuracy that can be obtained.
5. Demonstrate applications where over-head leveling can be used in the construction industry.
6. Have students research the local area for local datums that are currently used in leveling.
7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1 — Parts of a Level
2. TM 2 — Cross Hair Arrangements
3. TM 3 — Rod with Target
4. TM 4 — Rod Graduations
5. TM 5 — Bench Circuit Sequence
6. TM 6 — Standard Note Keeping
7. TM 7 — Differential Leveling
8. TM 8 — Reciprocal Leveling
9. TM 9 — Profile Leveling
10. TM 10 — Cross-Section Leveling
11. TM 11 — Cross-Section Leveling (Continued)
12. TM 12 — Cross-Section Leveling (Continued)
13. TM 13 — Borrow Pit Leveling
14. TM 14 — Error Classifications

D. Assignment sheets

1. Assignment Sheet #1 — Read Various Types of Level Rods
2. Assignment Sheet #2 — Enter Field Data in Standard Field Book Form

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1 — Make Minor Field Adjustments to a Leveling Instrument (Peg Test)
2. Job Sheet #2 — Perform a Completed Level Circuit Using the Differential Leveling Process

G. Test

H. Answers to test

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VERTICAL MEASUREMENTS
UNIT IV

INFORMATION SHEET

I. **Terms and definitions**

A. Backsight (BS) — A rod reading that is taken from a known point of elevation to obtain an instrument height

B. Bench mark (BM) — A stationary, relatively permanent object, natural or artificial, having a marked point whose elevation above or below an adopted datum is known or assumed

C. Cross section — A series of ground elevations taken at recorded offsets wherever existing ground changes grade, usually taken at 90° offsets to the baseline or centerline of the project

D. Elevation — The vertical distance from a datum, usually the NGVD, to a point or object

E. Foresight (FS) — A rod reading that is taken on an unknown point or object to obtain its elevation

F. Height of instrument (HI) — The exact position of the cross hairs of a leveling instrument above a known point in a specified datum

G. Horizontal line — A line perpendicular to the direction of gravity or parallel to a horizonta'

H. Level line — A a level surface, therefore a curved line (parallel to the earth's curvature)

I. Mean sea level (MSL) — The average height of the sea's surface for all stages of the tides over a 19 year period, usually taken at hourly intervals from 26 stations

J. National geodetic vertical datum (NGVD) — The nationwide reference surface for elevations of the United States. It was obtained by a least squares adjustment done in 1929. A readjustment program should be completed in 1987.

K. Parallax — The apparent displacement or the difference in apparent direction of an object as seen from two different points not on a straight line with the object

(NOTE: Parallax occurs when the cross hairs of a telescope appear to travel over the object sighted when the eye is shifted slightly in any direction.)

L. Profile — A surveyed line that has been stationed at equal intervals, and elevations of each interval point have been obtained

M. Temporary bench mark — A relatively stationary object that can be found by description having an established elevation on it, such as a fire hydrant

INFORMATION SHEET

N. Turning point (TP) — A stationary point used to temporarily transfer the position of the instrument without losing its reference elevation

O. Vertical datum — Any level surface in which elevations are referred to; a referencing system of point elevations

P. Vertical line — A line that follows the direction of gravity as indicated by a plumb line

II. **Uses of leveling results**

A. To design highways, railroads, and canals having grade lines that must conform to the existing topographical surroundings

B. To lay out construction projects according to engineered plans

C. To calculate volumes of earthwork in various types of construction

D. To analyze drainage characteristics of an area of land

E. To develop maps showing general ground configurations

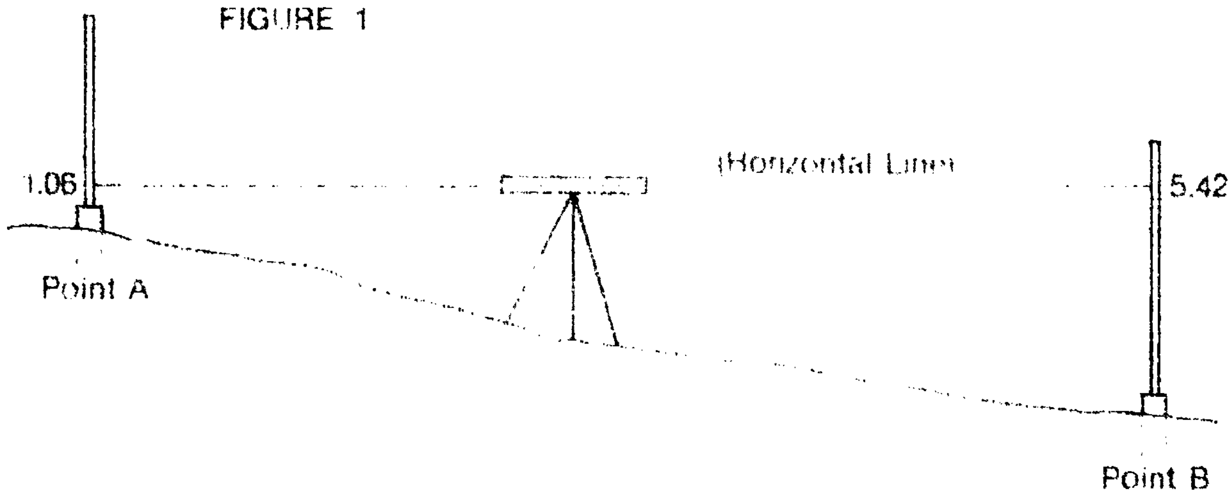
III. **Theory of leveling procedures**

A. The surveyor is able to sight through a telescope at a graduated rod (in feet or meters) and determine a measurement reading at a point where the cross hairs in the telescope intersect the rod.

B. Leveling has two purposes:

1. To find differences in elevations between points (Figure 1)

FIGURE 1

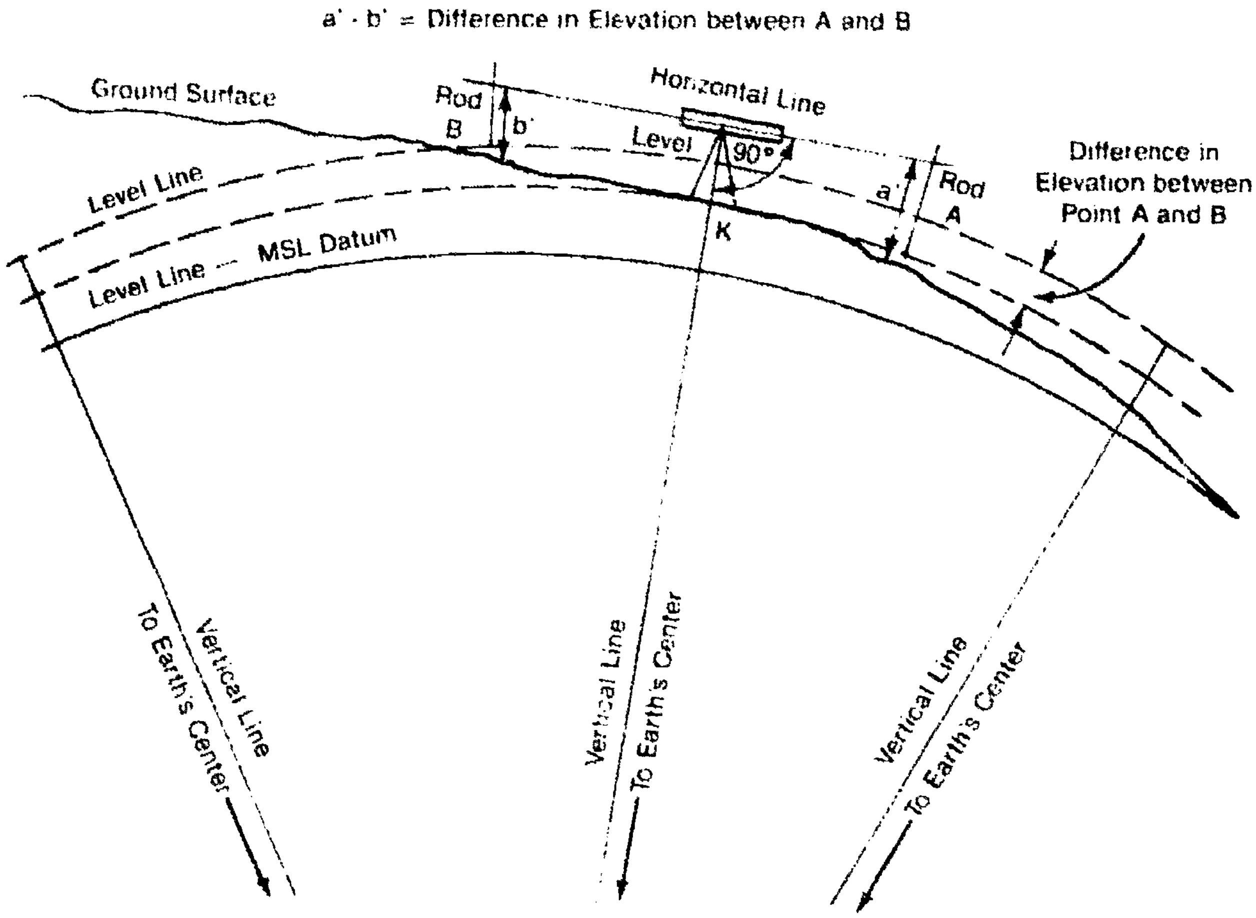


Example: Point B: 5.42' (rod reading)
Point A: 1.06' (rod reading)
Difference: 4.36'
Therefore: Point A is 4.36 feet higher than Point B.

INFORMATION SHEET

2. To find elevations of points (Figure 2)

FIGURE 2



Example: If the rod reading at "A" equals 6.27 ft and the rod reading at "B" equals 4.69 ft, the difference in elevation between "A" and "B" would be: 6.27 − 4.69 = 1.58 feet.

Had the elevation of "A" been 461.27 ft (above MSL), then the elevation of "B" would be 461.27 + 1.58 = 462.85 ft, that is:

461.27′ (elev. "A") + 6.27′ (rod reading at "A") − 4.69′ (rod reading at "B") = 462.85′ (elev. "B")

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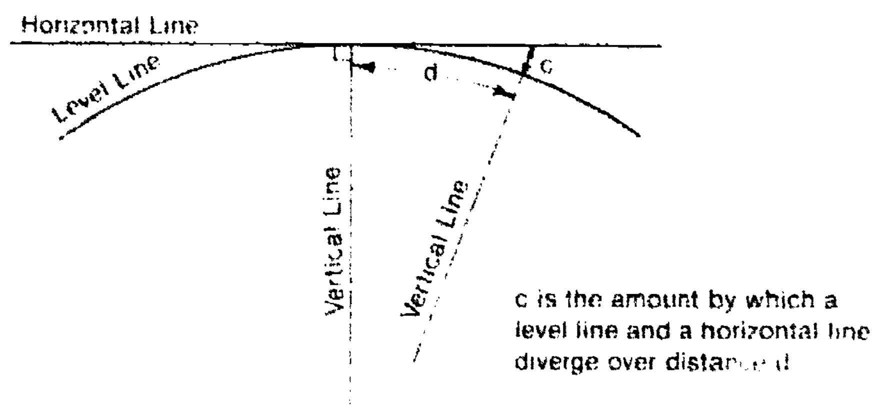
IV. Curvature and refraction errors

A. All leveling instruments are referenced to a horizontal line and all vertical elevations are based on a level line of sight. Therefore, all rod readings taken with a surveyor's level contain a curvature error "c" over a distance "d".

FIGURE 3



(NOTE: In Figure 3 the curvature of the level line has been greatly exaggerated to better illustrate the error involved with this leveling process.)

B. Curvature error can be calculated by using the following formula:

$$(R + C)^2 = R^2 + KA^2$$

$$R^2 + 2RC + C^2 = R^2 + KA^2$$

$$C\,(2R + C) = KA^2$$

$$C = \frac{KA^2}{2R + C} = \frac{KA^2}{2R}$$

Where R = mean radius of earth = 3959 miles or 6370 km

Example: Take 2500 ft as KA:

$$\frac{2500^2}{2(3959 \times 5280)} = 0.1495 = C$$

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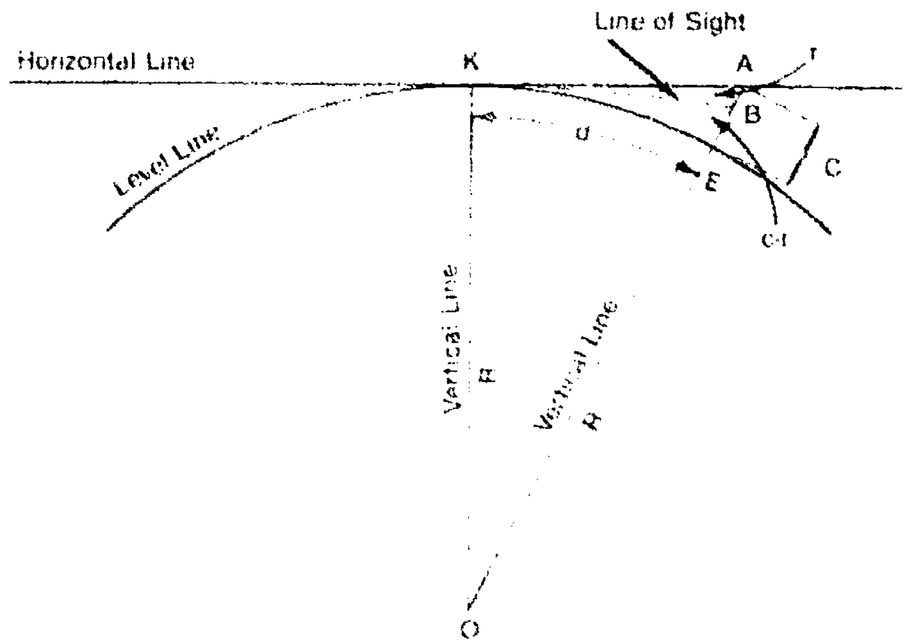
C When considering the divergence between a level and a horizontal line of sight, one must also account for the fact that all sight lines refract downward towards the earth's surface. Therefore, all rod readings taken with a surveyor's level also contain a refraction error "r" over a distance "d". (Figure 4)

FIGURE 4



D. Refraction is generally considered to be approximately one-seventh that of the curvature error calculated for that distance, or r = 0.14c.

In Example B where c = 0.1495,
r = 0.14 × 0.1495 = 0.0209
c − r = 0.1495 − 0.0209 = 0.1286

E. It can be seen from the calculations above that curvature and refraction errors are relatively small even at large distances. (Table 1)

Table 1

Distance (ft) =	100	200	300	400	500	1000	1 mile
(c − r) ft =	0.000	0.001	0.002	0.003	0.005	0.020	0.574
Distance (m) =	30	60	100	120	150	300	1 km
(c − r) m =	0.0001	0.0002	0.0007	0.001	0.002	0.006	0.152

F. The accuracy requirements for the type of level work to be executed will determine whether or not curvature and refraction errors must be calculated.

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V. **Major parts of a level** (Transparency 1)

(NOTE: The following parts are for a "dumpy level", but the basic parts are quite similar to those in many other types of levels.)

A. Telescope

B. Objective focusing pinion*

C. Sunshade

D. Level vial

E. Level bar

F. Clamp screw*

G. Spindle

H. Leveling head

I. Leveling screws*

J. Base plate

K. Tangent screw*

L. Level post

M. Level adjusting nuts*

N. Eyepiece focusing ring*

O. Cross hair reticle adjusting screws*

(NOTE: Adjustment components are starred.)

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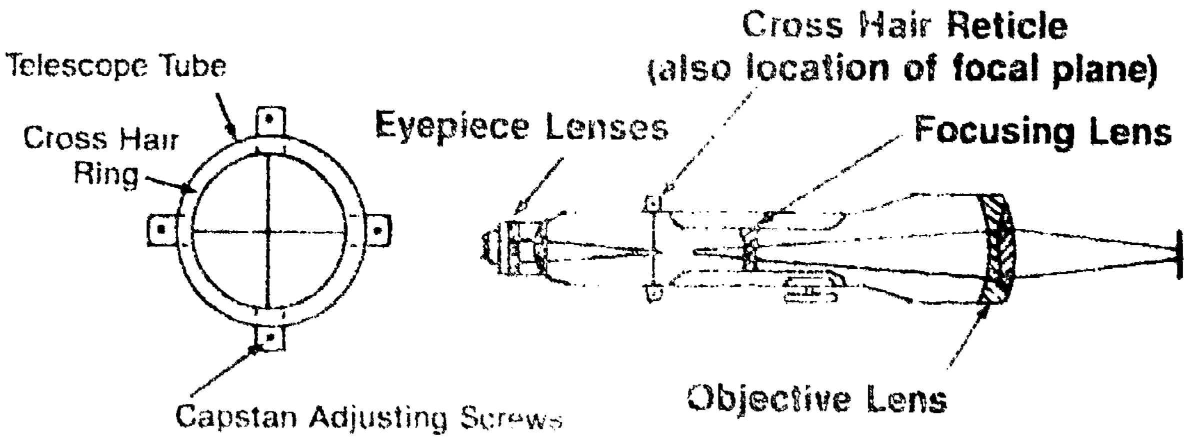
VI. Adjusting parts of a level

A. Telescope (Figure 5)

FIGURE 5



1. Rays of light pass through the objective lens

2. This then forms an inverted image in the focal plane

3. The image formed is then magnified by the eyepiece lenses so that the image can be clearly seen

4. The eyepiece lenses also focus the cross hairs which are located in the telescope at the principal focus plane

5. The focusing lens (negative lens) can be adjusted so that the images of varying distances can be brought into focus in the plane of the reticle

   (NOTE: Most telescopes designed today involve additional lenses in the eyepiece assembly so that the inverted image can be viewed as an erect image. The minimum focusing distance ranges from 4 to 6 feet depending on the manufacturer)

6. The cross hairs can be thin wires attached to a cross hair ring, or as in most modern equipment they are actual lines etched on a circular glass plate enclosed by a cross hair ring (Transparency 2)

7. The cross hair ring (slightly smaller than the diameter of the telescope tube) is held in place by 4 capstan screws that can be turned to adjust the cross hairs up or down and left or right if the instrument is found to be slightly out of adjustment (This will be discussed later in this chapter)

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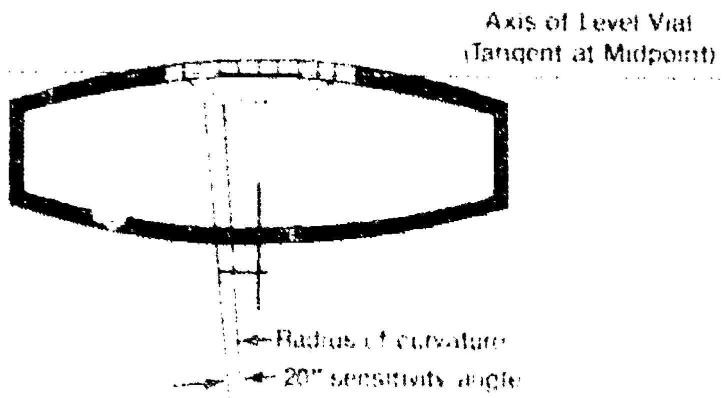
B. Level vial

1. Is a glass tube sealed at both ends that contains a sensitive liquid such as alcohol and a small air bubble within the tube

2. The tube is graduated with uniform, etched markings generally spaced at 2mm apart used to accurately determine the bubbles position

3. The "axis" of a level vial is an imaginary longitudinal line tangent to the upper inside surface at its midpoint. Therefore, when the bubble is centered in its run, the axis should be a horizontal line. See Figure 6.

FIGURE 6



4. The sensitivity of a level vial is directly related to the curvature of the glass tube used. For example, the larger the radius, the more sensitive a bubble.

5. Most automatic levels, theodolites, EDMI's and other types of equipment have circular bubbles rather than actual glass tubes, but sensitivity standards have yet to be established for this type.

C. Leveling head

1. In the case of the dumpy level, four leveling foot screws are utilized to set the telescope level.

2. The screws surround the center bearing of the instrument and are used to tilt the telescope using the center bearing as a pivot point.

3. The telescope tube is positioned directly over two opposite foot screws and moved into a level position by adjusting the two screws, keeping both of them snug but not overly tight.

4. Once the telescope is level in this position, it is moved 90 degrees, directly over the other two foot screws and the process is repeated.

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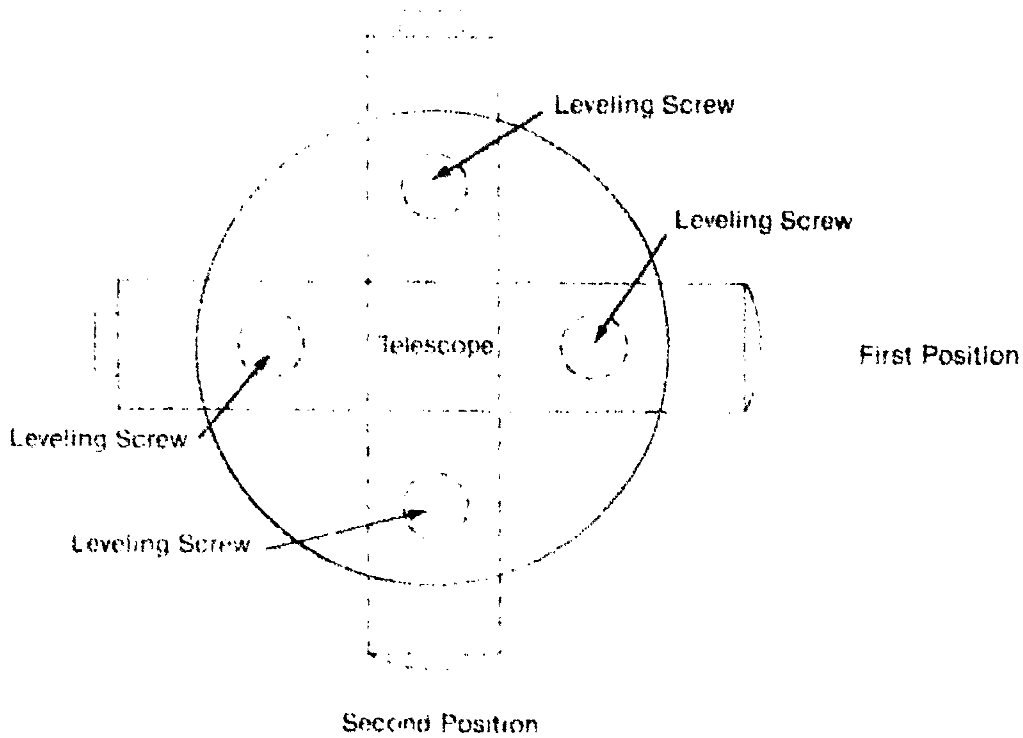
5. After the telescope is level in the second position, it should be turned 180° to check the bubble vial for possible error. Minor adjustments with the 4 foot screws can be made to average any minimum error in the tube. See Figure 7.

FIGURE 7



VII. Types of leveling equipment

A. Hand level (Figure 8)

1. Used for low-precision king various rough checks to level work.

2. Consists of a brass tube having a plain glass objective lens and peep-sight eyepiece.

3. A small level bubble mounted above a slot in the tube is viewed through the eyepiece by means of a prism or 45° mirror. A horizontal line extends across the tube.

4. Is normally held in one hand and leveled by raising or lowering the objective end until the bubble is level.

5. At this point the target can be viewed through the eyepiece and compared to the vertical position of the eye of the observer.

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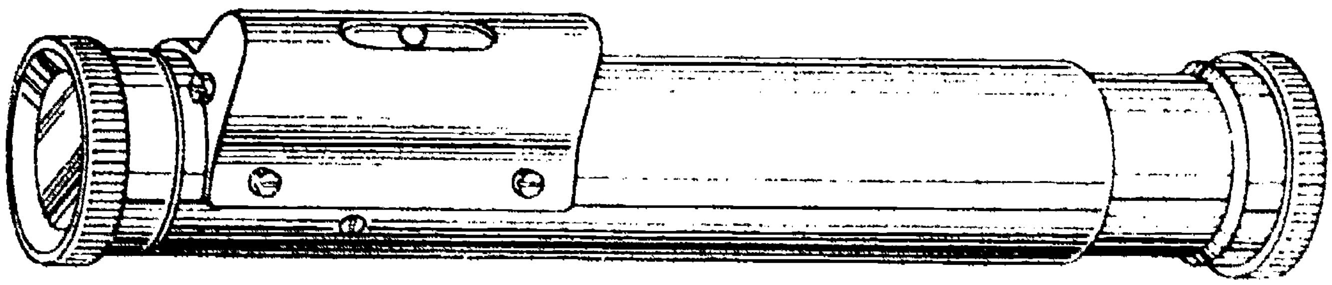
6. Most hand levels have no magnification so their uses are quite limited.

7. Some hand levels are capable of obtaining right angles which makes them convenient for right-angle offset work.

FIGURE 8



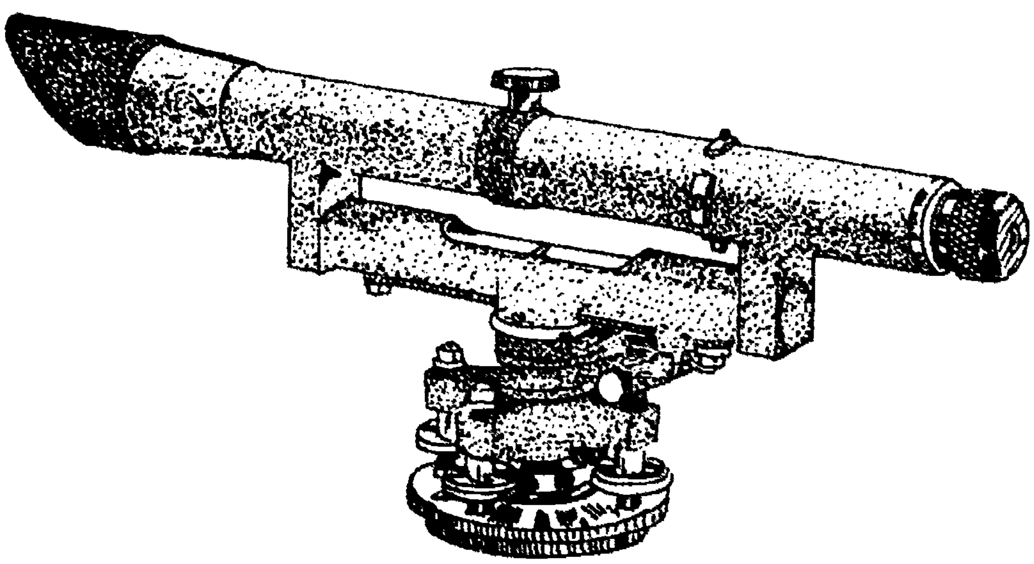
B. Dumpy level (Figure 9)

1. Has a telescope firmly attached and parallel to the level bar.

2. The level vial, attached to the level bar, remains in the same vertical plane as the telescope at all times.

3. Was at one time used extensively on all engineering works, but has since been replaced in many engineering capacities by more sophisticated, modern types of leveling instruments.

FIGURE 9



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C. Wye level

1. Has a non-fixed telescope that rests in Y-shaped supports called wyes.
2. Curved clips fasten the telescope in place.
3. Is operated like the dumpy level, but is simpler to adjust because the telescope can be lifted from the wyes and turned end for end.
4. Is now almost obsolete.

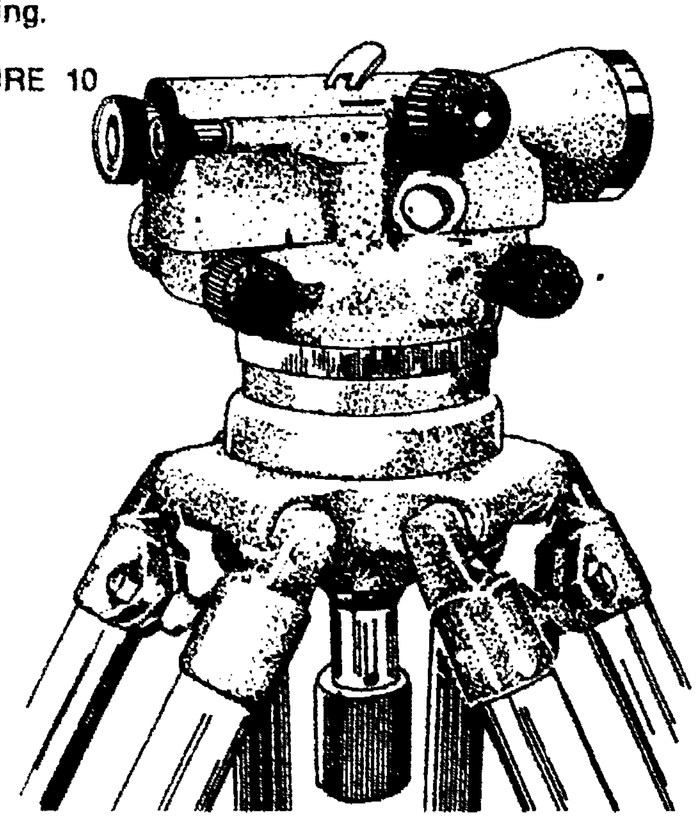
D. Tilting level (Figure 10)

1. Is used for more precise work and for many general purposes
2. A bull's eye level (circular spirit level) is utilized for quick approximate leveling.
3. Exact leveling is accomplished by adjusting a tilting screw to tip the telescope about a fulcrum at the vertical axis of the instrument, without changing the height of the instrument.
4. This tilting feature increases accuracy and saves time since only one screw needs to be adjusted to obtain a horizontal line of sight.

   (NOTE: Using this type of instrument, one can ensure that the telescope is level before each reading is taken.)

5. The tilting level can have either a three-screw leveling head or a four-screw. Most tilting levels used are of the three-screw type, for ease in leveling.

FIGURE 10



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E. Self-leveling or automatic level (Figure 11)

1. Employs a gravity reference prism or mirror compensator to automatically orient the line of sight

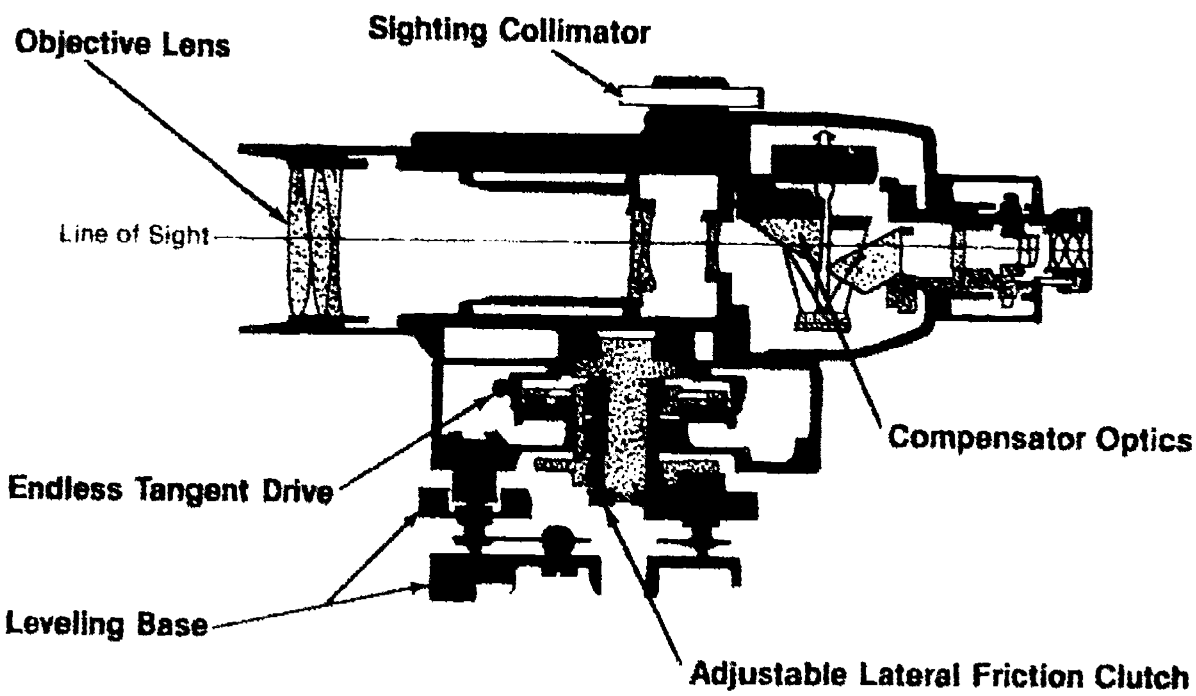
2. Can be quickly leveled using a circular spirit level

3. Once the bubble is approximately leveled, the compensator will take over and maintain a horizontal line of sight, even if the actual telescope is slightly tilted.

4. Extremely popular due to the ease in setting up and the precision that can be obtained with its use

(**CAUTION:** All automatic levels employ a compensator of some type, either freely moving prisms or mirrors hung by fine wires. If a wire or fulcrum were to break, it may not be detected during use; therefore all subsequent rod readings would be incorrect. The operation of a compensator can be verified by tapping the end of the telescope with your finger or slightly moving a level screw back and forth causing the line of sight to slightly bounce. This can be easily observed through the eyepiece. If movement is detected, the compensator should normally be in good working condition.)

FIGURE 11



INFORMATION SHEET

F. Tripods

1. Several types are available with either fixed or adjustable legs.

   a. Adjustable-leg tripods have an advantage in setting up over rough terrain and ease in storage.

   b. Fixed-leg tripods have an advantage in that they are usually more rigid and will not vibrate quite as much as an adjustable one.

   (NOTE: A sturdy tripod kept in good working condition is a necessary part of obtaining accurate level work.)

2. Leg extensions are available when it becomes necessary to set the instrument up high due to cornfields, brush, or other obstructions.

3. A domed-head tripod has become popular which can speed up the actual leveling up procedures normally done.

VIII. Types of level rods

A. There are two main classes of level rods.

1. *Self-reading rods*

   a. Are read by the instrument operator while sighting through the telescope and noting the apparent intersection of the cross-hairs on the rod.

   . Are the most common type.

2. *Target rods* (Transparency 3)

   a. Have a movable target that is set by the rod person at the position indicated by signals from the instrument operator.

   b. Are useful on long sights or when conditions are poor. The rod person records the actual reading.

B. One-piece rods are used for more precise work, with an "invar" strip with graduations held in place under temperature-compensating spring tension.

C. Rod graduations (Transparency 4)

1. Are accurately painted with alternate black and white spaces 0.01 ft wide.

2. The 0.1 and 0.05 ft marks are emphasized by spurs extending the black painting.

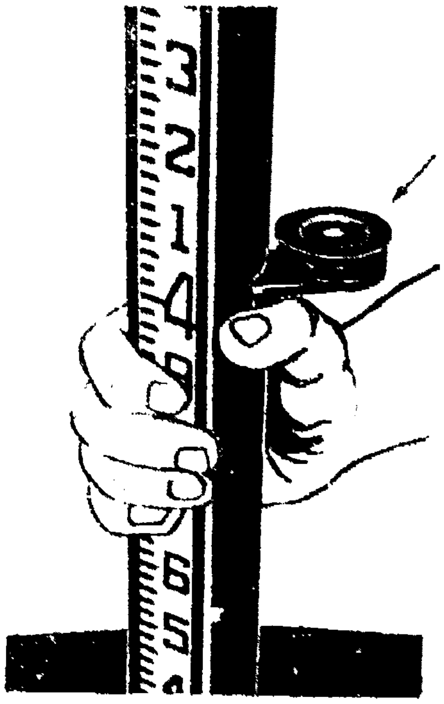
3. Tenths are designated by black figures and all foot marks by red numbers, all straddling the proper graduation.

INFORMATION SHEET

D. Most standard level rods can be read accurately with a level at distances up to 250 ft.

E. Rod levels can be used to ensure that the rod is being held plumb when being observed. (Figure 12)

FIGURE 12



IX. Setting up a leveling instrument

(CAUTION: Always take care when using level rods around electrical wires and overhead objects. "Always look up.")

A. When leveling, as opposed to transit work, the instrument can usually be set up in a relatively convenient location.

B. If the instrument must be set up on hard surfaces such as asphalt or concrete, the tripod legs should be spread out to avoid possibilities of knocking over the instrument due to wind or an unavoidable bump.

(NOTE: If possible, place one or two of the leg points in a crack of the pavement. This will add stability.)

C. When setting up on soft surfaces, the tripod is first set up so that the tripod head, or top, is nearly horizontal, and then the legs are firmly pushed into the earth.

(NOTE: When applying pressure on each foot peg to set the tripod leg, you should always place the *outside* edge of your foot against the tripod leg and apply *even* but *firm* pressure downward, not short or jerking motions.)

D. On hills or sloping ground it is customary to place one leg uphill and two legs downhill; the instrument person stands facing up hill while setting up the instrument.

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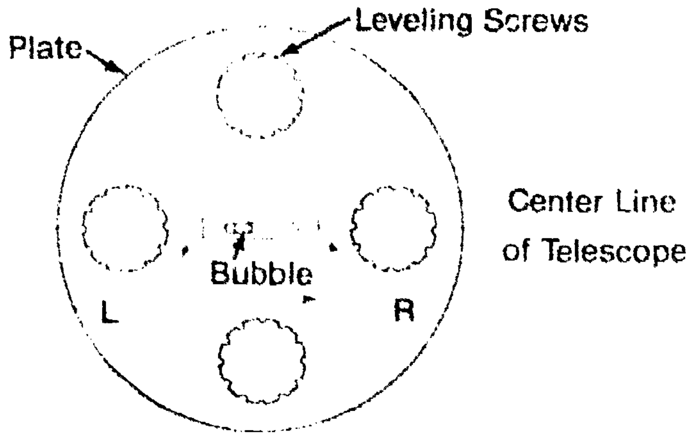
E. If a four-screw level is being used, the correct procedure for leveling the vial is to place the telescope parallel to two opposite leveling screws and adjust both screws simultaneously until the bubble is centered. Then rotate the telescope 90° over the two untouched screws and repeat the procedure. This process may need to be repeated again by rotating 180° for fine adjustments.

(NOTE: One rule to remember when adjusting four-screw instruments is to always move opposite screws in opposite directions, "thumbs in — thumbs out" rule. The level bubble always moves in the direction that the left thumb is moving. Never readjust the level vial between the backsight and foresight reading.)

FIGURE 13



F. When using a three-screw level instrument, any of the leveling screws can be manipulated at one time independently of the others, although most experienced surveyors often manipulate 2 of the screws at the same time. Once the (bull's eye) circular bubble has been leveled, the instrument can be revolved to check that the bubble remains centered.

G. Once the level has been set up and properly leveled preparation for the rod reading can take place.

(NOTE: Take care not to jolt or lean on the tripod after leveling the instrument.)

X. Proper field procedures to establish an elevation of an unknown point

A. Remove the instrument from its container by lifting the level bar or base, **not** by grasping the telescope.

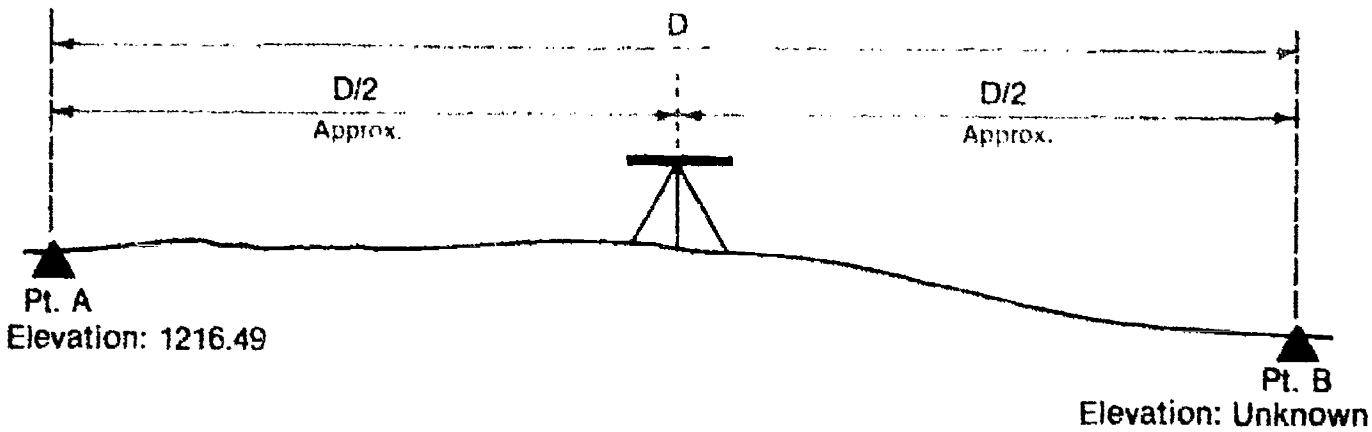
B. Securely attach the level to the tripod and transport to the initial set-up point.

(NOTE: The **safest** way to transport a level is in its container. but if proper care is taken while working level circuits, this is not necessary. The instrument, once securely fastened to the tripod, may be placed over the shoulder of the observer but preferably held in an upright position and moved on up to the next setup. Care taken when walking under trees or through heavy brush should be a top concern of any instrument person when progressing to the next setup.)

INFORMATION SHEET

C. Set up the instrument midway between point A and point B, and level it up. (Figure 14)

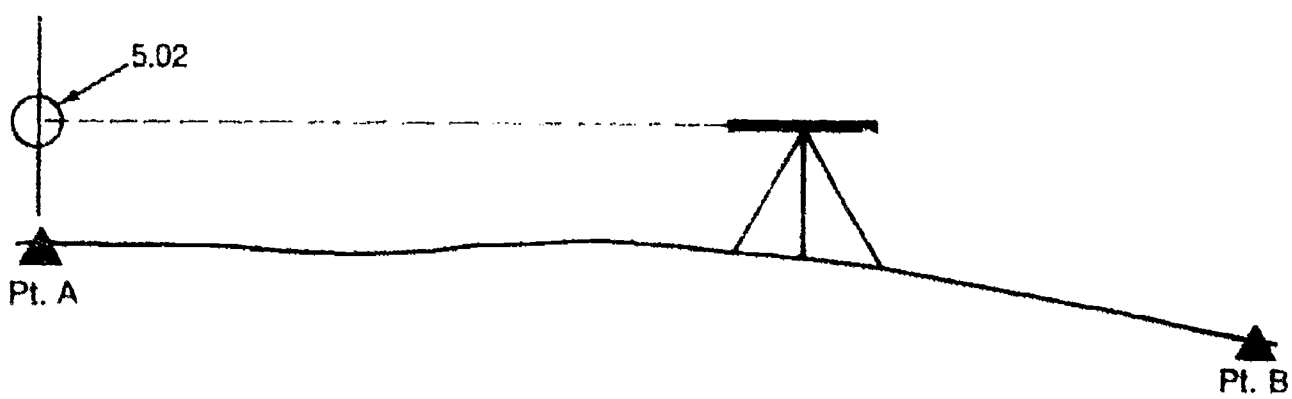
FIGURE 14



(NOTE: Point A is an established point of elevation. All types of leveling methods must start from either a point of known elevation or in some cases a point with an assumed elevation possibly in a local datum.)

D. Once the instrument is positioned and leveled up, take a rod reading towards point A by having the rod person place the leveling rod directly on the point of known elevation. (Figure 15)

FIGURE 15



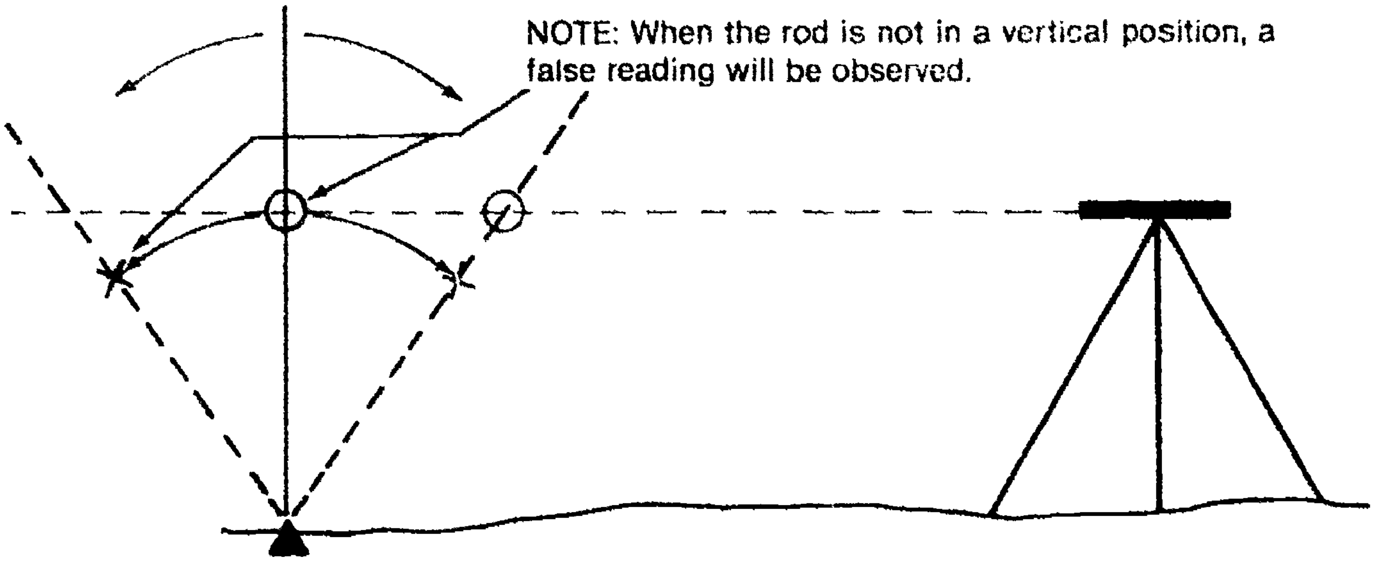
1. The rod person must hold the level rod in a vertical position by using a circular level bubble or by balancing the rod lightly between the finger tips.

2. A more common method of assuring that the reading is taken when the rod is held vertical is referred to as "waving" or "rocking" the rod, where the rod person slowly waves the rod ahead or towards the instrument and then back past the vertical point. This is done repeatedly until the instrument person signals that the proper rod reading has been recorded.

INFORMATION SHEET

3. The instrument observer must carefully view the rod during this rocking motion and pinpoint the lowest possible rod reading. It is at this point that the rod is at its most vertical position. (Figure 16)

FIGURE 16



E. With most methods of leveling, this initial rod reading taken from a known point is regarded as a "backsight" or a "plus" shot and is recorded in the backsight column of the field notes. (Figure 17)

FIGURE 17

STATION	+ B S	H I		F S	ELEVATION	DESCRIPTION	
B M "A"	5 02				1216 49	CHISELED "X" IN CONC STEP	

F. After carefully observing Point A and recording the rod reading (in this case 5.02), the instrument person signals to the rod person to proceed to Point B by moving both arms above his head and then down to his side.

(NOTE: Proper technique is to record the reading in the field book and then signal the rod person to move on.)

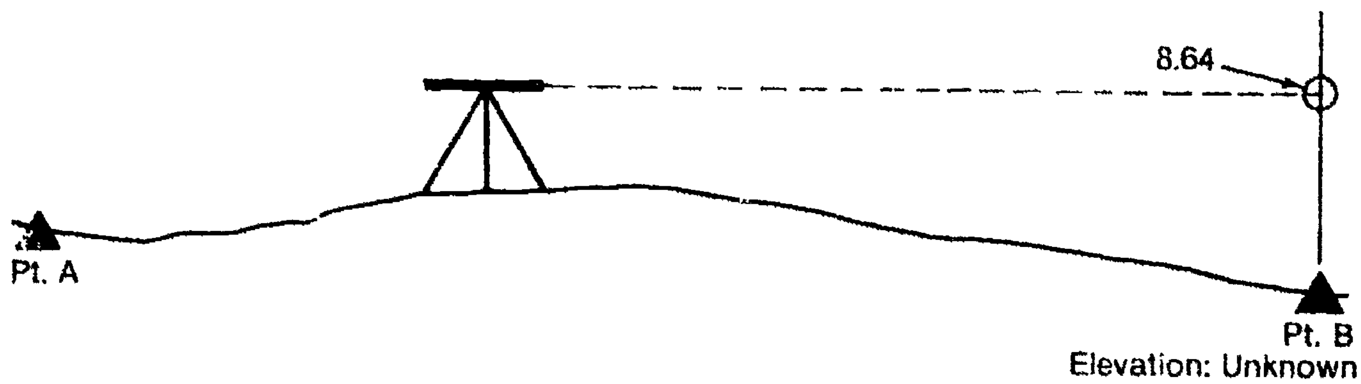
INFORMATION SHEET

G. Once the rod person has reached Point B, the observer rotates the telescope and focuses the cross hairs on the level rod presently resting on the point. (Figure 18)

1. The rod person once agai must position themselves behind the level rod and begin waving the rod slowly until an accurate rod reading, referred to as a "foresight" or "minus" shot, has been taken.

2. The observer carefully reads the lowest number that the cross-hair intersects with, and records.

FIGURE 18



H. This rod reading or foresight should be recorded in the proper column of the field notes, usually checked again, and then the observer will signal the rod person that they are finished. (Figure 19)

FIGURE 19

STATION	+ B S	H I		- F S	ELEVATION	DESCRIPTION
B M "A"	5 02				1216 49	CHISELED "." IN CONC STEP
PT "B"				8 64		NORTH RIM OF MANHOLE

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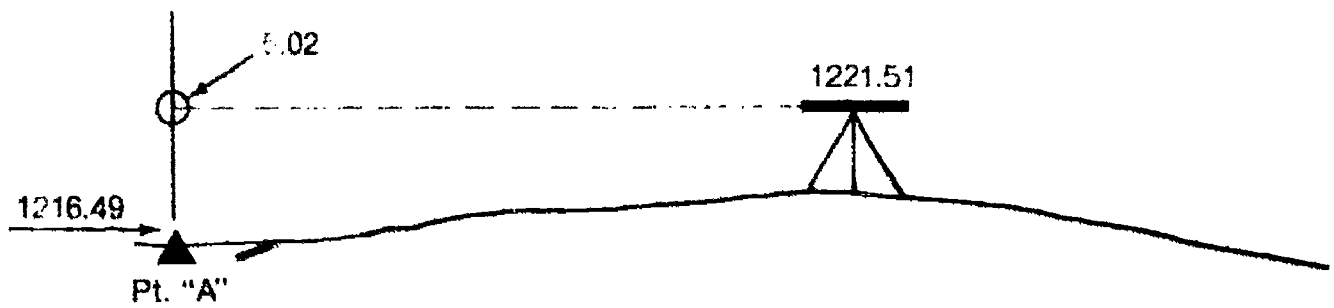
I. At this point, the elevation of Point B can be calculated, using the following steps:

1. The backsight

   a. 5.02 must be added to the known elevation of Point A, 1216.49, to determine the actual elevation of the cross hairs of the instrument known as the height of instrument (H.I.). (Figure 20)

1216.49	Elevation of Pt. A
+ 5.02	Backsight Rod Reading
1221.51	Height of Instrument

FIGURE 20



   b. The height of the instrument is recorded in the column referred to as the H.I. column. (Figure 21)

FIGURE 21

STATION	+ B.S.	H.I.		F.S.	ELEVATION	DESCRIPTION	
B.M. "A"	5.02	1221.51	+		1216.49	CHISELED X ON CURB STEP	

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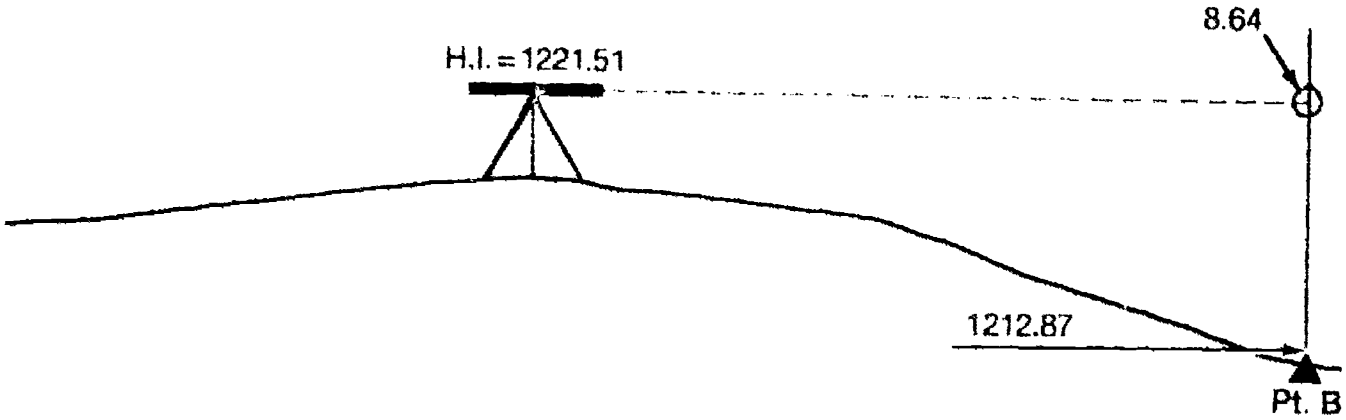
2. The foresight

   a. 8.64 must then be subtracted from the H.I. to determine the actual elevation of Point B. (Figure 22)

1221.51	Height of Instrument
– 8.64	Foresight Rod Reading
1212.87	Elevation of Pt. B

FIGURE 22



   b. The elevation of Point B is placed in the far right column labeled "ELEVATION" and is on the same line as Point B written in the first column used to describe information regarding that "station." (Figure 23)

FIGURE 23

STATION	+ B.S.	H.I.		F.S.	ELEVATION	DESCRIPTION	
B.M. "A"	5.02	1221.51			1216.49	CHISELED X IN CONC STEP	
PT "B"				8.64	1212.87	NORTH RIM OF MANHOLE	

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J. In many cases (due to large vertical or horizontal distances), several intermediate setups must be made to get to the actual point in which the elevation is needed. The procedure is identical in every way, except:

1. Intermediate points, called "turning points," must be established with known elevations.

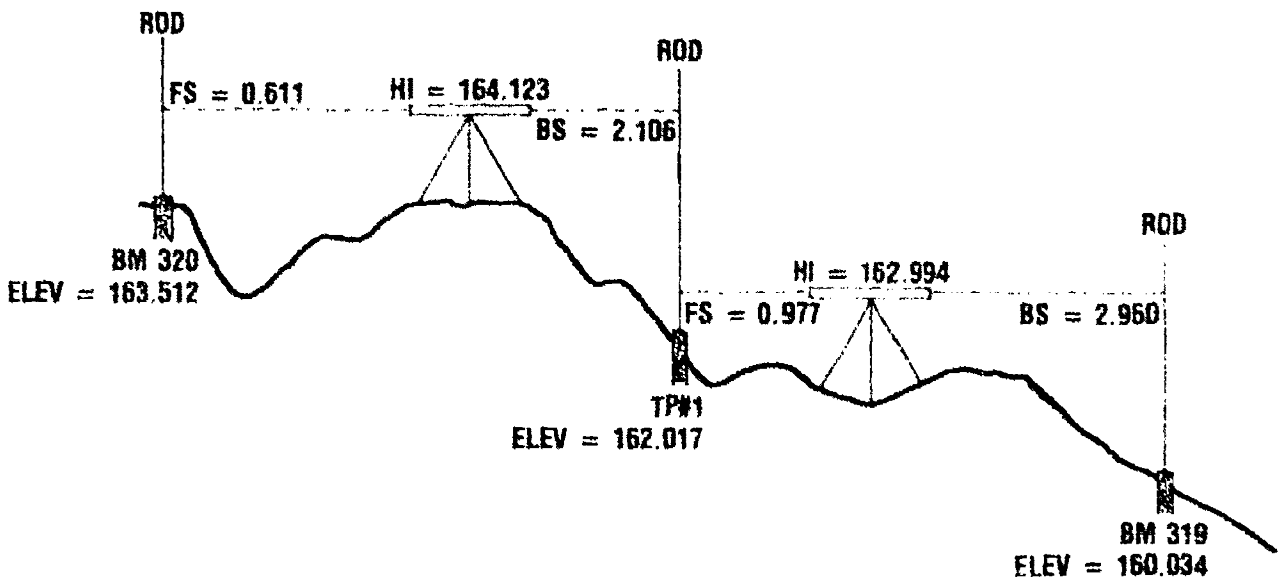
   (NOTE: Great care should be taken when choosing each location for a turning point. It should be stable, easy to define, and convenient for both instrument sightings, the foresight and backsight.)

2. After each setup is completed, a backsight is then taken on the previous "turning point" to establish a new height of instrument.

3. Next, another turning point is established to enable yet another instrument set-up.

4. This process is repeated until an accurate rod reading (foresight) can be observed on the point of which an elevation is needed. (See Figure 24)

FIGURE 24



INFORMATION SHEET

XI. Standard rules for note keeping (Transparency 6)

A. All recording is done in pencil.

B. Absolutely **no** erasure marks are made on data entries.

1. If a reading is recorded incorrectly, a single line should be placed through it and the correct value should be written directly above it.

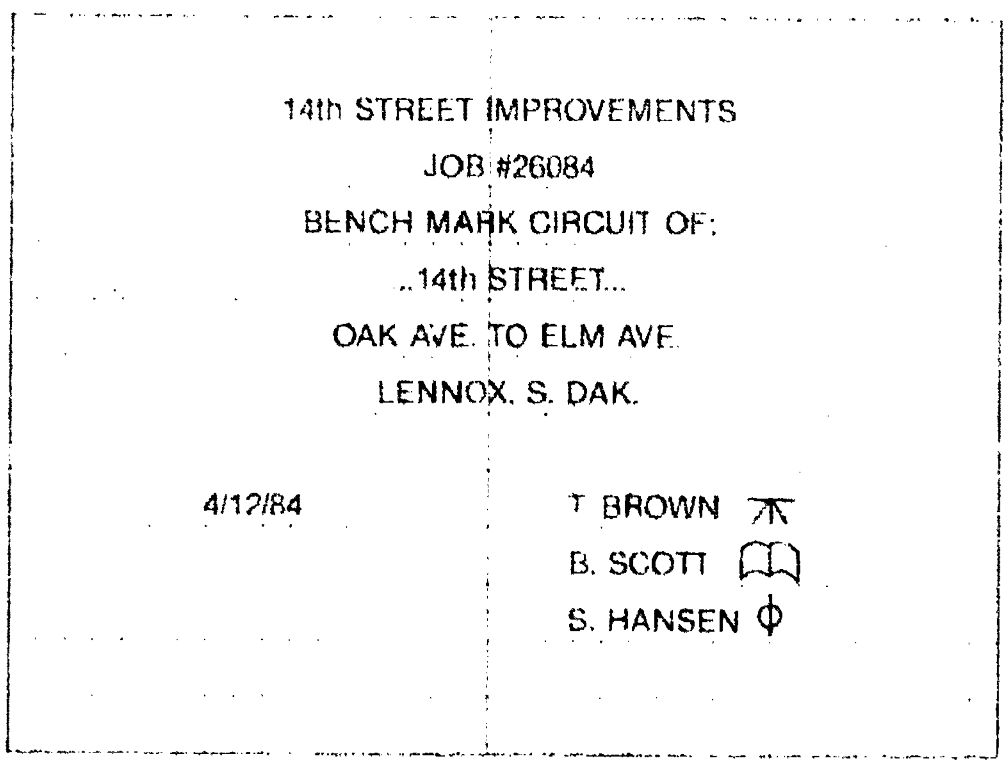
2. Evidence of erasure marks indicates possible error in the work performed or a forced closure

C. Pages should all be numbered as work progresses.

D. Each project should be labeled. (Figure 25)

1. Type of survey work
2. Project name
3. Project location
4. Project number or identification number
5. Names of all crew members and their duties
6. Date work took place

FIGURE 25



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E. Weather conditions should be noted.

1. Tempe ature
2. Wind conditions
3. Other conditions such as rain, fog, drizzle, snow, etc.

F. Type of instrument used should be noted.

G. Hand copying of any field notes is prohibited.

H. All reductions of field notes should be in ink or red pencil.

XII. Various applications of level work

A. Differential leveling (Transparency 7)

1. Used to determine differences in elevation between points that are remote from each other
2. Often referred to as bench mark leveling
3. Backsights and foresights should be kept as close to equal in horizontal length as possible.
4. Double-rodded lines of levels can be used on extremely accurate work, in which two turning points are established for each setup, with two level rods being used and readings recorded in separate note form columns.
5. Three-wire leveling can be done when performing precise differential leveling which involves reading all three cross wires (top, middle, and bottom) and averaging the three to obtain a better value.

B. Reciprocal leveling (Transparency 8)

1. Used when equal backsights and foresights cannot be obtained.

   Example: Over rivers, lakes, and canyons

INFORMATION SHEET

2. The instrument is set up at Point X near Point A, and rod readings are taken at Point A and Point B. Several readings are taken due to the distance of X-B. Once recorded, the instrument is relocated at Point Y and the process is repeated. (Figure 26)

FIGURE 26

3. The two differences in elevation between A and B determined from Point X and Y will normally not be identical. An average of the two can be obtained, thus minimizing curvature and refraction errors along with any small instrument errors.

C. Profile leveling (Transparency 9)

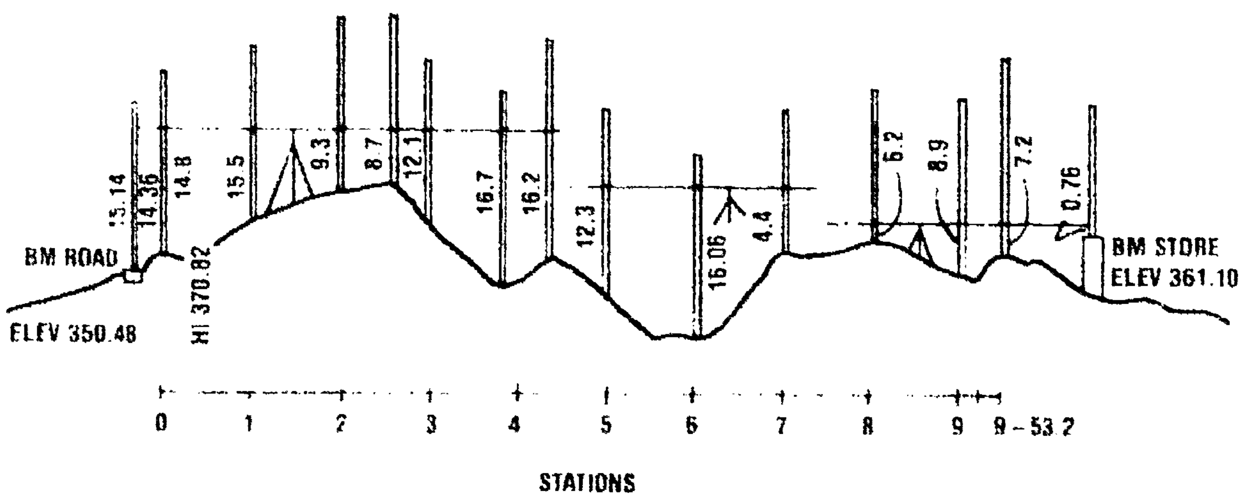
1. Used on route surveys for highways or pipelines where elevations are needed at specific intervals

2. A base line is established with "stations" or points marked along the line that can be easily found.

3. Rod shots are then taken along each of the stations and at any abrupt change in existing grade that may occur in between the station intervals. (Figure 27)

Example: Every 25 ft or 50 ft

FIGURE 27



INFORMATION SHEET

4. Normal turning points are set at 400-600 ft intervals as the profile of base line reading progresses.

5. Once the end of the desired profile is reached, normal benchmark leveling is implemented to return the complete level circuit to the beginning point, unless a point of known elevation has been previously established near the end of the profile.

   (NOTE: Readings on paved surfaces such as concrete roadways, curbs, and sidewalks are read to the nearest 0.01 of a foot, while rod shots on the ground can be read to the nearest 0.1 of a foot. Regardless, all foresights and backsights on turning points are always read to the nearest 0.01 of a foot.)

D. Cross-section leveling (Transparencies 10 and 11)

1. Commonly implemented along with profile leveling

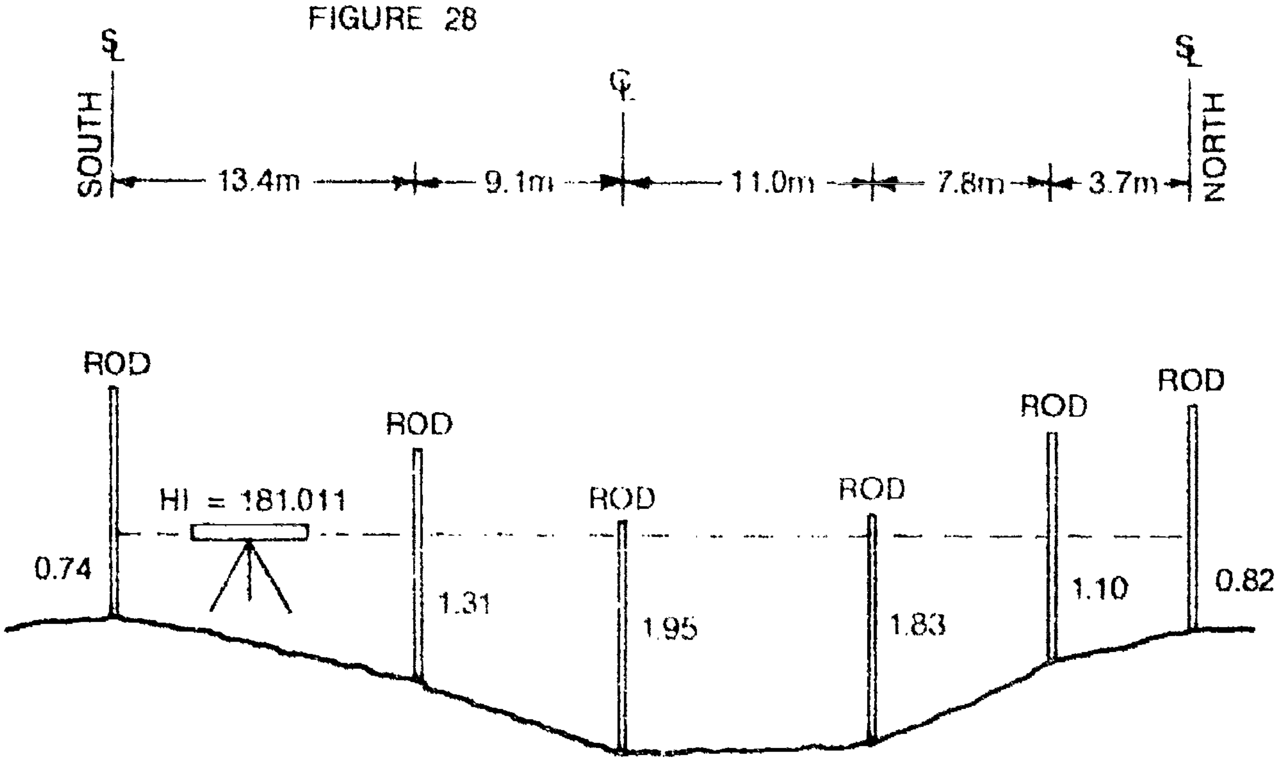
2. While profile leveling obtains elevations along a straight base line, cross-section level work is used to obtain elevations at certain right-angle or 90-degree offsets from the stationed profile line.

3. The offset distances right or left of the base line are determined by the shape of the existing terrain.

   Example: Rod readings are taken at any definite change in slope.

4. Cross-sections are commonly used to determine earth quantities that might be needed during the construction of the project, or actual areas of a ditch or swale that might be used in a potential drainage study. (Figure 28)

FIGURE 28

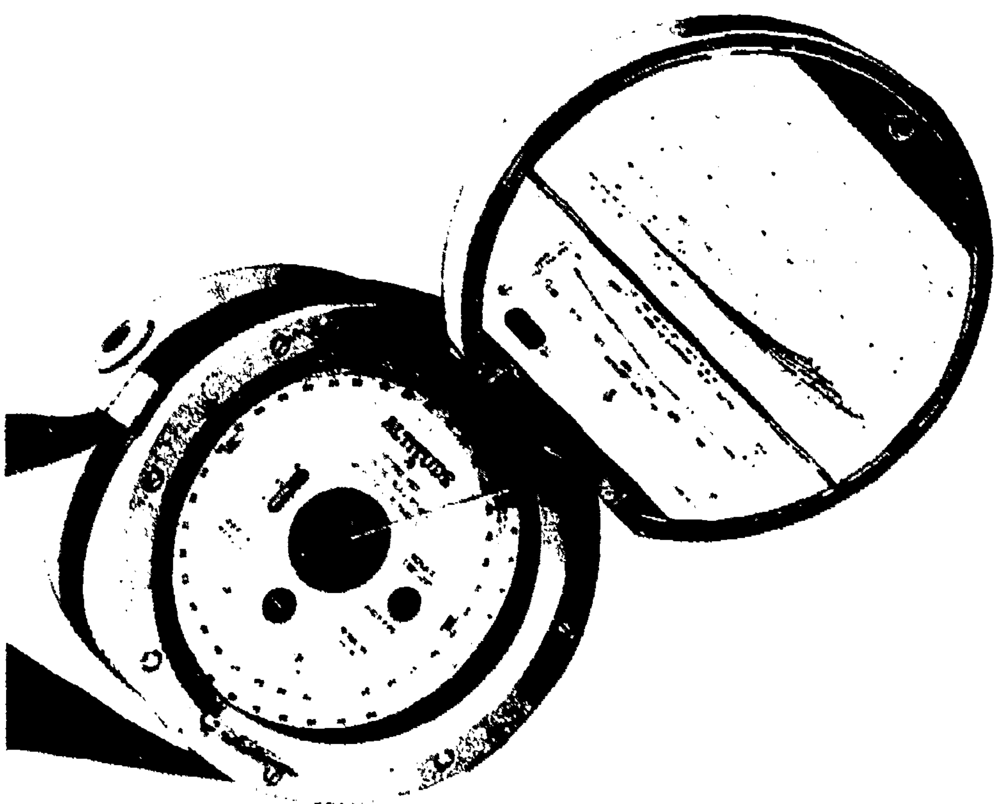


INFORMATION SHEET

E. Barometric leveling

1. A special barometer or surveying altimeter, an instrument that measures air pressure, can be used to find relative elevations of points on the earth's surface. (Figure 29)

FIGURE 29



2. Particularly suitable for work in rough terrain where standard leveling procedures would be extremely costly

3. Can be used where extensively large areas need to be covered and high orders of accuracy are not required

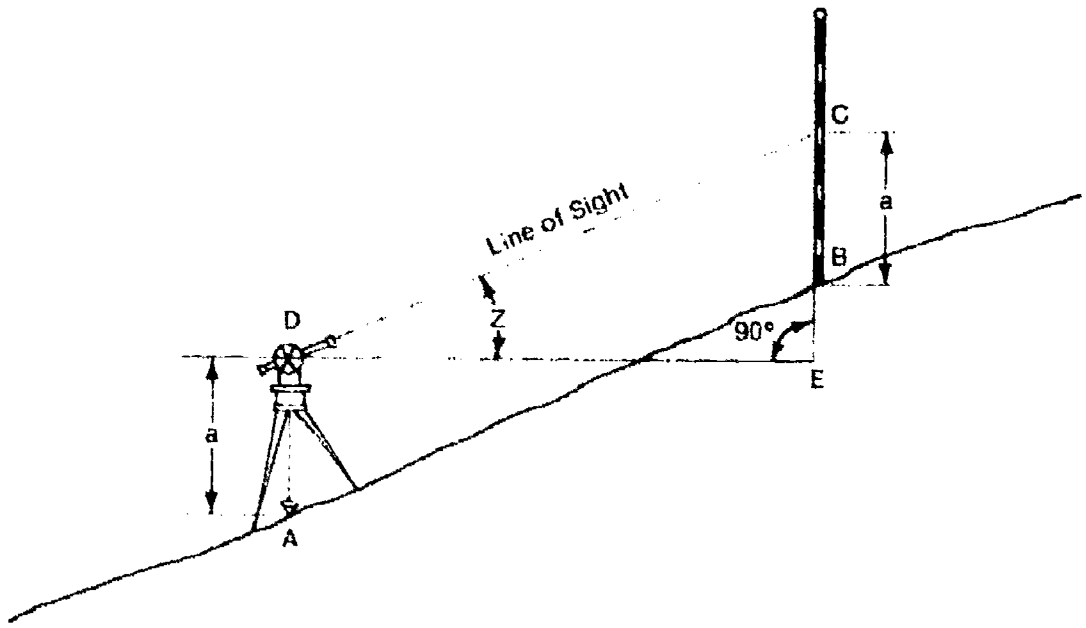
4. In stable weather conditions, accuracies of up to ±2 to ±3 ft are possible.

INFORMATION SHEET

F. Trigonometric leveling

1. Used to determine the elevation of a point by measuring the inclined or horizontal distance between two points, and recording the vertical angle to one point from a horizontal plane through the other point. (Figure 30)

FIGURE 30



2. Thus, in Figure 30, if the slope distance AB or DC and the vertical angle EDC are measured, then the difference in elevation between A and B is EC = DC sine EDC.

(NOTE: If the horizontal distance is determined (D-E), the equation then involves the tangent function rather than sine.)

3. Commonly used in topographic work and over very rugged terrain

4. For very long distances curvature and refraction errors must be eliminated.

G. Borrow pit leveling (Transparency 12)

1. Commonly used to determine the volume of material "borrowed" or transported to the construction site

2. Rod readings are taken either by the cross-section method or by a possible grid system layout over the existing or original ground where excavation will take place.

3. As excavation commences, additional readings are taken for top and bottom of excavation limits.

4. Removal quantities can then be calculated by comparing these rod readings to the original elevations before excavation.

INFORMATION SHEET

XIII. Duties of survey crew members

A. Survey party chief

1. Obtains necessary information prior to leaving the office for the survey site.

2. Discusses proper surveying procedures with survey crew prior to arriving at the location.

   Examples: What needs to be done, how the information should be obtained, special precautions to be followed

3. Maintains daily logs, reports, and vehicle-use records.

4. Keeps orderly, neat field notes while work is being performed.

B. Instrument person (observer)

1. Takes care of surveying instruments.

2. Checks that all battery packs are charged.

3. Is responsible for accurate readings taken while performing survey work.

C. Rod person

1. Takes care of all miscellaneous equipment.

2. Stores all equipment prior to leaving the site.

3. Cleans all level rods, tapes, etc.

4. Marks turning points and bench marks.

XIV. Sources of errors in leveling (Transparency 13)

A. Instrumental errors

1. Not in proper adjustment

2. Cross hairs not exactly horizontal

3. Level rod not correct length

4. Tripod leg loose or not securely set in ground

INFORMATION SHEET

B. Natural errors

1. Curvature of the earth
2. Refraction of the line of sight
3. Temperature variations on the leveling vial
4. Strong or gusty winds
5. Settlement of the instrument
6. Settlement of a turning point
7. Traffic and equipment vibration

C. Personal errors

1. Bubble not properly centered
2. Parallax (improper focusing on a point)

   (NOTE: To eliminate parallax, the observer must adjust the objective lens (or focus) on the object sighted, or adjust the eyepiece lenses (cross-hair focus) while viewing a white piece of paper held in front of the telescope. This process may need to be repeated several times to correct the problem completely.)

3. Faulty rod readings
4. Improper rod handling
5. Target setting

XV. **Common mistakes while leveling**

A. Use of an improperly graduated rod

1. Extremely worn at the joining sections
2. Worn graduations

B. Holding the rod in different locations during a turning point

(NOTE: Proper selection of turning points and where the rod will be held is extremely important and will greatly decrease the chances of a level circuit not closing accurately.)

1. Pick well-defined points to turn on
2. Mark turning point with keel or marking crayon if possible
3. Remain in same location while the instrument is being moved

INFORMATION SHEET

C. Reading a foot too high

1. The incorrect foot mark is within close vision of the cross hair.

2. Noting the footmarks above and below can eliminate this.

D. Reading a stadia hair — Accidentally focusing on the upper or lower stadia hair when taking a reading

E. Recording notes

1. Writing figures in wrong columns

2. Arithmetic errors when checking

3. Transposing digits when recording

F. Touching tripod during reading process

1. Common to beginners to put a hand on a tripod leg when viewing the rod, then removing it when checking the level bubble

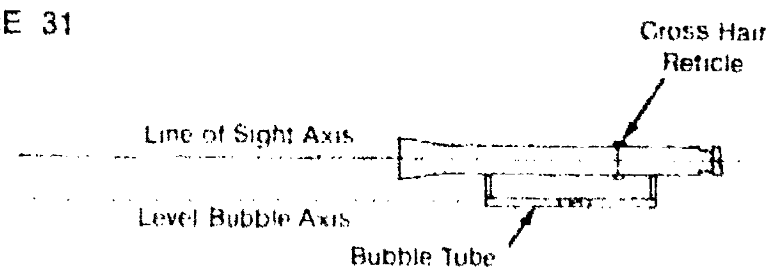
2. Keep both hands at the side or behind your back to help eliminate this problem.

3. Never straddle a tripod leg once the instrument is leveled.

XVI. **Minor field adjustments** (Peg test)

(NOTE: Minor field adjustments are used to check that the line of sight through the telescope is horizontal or parallel to the axis of the level bubble.)

FIGURE 31

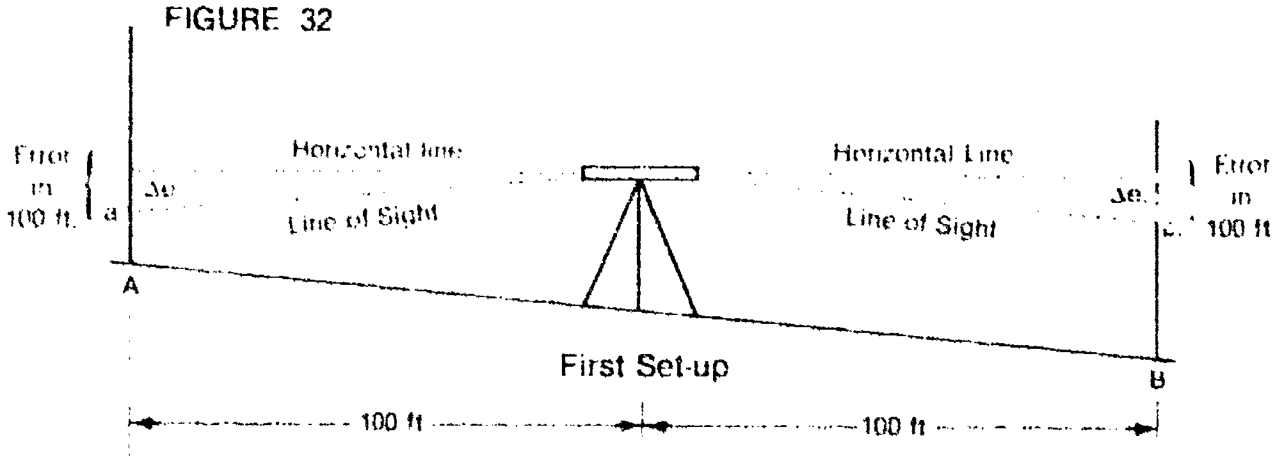


A. Place two stakes at a distance of 200 to 300 ft apart.

INFORMATION SHEET

B. Set the level up between the stakes at approximately the mid-way point. Rod readings are taken at both points and recorded (Figure 32)

FIGURE 32



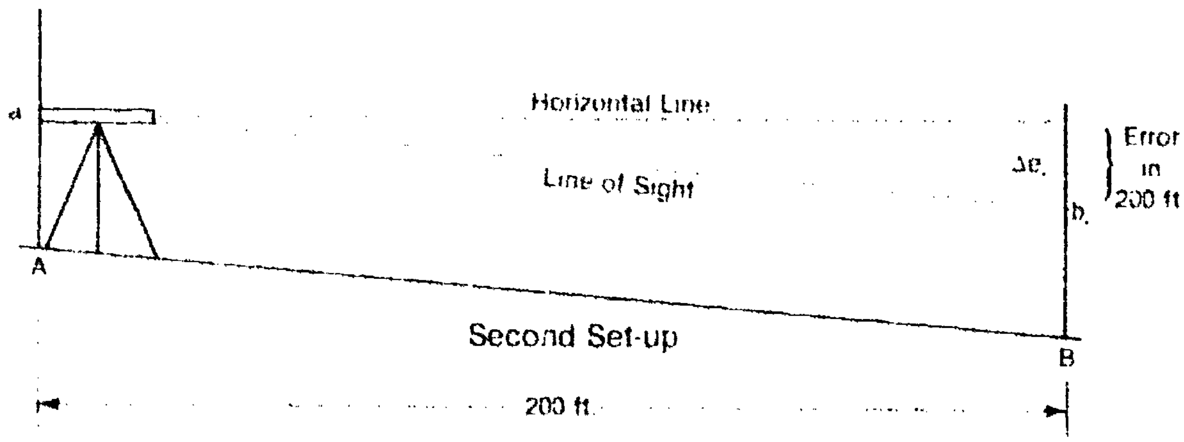
C. Move the level to one of the points (A) and set up so the eyepiece of the telescope just touches the level rod being held plumb over Point A.

(NOTE: Rather than setting up this close to Point A, the instrument can be set up a short distance from Point A (8-10 ft, so that an actual reading can be obtained at Point A rather than using a pencil as discussed later in "D".)

D. Take readings at both Points A and B and record.

(NOTE: The telescope can be viewed backwards when sighting Point A due to the close setup causing it impossible to focus on the rod normally, therefore reading a can be determined by moving a pencil point slowly up and down the rod See Figure 33.)

FIGURE 33

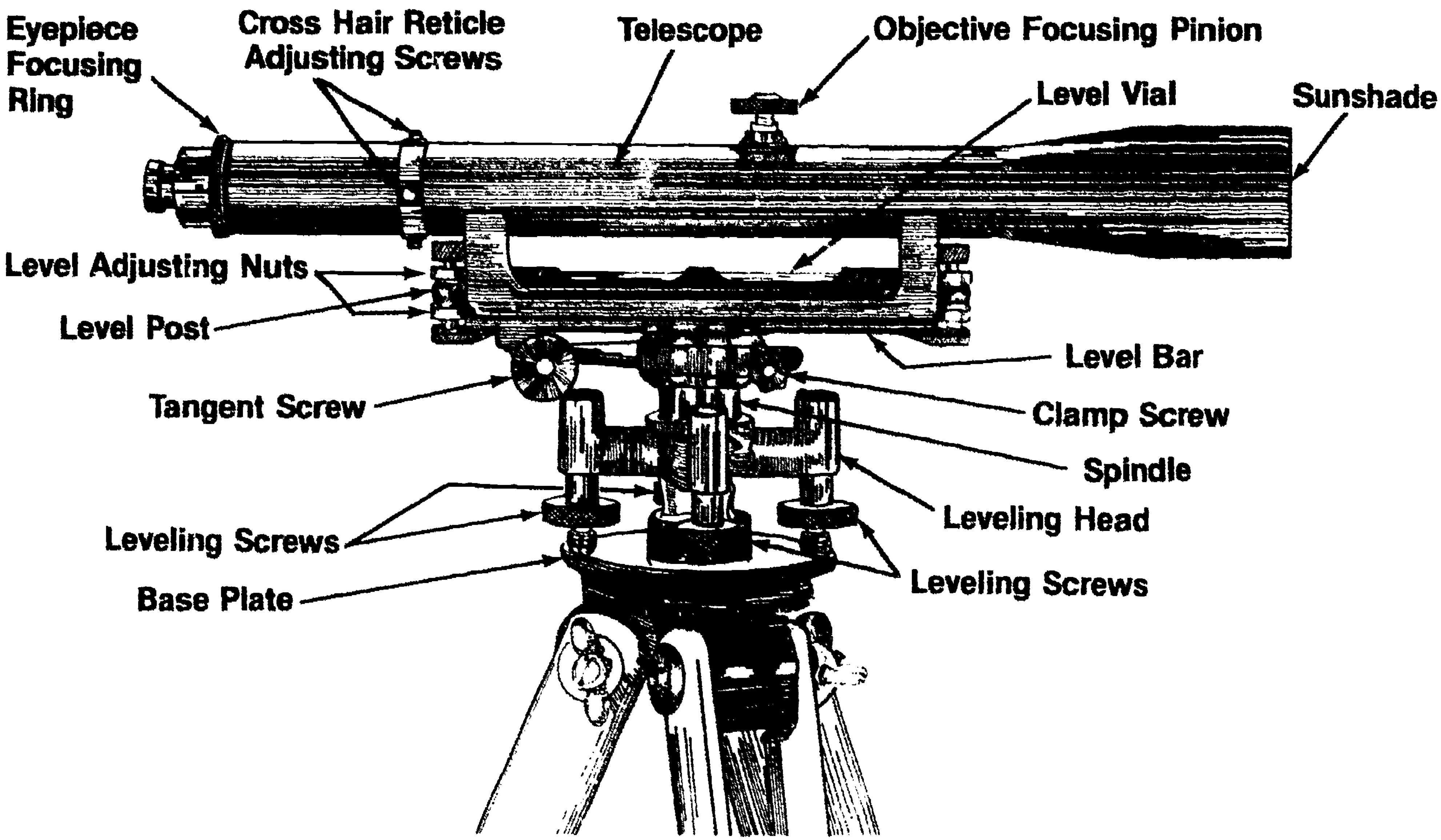


E. Determine the amount of error in the horizontal axis by subtracting the two original rod readings from each other and comparing it to the difference in the second set of rod readings.

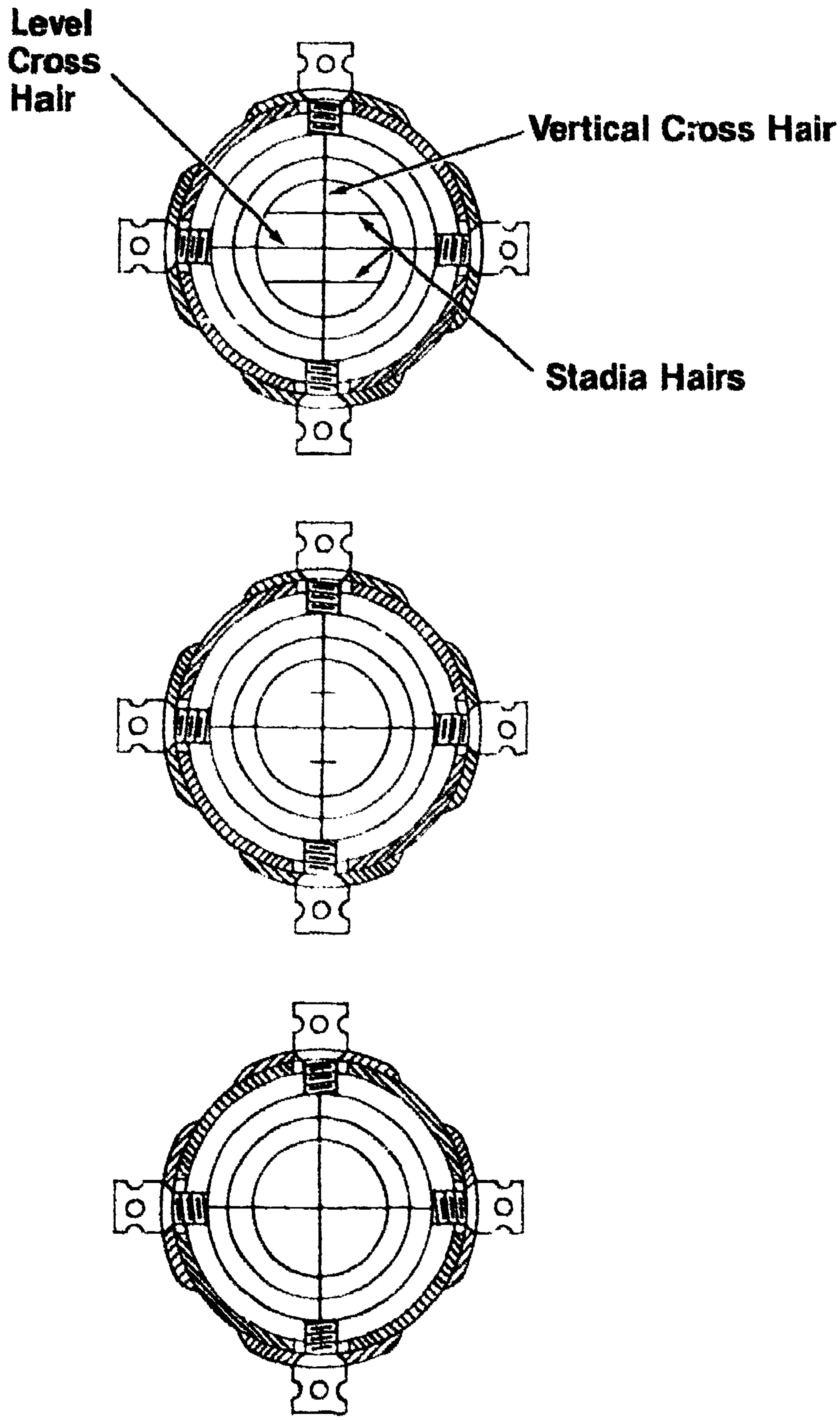
F. Eliminate the error by removing the adjusting screw cover, and if necessary adjust the capstan screws until the correct rod read intersects the cross hairs.

(NOTE: This procedure is quite simple and should become standard practice by any trained surveyor.)

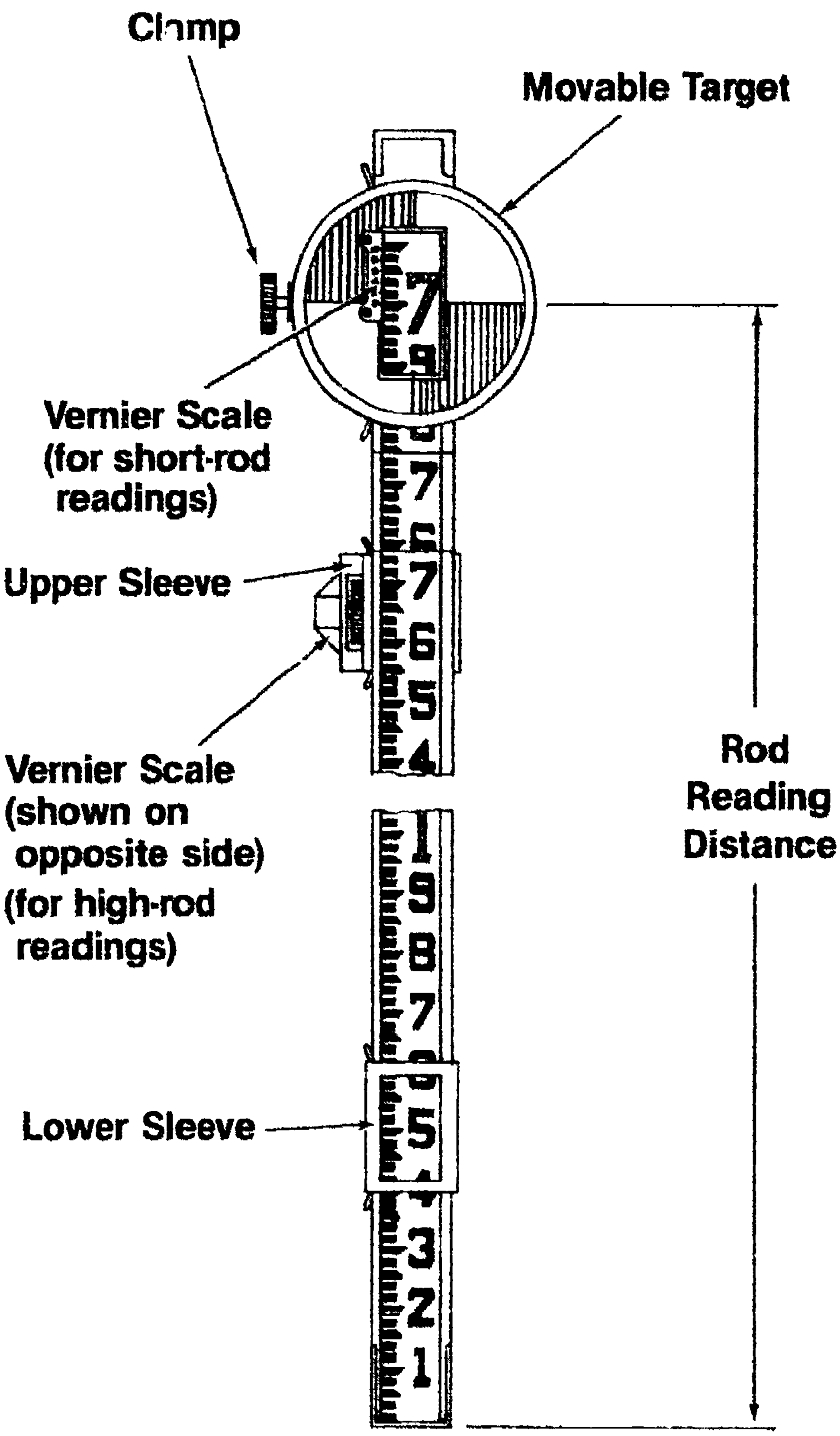
Parts of a Level



Cross Hair Arrangements

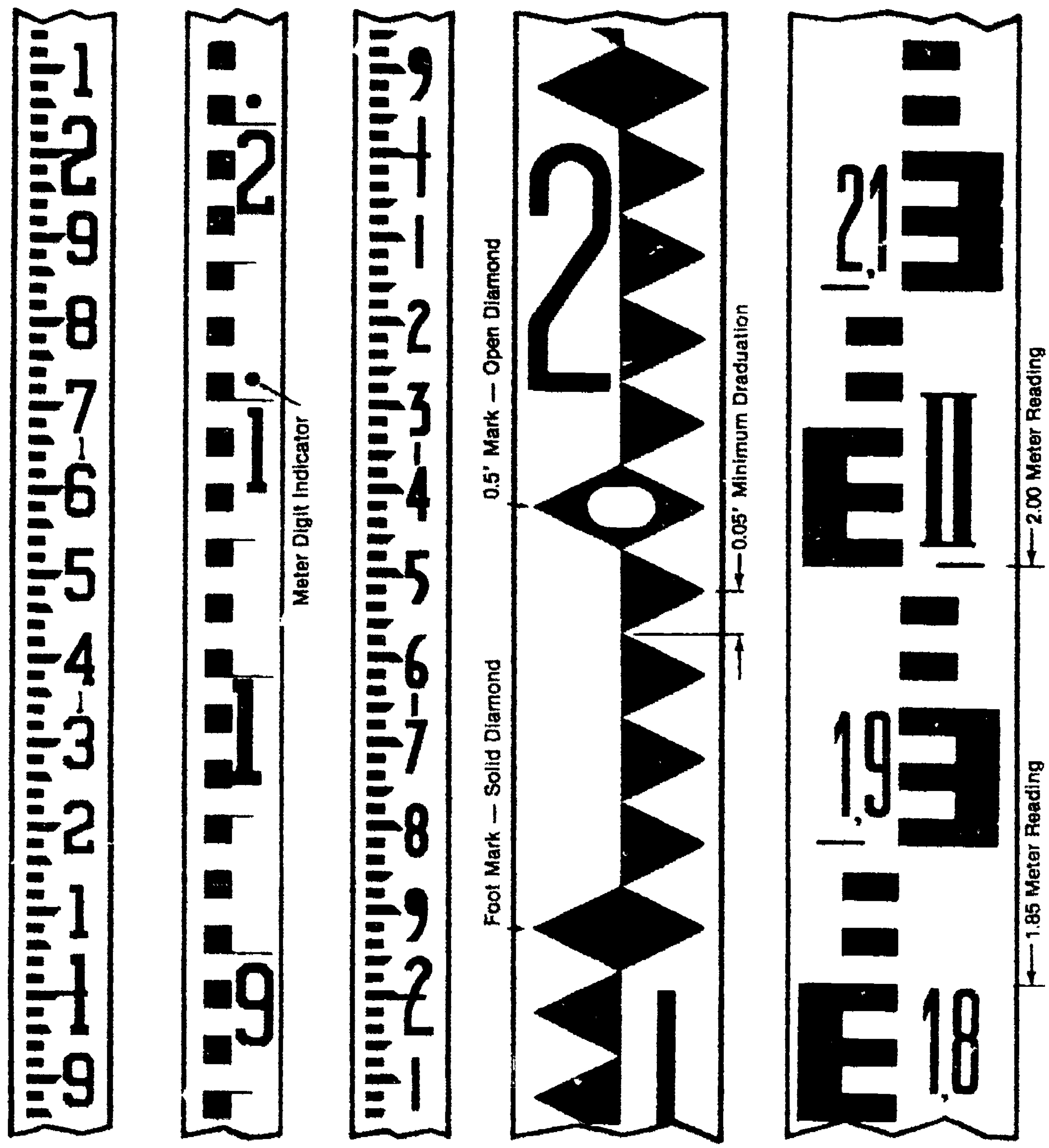


Rod with Target



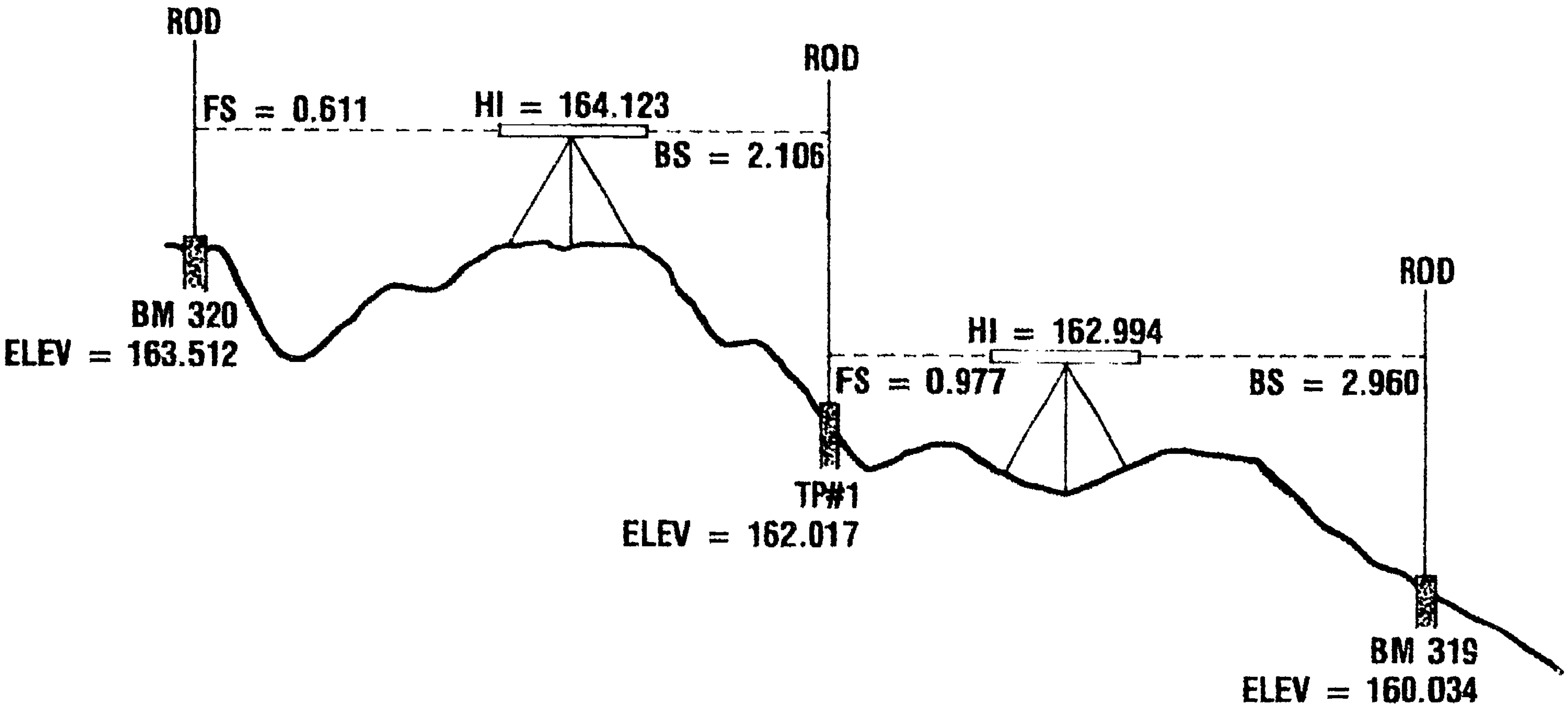
Front View
Philadelphia Rod

Rod Graduations



SK, Phila., & S.F.	Phila. & S.F.	Direct Elevation	Stadia	Stadia
(Feet, 10ths, 100ths)	(Meters, dm, cm)	(Feet, 10ths, 100ths)	(Feet, 10ths, 100ths)	(Meters, dm, cm)

Bench Circuit Sequence



Standard Note Keeping

BENCHMARK VERIFICATION
BM 319 to 320

STA	B.S. (+)	H.I.		F.S. (−)	ELEV.
BM 319	2.960	162.994			160.034
T.P. #1	2.106	164.123		0.977	162.017
BM 320				0.611	163.512
Σ	5.066			1.588	
ARITHMETIC CHECK					
	160.034	+ 5.066	− 1.588	=	163.512

JOB ANYTOWN, LEVEL #14 18°C CLOUDY
DATE APRIL 21, 1986 PAGE 28

DESCRIPTION
BRONZE PLATE SET IN --- ETC.
NAIL IN ROOT OF TREE
BRONZE PLATE SET IN --- ETC.

Differential Leveling

	DIFFERENTIAL		LEVELS		
STA	+ SIGHT	H.I.	− SIGHT	ELEV	DIST
BM 36				100.00	
	1.26	101.26			140
TP 1			9.38	91.88	140
	4.31	96.19			175
TP 2			10.93	85.26	175
	0.58	85.84			150
BM 108			2.76	83.08	150
	6.15		23.07		930
BM 108				83.08	
	7.23	90.31			165
TP 1			.78	89.53	165
	5.61	95.14			155
TP 2			1.52	93.62	155
	4.24	97.86			140
TP 3			.31	97.55	140
	4.23	101.78			165
BM 36			1.76	100.02	165
	21.31		4.37		1250
BM 36	TRUE	ELEV. =	1049.68 M.S.L.		
	ELEV. DIFF. AVG.		= −16.93		
			1032.75 M.S.L.		

YMCA CAMPGROUND | SW/4 SEC. 10 T19N R2E

BM 36 TO BM 108

BM 36 TOP OPERATING NUT OF FIRE HYDRANT NE. CORNER OF 54 St. & EASTERN

8-11-82
[illegible]
J. Wayne
M.T. Moore
D. [illegible]

BM 108 SW CORNER OF BACK PORCH CHISELED "X" IN CONCRETE

ROD SUMS

−23.07	+21.13
+ 6.15	− 4.37
−16.92	+16.94
	−16.92
loop closure	.02

PERMISSIBLE CLOSURE

$0.05\sqrt{M} = .05\sqrt{1250/5280}$

$= .03$

.02 < .03 CLOSURE OK

M.T. MOORE

Reciprocal Leveling

RECIPROCAL LEVELING

STA.	SIGHT		SIGHT	ELEV DIFF	ELEV
BM 36	0.72				1049.681
BM 109			10.618		
			10.621		
			10.616		
			10.619		
BM 109		AVG	10.619	-9.899	1039.782
BM 36	1.321				
	1.323				
	1.320				
	1.317				
	1.320	AVG			
			11.235	-9.915	1039.766
		MISCLOSURE		.016	
		MEAN		-9.907	
BM 109					1039.774

ACROSS BALL FIELDS

YMCA Camp Grounds

DESCRIPTION ON PAGE 10

11-2-87

Cloudy, Cap. $\frac{6\frac{1}{2}}{32}$

G. Johns N

J. Banks ⊼

J. Waldo ▯

BM 109 ½" IRON PIN
IN 12" Ø CONCRETE NE
PROPERTY CORNER

Profile Leveling

PROFILE LEVELS

STA	SIGHT	H.I.	SIGHT	INT SIGHT	ELEV
BM 11	0.56	955.37			954.81
0+00				1.42	953.95
+15				1.65	953.72
+35				0.9	954.5
TP1	.58	955.04	0.91		954.46
1+00				.7	954.3
2+00				1.8	953.2
3+00				4.6	950.4
+43				5.3	949.7
+51				11.8	943.2
+65				6.1	948.9
TP 2	12.36	961.42	5.98		949.06
4+00				11.1	950.3
5+00				9.9	951.5
6+00				7.8	953.6
7+00				5.1	956.3
TP 3	4.36	964.05	1.73		959.69
8+00				5.2	958.9
+22				5.93	958.12
+22.1				6.43	957.62
+35.6				6.18	957.87
+49.1				6.42	957.63
+49.2				5.91	958.14
BM 58			5.43		958.62
Σ	17.86		14.05		

BM 11 TO BM 58

BM 11 ODOT BRASS MONUMENT SE. CORNER SH51 & JARDOT

JARDOT ST FROM 6th TO VIRGINIA

6-18-84

Warm & Clear 85°

R. Gom

B. Hagen

D. Hasten

℄ 6th AVE

N. GUTTER

N. R/W OF 6th

℄ OF DRAINAGE

S. R/W OF VIRGINIA

TOP OF CURB VIRGINIA

S. GUTTER OF VIRGINIA

℄ VIRGINIA

N. GUTTER VIRGINIA

N. TOP OF CURB VIRGINIA

BM 58 60d SPIKE IN OG&E P.P. 40' N.W. OF ℄ OF PROFILE

Cross-Section Leveling

STA	B.S.	H.I.	I.S.	F.S.	ELEV
CROSS-SECTIONS FOR PROPOSED EXTENSION OF JARDOT ST.					
BM 11	7.22	962.03			954.81
0+00					
+15					
+35					
1+00					
TP 1	5.31	955.16		12.18	949.85
2+00					

K. Reeder Notes T. Lott Rod
C. Johnson ⊼ H. Gibson Tape
July 20, 1984 Partly Cloudy Level #6 Page 16

ODOT Brass Monument SE Corner 5th St & Jardot

LEFT ℄ RIGHT

100 75 50 38 0 38 50 75 100

100 75 50 38 0 38 50 75 100

100 75 50 25 25 50 75 100

100 81 69 46 35 12 0 18 41 58 72 94 100

100 75 40 18 0 15 35 75 100

Cross-Section Leveling
(Continued)

CROSS-SECTIONS FOR PROPOSED EXTENSION OF JARDOT ST

STA	B.S.	H.I.	I.S.	F.S.	ELEV
2+00					
TP1	5.31	955.16		12.18	949.85
1+00					
+35					
+15					
0+00					
BM 11	7.22	962.03			954.81

K Reeder Notes　　T Lott Rod
C. Johnson ⊼　　H. Gibson Tape　Level #6
July 20, 1984　　95° Partly Cloudy

	LEFT						℄					RIGHT	
2+00	$\frac{11^{2}}{100}$	$\frac{9^{5}}{75}$	$\frac{8^{8}}{40}$	$\frac{1^{9}}{18}$			$\frac{2^{8}}{0}$	$\frac{2^{3}}{15}$	$\frac{10^{[illegible]}}{33}$	$\frac{12^{[illegible]}}{75}$	$\frac{14^{2}}{100}$		
1+00	$\frac{18^{[illegible]}}{100}$	$\frac{16^{[illegible]}}{81}$	$\frac{12^{[illegible]}}{69}$	$\frac{10^{[illegible]}}{46}$	$\frac{9^{8}}{33}$	$\frac{7^{[illegible]}}{12}$	$\frac{[illegible]}{0}$	$\frac{7^{[illegible]}}{18}$	$\frac{8^{2}}{41}$	$\frac{9^{[illegible]}}{58}$	$\frac{11^{[illegible]}}{72}$	$\frac{12^{[illegible]}}{94}$	$\frac{22^{[illegible]}}{100}$
+35	$\frac{7^{[illegible]}}{100}$	$\frac{7^{2}}{75}$	$\frac{7^{1}}{50}$	$\frac{7^{[illegible]}}{25}$			$\frac{7^{5}}{0}$	$\frac{6^{[illegible]}}{25}$	$\frac{6^{9}}{50}$	$\frac{6^{[illegible]}}{75}$	$\frac{6^{[illegible]}}{100}$		
+15	$\frac{10^{[illegible]}}{100}$	$\frac{9^{[illegible]}}{75}$	$\frac{9^{[illegible]}}{50}$	$\frac{9^{2}}{38}$			$\frac{8^{[illegible]}}{0}$	$\frac{7^{7}}{38}$	$\frac{7^{4}}{50}$	$\frac{6^{[illegible]}}{75}$	$\frac{6^{[illegible]}}{100}$		
0+00	$\frac{10^{4}}{100}$	$\frac{9^{[illegible]}}{75}$	$\frac{9^{1}}{50}$	$\frac{8^{[illegible]}}{38}$			$\frac{8^{1}}{0}$	$\frac{7^{[illegible]}}{38}$	$\frac{7^{1}}{50}$	$\frac{6^{6}}{75}$	$\frac{6^{[illegible]}}{100}$		

ODOT Brass Monument SE Corner 4H51

℄ Jardot

Borrow Pit Leveling

BORROW – PIT LEVELING					
POINT	+	H.I.	–	ELEV	CUT
BM 22	6.32	966.32		960.00	
A,0			8.2	958.1	3.1
B,0			8.4	957.9	2.9
C,0			8.1	958.2	3.2
D,0			8.6	957.7	2.7
E,0			9.2	957.1	2.1
A,1			8.8	957.5	2.5
B,1			8.5	957.8	2.8
C,1			8.1	958.2	3.2
D,1			7.8	958.5	3.5
E,1			8.0	958.3	3.3
A,2			7.7	958.6	3.6
B,2			7.4	958.9	3.9
C,2			7.6	958.7	3.7
D,2			7.2	959.1	4.1
E,2			7.5	958.8	3.8
A,3			7.9	958.4	3.4
B,3			8.3	958.0	3.0
C,3			8.6	957.7	2.7
D,3			8.8	957.5	2.5
E,3			8.7	957.6	2.6

DOTTER FARM E/2 NW/4 SEC. 26/19N R2E

X N

"X" IN S.E. CORNER OF BARN FOUNDATION

3.1 Payne Co. OK

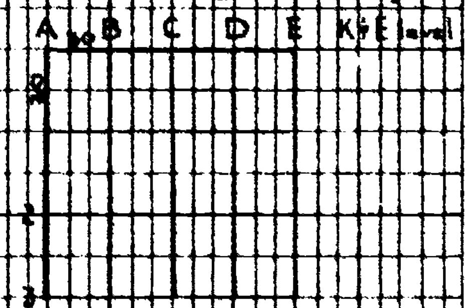
5.8 May 8, 1986

6.4 P. Shoemake

5.4 J. Wesley

2.1 B. Gambill

5.0



11.2

12.8

14.0

6.6

7.2

15.6

14.8

16.4 GRADE ELEVATION = 955.0

7.6

3.4 VOLUME = area of base × $\frac{h_1 + 2h_2 + 3h_3 + 4h_4}{4}$

6.0

5.4

5.0

2.6

156.4 ÷ 4

39.1 × 30 × 30 ÷ 27 = 1303 Cubic Yards

Error Classifications

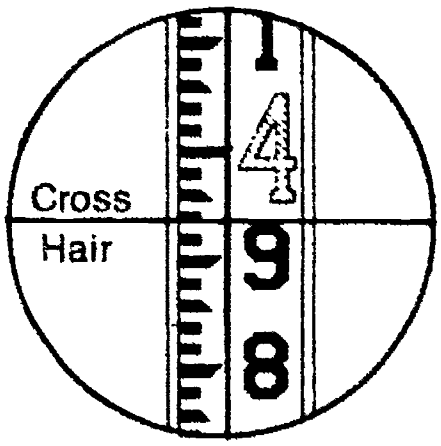
Source	Type	Cause	Procedure to Eliminate or Reduce
Instrumental	Systematic	Line of sight not parallel to axis of level tube	Adjust instrument; balance sum of backsight and foresight distances
		Rod not standard length (throughout length)	Standardize rod and apply corrections, same as for tape
Personal	Random	Parallax	Focus carefully
		Bubble not centered at instant of sighting	Check bubble before making each sight
		Rod not held plumb	Wave the rod, or use rod level
		Faulty reading of rod or setting of target	Check each reading before recording; for self-reading rod use fairly short sights
		Faulty turning points	Choose definite and stable points
Natural	Random	Temperature	Shield level from sun
	Systematic	Earth's curvature	Balance *each* backsight and foresight distance; or apply computed correction
	Random	Variations in atmospheric refraction	Same as for Earth's curvature; also take short sights, well above ground, and take backsight and foresight readings in quick succession
	Systematic	Settlement of tripod or turning points	Choose stable locations; take backsight and foresight readings in quick succession preferably alternating order of sights

VERTICAL MEASUREMENTS
UNIT IV

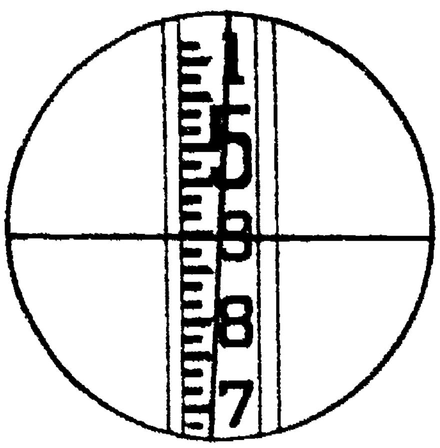
ASSIGNMENT SHEET #1 — READ VARIOUS TYPES OF LEVEL RODS

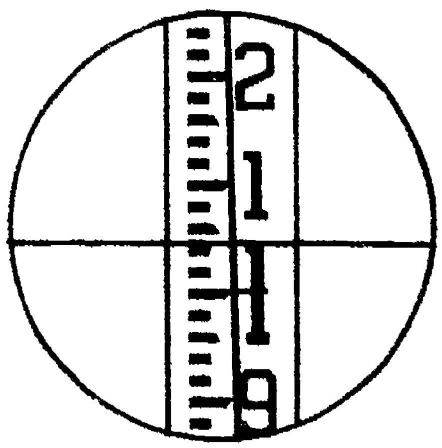
Directions: Accurately read the rod-readings that appear at the center cross-hair on each of the problems. Record your answers in the blanks provided.

Example:



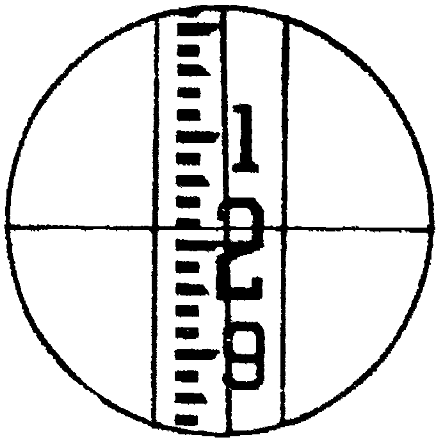
3.93

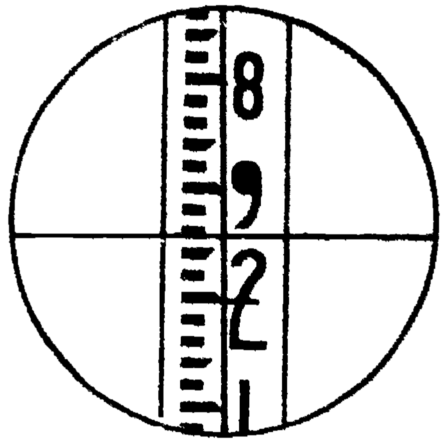




1. ______________________ 2. ______________________

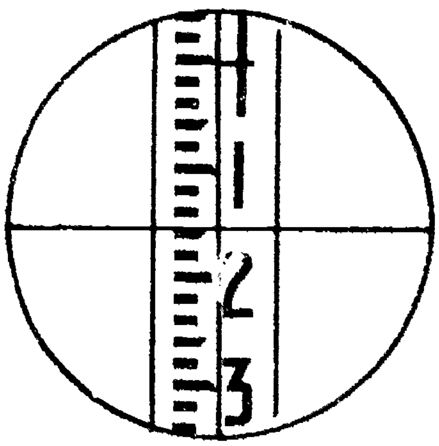
ASSIGNMENT SHEET #1

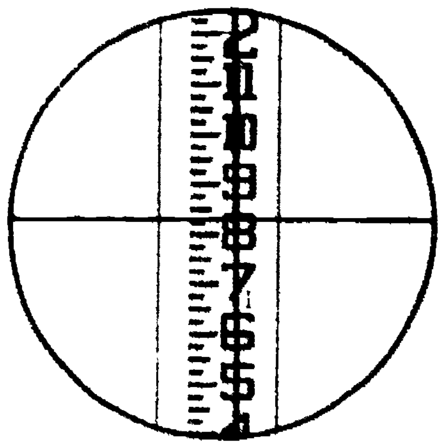




3. ____________________

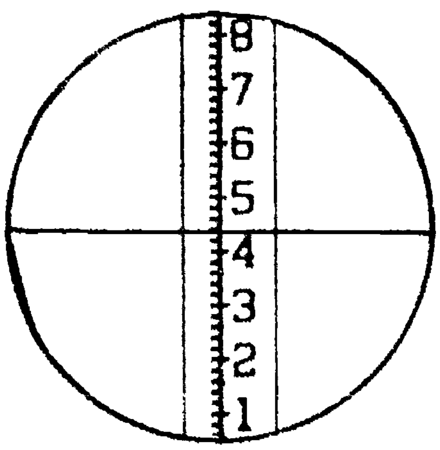
4. ____________________

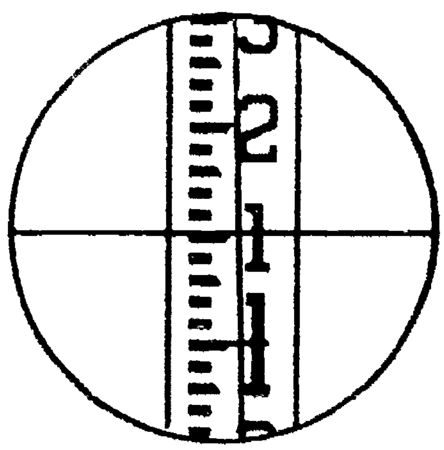




5. ____________________

6. ____________________

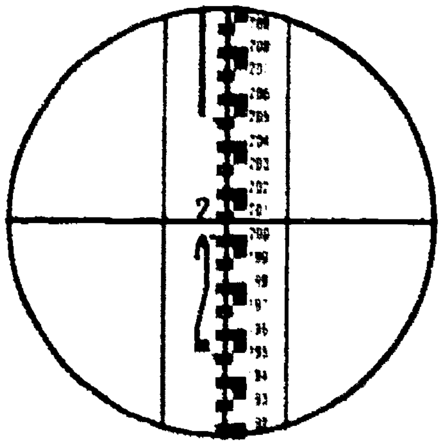


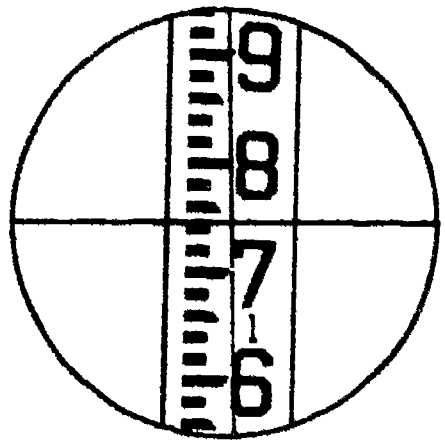


7. ____________________

8. ____________________

ASSIGNMENT SHEET #1





9. ______________________

10. ______________________

VERTICAL MEASUREMENTS
UNIT IV

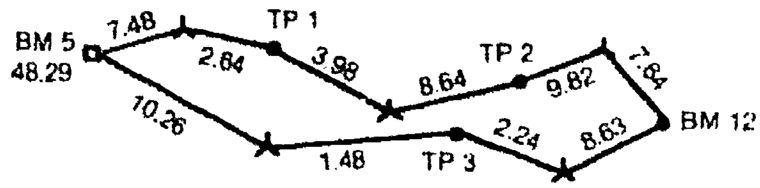
ASSIGNMENT SHEET #2 — ENTER FIELD DATA IN STANDARD FIELD BOOK FORM

Directions: From each of the "plan views" of level circuit runs, complete the proper field notes for each problem. Enter all survey data on the proper columns provided in the standard field note forms.

(NOTE: Along each line is a rod reading that resulted from that sight. The numbering of the T.P.'s indicates the direction of progress.)

Show the arithmetic check on each problem and record the circuit error on the line provided.

Example:



LEITZ BZ · Δ

BENCH CIRCUIT OF:

STA	BS	HI	FS	ELEV	
BM 5	7.48	55.77			48.29
TP 1	3.98	57.11	2.64	53.13	
TP 2	9.82	58.29	8.64	48.47	
BM 12	8.63	59.28	7.64	50.65	
TP 3	1.48	58.52	2.24	57.04	
BM 5			10.26	48.26	48.29
				.03 LOW	
	31.39		31.42		

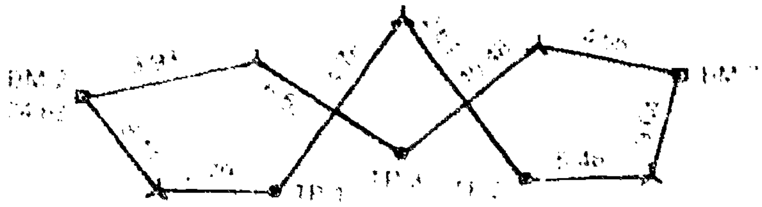
Bill T.
Ted C.
John R.

6/16/84
Sunny
Hot 89°

Circuit error .03

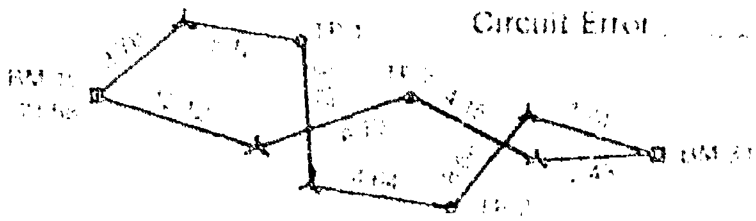
ASSIGNMENT SHEET #2

Problem 1:



Circuit Error ______

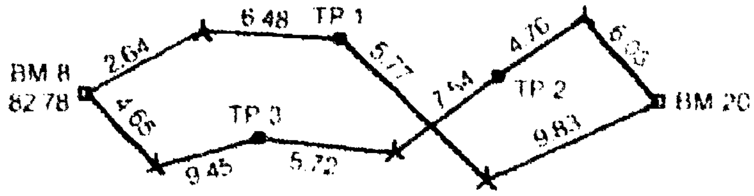
Problem 2:



Circuit Error ______

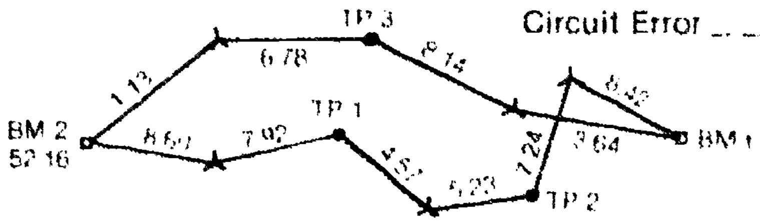
ASSIGNMENT SHEET #2

Problem 3:



Circuit Error ______

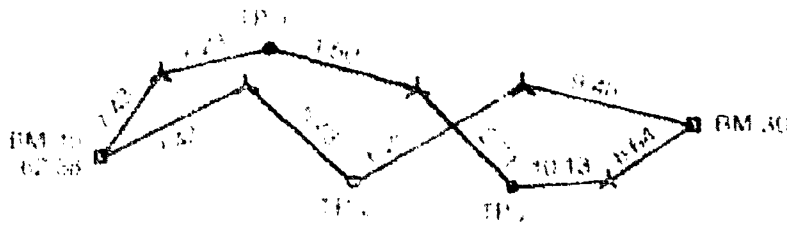
Problem 4:



Circuit Error ______

ASSIGNMENT SHEET #2

Problem 5.



Circuit Error ____________

VERTICAL MEASUREMENTS
UNIT IV

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 4.89
2. 1.04
3. 2.01
4. 1.94
5. 1.15
6. 1'8¾"
7. 1.43
8. 1.10
9. 2.015 (m)
10. 1.74

Assignment Sheet #2

Problem 1

STA	BS	HI	FS	ELEV
BM 2				74.63
TP 1	8.11	82.74	2.79	79.95
TP 2	4.78	84.73	2.61	82.12
BM 7	5.48	87.6	9.64	77.96
TP 3	4.55	82.51	10.48	72.03
BM 2	6.53	78.56	3.93	74.63
	29.45		29.45	

Circuit Error . 0

ANSWERS TO ASSIGNMENT SHEETS

Problem 2

STA	BS	HI	FS	ELEV
BM 15				71.58
TP 1	3.78	75.36	8.12	67.24
TP 2	9.17	76.41	4.64	71.77
BM 3	8.68	80.45	1.74	78.71
TP 3	2.43	81.4	4.15	76.99
BM 15	6.73	83.72	12.12	76.60
	30.79		30.77	

Circuit Error $\pm.02$

Problem 3

STA	BS	HI	FS	ELEV
BM 8				82.78
TP 1	2.64	85.42	6.48	78.94
BM 20	5.77	84.71	9.83	74.88
TP 2	6.03	80.91	4.76	76.15
TP 3	7.54	83.69	4.65	82.77
	31.43		31.44	

Circuit Error $-.01$

ANSWERS TO ASSIGNMENT SHEETS

Problem 4

STA	BS	HI	FS	ELEV
BM 2				52.16
TP 1	8.60	60.76	7.92	52.84
TP 2	4.57	57.41	5.23	52.18
BM 6	7.24	59.42	8.42	51.00
TP 3	3.64	54.64	8.14	46.50
BM 2	6.78	53.28	1.13	52.15
	30.83		30.84	

Circuit Error -.01

Problem 5

STA	BS	HI	FS	ELEV
BM 10				62.38
TP 1	7.43	69.81	7.23	62.58
TP 2	1.50	64.08	2.71	61.37
BM 30	10.13	71.50	8.64	62.86
TP 3	9.48	72.34	6.95	65.39
BM 10	5.43	70.82	8.43	62.39
	33.97		33.96	

Circuit Error +.01

VERTICAL MEASUREMENTS
UNIT IV

JOB SHEET #1 — MAKE MINOR FIELD ADJUSTMENTS TO LEVELING INSTRUMENTS (PEG TEST)

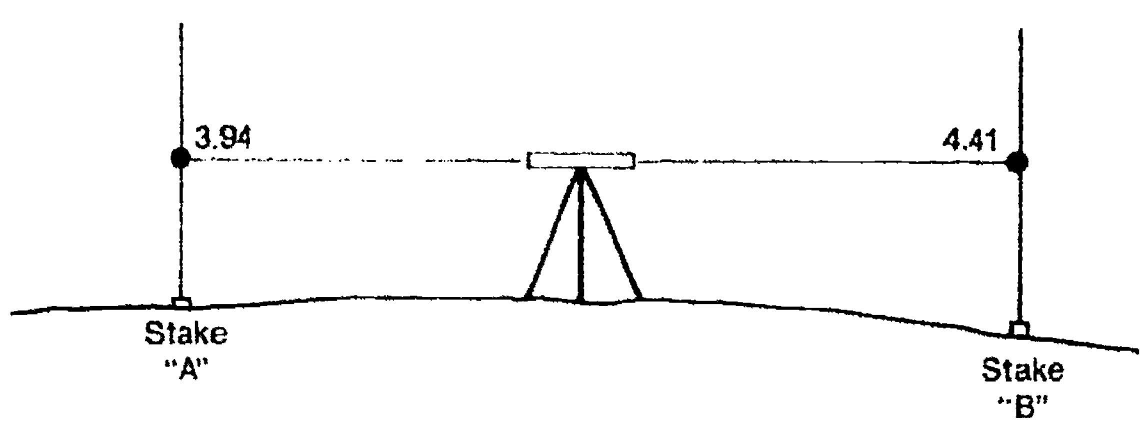
A. Tools and materials

1. Surveying level
2. Tripod
3. Level rod
4. 100 ft tape
5. Hammer
6. Wooden stakes, 2
7. Field book
8. Pencil

B. Procedure

1. Place two stakes 200′ to 300′ apart on level ground.
2. Secure the level to the tripod.
3. Set up the instrument at approximately the mid-way point between the stakes.
4. Record each of the readings in the field book for each of the two stakes. (Figure 1)

FIGURE 1



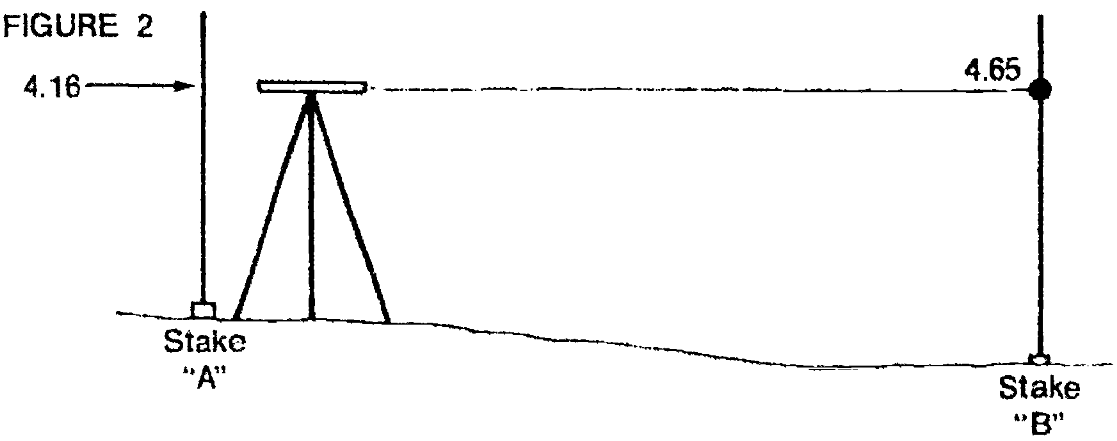
JOB SHEET #1

5. Move the instrument to Point A and set up so the eyepiece almost touches the rod when held on Point A.

   (NOTE: The instrument can be set up 8-10' away from Point A so that it can be focused and a reading obtained.)

6. Read the rod reading at Point A by slowly moving a pencil along the graduations while viewing the rod backwards through the telescope. Rotate the telescope toward Point B and read the center hair reading. Record both readings. (Figure 2)

FIGURE 2



7. Subtract the first two readings that were obtained while positioned in the middle from each other to determine the difference in elevation.

   Example:
   4.41 Reading @ Point B
   – 3.94 Reading @ Point A
   .47 Difference in elevation

8. Sub'ract the second set of readings from each other to determine the difference while sighting at unequal distances.

   Example:
   4.65 Reading @ Point B
   – 4.16 Reading @ Point A
   .49 Difference in elevation

   (NOTE: If the difference is the same in both set ups, the instrument is in good adjustment; if not, the difference in the two sets of readings is equal to the instrument error. This error can be adjusted out by a slight adjustment to the cross hairs.)

9. Remove the adjusting screw cover from the eyepiece of the level using the 4 capstan screws beneath the ring.

10. Slowly adjust the horizontal cross hair until the desired reading is intersected by the cross hairs.

    (NOTE: This maneuver requires adjusting the top and bottom capstan screws. **Always** loosen the opposite one before applying tension to the other screw. Your instructor should be present during this process when making your first attempt to adjust an instrument.)

JOB SHEET #1

11. Once the desired reading is set into the instrument, the cross hair ring can be replaced.

    (NOTE: The last adjustment to any capstan screw should be one of a tightening nature.)

12. Put the instrument away into its storage case.

13. Pick up all equipment.

14. Store equipment in proper locations previously assigned by the the instructor.

VERTICAL MEASUREMENTS
UNIT IV

JOB SHEET #2 — PERFORM A COMPLETED LEVEL CIRCUIT USING THE DIFFERENTIAL LEVELING PROCESS

A. Tools and materials

1. Instrument level
2. Wooden tripod
3. Level rod
4. Field book
5. Pencil
6. Paint or keel

B. Procedure

(NOTE: A bench mark to begin this circuit will be provided by the instructor, along with the description of the point for which an elevation is to be established.)

1. Remove instrument from its case and fasten to tripod.
2. Set up instrument approximately 150-200 ft from the given bench mark.
3. Level up instrument as previously outlined.
4. Focus instrument at beginning bench mark and determine center hair reading.
5. Record rod reading in appropriate column of the field book.

   (NOTE: This first reading is a backsight towards a known elevation, thus it should be located in the second column of the field notes. See Transparency 6.)

6. Turn instrument scope towards the next point, or turning point.

   (NOTE: Instrument person should signal that this will be a turning point, therefore indicating to the rod person to find a permanent point to "turn" on.)

7. Focus the objective lens on the level rod and determine the center hair reading.
8. Record the rod reading in the appropriate column of the field book.

   (NOTE: This rod reading is a foresight toward a turning point, and should be located in the fifth column of the field notes. See Transparency 6.)

JOB SHEET #2

9. Motion to the rod person that this is a turning point by raising one arm and slowly rotating it in a circular motion.

10. Pick up the instrument by the tripod legs and move on up the circuit toward the point of which a bench mark is required to set.

11. Locate the instrument approximately 150-200 ft past the turning point previously set.

12. Level up instrument.

13. Focus cross hairs on level rod while positioned on previous turning point.

14. Record rod reading (backsight) in appropriate column of field book. See Transparency 6.

15. Signal rod person that you have completed that rod shot.

16. Rotate instrument scope toward next turning point to be established.

17. Focus cross hairs on level rod now positioned on this point.

18. Record rod reading (foresight) in the appropriate column of the field book.

19. Signal rod person that this shot is a turning point.

20. Pick up instrument, and proceed up the circuit toward bench mark to be established.

21. Repeat the process each time until a foresight can be obtained on the desired bench mark position.

22. Once the foresight is taken, pick up instrument, reposition, and level it. Record a backsight on the same bench mark that was just shot.

23. Next, continue the total leveling procedure back to the original starting bench mark recording all backsights and foresights as previously described, ending with a foresight on the original bench mark.

24. Store all equipment in proper places.

25. Reduce field notes as previously done on Assignment Sheet #2.

26. Turn in completed "Bench Mark Circuit" field notes to instructor.

VERTICAL MEASUREMENTS
UNIT IV

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. The vertical distance from a datum, usually the NGVD, to a point or object

_____b. A surveyed line that has been stationed at equal intervals, and elevations of each interval point have been obtained

_____c. Any level surface in which elevations are referred to, a referencing system of point elevations

_____d. The average height of the sea's surface for all stages of the tides over a 19 year period. Usually taken at hourly intervals from 26 stations

_____e. A line in a level surface, therefore a curved line (parallel to the earth's curvature)

_____f. A stationary, relatively permanent object, natural or artificial, having a marked point whose elevation above or below an adopted datum is known or assumed

_____g. A stationary point used to temporarily transfer the position of the instrument without losing its reference elevation

_____h. The exact position of the cross hairs of a leveling instrument above a known point in a specified datum

_____i. A line that follows the direction of gravity as indicated by a plumb line

_____j. A line perpendicular to the direction of gravity or parallel to a horizontal plane

_____k. The nationwide reference surface for elevations of the United States. It was obtained by a least squares adjustment done in 1929. A readjustment program should be completed in 1987

_____l. A rod reading that is taken on an unknown point or object to obtain its elevation

1. Backsight
2. Bench mark
3. Cross section
4. Elevation
5. Foresight
6. Height of instrument
7. Horizontal line
8. Level line
9. Mean sea level
10. National geodetic vertical datum
11. Parallax
12. Profile

TEST

_____m. A rod reading that is taken from a known point of elevation to obtain an instrument height

_____n. The apparent displacement or the difference in apparent direction of an object as seen from two different points not on a straight line with the object

_____o. A relatively stationary object that can be found by description having an established elevation on it, such as a fire hydrant

_____p. A series of ground elevations taken at recorded offsets wherever existing ground changes grade, usually taken at 90° offset to the baseline or centerline of the project

13. Temporary bench mark
14. Turning point
15. Vertical datum
16. Vertical line

2. List three uses of leveling results.

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. Complete the following statements concerning the theory of leveling procedures by filling in the blanks with the correct words.

   a. The surveyor is able to sight through a telescope at a graduated rod and determine a measurement reading at a point where the ____________ in the telescope intersect the rod.

   b. Leveling has two purposes. Name one.

   ____

4. Distinguish between curvature and refraction by placing a "C" next to the formula for curvature and an "R" next to the formula for refraction. Some of the formulas below should be left blank because they are not formulas for curvature or refraction.

   _____a. 7C

   _____b. 0.14C

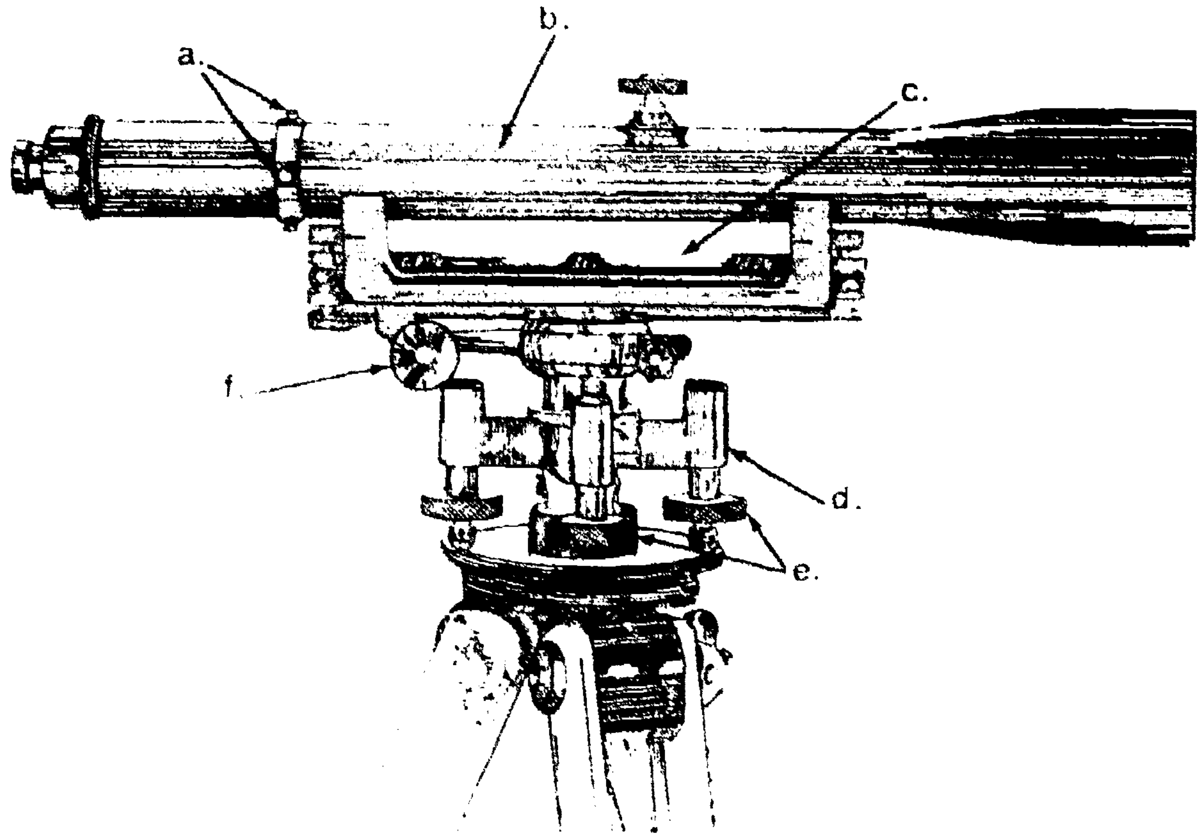
   _____c. $\frac{KA^2}{R}$

   _____d. $\frac{KA^2}{2R}$

   _____e. 0.07C

TEST

5. Identify the major parts of a level as shown in the dumpy level below. Choose your answers from the following list and place them in the appropriate blanks (not all of the following are needed): Base plate, level bar, level post, level vial, tangent screw, cross hair reticle adjusting screws, leveling screws, leveling head, telescope, eyepiece focusing ring.



a. ______________________ d. ______________________

b. ______________________ e. ______________________

c. ______________________ f. ______________________

6. Complete the following statements concerning adjusting parts of a level by circling the correct words.

   a. Telescope

      1) The eyepiece lenses focus the (**objective lenses, cross hairs**) which are located in the telescope at the principal focus plane.

      2) The focusing lens can be adjusted so that the images of varying distances can be brought into focus in the plane of the (**reticle, eyepiece**).

      3) The cross hairs can be thin (**threads, wires**) attached to a cross hair ring, or as in most modern equipment they are actual lines etched on a circular glass plate enclosed by a cross hair ring.

      4) The cross hair ring (slightly smaller than the diameter of the telescope tube) is held in place by 4 capstan (**bolts, screws**) that can be turned to adjust the cross hairs up or down and left or right if the instrument is found to be slightly out of adjustment.

TEST

b. Level vial

1) Is a glass tube sealed at **(one end, both ends)** that contains a sensitive liquid such as alcohol and a small air bubble within the tube.

2) The tube is graduated with uniform, etched markings generally spaced at **(2mm, 2 inches)** apart used to accurately determine the bubbles position.

3) The "axis" of a level vial is an imaginary longitudinal line tangent to the upper inside surface at its midpoint. Therefore, when the bubble is **(to the left of, centered in, to the right of)** its run, the axis should be a horizontal line.

4) The sensitivity of a level vial is directly related to the **(length, curvature)** of the glass tube used.

c. Leveling head

1) In the case of the dumpy level, **(three, four)** leveling foot screws are utilized to set the telescope level.

2) The screws surround the center bearing of the instrument and are used to **(tilt the telescope, turn the telescope left or right)** using the center bearing as a pivot point.

7. Match types of leveling equipment on the right with the correct characteristics and uses.

_____a. 1) Employs a gravity reference prism or mirror compensator to automatically orient the line of sight
2) Can be quickly leveled using a circular spirit level
3) Once the bubble is approximately leveled, the compensator will take over and maintain a horizontal line of sight, even if the actual telescope is slightly tilted.
4) Extremely popular due to the ease in setting up and the precision that can be obtained with their use

_____b. 1) Has a non-fixed telescope that rests in Y-shaped supports
2) Curved clips fasten the telescope in place.
3) Is now almost obsolete.

_____c. 1) Several types are available with either fixed or adjustable legs.
2) Leg extensions are available when it becomes necessary to set the instrument up high due to cornfields, brush, or other obstructions.

1. Hand level
2. Wye level
3. Dumpy level
4. Tilting level
5. Self-leveling or automatic level
6. Tripod

TEST

_____ d. 1) Has a telescope firmly attached and parallel to the level bar.

2) The level vial, attached to the level bar, remains in the same vertical plane as the telescope at all times

3) Was at one time used extensively on all engineering works, but has since been replaced in many engineering capacities by more sophisticated, modern types of leveling instruments.

_____ e. 1) Used for low-precision work and for making various rough checks to level work

2) Consists of a brass tube having a plain glass objective lens and peepsight eyepiece

3) A small level bubble mounted above a slot in the tube is viewed through the eyepiece by means of a prism or 45° mirror. A horizontal line extends across the tube.

4) Is normally held in one hand and leveled by raising or lowering the objective end until the bubble is level.

_____ f. 1) Is used for more precise work and for many general purposes.

2) A bull's eye level (circular spirit level) is utilized for quick approximate leveling.

3) Exact leveling is accomplished by adjusting a tilting screw to tip the telescope about a fulcrum at the vertical axis of the instrument, without changing the height of the instrument.

4) This tilting feature increases accuracy and saves time since only one screw needs to be adjusted to obtain a horizontal line of sight.

8. Complete the following statements concerning types of level rods by circling the correct words.

a. There are **(two, four)** main classes of level rods.

b. **(Adjusting, Self-reading)** rods are read by the instrument operator while sighting through the telescope and noting the apparent intersection of the cross-hairs on the rod. This is the most common type.

c. Target rods have a movable target that is set by the **(rod person, instrument operator)** at the position indicated by signals from the **(rod person, instrument operator)**.

TEST

d. **(One, Two)** -piece rods are used for more precise work, with an "invar" strip with graduations held in place under temperature-compensating spring tension.

e. Rod graduations are accurately painted with alternate black and white spaces 0.01 ft wide. Tenths are designated by black figures and all foot marks by **(green, red)** numbers, all straddling the proper graduation.

f. Most standard level rods can be read accurately with a level at distances up to **(100, 250)** ft.

g. **(Rod levels, Plumb bobs)** can be used to ensure that the rod is being held plumb when being observed.

9. Complete the following statements concerning the proper procedure for setting up a leveling instrument by circling the correct words.

a. If the instrument must be set up on hard surfaces such as asphalt or concrete, the tripod legs should be **(spread out, pushed in)**

b. When setting up on soft surfaces, the tripod is first set up so that the tripod head, or top, is nearly horizontal, and then the legs are **(set up on top of the surface, firmly pushed into the earth)**

c. On hills or sloping ground it is customary to place **(one leg, two legs)** uphill and **(one leg, two legs)** downhill; the instrument person stands facing uphill while setting up the instrument.

d. If a four-screw level is being used, the correct procedure for leveling the vial is to place the telescope parallel to two opposite leveling screws and adjust **(the left screw first, both screws simultaneously, the right screw first)** until the bubble is centered. Then rotate the telescope 180° over the two untouched screws and repeat the procedure. This process may need to be repeated again for fine adjustments.

e. When using a three-screw level instrument, any of the leveling screws can be manipulated at one time independently of the others, although most experienced surveyors often manipulate **(2, all)** of the screws at the same time. Once the (bull's eye) circular bubble has been leveled, the instrument can be revolved to check that the bubble remains centered.

10. Arrange in order the steps used to establish an elevation of an unknown point by placing the correct sequence numbers (1-9) in the appropriate blanks. The answers for two steps are given.

__5__ a. Record the initial rod reading taken from the known point in the backsight column of the field notes.

_____ b. Attach the level to the tripod and transport to the initial set-up point.

_____ c. Record the foresight reading in the proper column of the field notes, and signal the rod person that you are finished.

_____ d. Set up the instrument midway between Point A and Point B, and level it up.

TEST

_____e. Observer rotates the telescope and focuses the cross hairs on the level rod presently resting on Point B.

_____f. Take a rod reading towards Point A by having the rod person place the leveling rod directly on the point of known elevation.

_____g. Remove the instrument from its container by lifting the level bar or base.

_____h. Calculate the elevation of Point B.

__6__i. Instrument person signals to the rod person to proceed to point B.

11. Select true statements concerning standard rules for note keeping by placing an "X" next to the true statements.

_____a. All recording is done in ink.

_____b. Errors should be erased carefully.

_____c. Pages should be all numbered as work progresses.

_____d. Each project should be labeled.

_____e. Weather conditions should be noted.

_____f. Type of equipment used should be noted.

_____g. Hand copying of field notes is allowed if needed.

_____h. All reductions of field notes should be in green or black (standard lead) pencil.

12. Match the various applications of level work on the right with the correct characteristics and uses.

_____a. 1) Used to determine the elevation of a point by measuring the inclined or horizontal distance between two points and recording the vertical angle to one point from a horizontal plane through the other point
2) Involves sine or tangent functions
3) Commonly used in topographic work and over very rugged terrain

_____b. 1) Used on route surveys for highways or pipelines where elevations are needed at specific intervals
2) A base line is established with "stations" or points marked along the line that can be easily found
3) Rod shots are then taken along each of the stations

1. Differential leveling
2. Reciprocal leveling
3. Profile leveling
4. Cross-section leveling
5. Barometric leveling
6. Trigonometric leveling
7. Borrow pit leveling

TEST

_____ c. 1) Used to determine differences in elevation between points that are remote from each other.

2) Often referred to as bench mark leveling.

3) Backsights and foresights should be kept as close to equal in horizontal length as possible.

_____ d. 1) Commonly used to determine the volume of material transported to the construction site.

2) Rod readings are taken either by the cross-section method or by a possible grid system layout over the existing or original ground where excavation will take place.

3) As excavation commences, additional readings are taken for top and bottom of excavation limits.

4) Removal quantities can then be calculated by comparing these rod readings to the original elevations before excavation.

_____ e. 1) Commonly implemented along with profile leveling.

2) Is used to obtain elevations at certain right angle or 90-degree angle offsets from the stationed profile line.

_____ f. 1) A special barometer or surveying altimeter can be used to find relative elevations of points on the earth's surface.

2) Particularly suitable for work in rough terrain where standard leveling procedures would be extremely costly.

3) Can be used where extensively large areas need to be covered and high orders of accuracy are not required.

_____ g. [illegible] when equal backsights and foresights cannot be obtained.

2) The instrument is set up at Point X, near Point A, and rod readings are taken at Point A and Point B. Several readings are taken due to the distance of X-B. Once recorded, the instrument is relocated at Point Y and the process is repeated.

TEST

13. Distinguish between the duties of survey crew members by placing the following letters next to the appropriate duties and responsibilities.

- P — Survey party chief
- I — Instrument person
- R — Rod person

_____a. Takes care of all miscellaneous equipment (not instrument).

_____b. Keeps orderly, neat field notes while work is being performed.

_____c. Maintains daily logs, reports, and vehicle-use records.

_____d. Takes care of surveying instruments.

14. Classify the common errors that occur in leveling listed below by placing the following letters in the appropriate blanks:

- "I" Instrument error
- "N" Natural error
- "P" Personal error

_____a. Improper rod handling

_____b. Bubble not properly centered

_____c. Strong or gusty winds

_____d. Refraction of the line of sight

_____e. Level rod not correct length

_____f. Parallax

_____g. Cross hairs not exactly horizontal

_____h. Temperature variations on the leveling vial

_____i. Faulty rod readings

_____j. Tripod leg loose or not securely set in ground

_____k. Curvature of the earth

_____l. Settlement of a turning point

TEST

15. List three common mistakes that occur while leveling.

    a.

    b.

    c.

16. Describe the process of making minor field adjustments (peg test).

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

17. Read various types of level rods. (Assignment Sheet #1)

18. Enter field data in standard field book form. (Assignment Sheet #2)

19. Demonstrate the ability to:

    a. Make minor field adjustments to a leveling instrument (peg test). (Job Sheet #1)

    b. Perform a completed level circuit using the differential leveling process. (Job Sheet #2)

VERTICAL MEASUREMENTS
UNIT IV

ANSWERS TO TEST

1.
a.	4	i.	16
b.	12	j.	7
c.	15	k.	10
d.	9	l.	5
e.	8	m.	1
f.	2	n.	11
g.	14	o.	13
h.	6	p.	3

2. Any three of the following:
   a. To design highways, railroads, and canals having grade lines that must conform to the existing topographic surroundings
   b. To lay out construction projects according to engineered plans
   c. To calculate volumes of earthwork in various types of construction
   d. To analyze drainage characteristics of an area of land
   e. To develop maps showing general ground configurations

3. a. Cross hairs
   b. Either one of the following:
      1) To find differences in elevations between points
      2) To find elevations of points

4. a. Blank
   b. R
   c. Blank
   d. C
   e. Blank

5. a. Cross hair reticle adjusting screws
   b. Telescope
   c. Level vial
   d. Leveling head
   e. Leveling screws
   f. Tangent screw

6. a.
      1) Cross hairs
      2) Reticle
      3) Wires
      4) Screws

   b.
      1) Both ends
      2) 2mm
      3) Centered in
      4) Curvature

   c.
      1) Four
      2) Tilt the telescope

ANSWERS TO TEST

7. a. 5
   b. 2
   c. 6
   d. 3
   e. 1
   f. 4

8. a. Two
   b. Self-reading
   c. Rod person, instrument operator
   d. One
   e. Red
   f. 250
   g. Rod levels

9. a. Spread out
   b. Firmly pushed into the earth
   c. One leg, two legs
   d. Both screws simultaneously
   e. 2

10. a. 5   f. 4
    b. 2   g. 1
    c. 8   h. 9
    d. 3   i. 6
    e. 7

11. c,d,e,f

12. a. 6
    b. 3
    c. 1
    d. 7
    e. 4
    f. 5
    g. 2

13. a. R
    b. P
    c. P
    d. I

14. a. 3   g. 1
    b. 3   h. 2
    c. 2   i. 3
    d. 2   j. 1
    e. 1   k. 2
    f. 3   l. 2

ANSWERS TO TEST

15. Any three of the following:
    a. Use of an improperly graduated rod
    b. Holding the rod in different locations during a turning point
    c. Reading a foot too high
    d. Reading a stadia hair
    e. Recording notes improperly
    f. Touching tripod during reading process

16. Description should include the following:
    a. Place two stakes at a distance of 200 to 300 ft apart.
    b. Set the level up between the stakes at approximately the mid-way point. Rod readings are taken at both points and recorded.
    c. Move the level to one of the points (A) and set up so the eyepiece of the telescope just touches the level rod being held plumb over Point A.
    d. Take readings at both Points A and B and record.
    e. Determine the amount of error in the horizontal axis by subtracting the two original rod readings from each other and comparing it to the difference in the second set of rod readings.
    f. Eliminate the error by removing the adjusting screw cover, and if necessary adjust the capstan screws until the correct rod read intersects the cross hairs.

17.-18. Evaluated to the satisfaction of the instructor.

19. Performance skills evaluated to the satisfaction of the instructor.

ANGLES AND DIRECTIONS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to list the various types of meridians used in surveying, define the different types of horizontal and vertical angles used in giving a line a direction, distinguish between bearings and azimuths, and convert bearings to azimuths and azimuths to bearings. Competencies will be demonstrated by correctly completing the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to angles and directions with the correct definitions.
2. Distinguish between the systems of angular measurement.
3. Match types of reference meridians with the correct descriptions.
4. Label the types of vertical angles used in surveying.
5. Identify the types of horizontal angles.
6. Distinguish between the three common methods of giving direction to a line.
7. Convert bearings to azimuths and azimuths to bearings.
8. State the correct rule for converting back directions from either bearings or azimuths.
9. Convert bearings and azimuths to their opposite forms. (Assignment Sheet #1)
10. Calculate bearings and azimuths from interior angles. (Assignment Sheet #2)

OBJECTIVE SHEET

11. Calculate bearings and azimuths from deflection angles. (Assignment Sheet #3)

12. Convert bearings and azimuths into interior angles. (Assignment Sheet #4)

ANGLES AND DIRECTIONS
UNIT V

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Integrate the following activities throughout the teaching of this unit:

1. Teach basic use of calculators for conversion of degrees into decimal degrees and vice versa.

2. Display various isogonic charts to the group and discuss magnetic declination.

3. Discuss uses of geodetic north, grid north, and assumed north, and applications of where each might be used.

4. Determine the magnetic declination for your immediate area by the use of isogonic charts.

5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas r improvement.

H. Give test.

I. Evaluate test.

J. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM #1 — Reference Directions for Vertical Angles
2. TM #2 — Direction by Bearing or Azimuth

D. Assignment sheets

1. Assignment Sheet #1 — Convert Bearings and Azimuths to Their Opposite Forms
2. Assignment Sheet #2 — Calculate Bearings and Azimuths From Interior Angles
3. Assignment Sheet #3 — Calculate Bearings and Azimuths From Deflection Angles
4. Assignment Sheet #4 — Convert Bearings and Azimuths Into Interior Angles

E. Answers to assignment sheets

F. Test

G. Answers to test

REFERENCES USED IN WRITING THIS UNIT

A. Kavanagh, Barry and S.J. Glenn Bird. *Surveying: Principles and Applications.* Reston, VA: Reston Publishing Co., Inc., 1984.

B. Brinker, R.C. and P. R. Wolf. *Elementary Surveying*, 7th ed. New York: Harper & Row, 1984

C. Kissam, Phillip. *Surveying Practice*, 3rd ed. New York: McGraw-Hill, 1978.

SUGGESTED SUPPLEMENTAL MATERIAL

A. Davis, R. E., F. S. Foote, and J. H. Kelly. *Surveying*, 5th ed. New York: McGraw-Hill Book Company, 1966.

B. Kissam, Phillip. *Surveying for Civil Engineers.* New York: McGraw-Hill, 1976.

C. Breed, Hosmer (Fang, Barry). *Principles and Practices of Elementary Surveying*, 11th ed. New York: Wiley, 1977.

ANGLES AND DIRECTIONS
UNIT V

INFORMATION SHEET

I. **Terms and definitions**

A. Angle — The space made between two straight lines that intersect, normally measured in degrees or grads

B. Declination — The angle formed between a magnetic needle and the geographic meridian

C. Isogonic line — A line on a map joining points on the earth's surface at which the magnetic declination is the same

D. Latitude — A line that runs east-west, is parallel to the equator, and is formed by projecting the latitude angle out to the earth's surface

E. Longitude — A line that runs north-south, converging at the poles formed by projecting the longitude angle out to the surface of the earth at the equator

F. Meridian — A line formed on the mean surface of the earth joining the north and south poles

G. Polygon — A closed plane figure bounded by straight lines

II. **Systems of angular measurement**

A. Sexagegesmal system

1. Used in the United States

2. Based on degrees, minutes, and seconds, with the last unit further divided decimally

a. 360 degrees (°) in a complete circle

b. 60 minutes (') in a degree

c. 60 seconds (") in a minute

B. Grad system

1. Used in most European countries

2. 400 grads equal 360 degrees

C. Radian system

1. Is more suitable to computers

2. Based on the $2\pi R$ system

INFORMATION SHEET

III. Types of reference meridians

A. Geographic meridian (known as true meridian): The line formed by the intersection with the earth's surface of a plane that includes the earth's axis of rotation

B. Magnetic meridian: A line that runs parallel to the direction of a free moving magnetized needle, as in a compass

C. Grid meridian: A line that is parallel to a grid reference line or a central meridian

(NOTE: Longitudes and latitudes are also acceptable meridians.)

IV. Types of vertical angles (Transparency 1)

(NOTE: Vertical angles are used to determine heights of objects or points, and in slope distance corrections. Refer to Unit III for additional information on this.)

A. Plus or minus angles — Measured up (plus) or down (minus) from a horizontal line of projection

(NOTE: Plus angles are also called angles of elevation, and minus angles are called angles of depression.)

B. Zenith angle — Measured down from a point directly above the observer

C. Nadir angle — Measured up from a point directly below the observer

V. Types of horizontal angles

A. Interior angles: Measured angles on the inside of a closed polygon (Figure 1)

FIGURE 1

(NOTE: For a closed polygon of "N" sides, the sum of the interior angles will be: (N − 2 × 180°.)

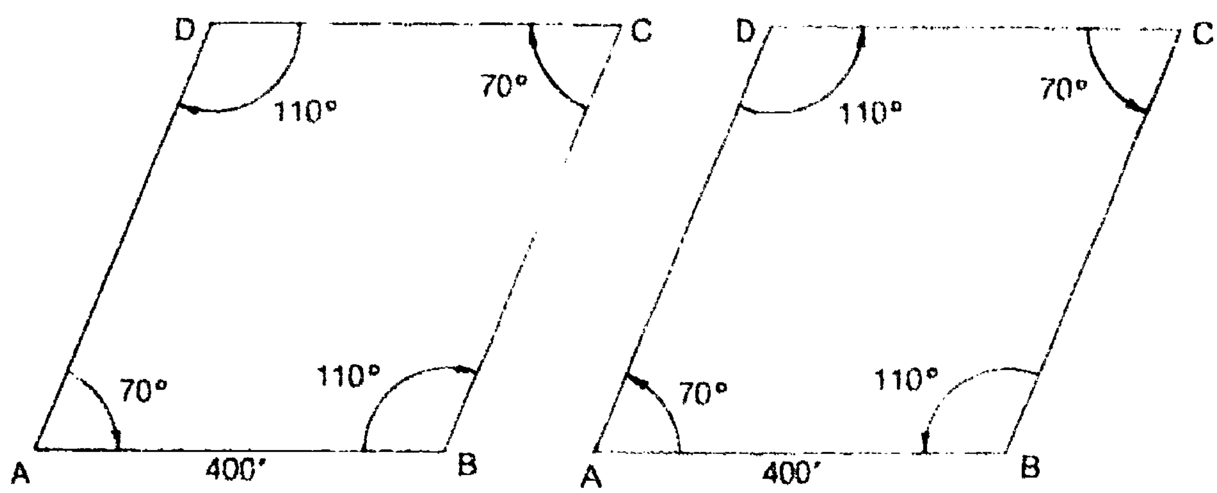
B. Exterior angles: Measured angles located on the outside of a closed polygon

(NOTE: The advantage gained by measuring exteriors along with interiors is that of a field check for any major errors made in reading either angle.)

INFORMATION SHEET

C. Angles to the right (clockwise) and angles to the left (counterclockwise) (Figure 2)

FIGURE 2

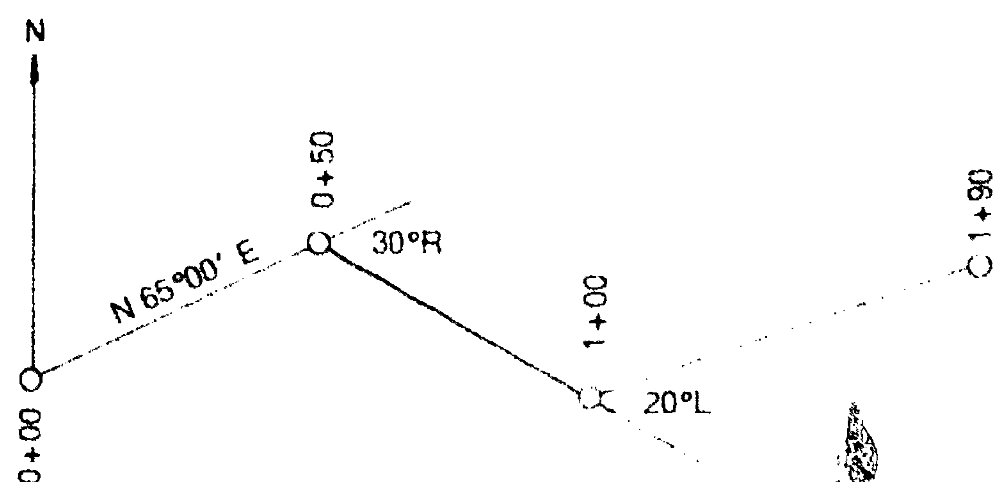


Angles to the Right

Angles to the Left

D. Deflection angles: Measured angles right or left from an extension of the back line through the forward line (Figure 3)

FIGURE 3



VI. **Methods of giving direction to a line** (Transparency 2)

A. Magnetic directions

1. A line is given a direction from magnetic north by the use of a compass.

2. The magnetic north pole is located about 1000 miles south of the geographical pole.

3. The horizontal angle between the direction taken by the compass needle and geographic or true north is the magnetic declination.

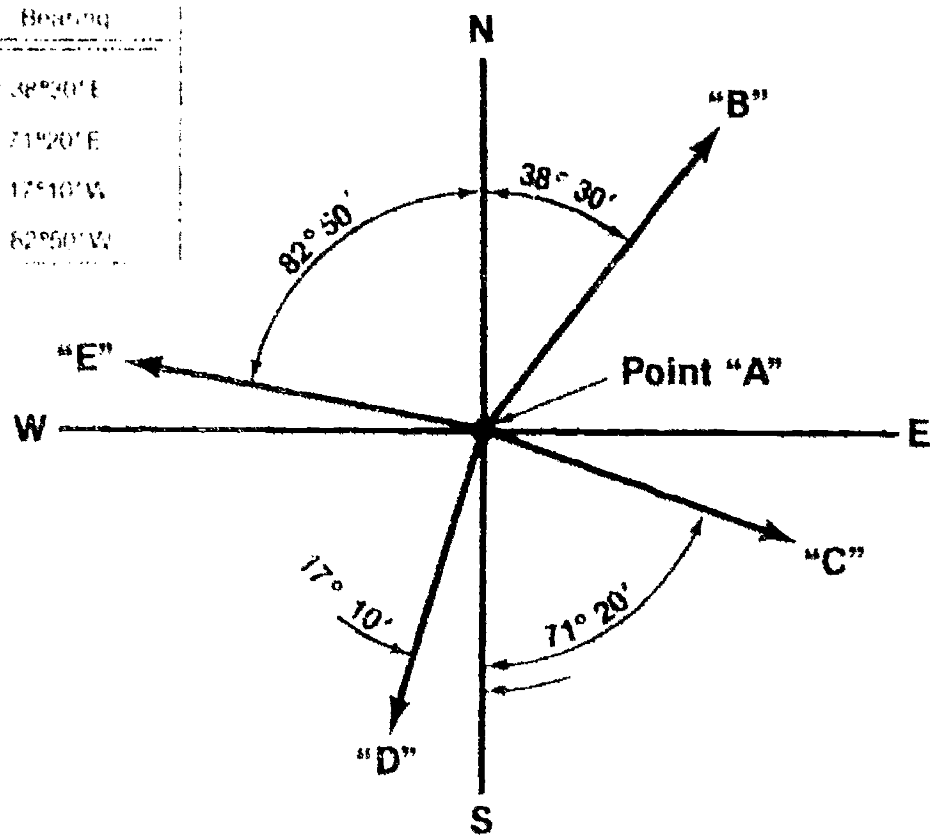
INFORMATION SHEET

B. Bearing directions

1. A bearing is the direction of a line given by the acute angle between the line and a meridian.
2. Are measured clockwise or counterclockwise
3. Are measured from the north or south end of a meridian
4. Require two letters (quadrant letters) and a numerical value (Figure 4)
5. Range from 0 to 90°: can **never** be greater than 90°

FIGURE 4

Line	Bearing
A-B	N 38°30' E
A-C	S 71°20' E
A-D	S 17°10' W
A-E	N 82°50' W



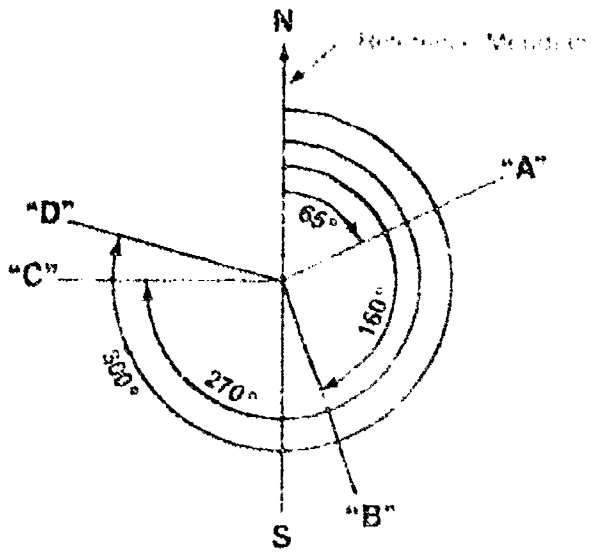
C. Azimuth directions

1. An azimuth is a direction of a line as given by the angle measured clockwise from a given meridian

INFORMATION SHEET

2. Are measured from north only in one survey, or from south only (Figure 5)

FIGURE 5



3. Are measured clockwise only

4. Range in magnitude from 0° to 360°

5. Require only a numerical value

6. Advantageous in some topographical work as well as in computations.

VII. Converting bearings and azimuths

A. Converting from north azimuths to bearings

1. Determine the proper quadrant letters

   a. If azimuth north (Az N) is 0° — 90°, bearing is NE

   b. Az N 90° — 180°, Brg SE

   c. Az N 180° — 270°, Brg SW

   d. Az N 270° — 360°, Brg NW

INFORMATION SHEET

2. Determine the numerical value by using the following relationships:

   a. NE quadrant: Bearing = Azimuth N

   b. SE quadrant: Bearing = 180° – Azimuth N

   c. SW quadrant: Bearing = Azimuth N – 180°

   d. NW quadrant: Bearing = 360° – Azimuth N

B. Converting from south azimuths to bearings

1. Determine the proper quadrant letters.

   a. If azimuth south (Az S) is 0° — 90°, bearing is SW.

   b. Az S 90° — 180°. Brg NW

   c. Az S 180° — 270°. Brg NE

   d. Az S 270° — 360°. Brg SE

2. Determine the numerical value by using the following relationships.

   a. SW quadrant: Bearing = Azimuth S

   b. NW quadrant: Bearing = 180° - Azimuth S

   c. NE quadrant: Bearing = Azimuth S - 180°

   d. SE quadrant: Bearing = 360° - Azimuth S

Converting from bearings to azimuths

1. NE quadrant: Azimuth = Bearing

2. SE quadrant: Azimuth = 180° – Bearing

3. SW quadrant: Azimuth = 180° + Bearing

4. NW quadrant: Azimuth = 360° – Bearing

INFORMATION SHEET

Example: Directions for lines in the four quadrants (azimuths from north):

Bearings	Azimuths	
N54°E	54°	
S68°E	112°	(180° – 68°)
S51°W	231°	(180° + 51°)
N15°W	345°	(360° – 15°)

VIII. **Reverse directions**

A. It can be said that every line has two directions

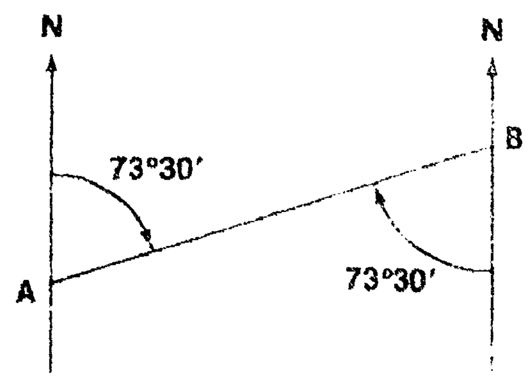
1. Forward direction: Oriented in the direction of fieldwork or computation staging.

2. Back direction: Oriented in the direction toward back stations (exact opposite).

B. To reverse a bearing direction, simply reverse the direction letters. (Figure 6)

FIGURE 6

Line	Bearing
AB	N 73°30'E
BA	S 73°30'W



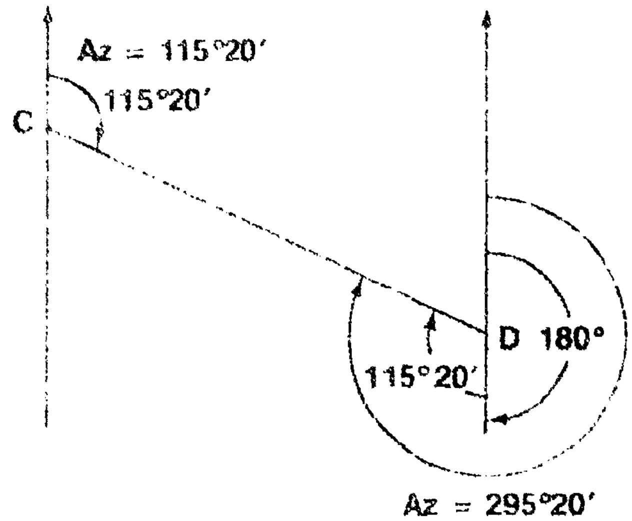
C. To reverse an azimuth direction, simply add 180° to the original direction. (Figure 7)

INFORMATION SHEET

D. If the original azimuth is greater than 180°, simply subtract 180° from it.

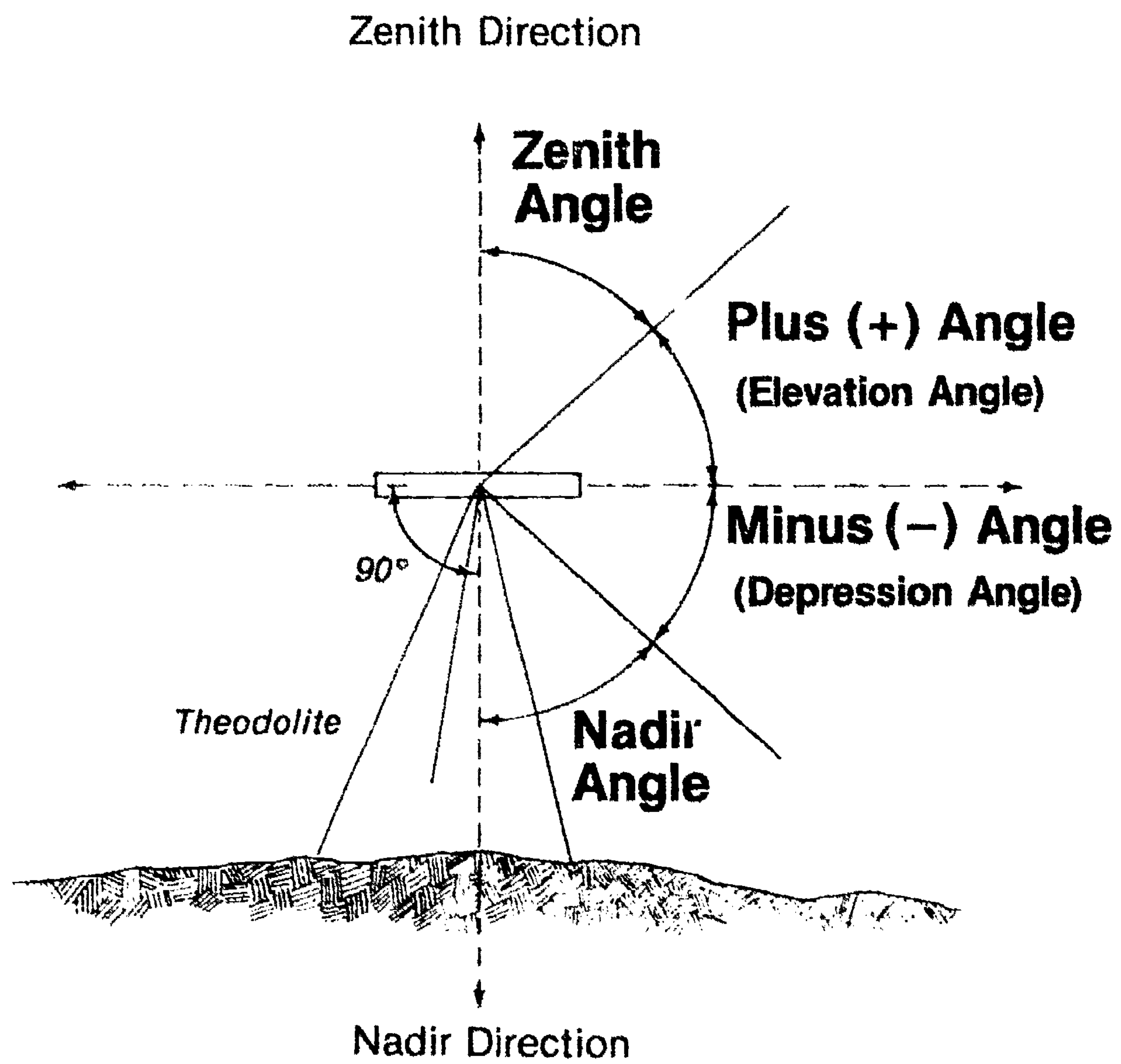
FIGURE 7

Line	Azimuth
CD	115°20'
DC	295°20'



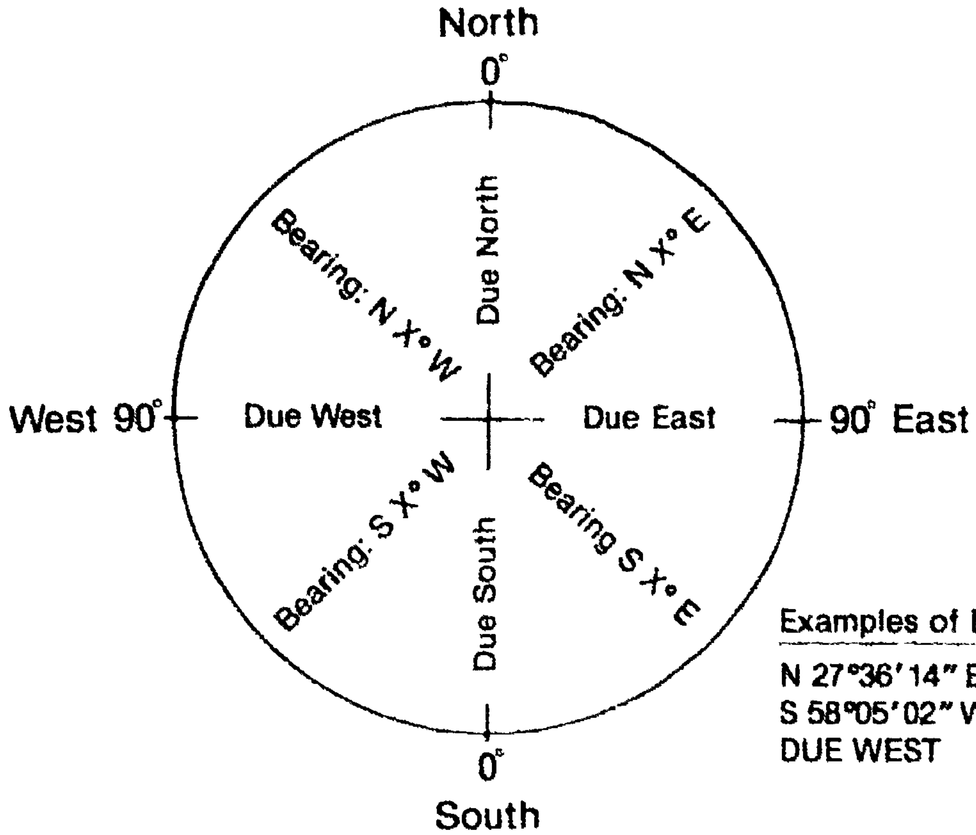
(NOTE: The key factor to remember is that a forward and back azimuth must differ by 180°.)

Reference Directions for Vertical Angles



Direction by Bearing or Azimuth

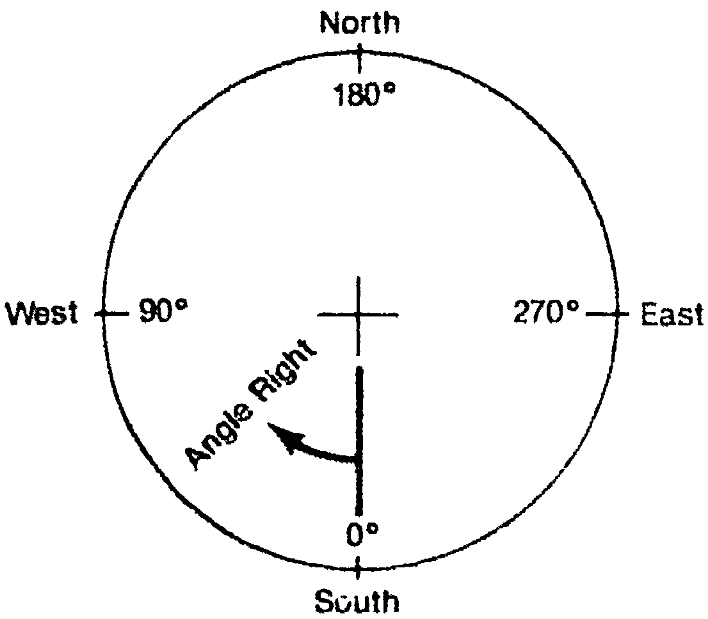
Direction by Bearing



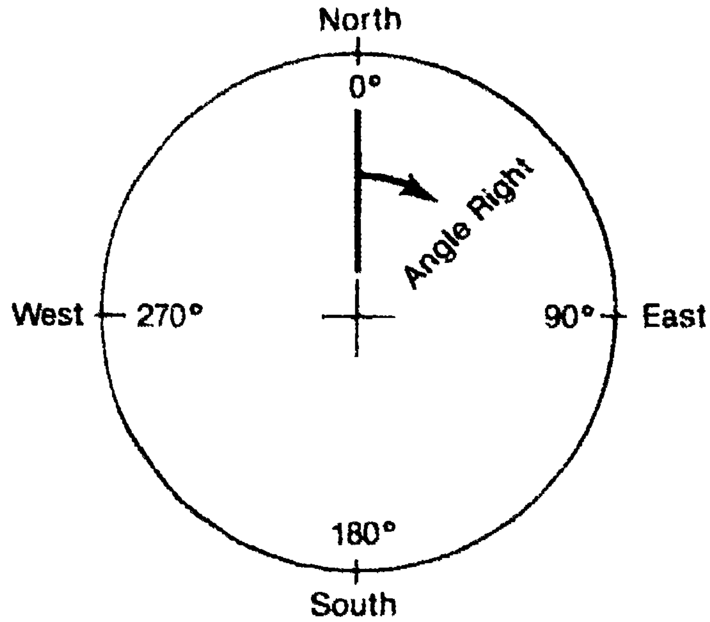
Examples of Bearings:

N 27°36′14″ E
S 58°05′02″ W
DUE WEST

Di:ection by Azimuth



Azimuth South (Az_S)
Example: Az_S = 246°07′53″



Azimuth North (Az_N)
Example: Az_N = 66°07′53″

ANGLES AND DIRECTIONS
UNIT V

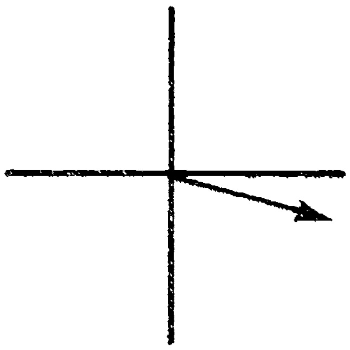
ASSIGNMENT SHEET #1 — CONVERT BEARINGS AND AZIMUTHS TO THEIR OPPOSITE FORMS

Directions: Accurately convert each of the given bearings or azimuths to its opposite form, first by sketching its direction on the provided quadrant drawing, then calculating its written form and recording your answers in the blanks provided.

Examples:

Azimuth to Bearing

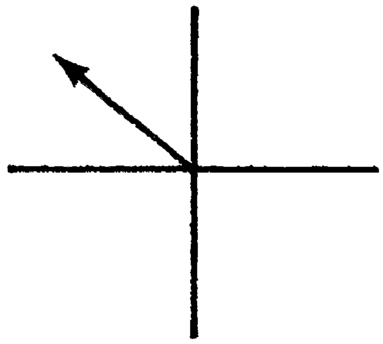
Given: Az N 102°30'



Bearing: S 77°30' E

Bearing to Azimuth

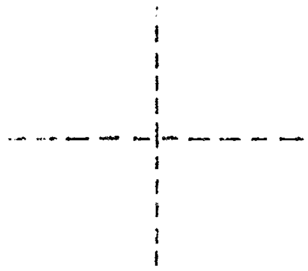
Given: N 42°51'W



Azimuth N: Az N: 222°51'

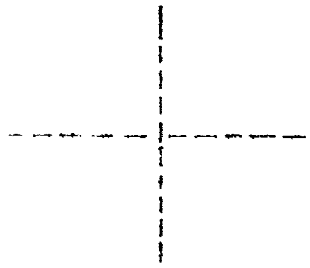
1. Azimuths to bearings:

a. Az N: 214°12'



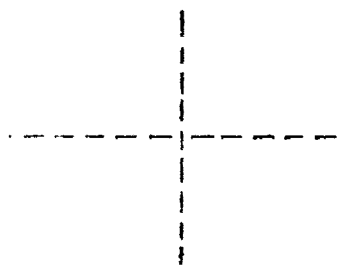
______

b. Az N: 14°43'



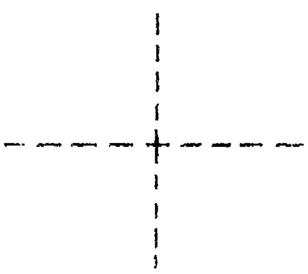
______

c. Az S: 172°35'



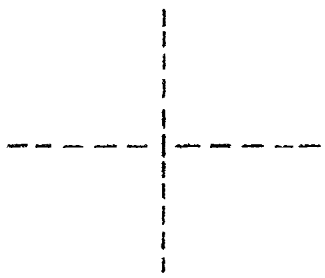
______

d. Az N: 172°41'



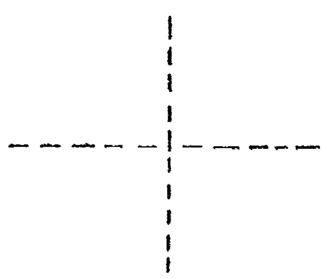
______

e. Az S: 273°54'



______

f. Az N: 298°26'

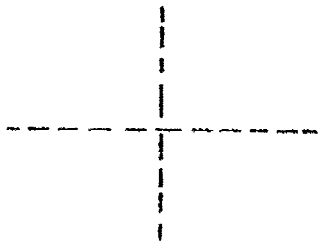


______

ASSIGNMENT SHEET #1

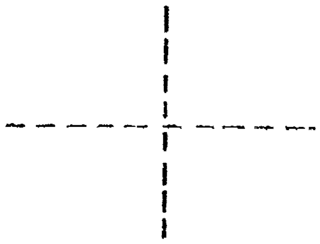
2. Bearings to azimuths

a. S 41°22'W



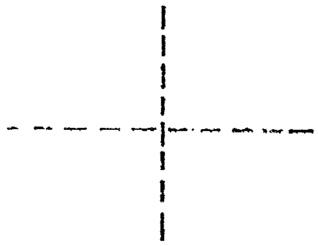
Az N: ____________

b. N 26°54'W



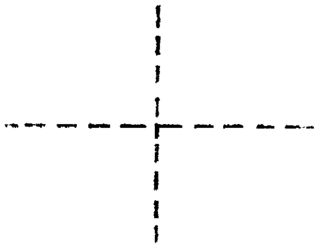
Az N: ____________

c. N 81°47'E



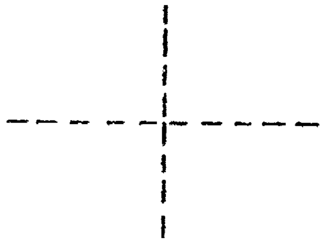
Az S: ____________

d. N 70°32'W



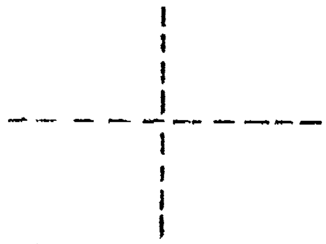
Az N: ____________

e. S 14°41'E



Az S: ____________

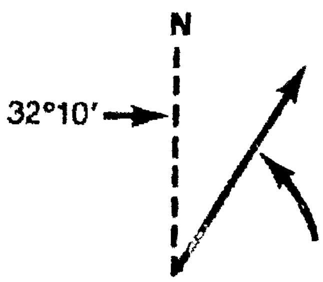
f. S 88°52'W



Az N: ____________

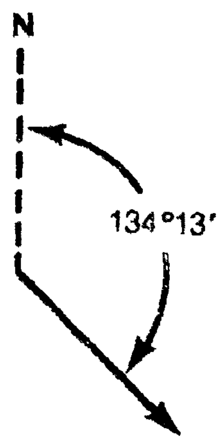
3. Bearings and azimuths from north

a.



Az N: ____________
Bearing: ____________

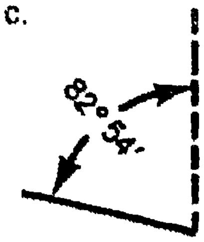
b.



Az N: ____________
Bearing: ____________

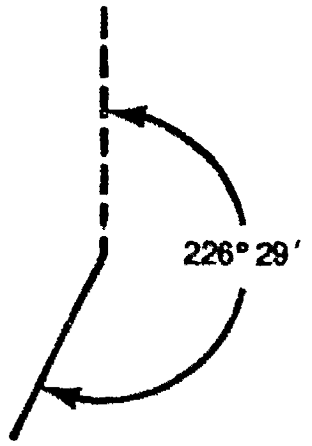
ASSIGNMENT SHEET #1

c.



Az S:________________
Bearing: ________________

d.



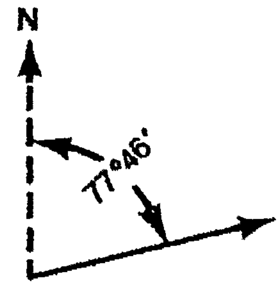
Az S:________________
Bearing:________________

ANGLES AND DIRECTIONS
UNIT V

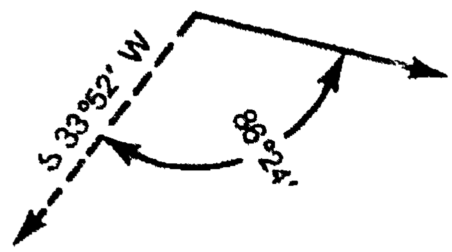
ASSIGNMENT SHEET #2 — CALCULATE BEARINGS AND AZIMUTHS FROM INTERIOR ANGLES

Directions: Calculate the correct bearing and azimuth for each of the given angles below. Record your answers in the blanks provided.

Example:

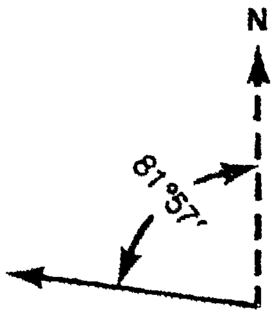


Az N: N 77°46'
Bearing: N 77°46' E



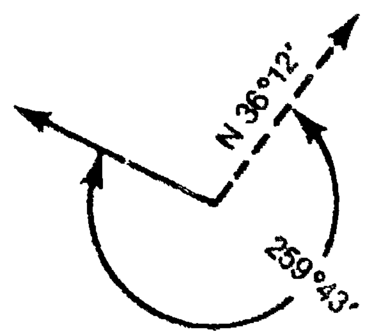
Az N: N 127°28'
Bearing: S 52°32' E

1.



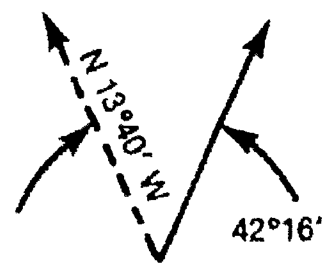
Az N: ____________
Bearing: ____________

2.



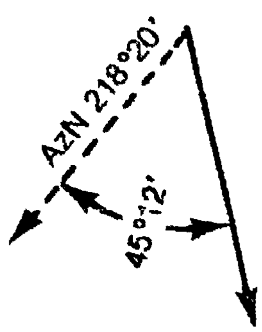
Az N: ____________
Bearing: ____________

3.



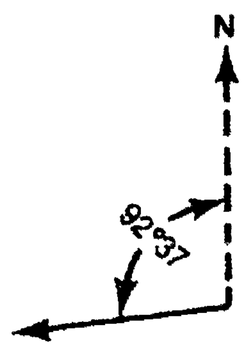
Az N: ____________
Bearing: ____________

4.



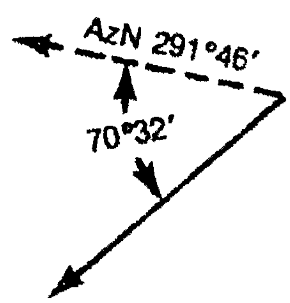
Az N: ____________
Bearing: ____________

5.



Az N: ____________
Bearing: ____________

6.

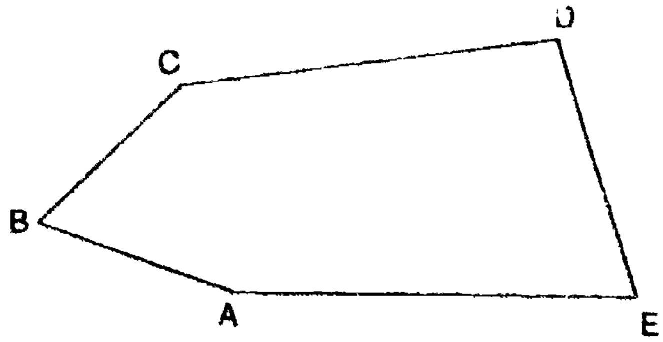


Az N: ____________
Bearing: ____________

ASSIGNMENT SHEET #2

7. Use the following sketch and listed interior angles to compute the bearings for each course:

	Angles
A —	161°25'40"
B —	63°47'00"
C —	140°28'50"
D —	101°30'20"
E —	72°48'10"
	537°178'120"
=	540°00'00" (closed)

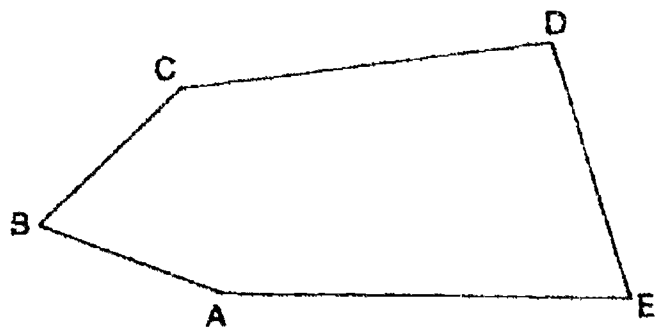


List each of the bearings for each course if course A-B had a bearing of N 76°40'10"W.

Course	Bearing
A-B	N 76°40'10"W
B-C	
C-D	
D-E	
E-A	

8. Use the following sketch and listed interior angles to compute the azimuths for each course:

	Angles
A —	161°25'40"
B —	63°47'00"
C —	140°28'50"
D —	101°30'20"
E —	72°48'10"
	537°178'120"
=	540°00'00" (closed)



List each of the azimuths for each course if course A-B had an azimuth of N283°19'50".

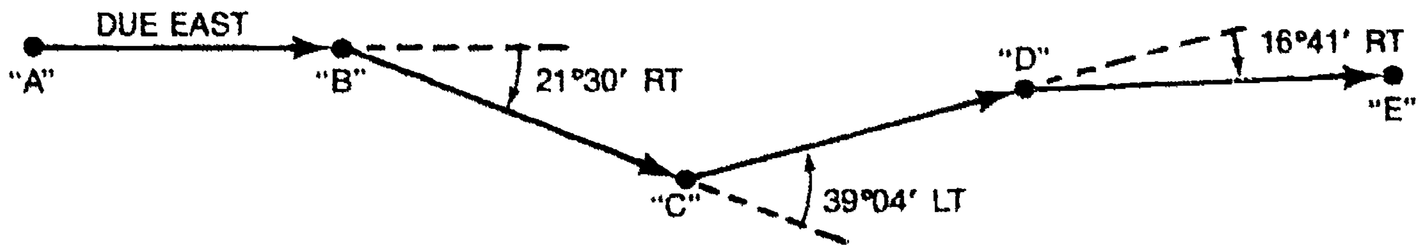
Course	Azimuth
A-B	N283°19'50"
B-C	
C-D	
D-E	
E-A	

ANGLES AND DIRECTIONS
UNIT V

ASSIGNMENT SHEET #3 — CALCULATE BEARINGS AND AZIMUTHS FROM DEFLECTION ANGLES

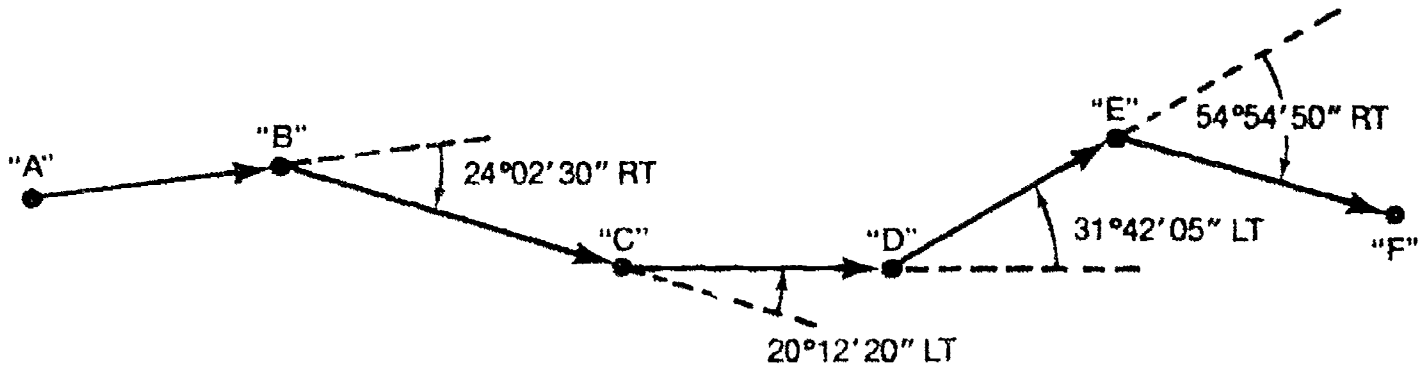
Directions: Accurately calculate the proper bearing or azimuth from each of the given deflection angles. Record answers in the blanks provided.

Example:



	Line A-B	Line B-C	Line C-D	Line D-E
Az:	N 90°00'	N 111°30'	N 72°26'	N 89°07'
Brg:	N 90°00' E	S 68°30' E	N 72°26' E	N 89°07' E

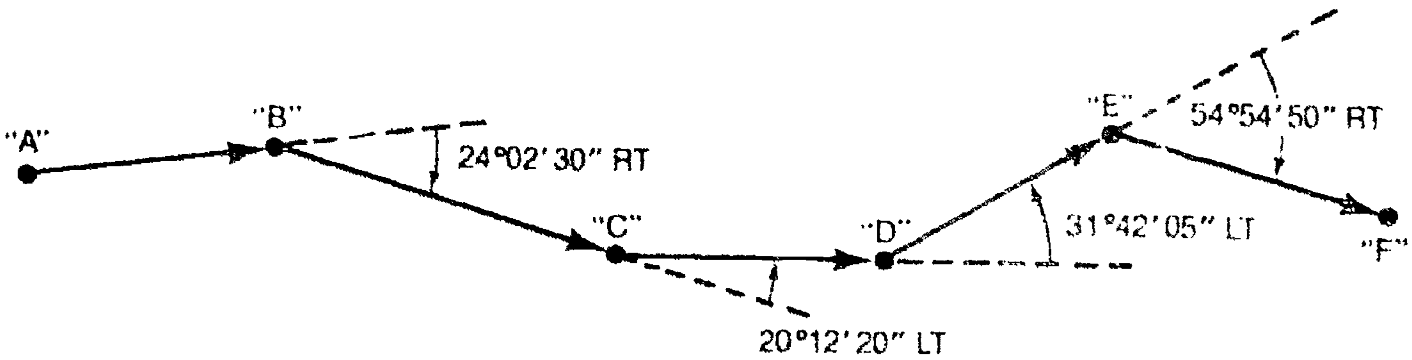
1. Compute the bearings for each of the following courses if course A-B has a bearing of N 86°12'20"E.



Course	Bearing
A-B	N 86°12'20"E
B-C	________
C-D	________
D-E	________
E-F	________

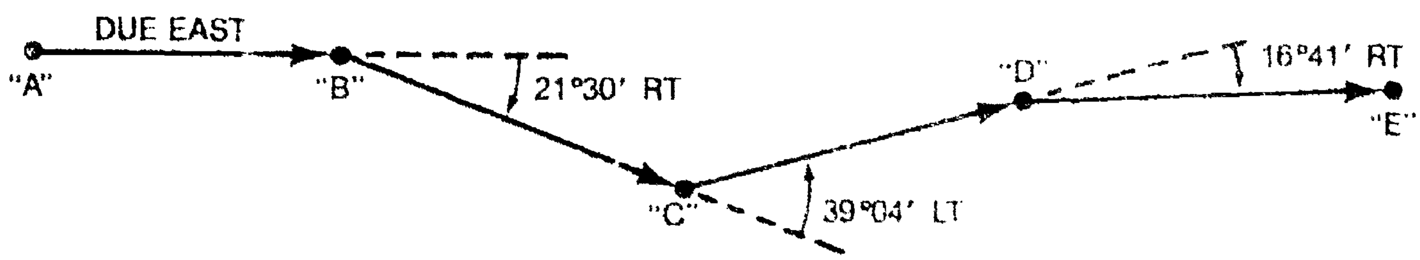
ASSIGNMENT SHEET #3

2. Compute the azimuths for each of the following courses if course A B had an azimuth of N 81°50′15″.



Course	Azimuth
A-B	N 81°50′15″
B-C	
C-D	
D-E	
E-F	

3. Compute the azimuths and bearings of each course if course A-B is S 87°31′40″E.



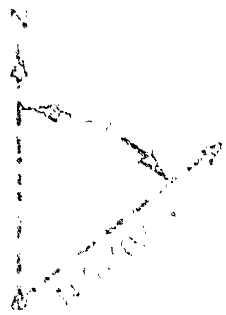
Course	Bearing	Azimuth
A-B	S 87°31′40″E	
B-C		
C-D		
D-E		

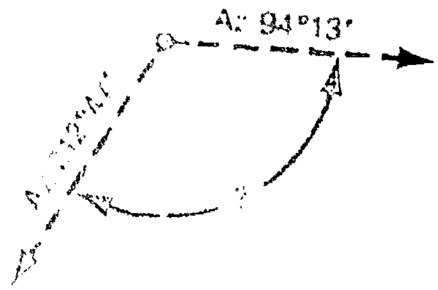
ANGLES AND DIRECTIONS
UNIT V

ASSIGNMENT SHEET #1 — CONVERT BEARINGS AND AZIMUTHS INTO INTERIOR ANGLES

[illegible] from the bearings or azi- [illegible]

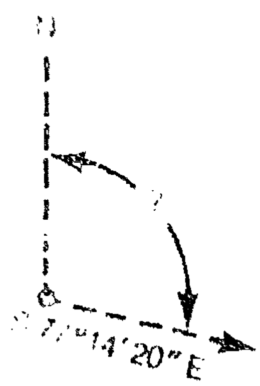
Example:





Interior angle ________ Interior angle ________118°34'________

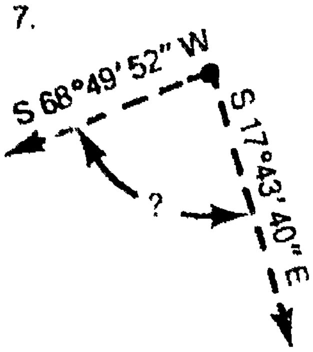
____



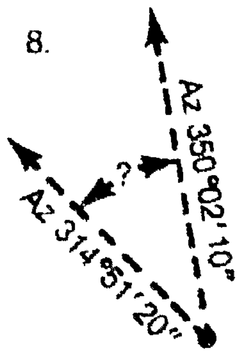
________ ________ ________

ASSIGNMENT SHEET #4

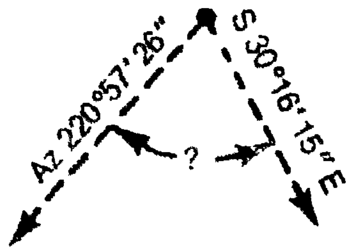
7.



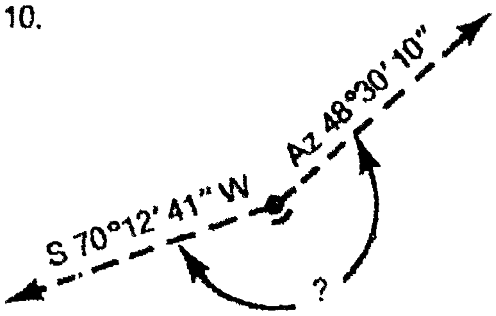
8.



9.



10.



ANGLES AND DIRECTIONS
UNIT V

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. a. S 34°12'0"W
   b. N 14°43'00"E
   c. N 07°25'00"W
   d. S 07°19'00"E
   e. S 86°06'00"E
   f. N 61°34'00"W

2. a. Az N 221°22'00"
   b. Az N 333°06'00"
   c. Az S 261°47'00"
   d. Az N 289°28'00"
   e. Az S 345°19'00"
   f. Az N 268°52'00"

3. a. Az N: 32°10'00"
   Brg: N 32°10'00"E
   b. Az N: 134°13'00"
   Brg: S 45°47'00"E
   c. Az S: 97°06'00"
   Brg: N 82°54'00"W
   d. Az S: 46°29'00"
   Brg: S 46°29'00"W

Assignment Sheet #2

1. Az: 278°03'00"
   Brg: N 81°57'00"W

2. Az: 295°55'00"
   Brg: N 64°05'00"W

3. Az: 28°36'00"
   Brg: N 28°36'00"E

4. Az: 173°08'00"
   Brg: S 06°52'00"E

5. Az: 267°23'00"
   Brg: S 87°23'00"W

6. Az: 221°14'00"
   Brg: S 41°14'00"W

7. A-B: N 76°40'10"W
   B-C: N 39°32'50"E
   C-D: N 79°04'00
   D-E: S 22°26'20
   E-A: S 84°45'30

8. A-B: N 283°19'50"
   B-C: N 39°32'50"
   C-D: N 79°04'00"
   D-E: N 159°33'40"
   E-A: N 264°45'30"

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3

1.	A-B: N 86°12′20″E	2.	A-B: N 81°50′15″
	B-C: S 69°45′10″E		B-C: N 105°52′45″
	C-D: S 89°57′30″E		C-D: N 85°40′25″
	D-E: N 58°20′25″E		D-E: N 53°58′20″
	E-F: S 66°44′45″E		E-F: N 108°53′10″

	Bearings	Azimuths
3.	A-B: S87°31′40″E	92°28′20″
	B-C: S 66°01′40″E	113°58′20″
	C-D: N 74°54′20″E	74°54′20″
	D-E: S 88°24′40″E	91°35′20″

Assignment Sheet #4

1.	60°03′00″	6.	102°45′40″
2.	82°58′00″	7.	86°33′32″
3.	125°53′00″	8.	35°10′50″
4.	46°47′50″	9.	71°13′41″
5.	59°36′55″	10.	201°42′31″

ANGLES AND DIRECTIONS
UNIT V

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a.	A line that runs north-south, converging at the poles, formed by projecting the longitude angle out to the surface of the earth at the equator		1. Angle
_____b.	A closed plane figure bounded by straight lines		2. Declination
_____c.	A line formed on the mean surface of the earth joining the north and south poles		3. Isogonic line
_____d.	A line on a map joining points on the earth's surface at which the magnetic declination is the same		4. Latitude
_____e.	The space made between two straight lines that intersect, normally measured in degrees or grads		5. Longitude
_____f.	The angle formed between a magnetic needle and the geographic meridian		6. Meridian
_____g.	A line that runs east-west, is parallel to the equator, and is formed by projecting the latitude angle out to the earth's surface		7. Polygon

2. Distinguish between the systems of angular measurement by placing an "X" next to the characteristics of the sexagegesmal system.

_____a. Used in the United States; based on degrees, minutes, and seconds

_____b. Used in most European countries; 400 grads equal 360 degrees

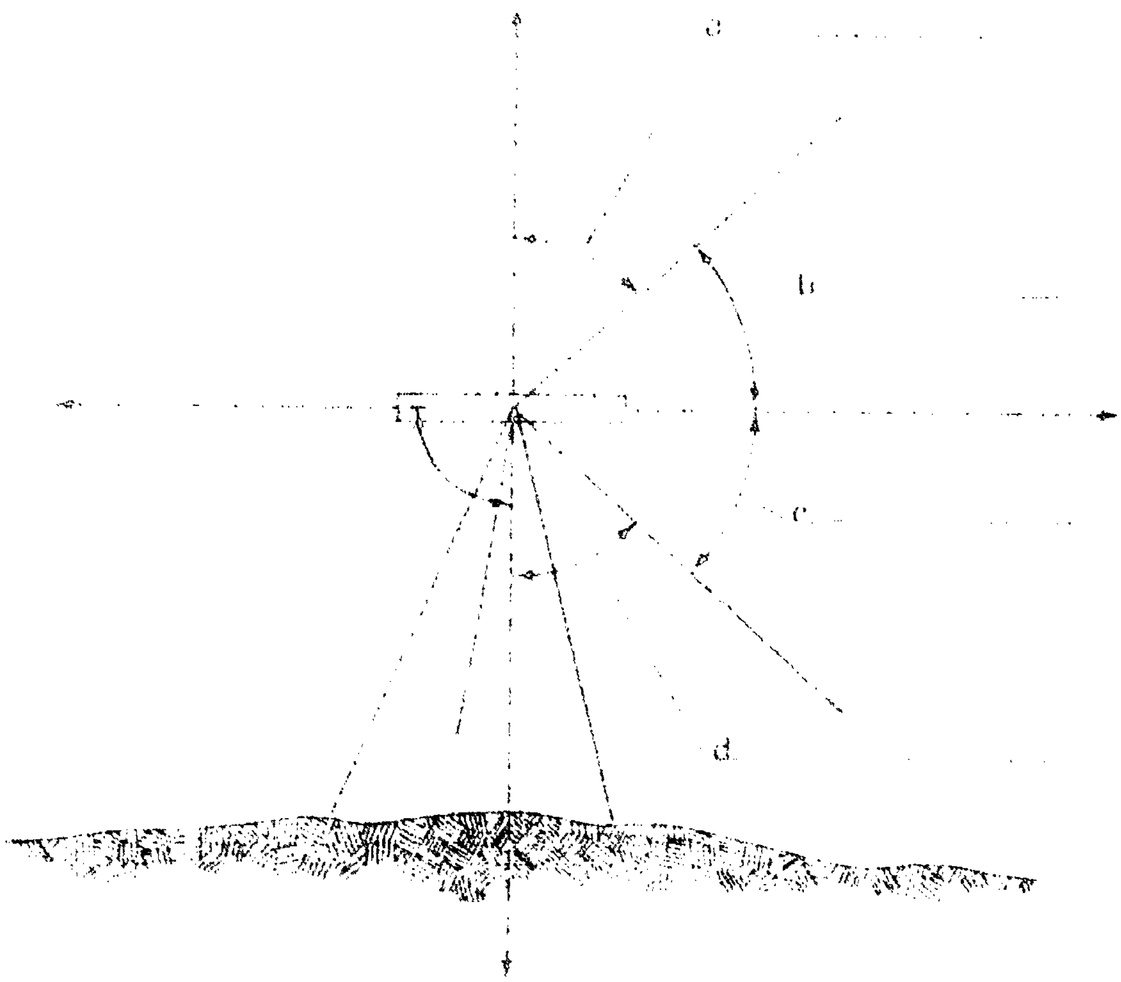
_____c. Is more suitable to computers; based on the $2\pi R$ system

3. Match the types of reference meridians on the right with the correct descriptions.

_____a.	A line that runs parallel to the direction of a free moving magnetized needle, as in a compass	1. Geographic meridian
_____b.	A line that is parallel to a grid reference or a central meridian	2. Grid meridian
_____c.	A line formed by the intersection with the earth's surface of a plane that includes the earth's axis of rotation	3. Magnetic meridian

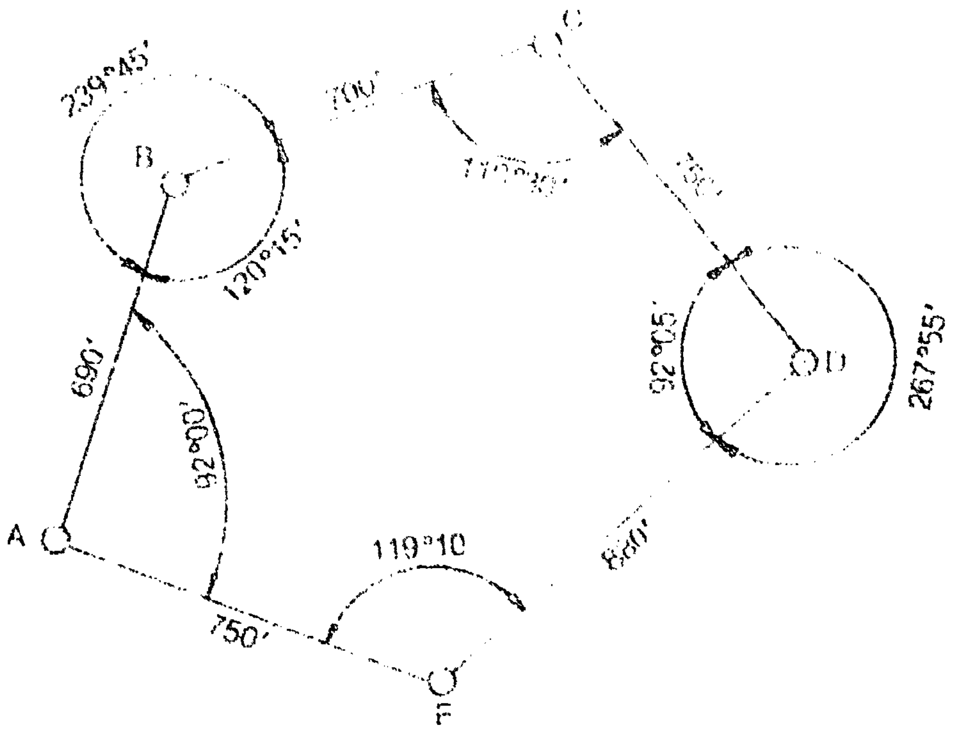
TEST

4. Label the types of vertical angles used in surveying.



TEST

5. Identify the types of horizontal angles by circling the correct answers below.

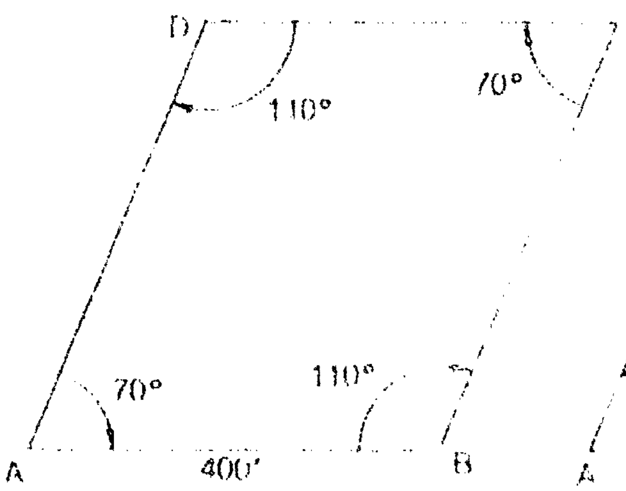


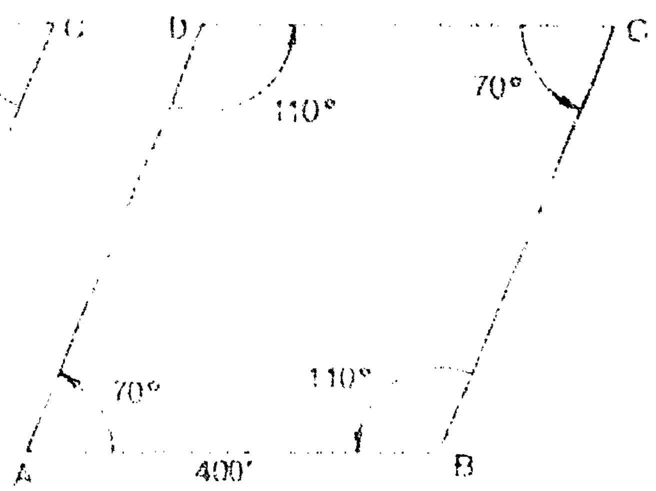
a. Angle measuring 110°30' -- **(Exterior, Interior)** angle

b. Angle measuring 239°45' -- **(Exterior, Interior)** angle

c. Angle measuring 267°55' -- **(Exterior, Interior)** angle

d. Angle measuring 92°05' -- **(Exterior, Interior)** angle





e. Angles to the **(left, right)**

f. Angles to the **(left, right)**

TEST

g. **(Reflection, Deflection)** angles

6. Distinguish between the three comm... methods of giving direction to a line by placing the following letters next to the correct descriptions:

   - M — Magnetic directions
   - B — Bearing directions
   - A — Azimuth directions

_____a. Require two letters (quadrant letters) and a numerical value

_____b. Require only a numerical value

_____c. Are measured from north only in any one survey, or from south only

_____d. Are based on the use of a compass

_____e. Are measured from the north or south end of a meridian

_____f. Range from 0 to 90°; can never be greater than 90°

_____g. Range in magnitude from 0° to 360°

_____h. Are measured clockwise only

_____i. Are measured clockwise or counterclockwise

7. Convert the following bearings and azimuths.

   a. Az N 14°43′ = Brg__________

   b. Az N 284°15′ = Brg__________

   c. Az S 92°45′ = Brg__________

   d. Bearing N 60°25′E = Az N__________

   e. Bearing S 27°40′15″W = Az N__________

TEST

8. State the correct rules for converting back directions from bearings and azimuths.

   a. To reverse a bearing direction, ______________________________

   b. To reverse an azimuth direction, ______________________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

9. Convert bearings and azimuths to their opposite forms. (Assignment Sheet #1)

10. Calculate bearings and azimuths from interior angles. (Assignment Sheet #2)

11. Calculate bearings and azimuths from deflection angles. (Assignment Sheet #3)

12. Convert bearings and azimuths into interior angles. (Assignment Sheet #4)

ANGLES AND DIRECTIONS
UNIT V

ANSWERS TO TEST

1. a. 5
   b. 7
   c. 6
   d. 3
   e. 1
   f. 2
   g. 4

2. a

3. a. 3
   b. 2
   c. 1

4. a. Zenith angle
   b. Plus angle
   c. Minus angle
   d. Nadir angle

5. a. Interior
   b. Exterior
   c. Exterior
   d. Interior
   e. Right
   f. Left
   g. Deflection

6. a. B
   b. A
   c. A
   d. M
   e. B
   f. B
   g. A
   h. A
   i. B

7. a. N 14°43'00"E
   b. N 75°45'00"W
   c. N 87°15'00"W
   d. 60°25'00"
   e. 207°40'15"

8. a. Reverse the directions letters
   b. Add 180° to the original direction

9.-12. Evaluated to the satisfaction of the instructor

ANGULAR MEASUREMENTS
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the major parts of a transit, interpret readings on different types of vernier scales, accurately set up a transit and a theodolite over desired points with satisfactory efficiency, and precisely execute the proper method of turning field angles. Competencies will be demonstrated by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to angular measurements with the correct definitions.
2. List uses of transits and theodolites.
3. Identify the major parts of a transit.
4. Distinguish between characteristics of transits and theodolites.
5. Distinguish between the major types of verniers.
6. Interpret readings on different styles of verniers.
7. List typical mistakes made in reading verniers.
8. Differentiate between the two major types of theodolites.
9. Describe the field procedure used to determine if minor instrument adjustments are necessary on plate-level vials and the vertical cross hair.
10. Accurately read various types of verniers on transits. (Assignment Sheet #1)

OBJECTIVE SHEET

11. Demonstrate the ability to:

    a. Set up a transit over a desired point. (Job Sheet #1)

    b. Measure and read angles in the field. (Job Sheet #2)

    c. Set up a theodolite over a desired point. (Job Sheet #3)

ANGULAR MEASUREMENTS
UNIT VI

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Discuss the need for speed in setting up instruments. You may wish to have contests to encourage students to work on their speed.

2. Have students set up the instrument on various types of terrain -- sloping, flat, pavement, steep, rough areas, etc.

3. Have students lay out desired angles as an exercise, putting points on line.

4. Have students practice on wiggling in on line between points.

5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1 — Parts of a Transit

2. TM 2 — Reading a Vernier

D. Assignment Sheet #1 — Accurately Read Various Types of Verniers on Transits

E. Answers to assignment sheet

F. Job sheets

1. Job Sheet #1 — Set Up a Transit Over a Desired Point

2. Job Sheet #2 — Measure and Read Angles in the Field

3. Job Sheet #3 — Set Up a Theodolite Over a Desired Point

G. Test

H. Answers to test

REFERENCES USED IN WRITING THIS UNIT

A. Kavanagh, Barry and S. J. Glenn Bird. *Surveying: Principles and Applications*. Reston, VA: Reston Publishing Co., Inc., 1984.

B. Brinker, R.C., and P.R. Wolf. *Elementary Surveying*, 7th ed. New York, NY: Harper and Row, 1984.

C. Kissam, Phillip. *Surveying Practice*, 3rd ed. New York, NY: McGraw Hill Book Company, 1978.

SUPPLEMENTARY TEXTBOOKS

A. Davis, R.E., F.S. Foote, and J.H. Kelly. *Surveying*, 5th ed. New York, NY: McGraw Hill Book Company, 1966.

B. Kissam, Phillip. *Surveying for Civil Engineers*. New York, NY: McGraw Hill Book Company, 1976.

C. Breed, Hosmer (Fang, Barry). *Principles and Practices of Elementary Surveying*, 11th ed. New York, NY: Wiley, 1977.

ANGULAR MEASUREMENTS
UNIT VI

INFORMATION SHEET

I. **Terms and definitions**

A. Least count — The smallest reading obtainable on a vernier without interpolating

$$\text{Least Count} = \frac{\text{value of the smallest division on the scale}}{\text{number of divisions on the vernier}}$$

B. Optical plummet — A sighting device built into the base of a theodolite that is used to indicate vertical direction

C. Plumb bob — A brass weight attached to a line on a transit that is used to indicate vertical direction

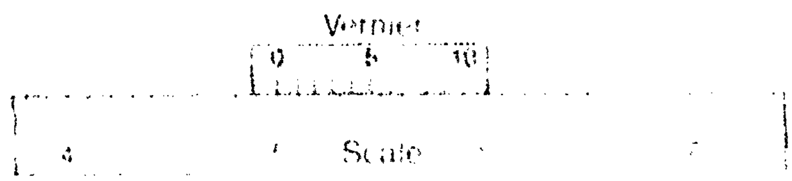
D. Theodolite — A precision instrument used for measuring horizontal and vertical angles

(NOTE: The graduated circles are normally more precisely graduated than that of a transit.)

E. Transit — A repeating surveying instrument for measuring horizontal and vertical angles

F. Vernier — A short auxiliary scale set parallel to and beside a primary scale; provides fractional parts of the smallest main-scale divisions without interpolating (Figure 1)

FIGURE 1



II. **Uses of transits and theodolites**

A. Primarily used for accurate measurement or layout of horizontal and vertical angles

B. Also used to determine horizontal and vertical distances by stadia, prolonging straight lines, and low order differential leveling

INFORMATION SHEET

III. **Major parts of a transit or theodolite** (Figure 2 and Transparency 1)

A. Alidade

1. Telescope
2. Vertical circle
3. Vertical circle vernier
4. Telescope level
5. Vertical tangent screw
6. Standards
7. Plate level
8. Upper plate
9. Horizontal circle verniers
10. Upper tangent screw
11. Inner spindle

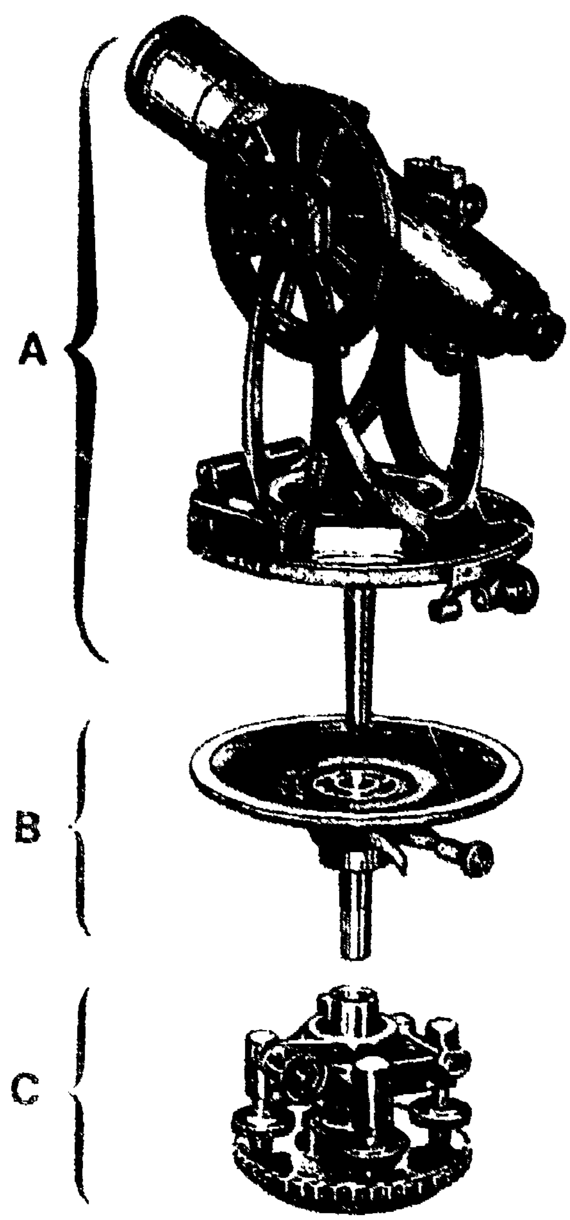
B. Horizontal circle assembly

1. Horizontal circle (lower plate)
2. Outer spindle
3. Upper clamp screw
4. Upper tangent screw

C. Leveling head assembly

1. Leveling head
2. Leveling screws
3. Base plate
4. Half ball joint
5. Lower clamp
6. Lower tangent screw

FIGURE 2



INFORMATION SHEET

IV. **Characteristics of transits and theodolites**

A. Transits

1. Normally are 4-screw instruments.

2. Normally have open verniers (non-magnified).

3. Typically utilize a plumb bob and string.

4. Usually have a vial level on the telescope.

5. Horizontal and vertical circles are normally made of polished metal with the graduations scribed into them.

6. Rotation of the instrument occurs on a brass spindle rather than ball bearings.

B. Theodolites

1. Telescopes are shorter than that of a transit.

2. Horizontal and vertical circles are made of glass with the graduations etched on their surface.

3. Graduations are more easily defined and are graduated into smaller increments.

4. Vertical circle is precisely indexed with respect to gravity by either an automatic compensator or a collimation level or index level.

5. Circle readings consist of a microscope with the optics inside the instrument.

6. Rotation about the vertical axis occurs within a steel cylinder or on precision ball bearings.

7. The leveling head consists of three leveling screws or "cams."

8. An optical plummet built into the base replaces the plumb bob and permits centering with greater accuracy.

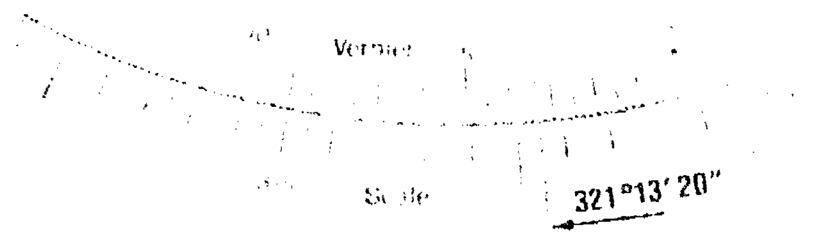
9. Bases are flat, and one tightening screw secures the instrument to a flat head tripod.

INFORMATION SHEET

V. Types of verniers

A. Direct or single vernier — Read in only one direction and must therefore be set with the graduations ahead of the zero (index) mark in the direction to be turned. (Figure 3)

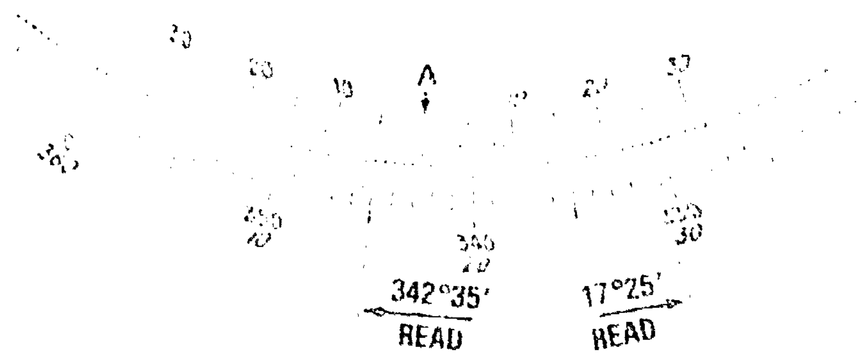
FIGURE 3 — Graduated 10 minutes reading to 10 seconds



B. Double or double direct vernier — Read either clockwise or counterclockwise, with only one-half being used at a time. Once the index mark is set coincident with 0°00′ on the circle, or at any known value, an observer is not limited to turning angles in one direction. (Figures 4, 5, and 6)

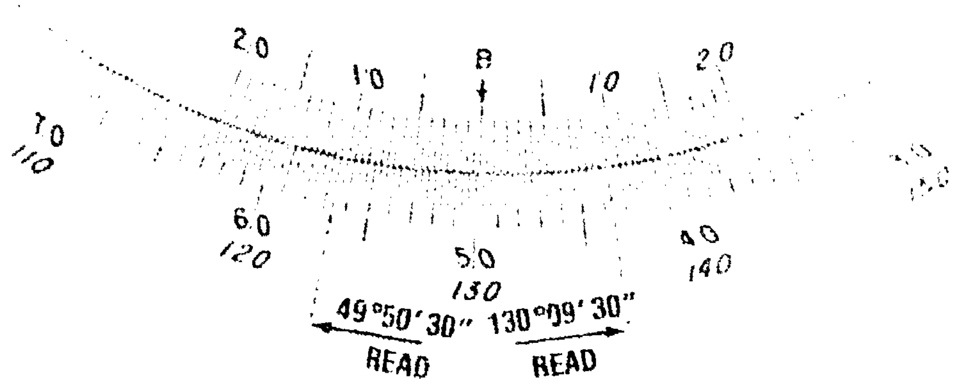
1. Graduated 30 minutes reading to one minute (Figure 4)

FIGURE 4



2. Graduated 20 minutes reading to 30 seconds (Figure 5)

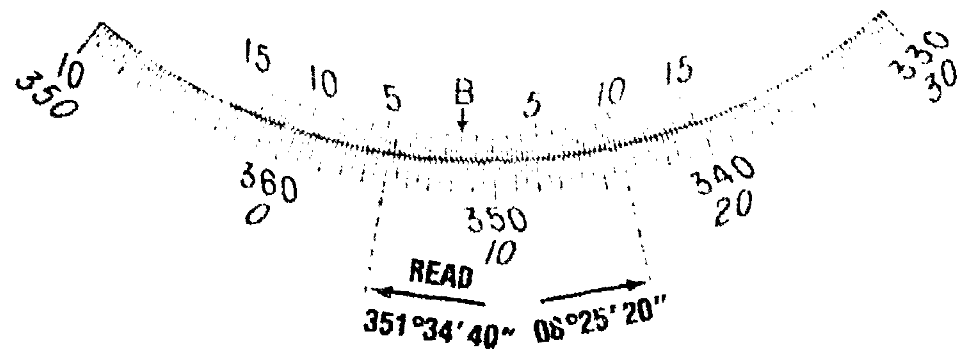
FIGURE 5



INFORMATION SHEET

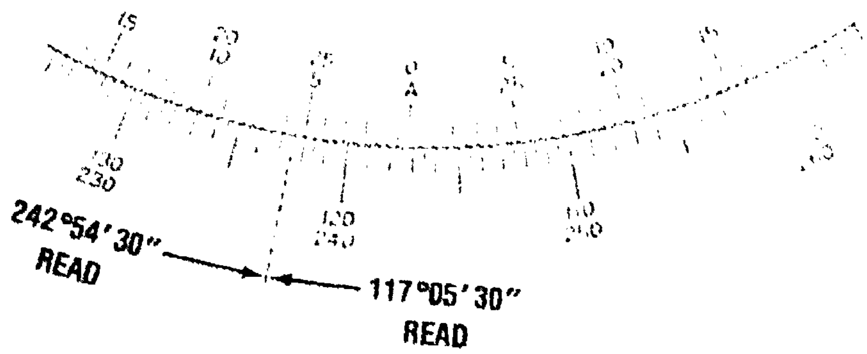
3. Graduated to 15 minutes reading to 20 seconds (Figure 6)

FIGURE 6



C. Folded vernier — Avoids the long vernier plate required by the normal double vernier. Its length is the same as a direct vernier with half the graduations placed on each side of the index mark. (Figure 7)

FIGURE 7 — Graduated 30 minutes reading to 30 seconds



(NOTE: The least count of any vernier can be found by the following relationship:

$$\text{Least Count} = \frac{\text{value of the smallest division on the scale}}{\text{number of divisions on the vernier}}$$

The combinations of scale graduations and vernier divisions generally used on transits are shown in Table 1.)

TABLE 1 — TRANSIT SCALES AND VERNIERS

SCALE GRADUATIONS	VERNIER DIVISIONS	LEAST COUNT	FIG. NO.
30'	30	1'	4
20'	40	30"	5
30'	60	30"	7
15'	45	20"	6
10'	60	10"	3

INFORMATION SHEET

VI. **Reading transit verniers** (Transparency 2)

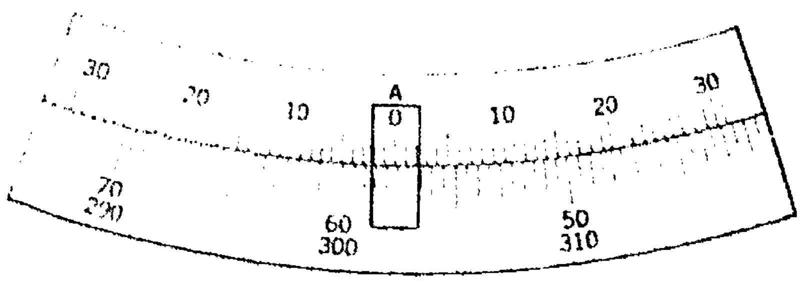
(NOTE: Practice is the best means of understanding and accurately reading verniers.)

A. A vernier is read by finding a graduation on it that coincides with any division on the circle scale.

(NOTE: On a double vernier there should be two such matching lines, one for the clockwise angle and the other for the opposite counterclockwise angle.)

B. A vernier index shows the number of degrees (and sometimes the multiple of 10, 15, 20, or 30 minutes) passed over on the scale. (Figure 8)

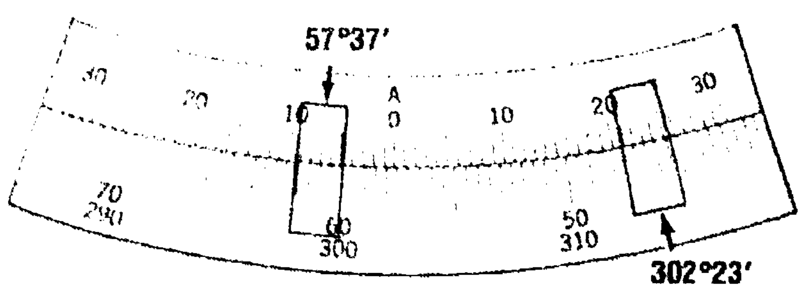
FIGURE 8



(NOTE: In Figure 8 the index would indicate on a clockwise angle that it has passed over 57°30'. The index would indicate on a counterclockwise angle that it has passed over 302°.)

C. The coincident vernier graduation gives directly the additional part of the degree. (This division on each side of the apparently matching lines should be checked for visual symmetry.) (Figure 9)

FIGURE 9



(NOTE: In Figure 9 the vernier graduation that apparently matches the circle graduation for a clockwise angle would be 57°37'00". The vernier graduation that apparently matches the circle graduation for a counterclockwise angle would be 302°23'00".)

INFORMATION SHEET

VII. Typical mistakes made in reading verniers

A. Not using a magnifying glass.

B. Reading the wrong direction from zero.

C. Failing to determine the least count correctly.

D. Omitting 10, 15, 20, or 30 minutes when the index is beyond those marks.

E. Failing to read directly on the line (parallax error)

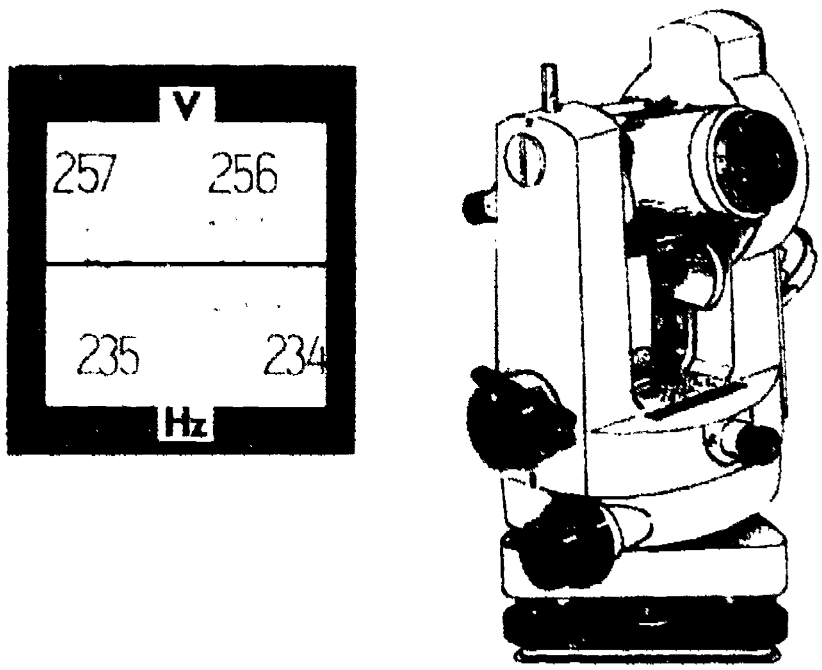
VIII. Types of theodolites

A. Repeating theodolite (Figures 10 and 11)

1. Equipped with a double vertical axis or a repetition clamp.

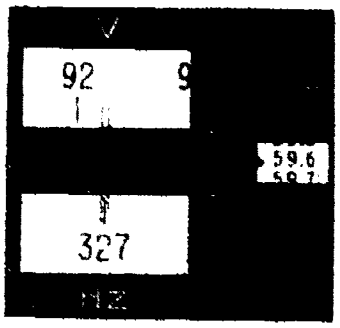
2. Enables angles to be repeated any number of times and added directly on the instrument circle.

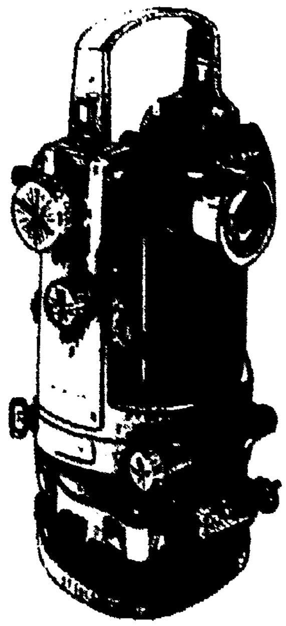
FIGURE 10



INFORMATION SHEET

FIGURE 11





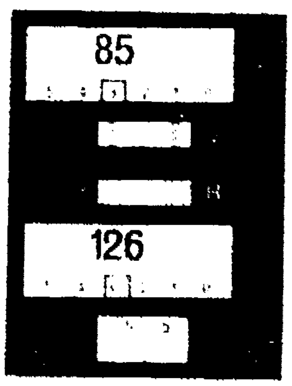
(NOTE: Both instruments have optical reading systems sh· n in the inset figures.)

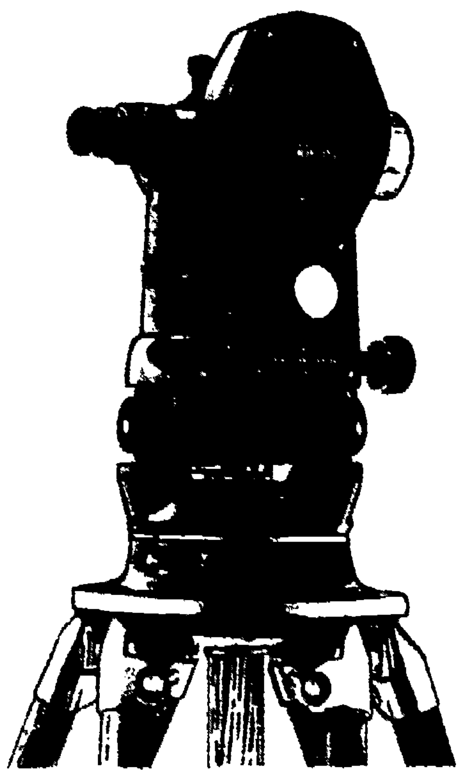
B. Directional theodolite (Figures 12 and 13)

1. Non-repeating type of instrument; has a single vertical axis so repetition cannot be performed.

2. Has no lower motion. (Directions rather than angles are read.)

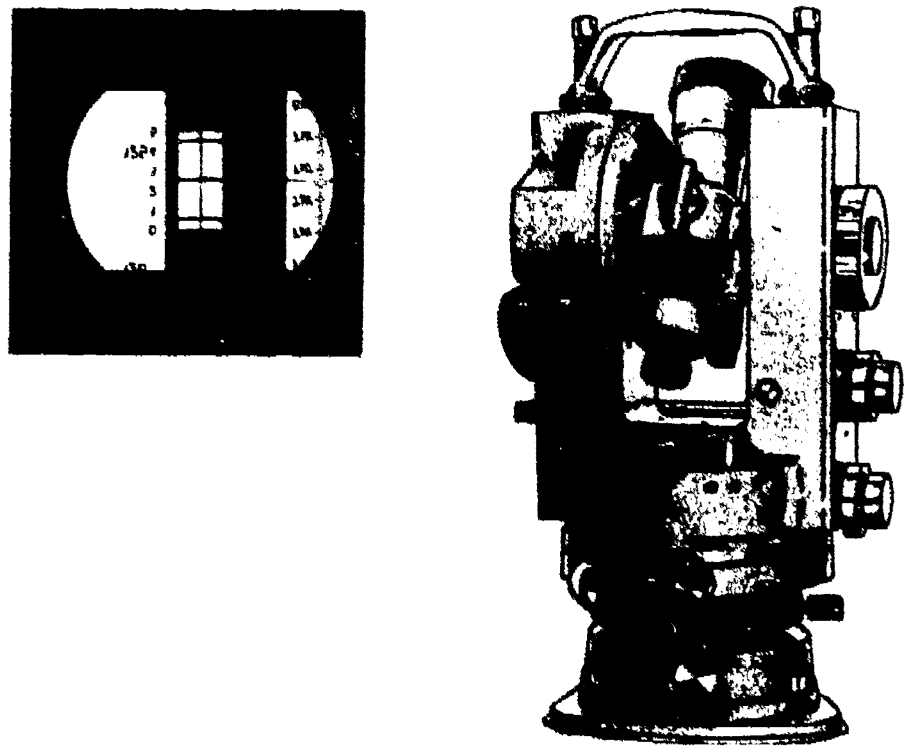
FIGURE 12





INFORMATION SHEET

FIGURE 13



IX. Instrument adjustments

A. Adjustment of plate-level vials

1. Field test — Set up instrument, bring one plate-level vial over two opposite leveling screws and center it. Revolve the instrument 180° over the same leveling screws. The distance the bubble moves from its centered position is double the error.

2. Correction — Turn the capstan screws at one end of the level vial to move the bubble halfway back to the centered position. Level the instrument with the leveling screws. Repeat the test until the bubble remains centered.

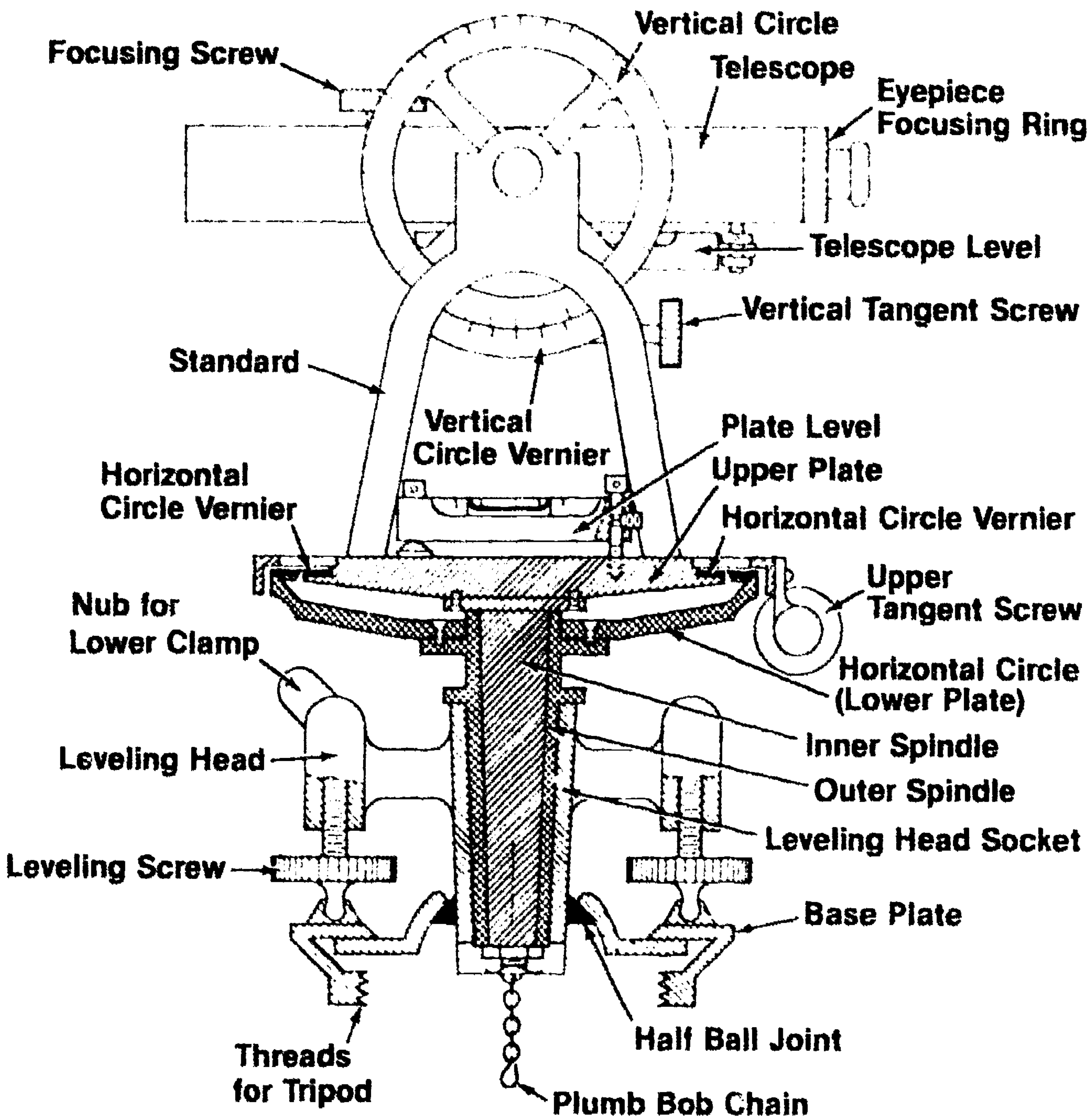
3. Adjust the other bubble in the same manner.

B. Adjustment of vertical cross hair

1. Field test — Sight a well-defined point with one end of the vertical cross hair. Turn the telescope on its horizontal axis so the cross hair moves along the point. If it departs, the cross hair is not perpendicular to the horizontal axis.

2. Adjustments should only be performed by trained operators. If done improperly, minor adjustment can be magnified intensely, leaving one with no option but to have the instrument completely adjusted by specialty personnel professionally trained in that area.

Parts of a Transit



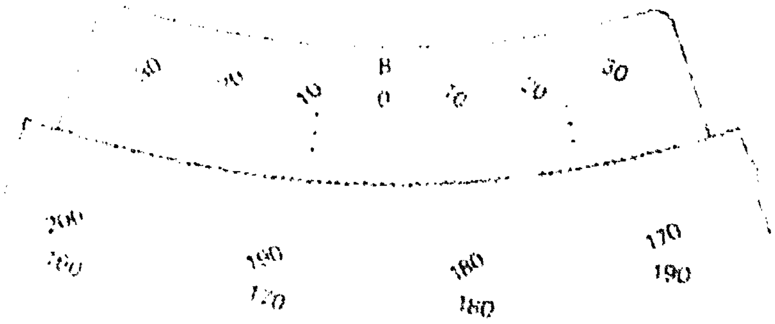
Cross Hatch Legend of Three Subassemblies

- Alidade
- Horizontal Circle Assembly
- Leveling Head Assembly

Reading a Vernier

Vernier Readings

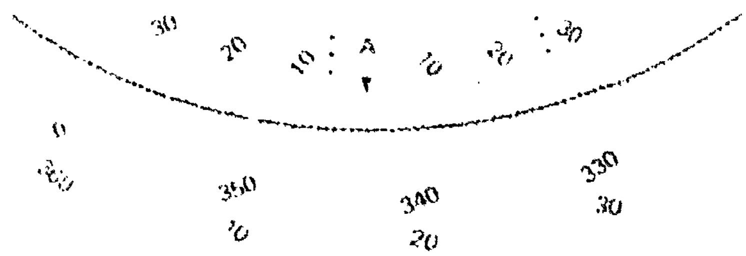
Clockwise	184°08'
Counterclockwise	175°52'
Check	359°60' = 360°00'



Graduated 30 Minutes Reading to One Minute
Double Direct Vernier

Vernier Readings

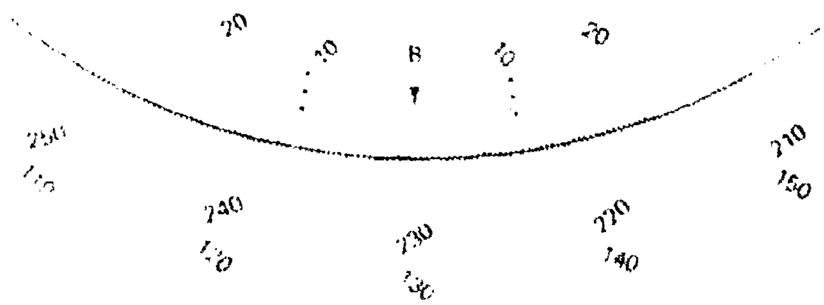
Clockwise	342°35'
Counterclockwise	17°25'
Check	360°00'



Graduated 20 Minutes Reading to 30 Seconds
Double Direct Vernier

Vernier Readings

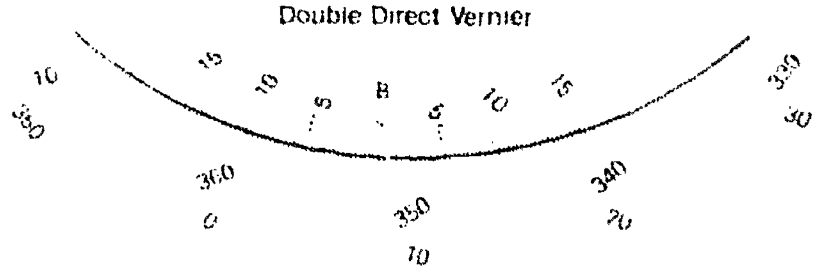
Clockwise	229°50'30"
Counterclockwise	130°09'30"
Check	360°00'00"



Graduated 15 Minutes Reading to 30 Seconds
Double Direct Vernier

Vernier Readings

Clockwise	351°35'40"
Counterclockwise	8°24'20"
Check	360°00'00"



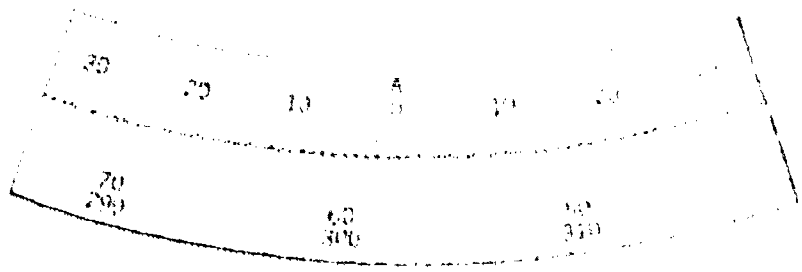
Clockwise Angles (i.e. Angles Turned to the Right) Utilize Only the Left Side Vernier Scale. Counterclockwise Angles (i.e. Angles Turned to the Left) Utilize Only the Right Side Vernier Scale.

ANGULAR MEASUREMENTS
UNIT VI

ASSIGNMENT SHEET #1 — ACCURATELY READ VARIOUS TYPES OF VERNIERS ON TRANSITS

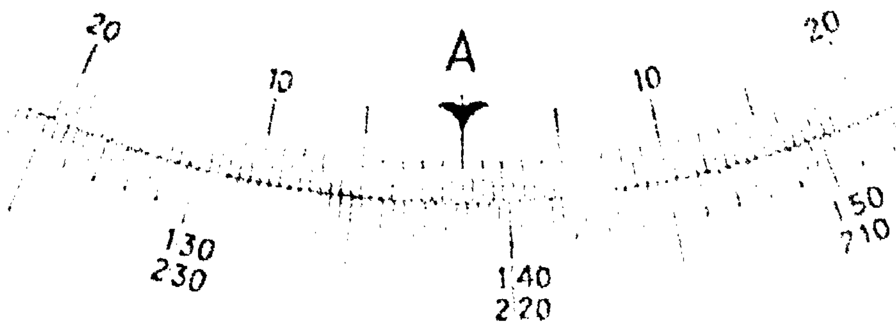
Directions: As accurately as possible interpolate the correct vernier reading for each problem and record your answer in the appropriate blank.

Example:



Clockwise 57°37'00"
Counterclockwise 302°23'00"

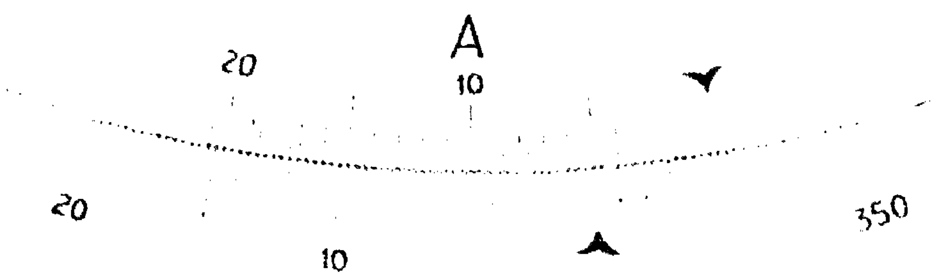
1.



Clockwise ____________

Counterclockwise ____________

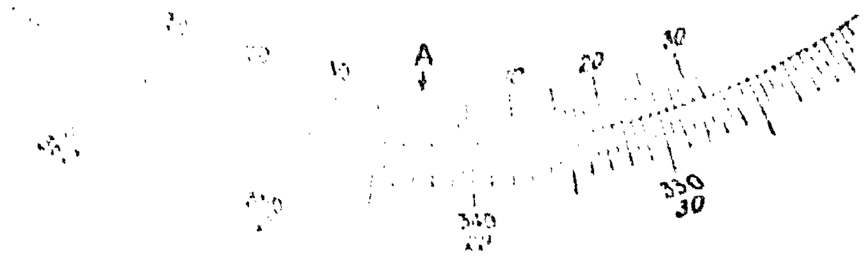
2.



Clockwise ____________

ASSIGNMENT SHEET #1

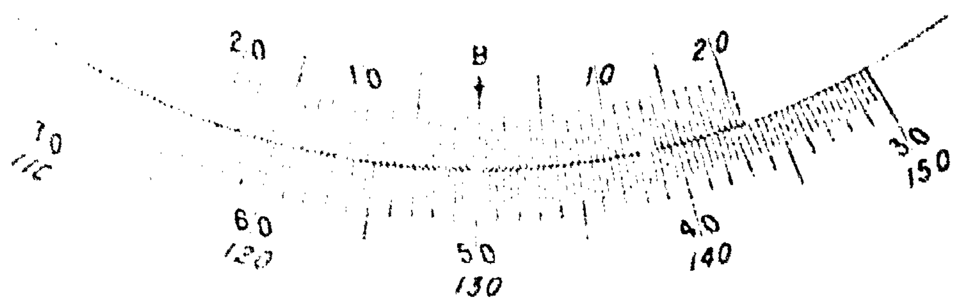
3.



Clockwise ______________

Counterclockwise ______________

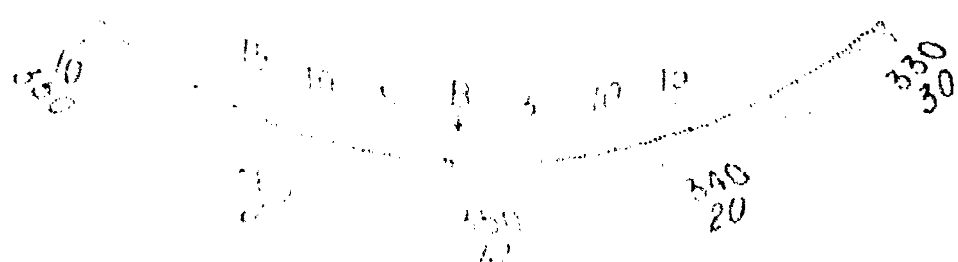
4.



Clockwise ______________

Counterclockwise ______________

5.

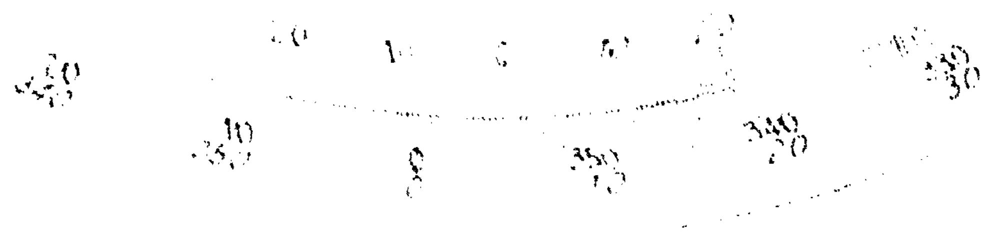


Clockwise ______________

Counterclockwise ______________

ASSIGNMENT SHEET #1

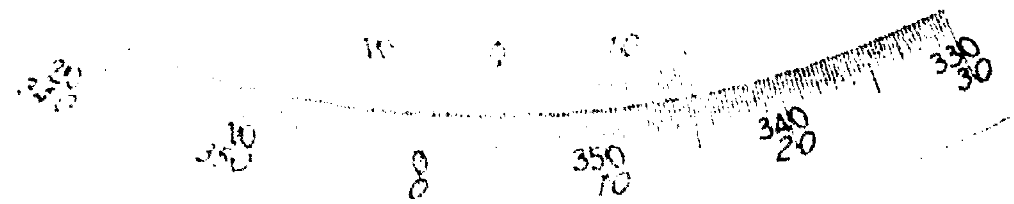
6.



Clockwise ______________

Counterclockwise ______________

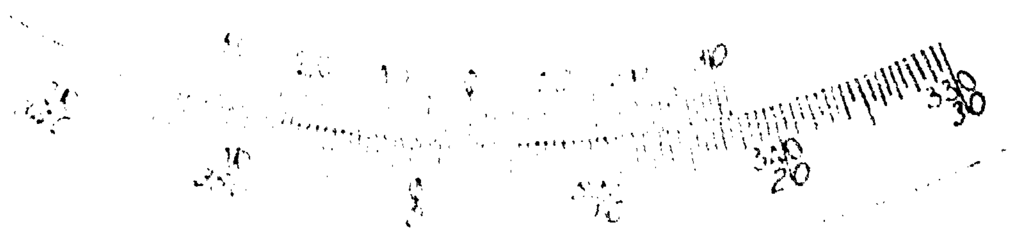
7.



Clockwise ______________

Counterclockwise ______________

8.



Clockwise ______________

Counterclockwise ______________

ANGULAR MEASUREMENTS
UNIT VI

ANSWERS TO ASSIGNMENT SHEET #1

(NOTE: Due to the loss of clarity in the printing process, the students' answers may vary slightly from these given.)

1. Clockwise 221°30'0"

   Counterclockwise 138°30'0"

2. Clockwise 355°0'0"

3. Clockwise 342°35'0"

   Counterclockwise 17°25'0"

4. Clockwise 49°50'30"

   Counterclockwise 130°09'30"

5. Clockwise 351°35'20"

   Counterclockwise 8°24'40"

6. Clockwise 355°10'30"

   Counterclockwise 4°49'30"

7. Clockwise 355°54'40"

   Counterclockwise 4°05'20"

8. Clockwise 357°19'0"

   Counterclockwise 2°41'0"

ANGULAR MEASUREMENTS
UNIT VI

JOB SHEET #1 — SET UP A TRANSIT OVER A DESIRED POINT

A. Tools and materials

1. Transit (4-screw)
2. Tripod
3. Hammer
4. Stake (with tack)

B. Procedure

1. Remove transit from its case. Hold it by its standards, never by the telescope.
2. Place on tripod. Screw leveling head on tripod snuggly while holding instrument with one hand.

   (NOTE: A transit may be carried while attached to the tripod by placing over one's shoulder. If passing under obstructions or indoors, the instrument should be carried in front with tripod cradled so the instrument can be seen. See Figure 1.)

   FIGURE 1

JOB SHEET #1

3. Pound stake with tack in center into the ground where set-up is going to take place.

4. Place instrument roughly over desired point and adjust the legs of the tripod so that:

   a. The instrument is at a convenient height.

   b. The tripod plate is nearly level.

   (NOTE: Usually two legs are placed on the ground and the instrument is roughly leveled and manipulated into position by moving the third leg. See Figure 2.)

   FIGURE 2

5. Tighten the wing nuts on the tripod legs when in position.

JOB SHEET #1

6. Secure a plumb bob to the plumb bob chain and hook. The bob should hang from the leveling head and be slightly above the desired point of set up. (Figure 3)

FIGURE 3

7. Slowly secure the tripod legs into the ground taking care not to jar the instrument. (Figure 4)

(NOTE: If necessary, adjust the plumb bob string so it remains hanging free above point. When the plumb bob point is within 1/4 inch from desired point, the instrument is then leveled.)

FIGURE 4

JOB SHEET #1

8. Loosen two adjacent leveling screws slightly to release tension so that the transit can be shifted laterally until it is precisely over the point. Then retighten the same two screws.

9. Center the leveling tubes or plate levels directly over two opposite leveling screws by rotating the alidade.

10. Begin adjusting the level bubble by turning the two (opposite) leveling screws that are directly beneath the level vial. Proper tension is important at this stage. Leave the screws firmly secure but not bound.

    (NOTE: The general rule of "thumbs-in, thumbs-out" can be used to gradually tip the alidade until the bubble is centered in the level vial.)

11. Duplicate this procedure using the two remaining leveling screws and the opposite level vial.

12. Repeat the leveling steps a second or third time to eliminate any minor adjustments to the level bubbles.

13. Once the instrument is accurately leveled, the screws may be loosened slightly and the leveling head shifted to position the plumb bob point directly over the desired point of setup. Care must be taken if this is done.

    a. It can be shifted right or left but not turned on the leveling head.

    b. Any leveling screw must be retightened back to its original point.

ANGULAR MEASUREMENTS
UNIT VI

JOB SHEET #2 — MEASURE AND READ ANGLES IN THE FIELD

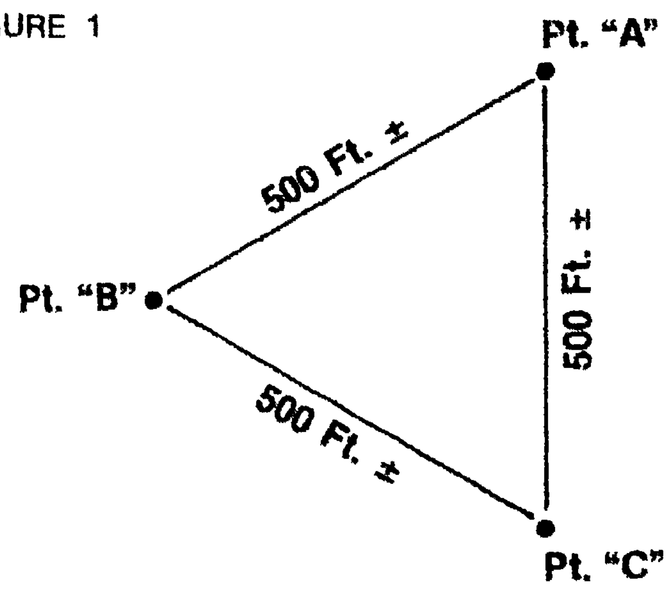
A. Tools and materials

1. Transit
2. Tripod
3. Range poles
4. Stakes
5. Hammer
6. Field book
7. Pencil

B. Procedure

1. Set three stakes in ground approximately 500′ apart with an acute angle between them. (Figure 1)

FIGURE 1



2. Set up the transit over Point "A".

   (NOTE: Refer to Job Sheet #1 for instruction. Assuming that the instrument is over the point and level, the following procedure is used to turn and "double" an angle. Turning an angle at least twice permits the elimination of mistakes and increases precision owing to the elimination of most instrument errors.)

JOB SHEET #2

3. Set the scales to zero. (Figure 2)

   a. Loosen both the upper and lower motion clamps.

   b. Hold the alidade stationary, and revolve the circle by pushing on the circle underside with the fingertips.

   c. When zero is close to the index point of the vernier, tighten the **upper** clamp.

   d. With a magnifying glass, slowly turn the **upper** tangent screw until the zeros are precisely in line.

   FIGURE 2

4. Sight the initial point (or backsight), in this case Point "C".

   a. With the upper clamp tightened and the lower clamp loose, turn and point the telescope towards the initial point.

   b. Once relatively close to the desired position, tighten the **lower** clamp.

   c. While observing the point through the telescope, slowly turn the **lower** tangent screw until precisely in line with the initial point.

   (NOTE: The vertical cross hair should be centered on the point being observed. Backsights should be equal to or longer than foresights.)

5. Turn the horizontal angle.

   a. Loosen the **upper** clamp and turn the telescope clockwise toward the final point (or foresight in this case Point "B".

JOB SHEET #2

b. When point is close to the vertical cross hair, tighten the **upper** clamp.

c. Slowly turn the **upper** tangent screw until the vertical cross hair is precisely in position.

6. Read the angle. (Figure 3)

FIGURE 3

a. Observe the vernier and determine the angle using a magnifying glass.

b. Record the value in the field book in the appropriate column. (Figure 4)

7. Repeat the angle.

a. After the initial angle had been recorded, "plunge" or "invert" the telescope.

b. Loosen the lower motion and sight the initial point or original backsight point.

c. Tighten the **lower** clamp.

d. Repeat steps 5 and 6 except that the telescope is now inverted and the initial horizontal angle setting is that of the initial angle.

e. Record the "doubled" angle in the appropriate column. (Figure 4)

(NOTE: This job skill can be performed again from Point "B" recording the angle of A-B-C. The instrument can also be set on Point "C" and that angle measured.)

JOB SHEET #2

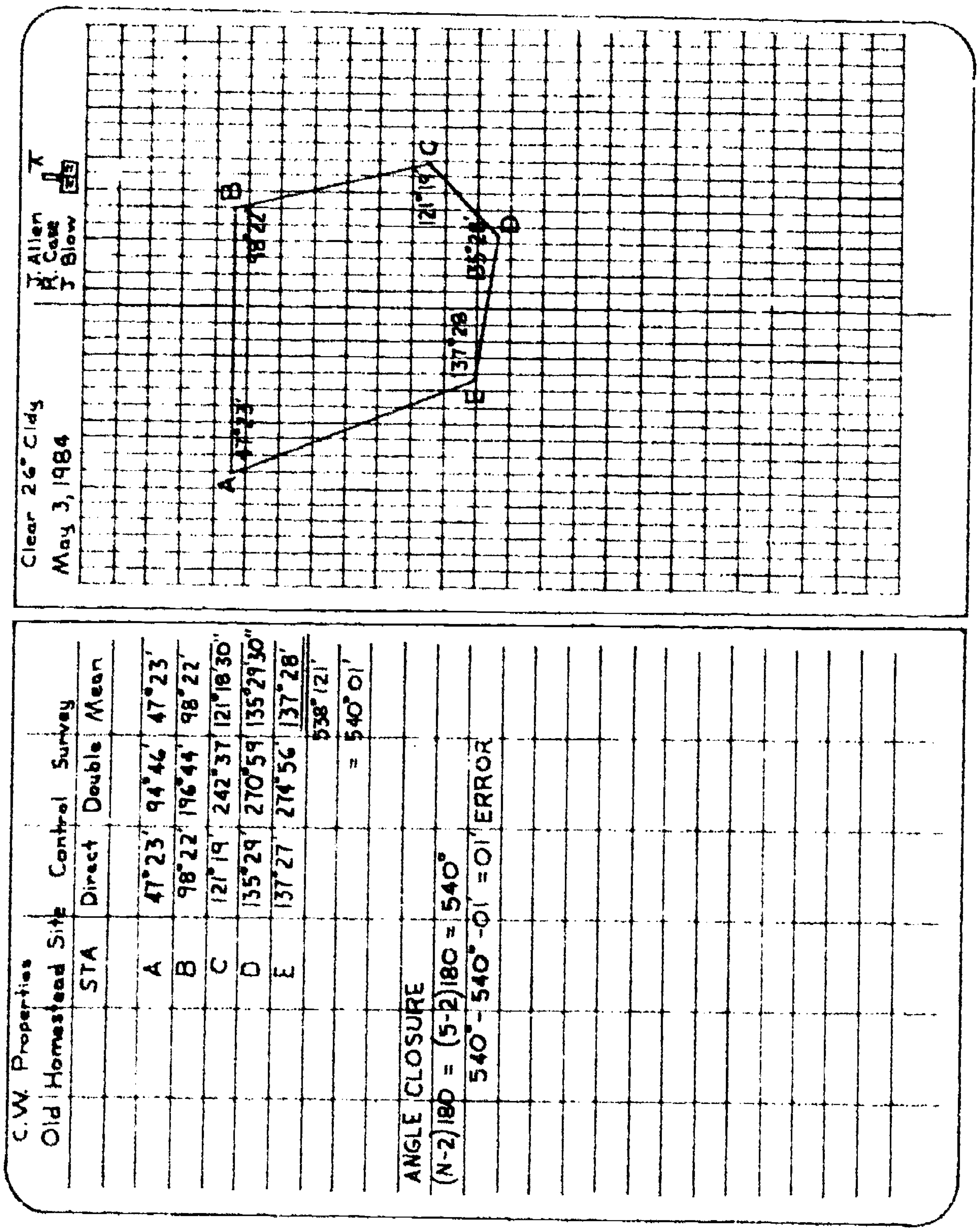


FIGURE 4

ANGULAR MEASUREMENTS
UNIT VI

JOB SHEET #3 — SET UP A THEODOLITE OVER A DESIRED POINT

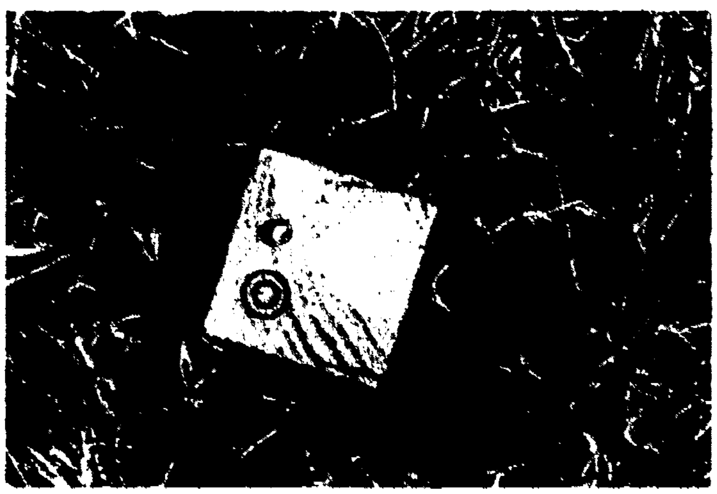
A. Tools and materials

1. Theodolite (3-screw)
2. Tripod
3. Hammer
4. Stake and tack

B. Procedure

1. Remove instrument from its case.
2. Place it on the tripod, taking care to securely fasten the 5/8" nut on the bottom of the tripod.
3. Place instrument over the point with the tripod plate as level as possible.
4. Check to see that the station point can be seen through the optical plummet. (Figure 1)

FIGURE 1



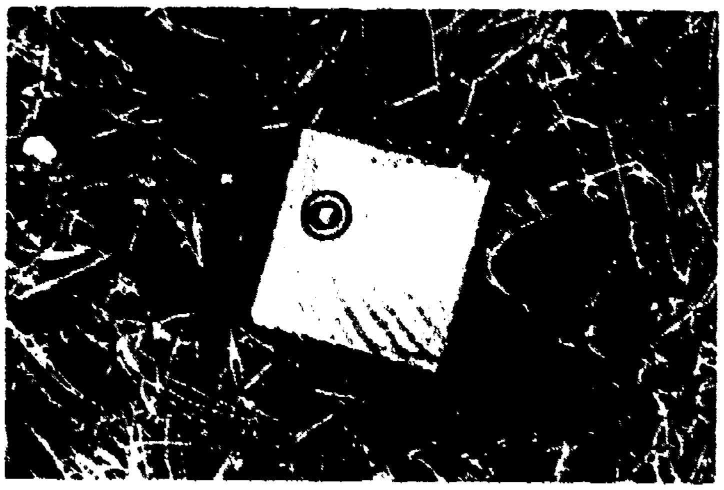
(NOTE: The theodolite can be set up in much the same manner as a transit, the major difference lying in the use of an optical plummet. Although the optic plummet results in more precise positioning, it is, for the beginner, more difficult to use. Therefore, to reduce setup time, a systematic approach is recommended.)

5. Firmly set the tripod legs in the ground.

JOB SHEET #3

6. While looking through the optical plummet, manipulate the leveling screws until the cross hairs or bull's eye of the optical plummet is directly on the station point. (Figure 2)

FIGURE 2



7. Level up the circular bubble on the theodolite by adjusting the tripod legs up or down. (Figure 3)

FIGURE 3

8. Verify that the cross hair or bull's eye is still quite close to being over the station point.

9. Center the circular bubble exactly by making minor adjustments to the leveling screws.

10. Loosen the tripod clamp bolt slightly and slide the theodolite until the cross hair is directly over the station point.

    (NOTE: When sliding the instrument across the base of the tripod, do not twist or turn the instrument, but move it in a rectangular fashion.)

11. To precisely level the instrument, center the tubular level by aligning the bubble parallel with the adjacent foot screws. Once centered, turn instrument 90° and relevel vial using the untouched leveling screw.

ANGULAR MEASUREMENTS
UNIT VI

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

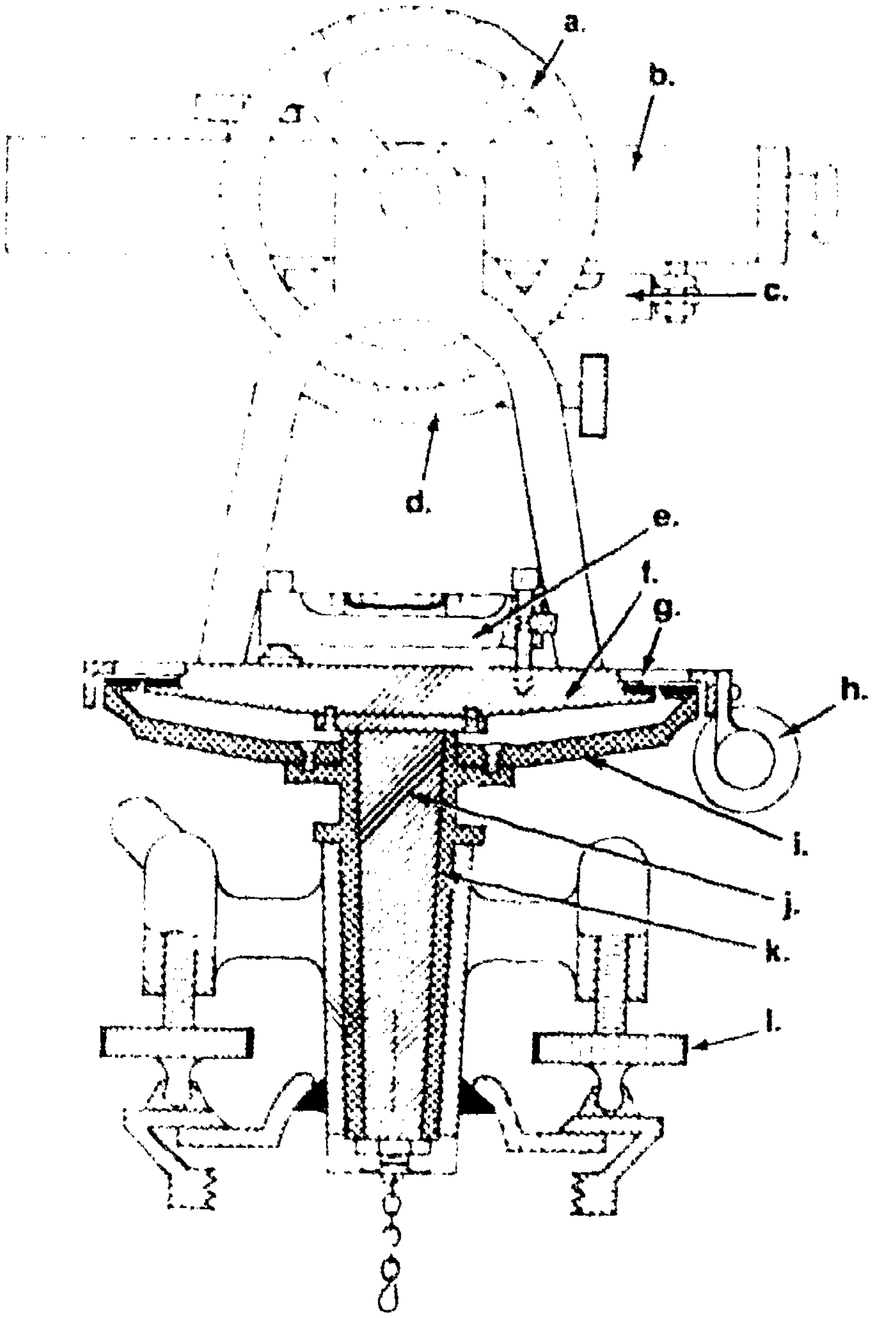
_____a.	A repeating surveying instrument for measuring horizontal and vertical angles	1. Least count
_____b.	A sighting device built into the base of a theodolite used to indicate vertical direction	2. Optical plummet
_____c.	A short auxiliary scale set parallel to and beside a primary scale; provides fractional parts of the smallest main-scale divisions without interpolating	3. Plumb bob
_____d.	The smallest reading obtainable on a vernier without interpolating	4. Theodolite
_____e.	A brass weight attached to a line on a transit that is used to indicate vertical direction	5. Transit
_____f.	A precision instrument used for measuring horizontal and vertical angles	6. Vernier

2. List one use of transits and theodolites.

____

TEST

3. Identify the major parts of the following transit and place your answers in the blanks provided.



a. ______________________ g. ______________________

b. ______________________ h. ______________________

c. ______________________ i. ______________________

d. ______________________ j. ______________________

e. ______________________ k. ______________________

f. ______________________ l. ______________________

TEST

4. Distinguish between [illegible]
next to the [illegible]

_____ a. [illegible]

_____ b. [illegible]

_____ c. [illegible]

_____ d. [illegible]
the [illegible]

_____ e. Horizontal and [illegible]
[illegible]

_____ f. [illegible]

_____ g. [illegible]

_____ h. [illegible]

_____ i. [illegible]

_____ j. [illegible]

5. Distinguish between [illegible]
[illegible]
[illegible] next to the [illegible]

_____ a. [illegible]

_____ b. [illegible]

_____ c. [illegible]

TEST

6. Interpret the following readings on the different styles of verniers.

a. Clockwise ______________________________

Counterclockwise ______________________________

b. Clockwise ______________________________

Counterclockwise ______________________________

7. List three typical mistakes made in reading verniers.

a. ______________________________

b. ______________________________

c. ______________________________

8. Differentiate between the two major types of theodolites by placing an "X" next to the description(s) of a repeating theodolite, and an "O" next to the description(s) of a directional theodolite.

_____a. Has no lower motion. (Directions rather than angles are read.)

_____b. Equipped with a double vertical axis.

_____c. Has a single vertical axis.

_____d. Enables angles to be repeated any number of times and added directly on the instrument circle.

TEST

9. Describe the field test procedure used to determine if minor instrument adjustments are necessary on plate-level vials and the vertical cross hair.

   a. Plate-level vials ____

   b. Vertical cross hair ____

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

10. Accurately read various types of verniers on transits. (Assignment Sheet #1)

11. Demonstrate the ability to:

    a. Set up a transit over a desired point. (Job Sheet #1)

    b. Measure and read angles in the field. (Job Sheet #2)

    c. Set up a theodolite over a desired point. (Job Sheet #3)

ANGULAR MEASUREMENT
UNIT VI

ANSWERS TO TEST

1. a. 5
   b. 2
   c. 6
   d. 1
   e. 3
   f 4

2. Either one of the following:
   a. Primarily used for accurate r rement or layout of horizontal and vertical angles
   b. Also used to determine horizontal and vertical distances by stadia, prolonging straight lines, and low order differential leveling

3. a. Vertical circle
   b. Telescope
   c. Telescope level
   d. Vertical circle vernier
   e. Plate level
   f. Upper plate
   g. Horizontal circle vernier
   h. Upper tangent screw
   i. Horizontal circle (lower plate)
   j. Inner spindle
   k. Outer spindle
   l. Leveling screw

4.

a.	TH	f.	TH
b.	TR	g.	TH
c.	TR	h.	TR
d.	TR	i.	TH
e.	TH	j.	TH

5. a. O
   b. X
   c. F

6. a. Clockwise — 184°08′
   Counterclockwise — 175°52′
   b. Clockwise — 342°35′
   Counterclockwise — 17°25′

7. Any three of the following:
   a. Not using a magnifying glass.
   b. Reading the wrong direction from zero.
   c. Failing to determine the least count correctly.
   d. Omitting 10, 15, 20, or 30 minutes when the index is beyond those marks.
   e. Failing to read directly on the line (parallel error).

ANSWERS TO TEST

8. a. O
   b. X
   c. O
   d. X

9. Descriptions should include:
   a. Set up instrument, bring one plate-level vial over two opposite leveling screws and center it. Revolve the instrument 180° over the same leveling screws. The distance the bubble moves from its centered position is double the error.
   b. Sight a well-defined point with one end of the vertical cross hair. Turn the telescope on its horizontal axis so the cross hair moves along the point. If it departs, the cross hair is not perpendicular to the horizontal axis.

10. Evaluated to the satisfaction of the instructor

11. Performance skills evaluated to the satisfaction of the instructor

TRAVERSING AND RELATED CALCULATIONS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the types of traverses commonly used, describe the methods used to obtain traverse angles, arrange in order the steps taken to properly compute a traverse closure, accurately compute traverse closures and areas, and perform traversing operations. Competencies will be demonstrated by correctly performing the procedures outlined in the job and assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to traversing with the correct definitions.
2. Identify the types of traverses commonly used in surveying.
3. Describe the methods of measuring traverse angles or directions.
4. Select true statements concerning the proper location of traverse station points.
5. List major sources of error in traverse operations.
6. Arrange in order the nine primary steps taken when computing a traverse closure.
7. Select true statements concerning observations or assumptions that can be made when calculating areas by means of the D.M.D. method.
8. Complete statements concerning rules to follow when calculating areas by means of the coordinate method.
9. Compute traverse closure and adjustment by the compass rule. (Assignment Sheet #1)

OBJECTIVE SHEET

10. Compute traverse closure and adjustment by the transit rule. (Assignment Sheet #2)

11. Calculate area of a closed traverse by the D.M.D. method. (Assignment Sheet #3)

12. Calculate area of a closed traverse by the coordinate method. (Assignment Sheet #4)

13. Demonstrate the ability to:

    a. Perform a closed loop traverse. (Job Sheet #1)

    b. Perform a closed connecting traverse. (Job Sheet #2)

TRAVERSING AND RELATED CALCULATIONS
UNIT VII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparency from the transparency master included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparency to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedure outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Invite a land surveyor into the class to discuss the uses and importance of traversing and accurate closures.
2. Have students perform field procedures involved in traversing and then establish the accuracy of their work.
3. Have students calculate the area of the traverses they are performing in the field.
4. Have students research various types of computer programs that can be used for traverse calculations.
5. If your school has any programs that can be run for traverse computations, schedule the students in groups of two to work through example problems.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency Master #1 — Types of Traverses

D. Assignment sheets

1. Assignment Sheet #1 — Compute Traverse Closure and Adjustment by the Compass Rule

2. Assignment Sheet #2 — Compute Traverse Closure and Adjustment by the Transit Rule

3. Assignment Sheet #3 — Calculate Areas of a Closed Traverse by the D.M.D. Method

4. Assignment Sheet #4 — Calculate Area of a Closed Traverse by the Coordinate Method

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1 — Perform a Closed Loop Traverse

2. Job Sheet #2 — Perform a Closed Connecting Traverse

G. Test

H. Answers to test

REFERENCES USED IN WRITING THIS UNIT

A. Kavanagh, Barry F., and S. J. Glenn Bird. *Surveying: Principles and Applications*. Reston, Virginia: Reston Publishing Co., Inc., 1984.

B. Brinker, Russell and P.R. Wolf. *Elementary Surveying*, 7th ed. New York: Harper & Row, 1984.

C. Wirshing and Wirshing. *Introductory Surveying*. McGraw-Hill, 1985.

SUGGESTED SUPPLEMENTAL MATERIALS

A. Davis, R.E., F.S. Foote, and J.H. Kelly. *Surveying*, 5th ed. New York: McGraw-Hill, 1976.

B. Kissam, Phillip. *Surveying for Civil Engineers*. New York: McGraw-Hill, 1976.

C. Kissam, Phillip. *Surveying Practice*, 3rd ed. New York: McGraw-Hill, 1978.

D. Hong, John S. *Fundamentals of Land Measurement*. Chicago, IL: Chicago Title Insurance Company, 1971.

TRAVERSING AND RELATED CALCULATIONS
UNIT VII

INFORMATION SHEET

I. **Terms and definitions**

A. Angular error — The amount of error that occurs when measuring angles of a traverse

B. Azimuth — The horizontal bearing of a line measured clockwise from the meridian

C. Bearing — The horizontal angle turned between a datum direction such as true north and a given line

D. Coordinates — Numbers used to locate and define the position of a point with respect to two perpendicular axes, the Y-axis (north-south) and the X-axis (east-west)

E. Departure — The east-west rectangular component of a line

F. Error of closure — The net accumulation of the random errors associated with the measurement of the traverse angles and distances

G. Instrument point — The station over which the survey instrument is set up, usually where the data for that particular area is being collected

H. Latitude — The north-south rectangular component of a line

I. Meridian distance — The perpendicular distance from the center point of the line or traverse course to the reference meridian

J. Polygon — A closed plane figure bound by straight lines

K. Ties — Horizontal measurements to a survey point from existing objects or offset points, used to reestablish the point if it is destroyed

L. Traverse — A control survey of established lines with known lengths and measured angles at each point or station

M. Traverse point — A point, usually set in a convenient location to the project, that has a known location horizontally in reference to the other points of the traverse

II. **Types of traverses** (Transparency 1)

A. Open traverses

1. Consist of a series of lines that are connected but do not return to the point of beginning or do not close upon another point of known position.

2. Are sometimes used on route location but are generally avoided because they offer no means of checking for errors and mistakes.

INFORMATION SHEET

B. Closed traverses

1. Provide means to check the measured angles and distances measured

2. There are two types

a. Loop traverse — The line returns to the starting point forming a closed polygon

b. Connecting traverse — The line starts at a known point of position and finishes upon another station point of known location.

(NOTE: This type is geometrically open, but mathematically closed.)

III. Methods of measuring traverse angles or directions

A. Compass bearings — Bearings are read directly on a compass as sights are taken along the lines or traverse courses.

B. Interior angles — The inside angles of the traverse or polygon are measured using a transit or theodolite. They can be measured either clockwise or counterclockwise.

C. Deflection angles — Are commonly used on route surveys in which the angle is measured right or left from the back direction extended.

D. Angles to the right — Are angles measured from a backsight on the previous point and measured clockwise (to the right) to the next point of the traverse.

IV. Proper location of traverse station points

A. Position of traverse station varies with the type of survey being performed.

1. Property surveys — The points should be placed at each corner of the property unless the line of sight is obstructed or the point cannot be occupied.

2. Route surveys — The stations should be set at each angle point where the direction of the route changes. Additional points can be set due to long lines or rolling terrain that would impair accuratc measurements.

3. Topographical surveys — The traverse points are set at locations to permit the best coverage of the area to be mapped.

INFORMATION SHEET

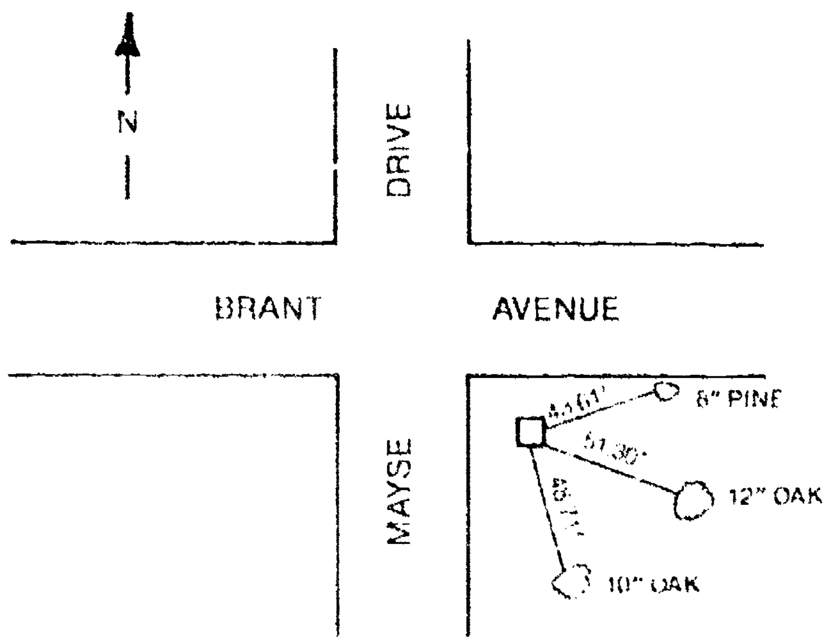
B. Referencing points

1. Traverse stations can be lost if not properly described and preserved.

2. Ties are used to aid in finding a survey point or to relocate one that has been destroyed.

   (NOTE: Ties should be made to all traverse points when they are established. Distances should be less than 100 feet whenever possible. See Figure 1.)

FIGURE 1



V. Sources of error in traverse operations

A. Errors in measurement of angles and distances

B. Poor selection of traverse points resulting in bad sighting conditions due to:

1. Alternate sun and shadow
2. Visibility of only the top of the rod
3. Line of sight passing too close to the ground
4. Lines that are too long or too short
5. Sighting into the sun
6. Sighting through timber

C. Failing to measure the angles an equal number of times direct and reversed

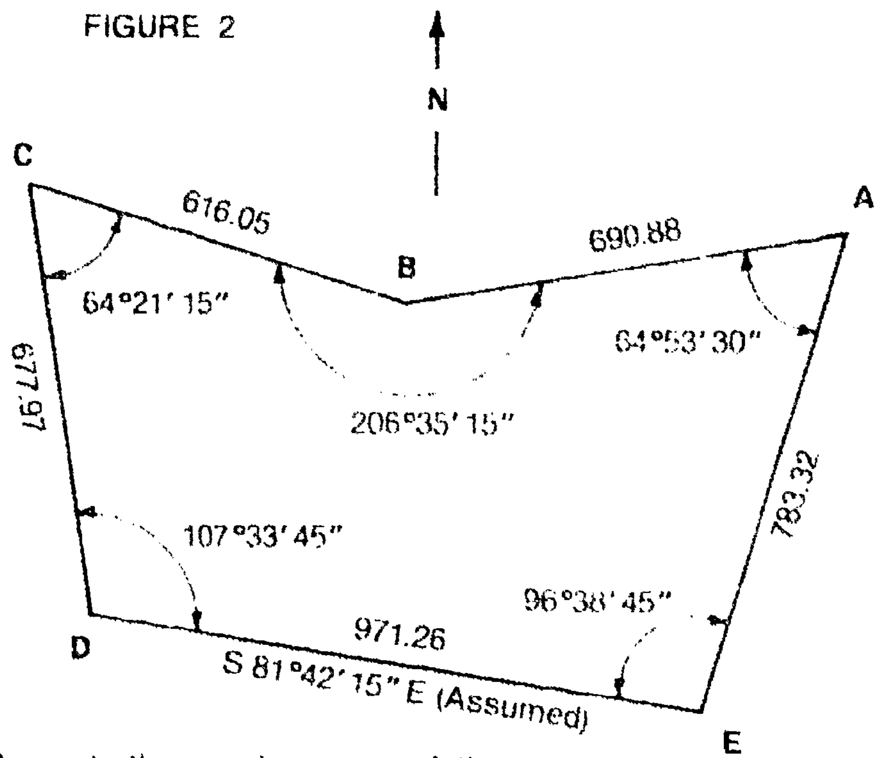
INFORMATION SHEET

VI. Primary steps taken when computing a traverse closure

A. Draw a sketch of the traverse to scale.

1. Show point or I.D. numbers.
2. Indicate actual field measured angles and distances.
3. A sketch will aid as a check for any blunders. (Figure 2)

FIGURE 2



B. Compute the angular error as follows:

Sum of the angles of a closed polygon = (N-2)(180°)
Where: N = Number of angles
So the number of angles in this example should equal:
(5-2)(180°) = 540°

1. Find the sum of the angles measured:

A	=	64°53′30″
B	=	206°35′15″
C	=	64°21′15″
D	=	107°33′45″
E	=	96°38′45″
Sum	=	540°02′30″

Thus: 540°02′30″ − 540° = 02′30″ error

Since there are five angles, the error should be proportioned equally.

$\frac{02'30''}{5 \text{ angles}}$ = 30 seconds error per angle

(NOTE: Normally up to 1 minute of error is allowable in beginning work by students, so this error is acceptable.)

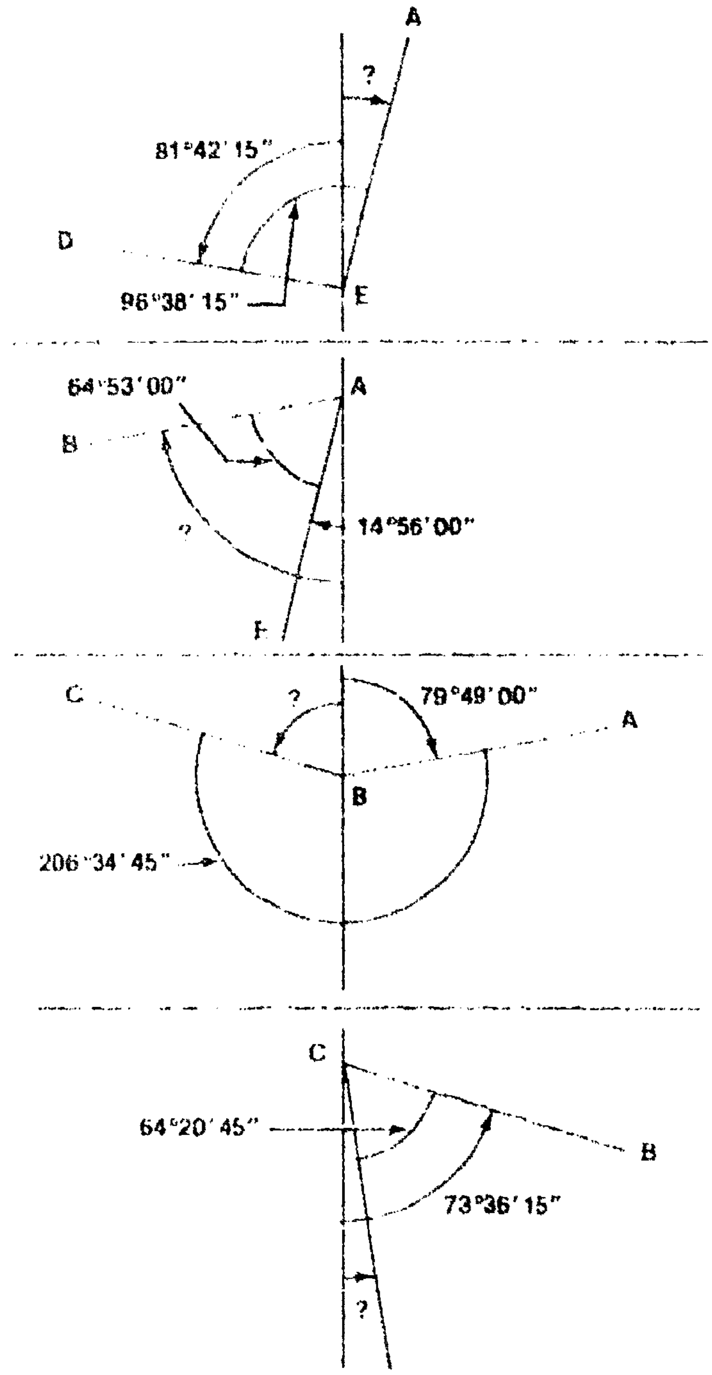
INFORMATION SHEET

2. Adjust the angles. Subtract 30 seconds from each of the angles in the traverse.

A =	64°53'30"	−30" =	64°53'00"	
B =	206°35'15"	−30" =	206°34'45"	
C =	64°21'15"	−30" =	64°20'45"	
D =	107°33'45"	−30" =	107°33'15"	
E =	96°38'45"	−30" =	96°38'15"	
		Sum =	540°00'00"	Check

C. Compute the bearings. Starting with the known bearing of DE = S81°42'15"E, compute the bearings by applying the corrected angles successively. See Figure 3. Note in Figure 3 the traverse leg, which has a known bearing, is the starting point for working out the traverse.

FIGURE 3



96°38'15"
−81°42'15"
14°56'00"

EA = N 14°56'00" E

64°53'00"
+14°56'00"
79°49'00"

AB = S 79°49'00" W

79°49'00"
+206°34'45"
286°23'45"

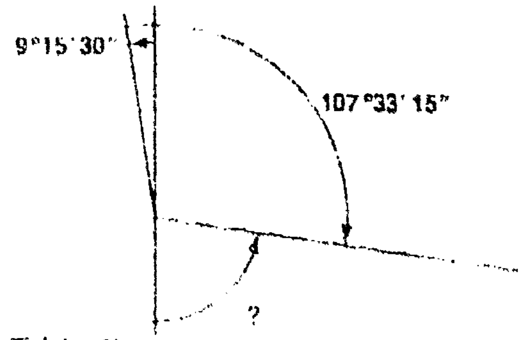
359°59'60"
−286°23'45"
73°36'15"

BC = N 73°36'15" W

73°36'15"
−64°20'45"
09°15'30"

CD = S 09°15'30" E

INFORMATION SHEET



$$
\begin{array}{r}
107°33'15'' \\
\underline{-09°15'30''} \\
-98°17'45'' \\
\underline{+179°59'60''} \\
81°42'15''
\end{array}
$$

(Bearings check)

D. Compute latitudes and departures (Table 1)

1. From a horizontal x axis and a vertical y axis a line of certain bearing (or azimuth) and of a definite length will have: a Δy component called a *latitude* and a Δx component called a *departure*. The latitude of a line is given by the following equation:

$$\Delta y = L \cos \beta$$

where Δy = latitude
L = length of line
β = bearing of line

2. The departure of a line is given by the following equation:

$$\Delta x = L \sin \beta$$

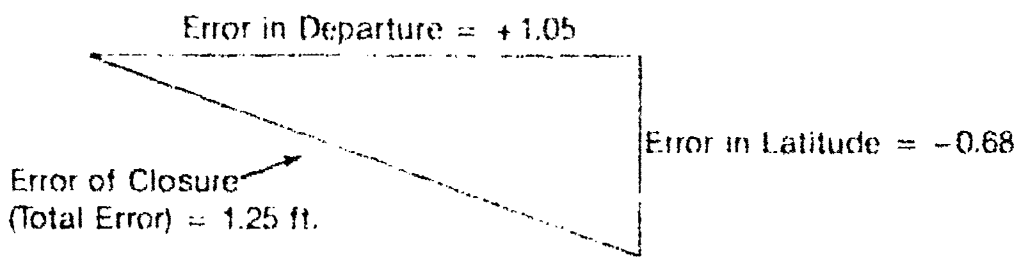
where Δx = departure
L = length of line
β = bearing of line

(NOTE: For latitudes, the north (N) direction is positive; the south (S) direction is negative. For departures, the east (E) direction is positive; the west (W) direction is negative. In the examples and problems which follow, use a calculator to compute the trigonometric functions. Logarithmic computations will not be used here as they are more cumbersome; computers and calculators are so universally available to all survey parties that logarithms are rarely used.)

TABLE 1 — LATITUDES AND DEPARTURES

Course	Bearing	Distance	Latitude North(+)	Latitude South(−)	Departure East(+)	Departure W[illegible]−)
A to B	S79°49′00″W	690.88		−122.15		−[illegible].99
B to C	N73°36′15″W	616.05	+173.89			−591.00
C to D	S09°15′30″E	677.97		−699.14	+109.08	
D to E	S81°42′15″E	971.26		−140.14	+961.10	
E to A	N14°56′00″E	783.32	+756.86		+201.86	
		3739.48	+930.75	−931.43	+1272.04	−1270.99

Difference = −0.68 and +1.05



INFORMATION SHEET

E. Compute the error of closure (Table 1)

1. The traverse begins and ends at the same point, so the sum of the latitudes and the sum of the departures should both be zero. By adding the columns, the error can be found.

   Lat error = Sum of all latitudes Dep. error = Sum of all departures

2. The total error of the survey can be found by:

   $$\text{Total error of closure} = \sqrt{\text{Lat. Error}^2 + \text{Dep. Error}^2}$$

F. Compute the measure of accuracy which is the ratio of the total error to the total length of the survey.

Therefore: Total distance surveyed ÷ total error = accuracy of survey

(NOTE: The minimum accuracy of the usual traverse should be 3rd order work or 1:3000. If the ratio is lower, a blunder may exist.)

G. Compute corrections for latitudes and departures (Tables 2 and 3)

(NOTE: There are three methods for adjusting latitudes and departures to ensure that the sums of the latitudes and departures equal zero: the compass rule, the transit rule, and the least squares method. Each method is described below.)

1. The compass (or Bowditch) rule applies corrections in proportion to the lengths of the courses. The equation is as follows (*correction* indicates the correction to a latitude or departure):

   $$\text{Correction} = \frac{C}{L} S$$

   where C = Total error in sum of latitudes or departures *with sign changed*
   L = Total length of survey
   S = Length of the particular course

INFORMATION SHEET

TABLE 2 — COMPASS RULE CORRECTIONS

Course	Correction to Latitudes	Correction to Departures
A — B	$\frac{0.68}{3739} \times 691 = 0.13$	$\frac{-1.05}{3738} \times 691 = -0.19$
B — C	$\frac{0.68}{3739} \times 616 = 0.11$	$\frac{-1.05}{3738} \times 616 = -0.17$
C — D	$\frac{0.68}{3739} \times 678 = 0.12$	$\frac{-1.05}{3738} \times 678 = -0.19$
D — E	$\frac{0.68}{3739} \times 971 = 0.18$	$\frac{-1.05}{3738} \times 971 = -0.27$
E — A	$\frac{0.68}{3739} \times 783 = 0.14$	$\frac{-1.05}{3738} \times 783 = -0.23$
	Sum = 0.68	Sum = −1.05

(NOTE: The compass rule is more mathematically correct than the transit rule; however, it changes the latitudes and departures in such a way that both the bearings and lengths of the courses are changed.)

2. The transit rule applies corrections in proportion to the lengths of the latitudes and departures. The equation is as follows:

$$\text{Correction} = \frac{C}{l} s$$

Where C = Total error in sum of latitudes or departures *with sign changed*

l = Total sum of the latitudes or departures *disregarding the sign*

s = Length of particular latitude or departure

TABLE 3 — TRANSIT RULE CORRECTIONS

Course	Correction to Latitudes	Correction to Departures
A — B	$\frac{0.68}{1862} \times 122 = 0.04$	$\frac{-1.05}{2543} \times 680 = -0.28$
B — C	$\frac{0.68}{1862} \times 174 = 0.06$	$\frac{-1.05}{2543} \times 591 = -0.24$
C — D	$\frac{0.68}{1862} \times 669 = 0.24$	$\frac{-1.05}{2543} \times 109 = -0.04$
D — E	$\frac{0.68}{1862} \times 140 = 0.05$	$\frac{-1.05}{2543} \times 961 = -0.41$
E — A	$\frac{0.68}{1862} \times 757 = 0.29$	$\frac{-1.05}{2543} \times 202 = -0.08$
	Sum = 0.68	Sum = −1.05

(NOTE: The transit rule changes latitudes and departures in such a way that course lengths are slightly changed but bearings remain nearly the same.)

INFORMATION SHEET

3. The least squares method is based on the theory of probability. It simultaneously adjusts the angles and distances to make the sum of the squares of the residuals a minimum. It is the best method for adjusting traverses, but has not been used extensively due to the lengthy computations required, until recently with the rapid growth of computer calculations.

H. Calculate adjusted latitudes and departures (Table 4)

1. Using the proper algebraic signs add the previously computed corrections to the corresponding latitude or departure.

2. The final sum of the latitudes or departures should equal zero. (Norths being positive and souths being negative) or (easts being positive and wests being negative).

TABLE 4 — ADJUSTING LATITUDES AND DEPARTURES

	Unadjusted		Corrections*		Adjusted	
Course	Lat	Dep	Lat	Dep	Lat	Dep
A — B	−122.15	−679.99	+0.13	−0.19	−122.02	−680.18
B — C	+173.89	−591.00	+0.11	−0.17	+174.00	−591.17
C — D	−669.14	+109.08	+0.12	−0.19	−669.02	+108.89
D — E	−140.14	+961.10	+0.18	−0.27	−139.96	+960.83
E — A	+756.86	+201.86	+0.14	−0.23	+757.00	+201.63
Sums =	−0.68	+1.05	+0.68	−1.05	0.00	0.00

*Calculated by compass rule.

I. Compute the coordinates. (Table 5)

1. Choose beginning coordinate values so that all points will be positive.

Example: Pt. D: N: 10,000.00
E: 10,000.00

Therefore: Pt. E will be the most southerly point.
Pt. C will be the most westerly and northerly point.
Pt. A will be the most easterly point.

(NOTE: Usually a traverse point (commonly the most southwesterly) is given coordinates: N:10,000.00 and E:10,000.00. This is to ensure that all points to follow in the traverse will have positive values.)

INFORMATION SHEET

2. Coordinates are determined by successive algebraic addition of the **adjusted** latitudes and departures.

TABLE 5 — COMPUTING COORDINATES

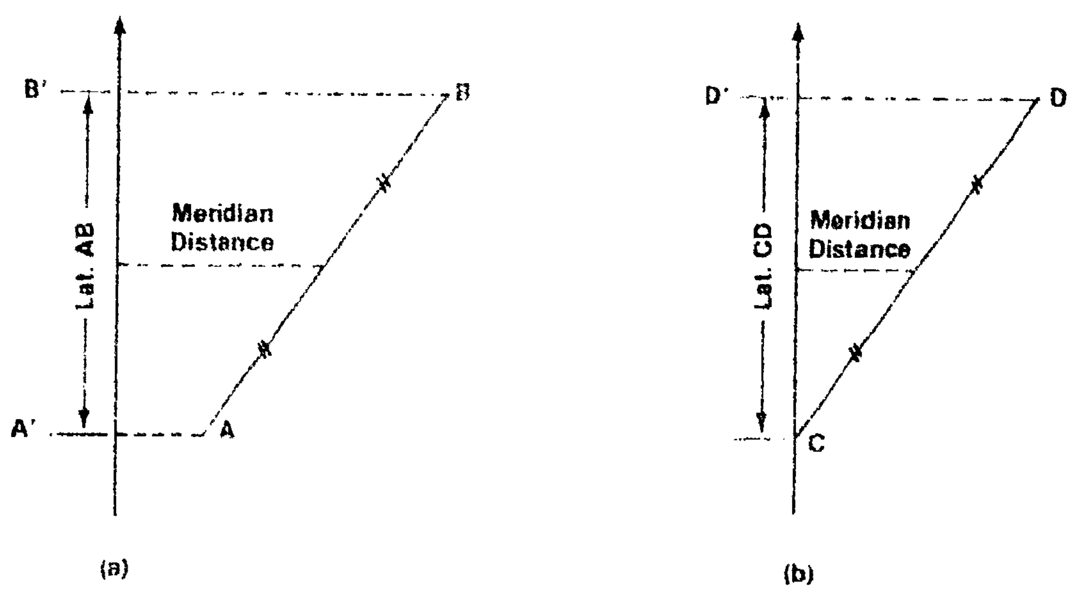
	(Adjusted) Latitude	(Adjusted) Departure	Coordinates North	Coordinates East
Pt. D			10000.00 (assumed)	10000.00 (assumed)
to	−139.96	+960.83		
Pt. E			9860.04	10960.83
to	+757.00	+201.63		
Pt. A			10617.04	11162.46
to	−122.02	−680.18		
Pt. B			10495.02	10482.28
to	+174.00	−591.17		
Pt. C			10669.02	9891.11
to	−669.02	+108.89		
Pt. D			10000.00 (checked)	10000.00 (checked)

3. A check can be made by carrying computations around to the starting point, which should have the same coordinates as before.

VII. **Calculating areas by the D.M.D. (double-meridian-distance) method**

A. This method utilizes balanced latitudes and departures to directly calculate the area within a closed traverse. By definition, the meridian distance of a line is the distance from the midpoint of the line to some meridian. (Figure 4)

FIGURE 4



Meridian distances and areas: (a) meridian is located some distance from straight line (*AB*); (b) meridian is through one end of straight line (*CD*).

INFORMATION SHEET

B. The method is based on the fact that the area of a right triangle equals one-half of the product of the two sides. Since latitudes and departures are at right angles to each other, the area bounded by the distance, the latitude, and the departure is a right triangle. This area can be determined by taking one-half of the product of the latitude and the departure. However, the triangle may add to or subtract from the total area of the irregular figure depending on its location.

C. To avoid determining a plus or minus area for each triangle, a slight refinement is made. The departure is added twice; first in determining the DMD of the course and then when the next course's DMD is determined. Multiplying the DMD of each course by its latitude results in twice the area, but the sign of this product illustrates whether the area adds to or subtracts from the figure area. See Example problem.

Example problem: Given: The area shown in Figure 5 and Table 6. Follow a step-by-step procedure to find the area of this figure by the DMD method.

Solution:

1. All the latitudes and departures are computed and recorded in the table.

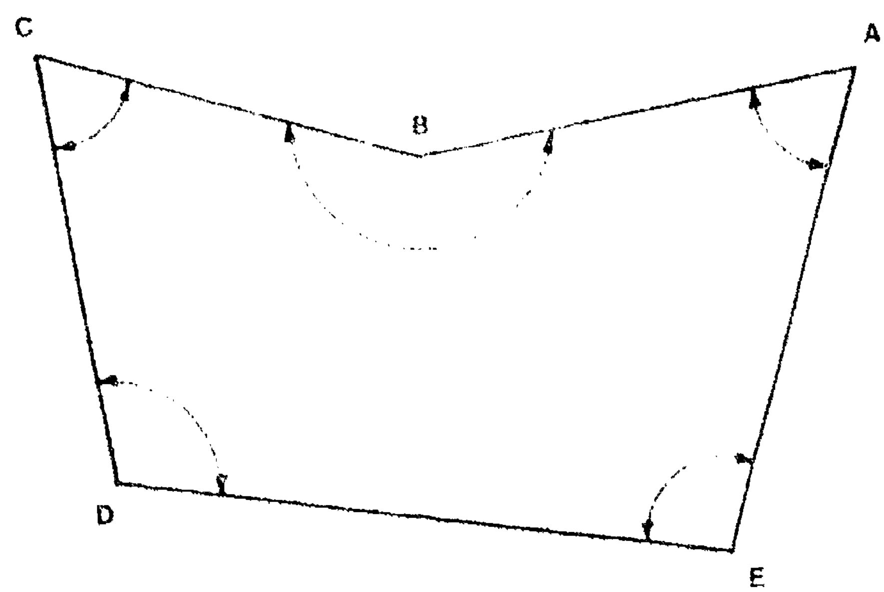
2. The most westerly station (*C*) is selected as the first point and line *CD* is selected as the first course to avoid negative areas in the DMD.

3. The DMD of the first course equals the departure of the course itself, 108.89.

4. The DMD of any other course (for example, *DE*) equals the DMD of the preceding course (*CD*), plus the departure of the preceding course (*CD*), plus the departure of the course itself (*DE*). Thus

DMD of *DE* = +108.89 + 108.89 + 960.83 = +1178.61

FIGURE 5



INFORMATION SHEET

TABLE 6 — CALCULATING AREA BY DMD

Course	Latitude	Departure	D.M.D.	Doubled Areas
C — D	−669.02	+108.89	+108.89	−72,850
			+108.89	
			+960.83	
D — E	−139.96	+960.83	+1178.61	−164,958
			+960.83	
			+201.63	
E — A	+757.00	+201.63	+2341.07	+1,772,190
			+201.63	
			−680.18	
A — B	−122.02	−680.18	+1862.52	−227,265
			−680.18	
			−591.17	
B — C	+174.00	−591.17	+591.17	+102,864

Doubled Area = +1,409,986
Area, sq. ft. = 704,993
÷43,560 sq. ft. = 16.18 Acres

(NOTE: For the next course, the same procedure is followed. Thus

DMD of *EA* = DMD of preceding course + departure of preceding course + departure of the course itself
= +1178.61 + 960.83 + 201.63 = +2341.07

5. The DMD of the last course is numerically equal to its departure but with opposite sign (+591.17).

6. Each DMD value is multiplied by its latitude, and positive products are entered under north double areas and negative products under south double areas.

7. The sum of all the south double areas minus the sum of all the north double areas, *disregarding sign*, equals twice the cross-sectional area. Dividing by 2 gives the true cross-sectional area.

All the computations have been worked out in the Table 6 which accompanies Figure 5.

D. The preceding analysis leads to the following observations:

★1. The DMD of the first course is equal to the departure of the first course.

INFORMATION SHEET

★2. The DMD of each succeeding course is equal to the DMD of the previous course + the departure of the previous course + the departure of the course itself.

★3. The DMD of the last course will turn out to be equal to the departure of the last course, but opposite in sign.

(NOTE: A method called DPD [Double Parallel Distance] works on the same principle as DMD, but it uses the latitudes rather than the departures.)

VIII. Calculating areas by the coordinate method

A. Using the coordinates of each traverse point, areas can be calculated with the following equation:

where E = East coordinate
N = North coordinate
a = Traverse point "A"

Doubled Area: Ec (Nd − Nb) + Eb (Nc − Na) + Ea (Nb − Ne) + Ee (Na − Nd) + Ed (Ne − Nc)

Example: 9891.11 (10000.00 − 10495.02) + 10482.28 (10669.02 − 10617.04) + 11,162.46 (10495.02 − 9860.04) + 10960.83 (10617.04 − 10000.00) + 10000.00 (9860.04 − 10669.02) =

Doubled Area: 1,409,981.04
area sq. ft: 704,990.52
÷ 43560 sq. ft.: 16.18 acres

B. Differences in methods of calculating area by DMD's or by coordinates could produce answers that slightly vary. (See Table 6)

C. The previous equation is based on the summation of trapezoidal areas.

D. Most computers have programs that can be easily entered to aid in eliminating any confusion.

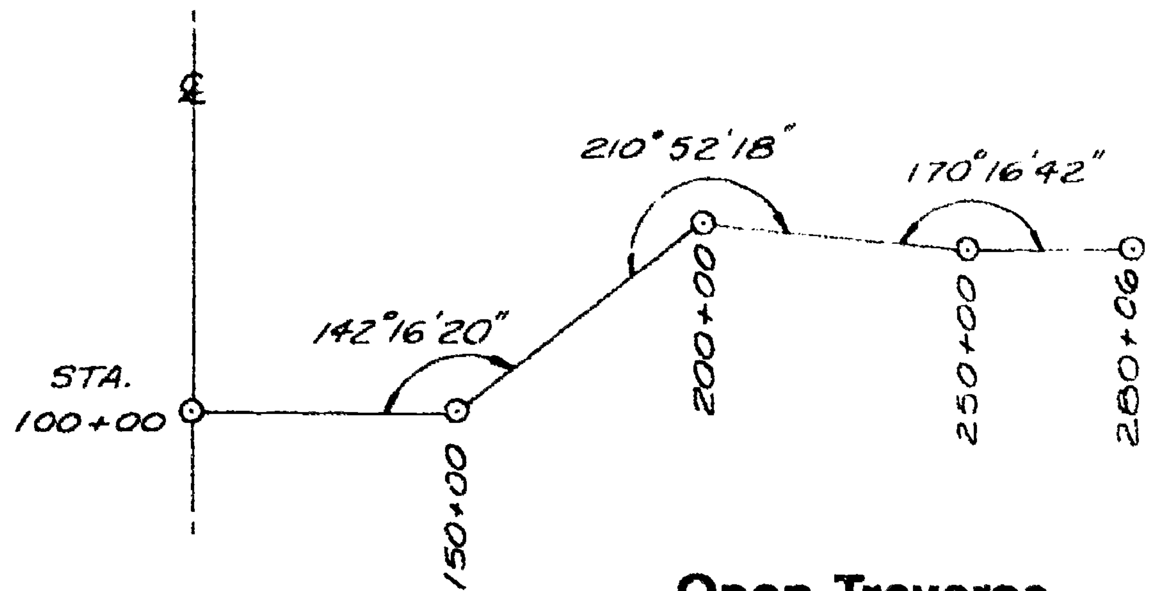
E. Rules to follow when calculating by coordinate method

★1. Always start at the most westerly point.

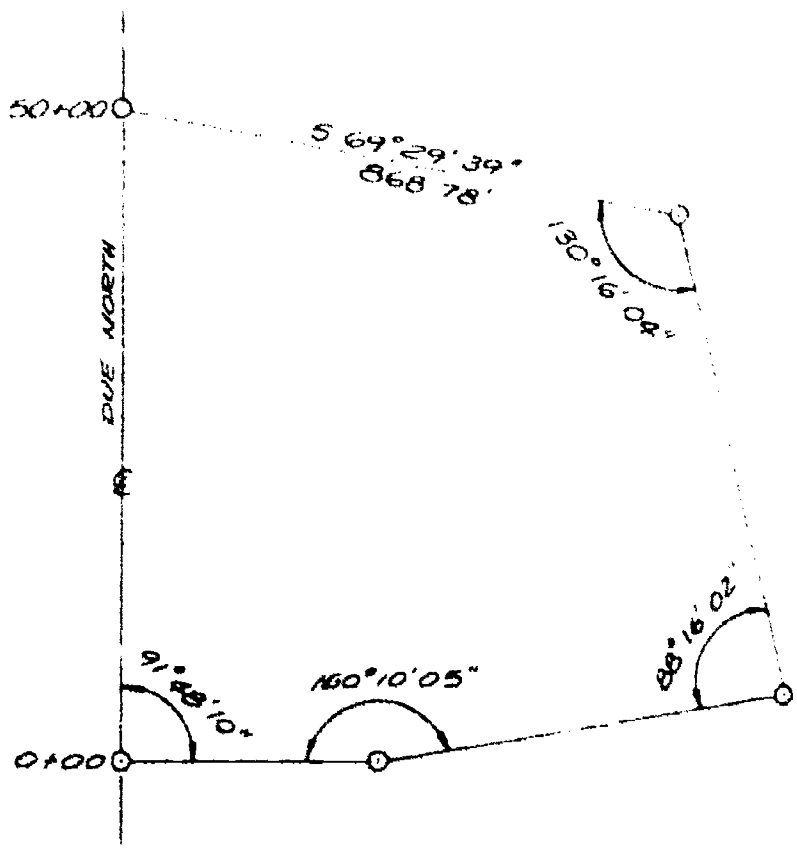
★2. Always work in a clockwise order.

★3. Always multiply the east coordinate by the difference between the previous point's north coordinate and the next point's north coordinate.

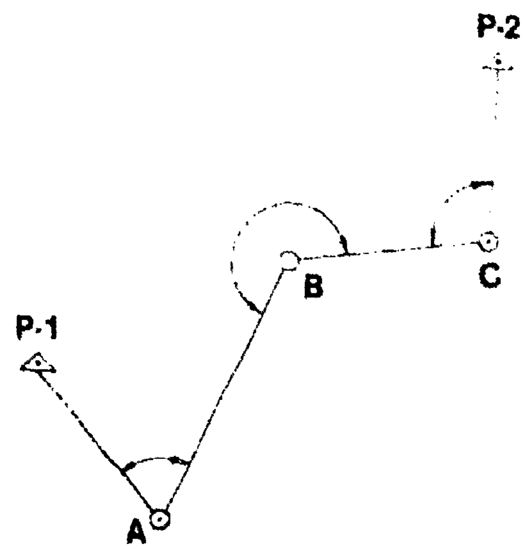
Types of Traverses



Open Traverse



Loop Traverse



Connecting Traverse

Closed Traverses

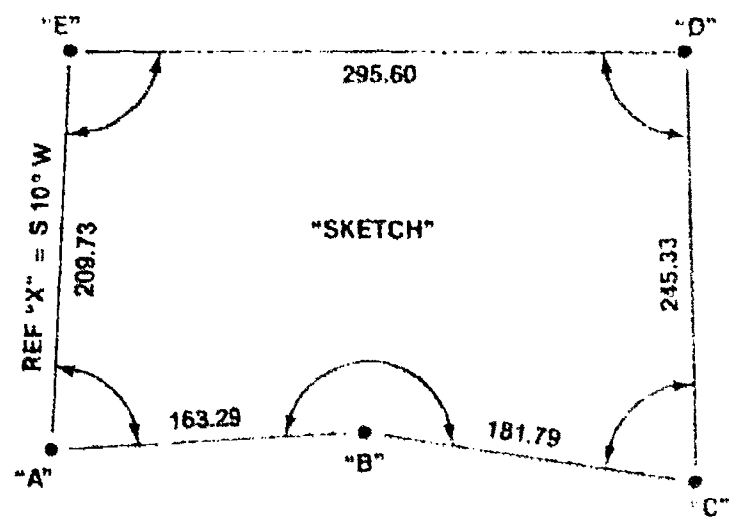
TRAVERSING AND RELATED CALCULATIONS
UNIT VII

ASSIGNMENT SHEET #1 — COMPUTE TRAVERSE CLOSURE AND ADJUSTMENT BY THE COMPASS RULE

Given: A loop traverse *ABCDE*. The coordinates of point *A* are N10,000.00 E10,000.00. Bearing of line *EA* = S10°00′00″W. Interior angles and distances are listed below.

Interior Angles	Distances
A = 79°10′30″	A-B = 163.29
B = 187°20′30″	B-C = 181.79
C = 80°38′45″	C-D = 245.33
D = 88°56′00″	D-E = 295.60
E = 103°53′45″	E-A = 209.73

FIGURE 1



Compute the closure and adjust by the compass rule.

Solution

1. Compute the angular error.

2. Adjust the angles.

3. Compute the bearings. Start with the known bearing *EA* = S10°00′00″W. Compute the bearings by applying corrected angles successively.

4. Compute the latitudes and departures.

ASSIGNMENT SHEET #1

5. Compute the error.

   Total error in latitude = ____________
   Total error in departure = ____________
   Error of closure = ____________

6. Compute the measure of accuracy (the ratio of the total error to the total length of the survey). Accuracy ratio = ____________

7. Adjust the latitudes and departures using the compass rule.

8. Compute the adjusted latitudes and departures. Add the corrections algebraically to the unadjusted latitudes and departures.

9. Compute the coordinates. We know the coordinates of point *A* are N10,000.00 and E10,000.00 from the traverse data. Notice that the survey is correct since the final computed coordinates of point *A* are exactly the same as the given coordinates of point *A*.

	North	East
Point "A"	10,000.00	10,000.00
Point "B"	____________	____________
Point "C"	____________	____________
Point "D"	____________	____________
Point "E"	____________	____________

TRAVERSING AND RELATED CALCULATIONS
UNIT VII

ASSIGNMENT SHEET #2 — COMPUTE TRAVERSE CLOSURE AND ADJUSTMENT BY THE TRANSIT RULE

Given: A loop traverse *ABCDE*. The bearing of line *CD* = S31°15'30"E. Coordinates of point *C* = N10,000.00, E10,000.00. Interior angles and distances are listed below.

Interior Angles	Distances
A = 91°18'15"	A-B = 554.19
B = 94°27'30"	B-C = 425.31
C = 109°52'00"	C-D = 426.05
D = 102°26'15"	D-E = 345.20
E = 142°06'00"	E-A = 322.21

Compute the traverse, making corrections by the transit rule.

Solution

Start by making a sketch to scale.

1. Compute the angular error.
2. Adjust the angles.
3. Compute the bearings. Start with the given bearing of *CD* = S31°15'30"E, and compute the bearings by applying the corrected angles successively.
4. Compute the latitudes and departures.
5. Compute the error of closure.

   $$\text{Error of closure} = \sqrt{(\text{departure error})^2 + (\text{latitude error})^2}$$

6. Compute the accuracy (ratio of the total error to the total length of the survey).

   Accuracy = ______________

7. Adjust the latitudes and departures using the transit rule.
8. Transfer the values obtained to the adjustment of survey.
9. With the corrections logged, now compute the coordinates. Since you have the coordinates of point *C* given as N10,000.00, E10,000.00, begin at point *C* and compute coordinates for each point.

TRAVERSING AND RELATED CALCULATIONS
UNIT VII

ASSIGNMENT SHEET #3 — CALCULATE AREA OF A CLOSED TRAVERSE BY THE D.M.D METHOD

Directions: Using the traverse information given in Assignment Sheet #1 and your calculated answers, calculate the area of this traverse using the D.M.D. method.

Solution:

1. Begin at the most westerly traverse point.

2. Follow the following equations:

   a. The D.M.D. of the first course is equal to the departure of the first course.

   b. The D.M.D. of each succeeding course is equal to the D.M.D. of the previous course plus the departure of the previous course plus the departure of the course itself.

   c. The D.M.D. of the last course will be equal to the departure of the last course with the sign changed.

3. Multiply the latitude by each of its D.M.D.'s using the correct algebraic signs to find the doubled areas of each course.

4. Add up the doubled areas (using the signs) to find the total doubled area.

5. Divide this answer by 2. This equals the total sq. ft.

6. Divide the sq. ft. by 43,560 to obtain the acres.

   Doubled Area (sq. ft.): ____________

   Area in sq. ft.: ____________

   Area in acres: ____________

TRAVERSING AND RELATED CALCULATI 'NS
UNIT VII

ASSIGNMENT SHEET #4 — CALCULATE AREA OF A CLOSED TRAVERSE BY THE COORDINATE METHOD

Directions: Using the traverse information given in Assignment Sheet #2 and your calculated coordinates of each point, calculate the enclosed area by using the coordinate method.

Solution:

1. Follow the equation listed below:

   Doubled area = Ec (Nd – Nb) + Eb (Nc – Na) + Ea (Nb – Ne) + Ee (Na – Nd) + Ed (Ne – Nc)

   Where: E = East coordinate
   N = North coordinate
   a = Traverse point "A"

2. Divide doubled area by 2 to obtain sq. ft.

3. Divide area in sq. ft. by 43,560 to obtain area in acres.

   Doubled area: ____________

   Area in sq. ft.: ____________

   Area in acres: ____________

TRAVERSING AND RELATED CALCULATIONS
UNIT VII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

Total error in Lat. = +0.098
Total error in Dep. = +0.429
Error of closure = 0.440
Accuracy ratio = 1:2489.75

Coordinates
Pt. A: N10000.00 E10000.00
Pt. B: N10002.33 E10163.21
Pt. C: N9981.67 E10343.75
Pt. D: N10226.68 E10331.53
Pt. E: N10206.56 E10036.50

Assignment Sheet #2

Total error in Lat. = -.265
Total error in Dep. = -.303
Error of closure = 0.402
Accuracy ratio = 1:5,183.40

Coordinates
Pt. A: N 10,017.07 E 10,724.09
Pt. B: N 10,330.89 E 10,267.18
Pt. C: N 10,000 E 10,000
Pt. D: N 9,635.87 E 10,221.03
Pt. E: N 9,747.44 E 10,547.64

Assignment Sheet #3

Double area (sq. ft.): 140414
Area in sq. ft.: 70207.01
Area in acres: 1.61

Assignment Sheet #4

Doubled area (sq. ft.): 570,846.58
Area in sq. ft.: 285,423.29
Area in acres: 6.55

TRAVERSING AND RELATED CALCULATIONS
UNIT VII

JOB SHEET #1 — PERFORM A CLOSED LOOP TRAVERSE

A. Equipment and materials

1. Theodolite or transit
2. Tripod
3. Chain
4. Chaining pins
5. Plumb bob
6. Range pole
7. 4 wooden stakes or nails
8. Hammer
9. Field book and pencil
10. Flagging material

B. Procedure

1. Set up traverse.

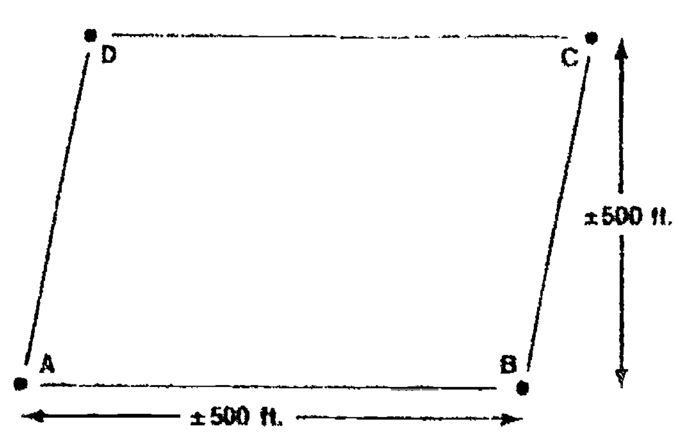
   a. Locate an area of land approximately 500 ft. by 500 ft. in size, preferably flat for the first exercise.

   b. Walk the perimeter of the site placing the stakes or nails in the ground at approximate corners, taking care when locating the traverse points to be sure to have clear vision to each of the adjacent corners.

   c. Mark each corner with flagging so each can be found easily.

2. Make a sketch of the traverse in the field book. Label each point with a letter.

FIGURE 1



JOB SHEET #1

3. Set up the instrument over point A.

    a. Level it up.

    b. Zero up the vernier.

4. Backsight Pt. D while the rod person is holding a chaining pin over the exact point. Once you have backsighted and are sure the instrument vernier reads 0°00'00", signal the rod person you are finished.

5. Loosen the upper clamp and rotate the instrument towards Pt. B. Take care not to bump any adjustment or tangent screws.

6. Foresight Pt. B.

    a. Carefully sight Pt. B while the rod person is holding the chaining pin over the exact point.

    b. Once the cross hairs are centered on the pin, lock the upper motion.

    c. Signal the rod person that the angle has been turned and you have completed.

7. Carefully read angle D-A-B on the vernier and record in field book.

8. Measure distance A-B.

    a. Prior to moving instrument to next point, begin measuring horizontal distance.

    b. With 3-person survey party, the instrument person should give alignment while sighting through the telescope a Pt. B while the rod person and chain person tape the distance.

    c. Taping should begin at Pt. A toward Pt. B.

    d. Upon reaching Pt. B the chain person should call out distance or document, and then the process is taped back from B to Pt. A.

    e. Both distances should be recorded in the field book upon reaching Pt. A.

9. Pick up instrument and transport to Pt. B where the process is repeated again consecutively around the entire traverse.

10. Upon completion of the field work, a traverse closure should be completed by all crew members to determine the accuracy of the traverse performed.

TRAVERSING AND RELATED CALCULATIONS
UNIT VIII

JOB SHEET #2 — PERFORM A CLOSED CONNECTING TRAVERSE

A. Equipment and materials

1. Theodolite or transit
2. Tripod
3. Chain
4. Chaining pins
5. Plumb bob
6. Range pole
7. 4 wooden stakes or nails
8. Hammer
9. Field book and pencil
10. Flagging material

B. Procedure

1. Set up traverse.

    a. Locate a long but narrow strip of land approximately 1500′ to 2000′ by 100′ wide, preferably flat for the first exercise.

    b. Drive a stake at a beginning point (random) and secure flagging to it so it is visible.

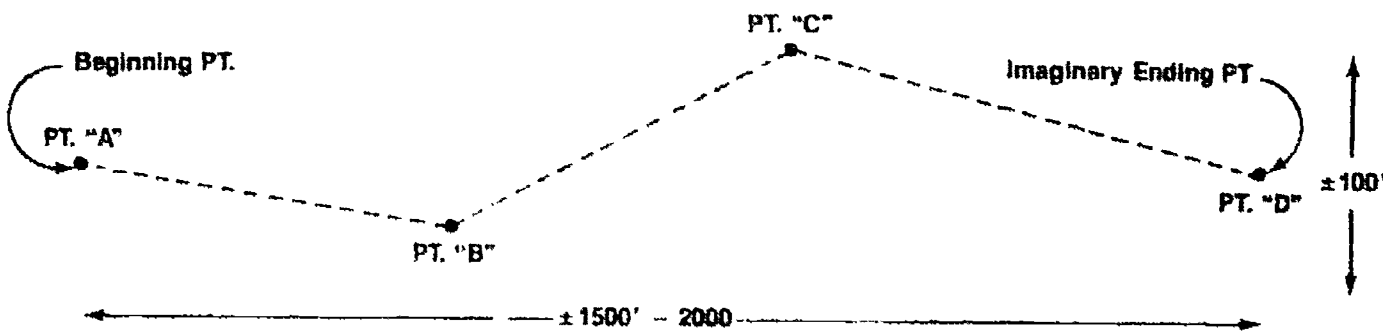
    c. Walk toward the imaginary ending point approximately 400-500 ft. away. (Deviating from a straight line is suggested on this exercise, for it will make each deflection from pt. to pt easily visible.)

    d. Drive another stake at Pt. B and flag it.

JOB SHEET #2

e. Again walk toward the ending point in a zigzag pattern approximately 400-500 ft. and place another stake.

FIGURE 1



f. Continue until all points have been set and marked.

2. Make a sketch of this connecting traverse, labeling each point in the field book.

3. Set up the instrument over Pt. A.

   a. Level it up.

   b. Zero up the vernier.

4. Backsight a reference mark (given by your instructor).

   a. Carefully sight the reference mark while the rod person is holding a chaining point on the reference mark.

   b. Once you have a clear sight and the instrument is zeroed, lock the lower tangent and signal the rod person you have completed.

5. Turn the field angle (by following either a. or b. procedure.)

   a. By inverting the telescope and loosening the upper tangent screw and sighting Pt. B, which is referred to as a deflection angle "Right" or "Left"

   (or)

   b. By simply loosening the upper tangent screw and turning clockwise (right) or counterclockwise (left) toward Pt. B

6. Foresight Pt. B.

   a. Carefully sight Pt. B while the rod person is holding a chaining pin over the point.

   b. Once the cross hair is centered, lock the upper motion.

   c. Signal the rod person that the angle has been completed.

JOB SHEET #2

7. Carefully read angle. Document either:

   Deflection Rt.
   Deflection Lt.
   Angle Right
   Angle Left

8. Measure distance A-B.

   a. Prior to moving instrument to next point, begin measuring horizontal distance.

   b. With 3-person survey party, the instrument person should give alignment while sighting through the telescope at Pt. B while the rod person and chain person tape the distance.

   c. Taping should begin at Pt. A toward Pt. B.

   d. Upon reaching Pt. B the chain person should call out distance or document, and then the process is taped back from B to Pt. A.

   e. Both distances should be recorded in the field book upon reaching Pt. A.

9. Pick up instrument and transport to Pt. B where the process is repeated again consecutively around the entire traverse.

10. Upon reaching Pt. D and carefully measuring distance C-D,

    a. Consult your instructor for possible closure data.

    b. Sight and read angle to original reference point if at all possible.

    (NOTE: Connecting traverses are many times not able to mathematically close unless coordinates of both beginning and ending points are obtained.)

TRAVERSING AND RELATED CALCULATIONS
UNIT VII

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a.	The station over which the survey instrument is set up, usually where the data for that particular area is being collected	1.	Angular error
_____b.	Numbers used to locate and define the position of a point with respect to two perpendicular axes	2.	Azimuth
_____c.	A closed plane figure bound by straight lines	3.	Bearing
_____d.	The east-west rectangular component of a line	4.	Coordinates
_____e.	The amount of error that occurs when measuring angles of a traverse	5.	Departure
_____f.	The horizontal angle turned between a datum direction such as true north and a given line	6.	Error of closure
_____g.	A point, usually set in a convenient location to the project, that has a known location horizontally in reference to the other points of the traverse	7.	Instrument point
_____h.	The horizontal bearing of a line measured clockwise from the meridian	8.	Latitude
_____i.	The perpendicular distance from the center point of the line or traverse course to the reference meridian	9.	Meridian distance
_____j.	A control survey of established lines with known lengths and measured angles at each point or station	10.	Polygon
_____k.	The net accumulation of the random errors associated with the measurement of the traverse angles and distances	11.	Ties

TEST

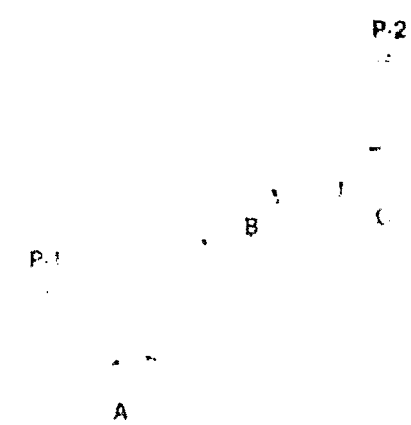
_____ l. The north-south rectangular component of a line

_____ m. Horizontal measurements to a survey point from existing objects or offset points, used to reestablish the point if it is destroyed

12. Traverse

13. Traverse point

2. Identify the types of traverses commonly used in surveying. Select your answers from the following list: open traverse, closed loop traverse, and closed connecting traverse.



a. ______________________ b. ______________________

c. ______________________

3. Describe the following methods of measuring traverse angles or directions.

a. Compass bearings — ____

____

b. Interior angles — ____

____

TEST

c. Deflection angles -- ____

____

d. Angles to the right -- ____

____

4. Select true statements concerning the proper location of traverse station points by placing an "X" next to the true statements.

_____a. Position of traverse station varies with the type of survey being performed.

_____b. For property surveys the traverse station points should be placed at each corner of the property unless the line of sight is obstructed or the point cannot be occupied.

_____c. Traverse stations can be lost if not properly described and preserved.

_____d. Bench marks are used to aid in finding a survey point or to relocate one that has been destroyed.

5. List three major sources of error in traverse operations.

a. ____

b. ____

c. ____

6. Arrange in order the nine primary steps taken when computing a traverse closure by placing the correct sequence numbers (1-9) in the appropriate blanks.

__5__a. Compute the error of closure

_____b. Compute the coordinates

_____c. Calculate adjusted latitudes and departures

_____d. Draw a sketch of the traverse to scale

_____e. Compute the measure of accuracy

_____f. Compute corrections for latitudes and departures

_____g. Compute the bearings

_____h. Compute the angular error

_____i. Compute latitudes and departures

TEST

7. List the three observations or assumptions that can be made when calculating areas by means of the D.M.D. method.

   a. ____

   ____

   b. ____

   ____

   c. ____

   ____

8. Complete statements concerning rules to follow when calculating areas by means of the coordinate method by circling the correct words.

   a. Always start at the most (**easterly, westerly**) point.

   b. Always work in a (**clockwise counterclockwise**) order.

   c. Always multiply the (**east, west**) coordinate by the difference between the previous point's north coordinate and the next point's north coordinate.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

9. Compute traverse closure and adjustment by the compass rule. (Assignment Sheet #1)

10. Compute traverse closure and adjustment by the transit rule. (Assignment Sheet #2)

11. Calculate area of a closed traverse by the D.M.D. method. (Assignment Sheet #3)

12. Calculate area of a closed traverse by the coordinate method. (Assignment Sheet #4)

13. Demonstrate the ability to:

    a. Perform a closed loop traverse. (Job Sheet #1)

    b. Perform a closed connecting traverse. (Job Sheet #2)

TRAVERSING AND RELATED CALCULATIONS
UNIT VII

ANSWERS TO TEST

1. a. 7 h. 2
   b. 4 i. 9
   c. 10 j. 12
   d. 5 k. 6
   e. 1 l. 8
   f. 3 m. 11
   g. 13

2. a. Closed loop
   b. Closed connecting
   c. Open

3. Descriptions should include:
   a. Compass bearings — Bearings are read directly on a compass as sights are taken along the lines or traverse courses.
   b. Interior angles — The inside angles of the traverse or polygon are measured using a transit or theodolite. They can be measured either clockwise or counterclockwise.
   c. Deflection angles — Are commonly used on route surveys in which the angle is measured right or left from the back direction extended.
   d. Angles to the right — Are angles measured from a backsight on the previous point and measured clockwise (to the right) to the next point of the traverse.

4. a, b, c

5. a. Errors in measurement of angles and distances
   b. Poor selection of traverse points resulting in bad sighting conditions due to:
      1) Alternate sun and shadow
      2) Visibility of only the top of the rod
      3) Line of sight passing too close to the ground
      4) Lines that are too long or too short
      5) Sighting into the sun
      6) Sighting through timber
   c. Failing to measure the angles an equal number of times direct and reversed

6. a. 5 f. 7
   b. 9 g. 3
   c. 8 h. 2
   d. 1 i. 4
   e. 6

7. a. The DMD of the first course is equal to the departure of the first course.
   b. The DMD of each succeeding course is equal to the DMD of the previous course + the departure of the previous course + the departure of the course itself.
   c. The DMD of the last course will turn out to be equal to the departure of the last course, but opposite in sign.

ANSWERS TO TEST

8. a. Westerly
   b. Clockwise
   c. East

9.-12. Evaluated to the satisfaction of the instructor.

13. Performance skills evaluated to the satisfaction of the instructor.

TOPOGRAPHIC SURVEYING
UNIT VIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the methods used to locate topographic details, construct a contour drawing from a grid layout of elevation spot shots, and perform various types of topographic surveys. Competencies will be demonstrated by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to topographic surveying with the correct definitions.
2. List purposes of topographic surveys.
3. Distinguish between the two classifications of topographic surveys.
4. Identify the methods of locating topographic details.
5. Distinguish between the three methods of topographic surveying.
6. Complete statements concerning stadia principles.
7. Select characteristics of contours.
8. Distinguish between the methods of locating contours.
9. List techniques for keeping good topographic field notes.
10. Construct an accurate contour drawing. (Assignment Sheet #1)
11. Layout and plot contours from radial survey notes. (Assignment Sheet #2)

OBJECTIVE SHEET

12. Demonstrate the ability to:

    a. Perform a radial topo survey. (Job Sheet #1)

    b. Perform a right-angle offset survey. (Job Sheet #2)

TOPOGRAPHIC SURVEYING
UNIT VIII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Have students re-establish existing points from other traverses that have been completed and perform topographical surveys of that area.
2. Have students plot up other small topographic surveys from field notes on drafting vellum in addition to Assignment Sheet #2.
3. Demonstrate the use of a stadia protractor in plotting up topographic features.
4. Discuss various types of topo symbolization used in field note keeping.
5. Have students perform a grid-topo survey.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

   1. TM 1 — Contour Line Configurations

   2. TM 2 — Standard Offset Topo Notes

   3. TM 3 — Stadia Topo Notes

D. Assignment sheets

   1. Assignment Sheet #1 — Construct an Accurate Contour Drawing

   2. Assignment Sheet #2 — Layout and Plot Contours from Radial Survey Notes

E. Answers to assignment sheets

F. Job sheets

   1. Job Sheet #1 — Perform a Radial Topo Survey

   2 Job Sheet #2 — Perform a Right-Angle Offset Survey

G. Test

H. Answers to test

REFERENCES USED IN WRITING THIS UNIT

A. Kavanagh, Barry and S. J. Glenn Bird. *Surveying: Principles and Applications.* Reston, VA: Reston Publishing Co., Inc., 1984.

B. Brinker, R.C., and P.R. Wolf. *Elementary Surveying*, 7th ed. New York, NY: Harper and Row, 1984.

C. Kissam, Phillip. *Surveying Practice*, 3rd ed. New York, NY: McGraw Hill Book Company, 1978.

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A. Davis, R.E., F.S. Foote, and J.H. Kelly. *Surveying*, 5th ed. New York, NY: McGraw Hill Book Company, 1966.

B. Kissam, Phillip. *Surveying for Civil Engineers.* New York, NY: McGraw Hill Book Company, 1976.

C. Breed, Hosmer (Fang, Barry). *Principles and Practices of Elementary Surveying*, 11th ed. New York, NY: Wiley, 1977.

TOPOGRAPHIC SURVEYING
UNIT VIII

INFORMATION SHEET

I. **Terms and definitions**

A. Contour — A line that connects points of the same or equal elevation

B. Cultural features — Artificial features that are products of people such as roads, trails, buildings, bridges, canals, etc.

C. Interpolation — Estimating the position of a point between two known points; commonly used when plotting contour lines

D. Relief — The difference in elevation or inequality of a land surface; the type of terrain on a given parcel of land

E. Stadia — A method of determining approximate horizontal distances (± 1 foot in 300 feet) by the use of two additional cross hairs in most transits and levels, one above and one below the center hair; a form of tacheometry

F. Tacheometry — A method of making a horizontal distance measurement by the use of a fixed angle intercept

G. Topography — The configuration of a surface including its relief and the position of its natural and manmade features

II. **Purposes of topographic surveying**

A. To determine the location of all natural and cultural features on the site.

B. To determine the configuration (relief) of the earth's surface.

C. To determine the most desirable and economical location of highways, railways, canals, pipelines, buildings, and many other facilities.

III. **Classifications of topographic surveys**

A. Aerial (photogrammetric) surveys

1. Involve the use of actual photographs taken from airplanes, helicopters and satellites (photogrammetry).

2. Photographs are used to determine topographic features including ground elevations, vegetation, terrain, etc.

(NOTE: Refinement of equipment and improved procedures have made photogrammetry accurate and economical.)

INFORMATION SHEET

B. Ground surveys

1. Involve the actual survey crew performing on-site control surveys to obtain all topographic features including elevation, terrain, property lines, vegetation, etc.

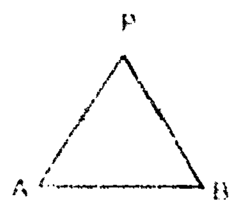
2. Used frequently for smaller areas to be mapped.

3. Even on large projects where aerial methods are to be employed, ground surveys are still performed to establish horizontal and vertical control.

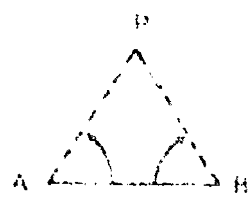
IV. **Methods of locating topographic details**

(NOTE: Most methods are based on horizontal control of at least one line, referred to as baseline AB.)

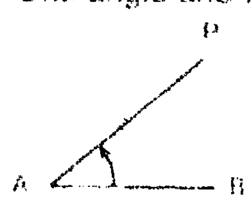
A. Two distances — Intersecting method



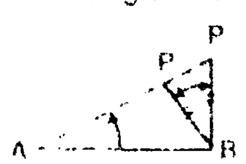
B. Two angles — Intersecting method



C. One angle and the adjacent distance — Polar method

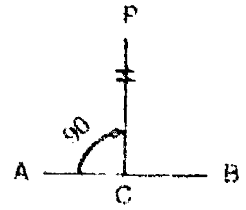


D. One angle and the opposite distance — Polar method

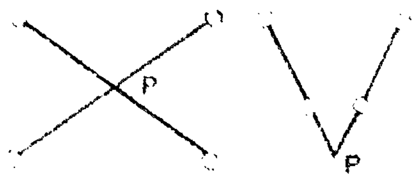


INFORMATION SHEET

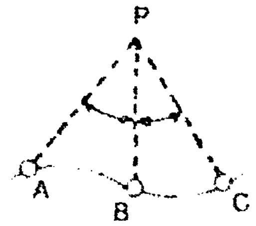
E. One distance and a right-angle offset — Rectangular method



F. Intersection of lines from straddle points — Intersecting method



G. Two angles at the point to be located — Resecting method



V. **Methods of topographic surveying**

A. Radial surveys (Figure 1)

(NOTE: Normally a traverse has been established and closure and adjustments have been performed prior to this.)

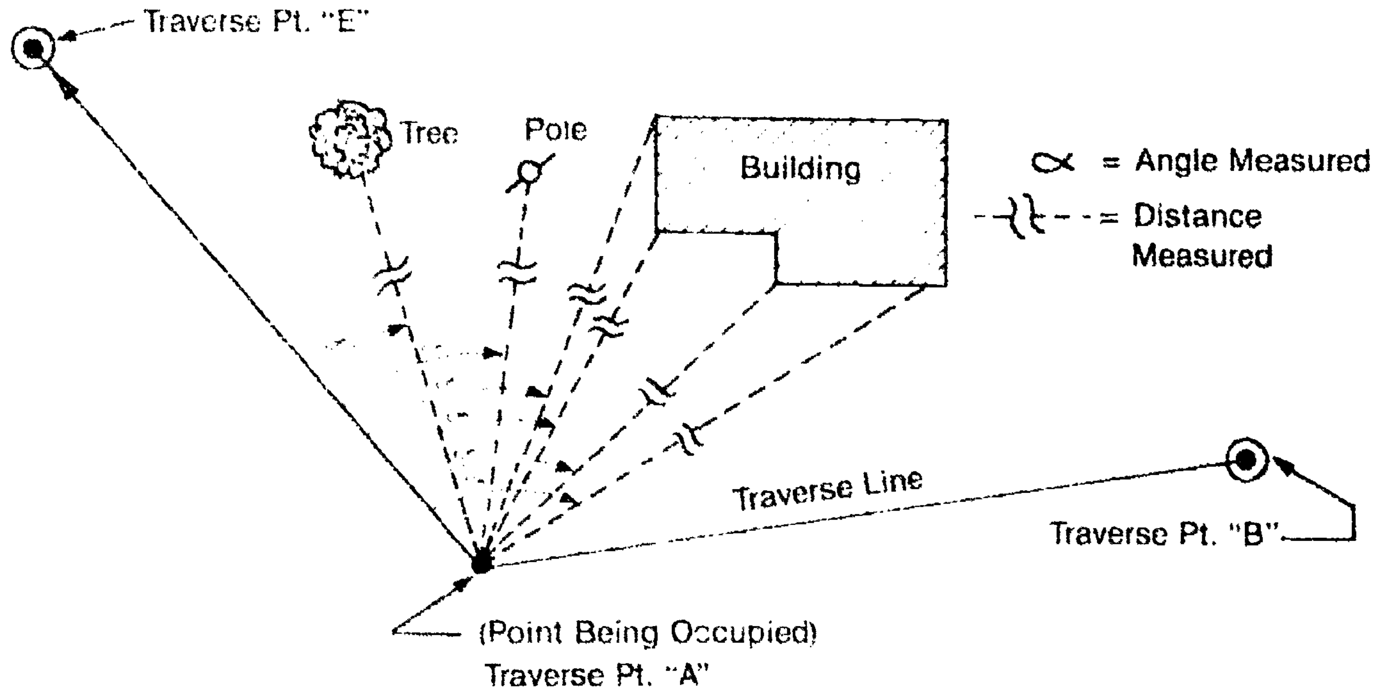
1. A traverse point is occupied with a transit or theodolite.

2. The instrument is oriented to a backsighted point on the traverse and the circle is zeroed.

INFORMATION SHEET

3. Each topographic feature, e.g. tree, bush, building corner, etc. is observed and an angle and distance to that point is recorded.

FIGURE 1



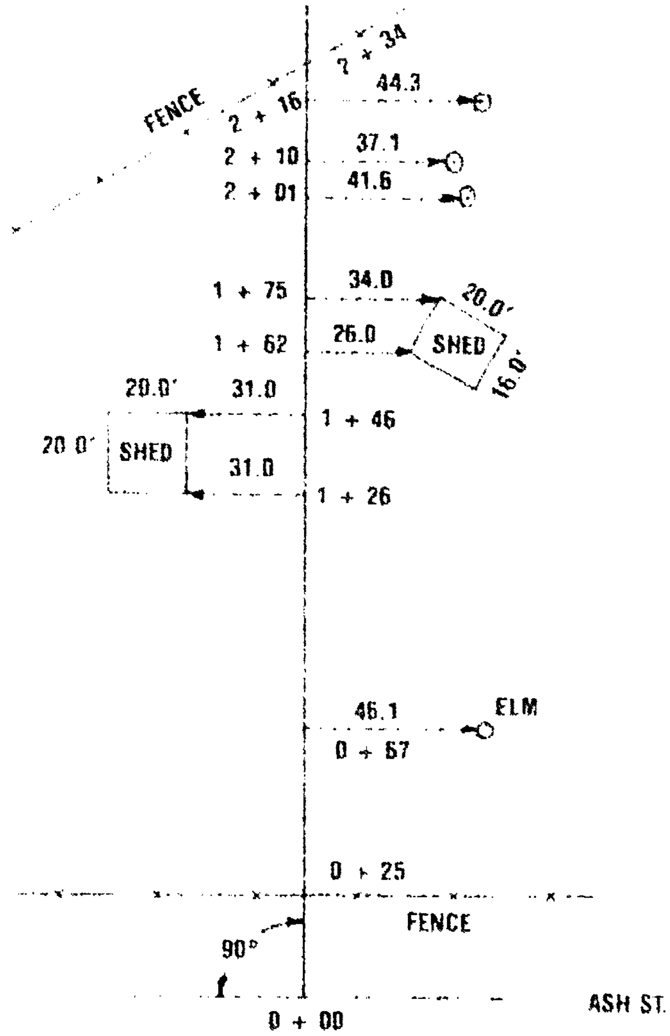
4. After all items have been sighted and recorded from that instrument setup, the instrument can be relocated on the next traverse point and the procedure repeated.

INFORMATION SHEET

B. Right-angle offset surveys (Figure 2)

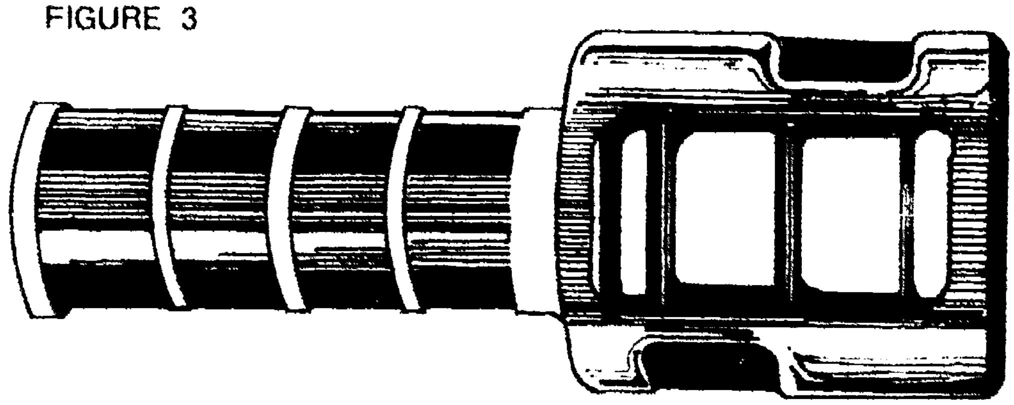
1. A baseline is set up with stations laid out (usually every 100 ft.)

FIGURE 2



2. Right angles are established at each of the objects that are to be located, either by estimating 90° or by the use of a double-pentagon prism. (Figure 3)

FIGURE 3



INFORMATION SHEET

3. The station along the baseline is noted where the right-angle is made, and a horizontal distance is measured from this point to the object to be located.

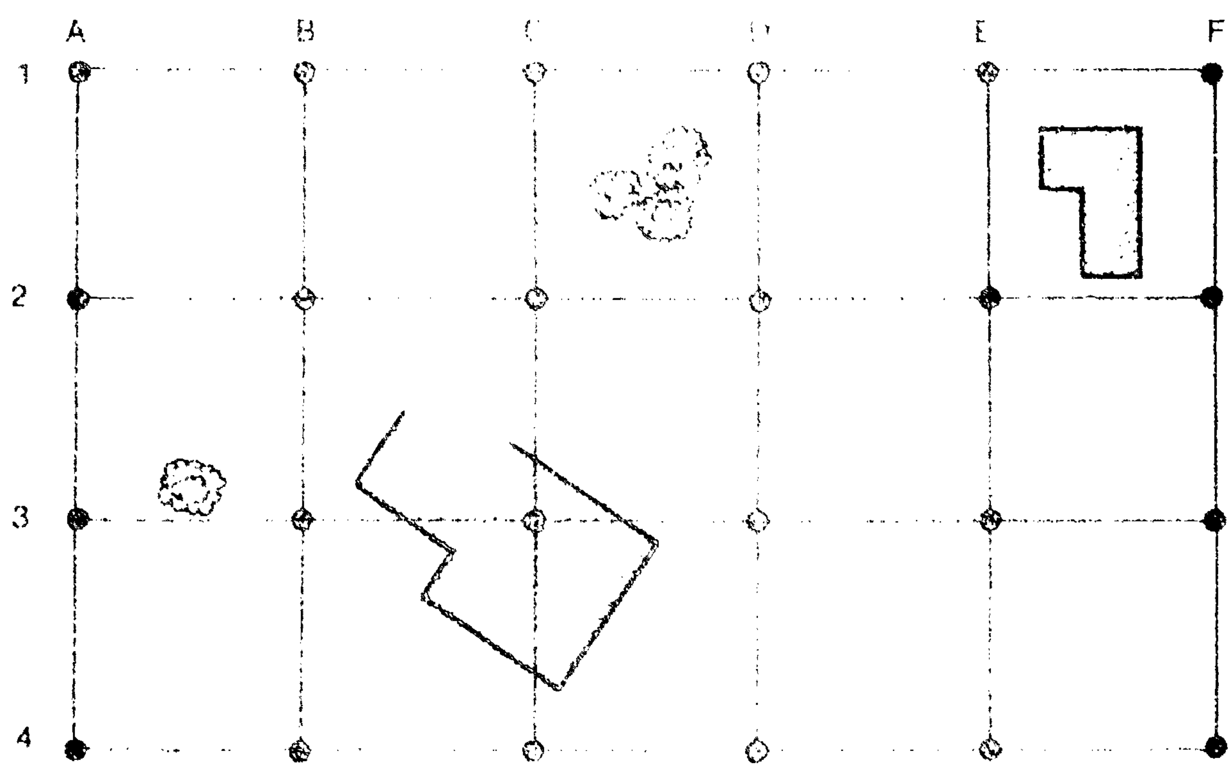
4. This procedure simply progresses along the stationed baseline throughout the length of the survey.

C. Grid layout surveys (Figure 4)

1. A grid-like system of points are laid out across the overall area to be surveyed.

2. Lines and points are identified by using letters and/or numbers.

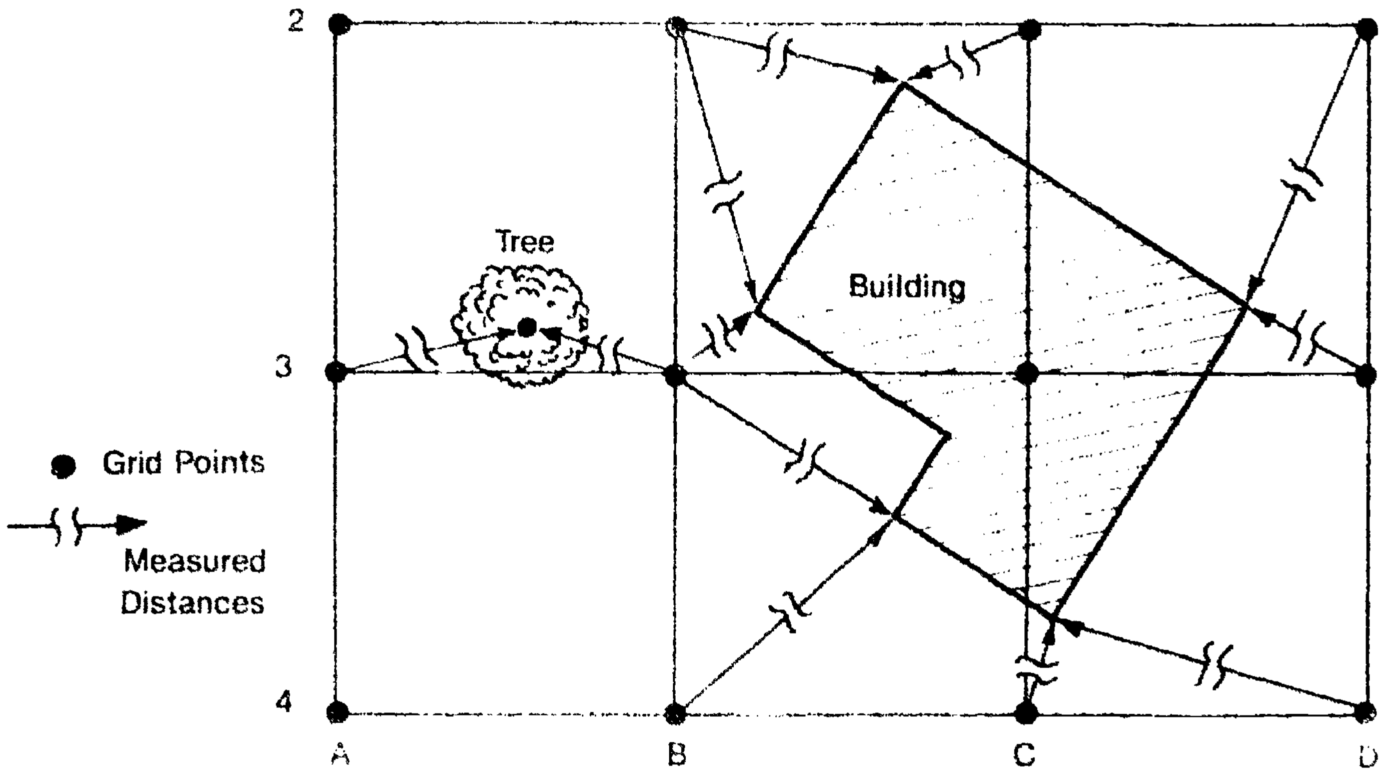
FIGURE 4



INFORMATION SHEET

3. Measurements are made from grid points to each of the features that must be located. (Figure 5)

FIGURE 5



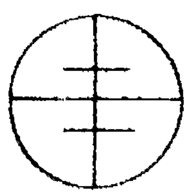
VI. **Stadia principles**

A. Is a form of tacheometry that relies on a fixed angle intercept for measuring distances.

B. Is commonly used in topographic surveys where a limited accuracy of 1/400 is acceptable.

C. Involves a transit, theodolite, or sometimes a level that is equipped with a cross-hair reticle that has stadia hairs. (Figure 6)

FIGURE 6



Cross Hair Reticle

1. Most stadia hairs are positioned in the reticle so that if a level rod were held at 100 feet from the instrument, the rod readings at the upper stadia hair and lower stadia hair would differ by 1.00 foot.

(NOTE: Some manufacturers make instruments with different stadia ratios such as 1 foot = 200 feet. Verify the ratio before using.)

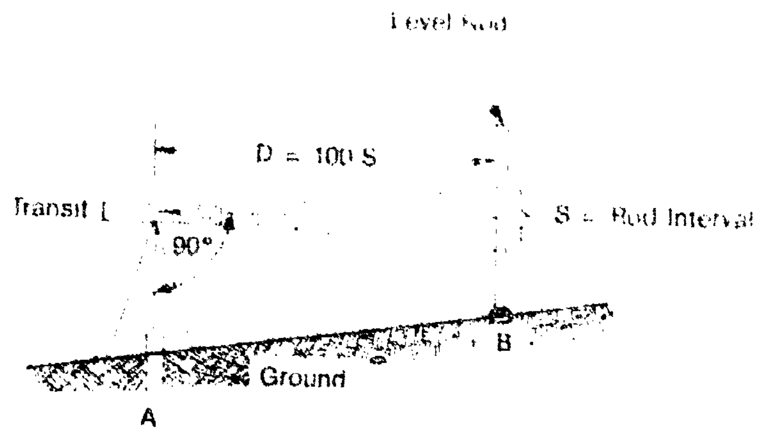
INFORMATION SHEET

2. It can be seen in Figure 7 that the distance can be easily determined by sighting the rod with the telescope level and determining the rod interval.

3 The rod Interval is then multiplied by 100 to get the horizontal distance.

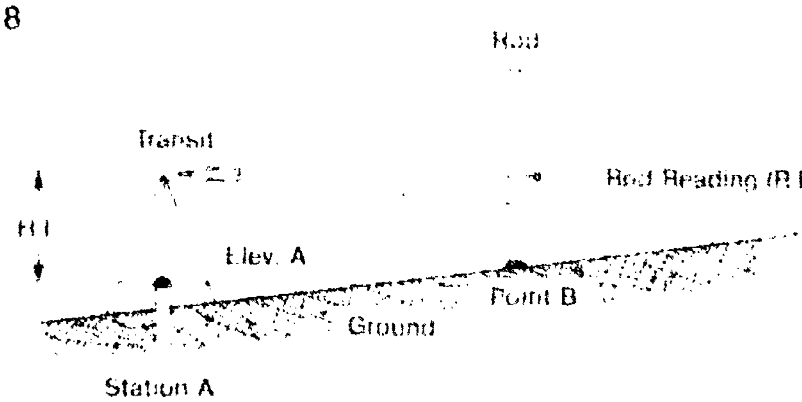
$D = 100\ S$

FIGURE 7



4. Ground el tions can also be established by stadia methods. Determine the height of the instrument by measuring the distance above the point occupied and then read the center rod reading in the cross-hair reticle at the point the rod is being held. (Figure 8)

FIGURE 8



Elevation A + H.I. – R.R. = Elevation B

D. Stadia methods are also suitable for inclined measurements required in rolling topography.

1. The computations are modified to account for the effects of a sloped sighting.

INFORMATION SHEET

2. The distance from the instrument to the rod must be reduced from slope to horizontal.

3. The rod interval must be reduced (due to a sloped sighting on the rod) to what it would have been if the sighting was perpendicular to the rod.

4. The accurate horizontal distance can be computed by the following relationships:

   Where = S is the rod interval when the line of sight is horizontal
   S' is the rod interval when the line of sight is inclined.

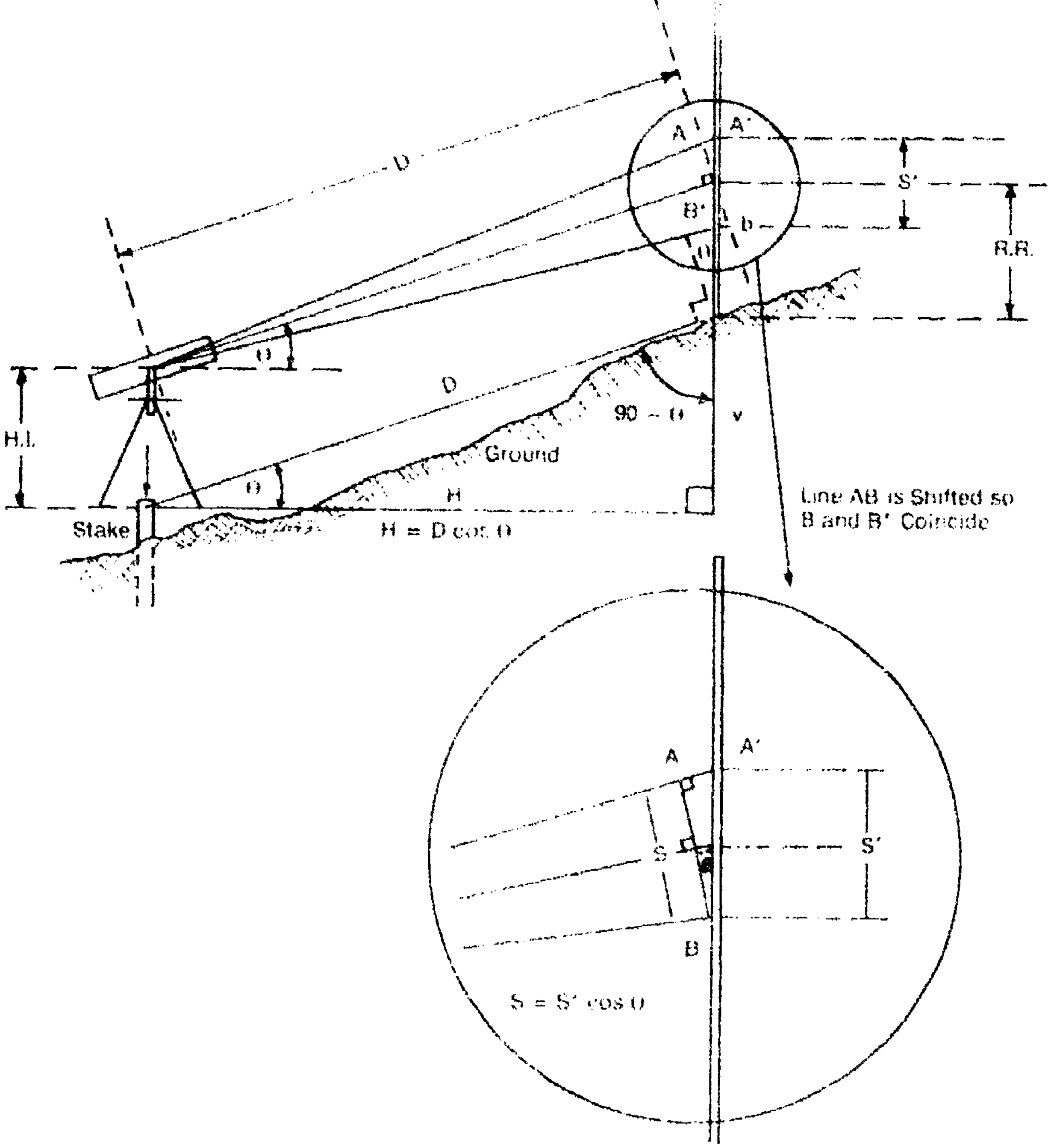
   The following equations apply: (Figure 9)

$$D = 100\,S$$
$$S = S' \cos\theta$$
$$D = 100\,S' \cos\theta$$
$$H = D \cos\theta$$
$$H = 100\,S' \cos^2\theta$$

$$V = D \sin\theta$$
$$D = 100\,S' \cos\theta$$
$$V = 100\,S' \cos\theta \sin\theta$$

INFORMATION SHEET

FIGURE 9



5. An actual vertical position of a point can be determined by using the following relationship: (Figure 10)

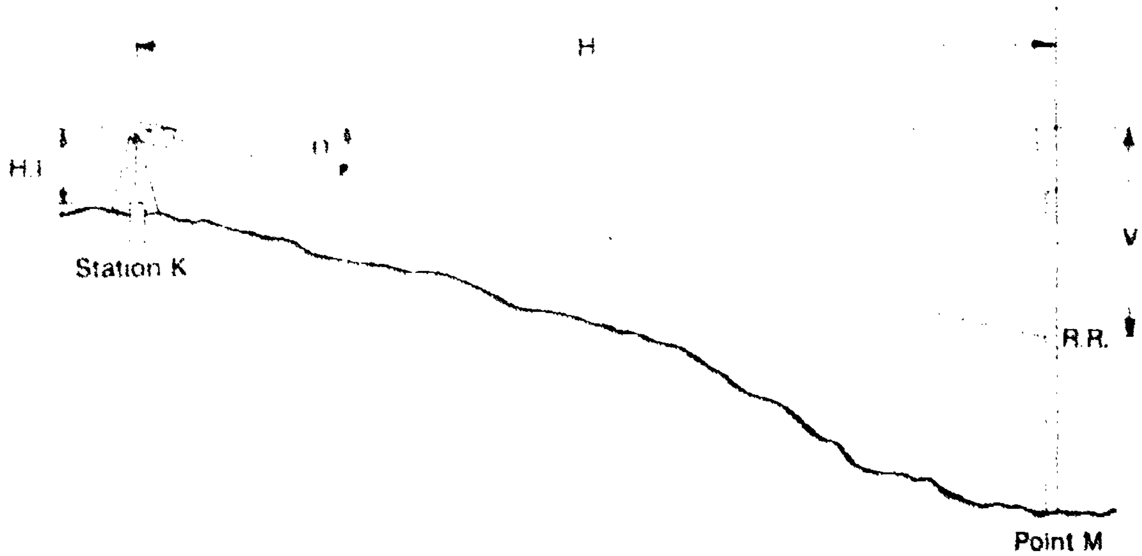
   Elevation station K (⩘) + HI ± V − RR = Elevation of Point M

   (NOTE: The rod reading can be eliminated from the equation if the center hair is positioned at the same height as the instrument height, therefore cancelling the HI and RR out.)

   Elevation station K (⩘) ± V = Elevation of Point M

INFORMATION SHEET

FIGURE 10



Elevation Station K (?) + H.I. ± V − R.R. = E[illegible]tion of Point M (Rod)

VII. Contour characteristics (Transparency 1)

(NOTE: A contour is a line connecting points of equal elevation. Contours can be visible, as in a lake shoreline, but usually on the ground, elevations of only a few points are located and contours are sketched in between these points.)

A. Contour lines must close upon themselves, but this may occur outside of the surveyed area.

B. Contours are perpendicular to the direction of maximum slope.

C. The slope between contour lines is assumed to be uniform.

D. The distance between contours indicates the steepness of a slope.

E. Concentric closed contours that increase in elevation represent hills. Hachure marks may be placed on the **outside** of each contour line to represent hills.

F. A contour closed around lower ground is called a depression contour. Hachure marks are placed on the **inside** of depression contours.

G. Contours of different elevation never meet except on a vertical surface such as a wall, cliff, or natural bridge.

H. Contours never cross each other, except when a cave or overhanging shelf is encountered.

I. A contour cannot branch or wye into two contours of the same elevation.

J. Controlling features that aid in contour location are usually drainage lines, swales or high ridges.

INFORMATION SHEET

VIII. **Methods of locating contours**

A. Direct method - Locating each contour desired and then recording its position

1. The contour elevation is subtracted from the height of instrument to determine the desired rod reading.

2. The rod person selects (by trial and error) points on the ground that indicate that rod reading.

3. The horizontal angle and distance to that point is then recorded to locate that rod reading.

B. Indirect method — Locating all critical points of elevation such as high and low points and any change in slope.

1. Elevations are established at all critical elevation points.

2. The rod person selects all changes in slope, high points, etc. and determines that elevation and horizontal location.

3. Contours are then interpolated between each established elevation point.

C. Grid method — A grid system is laid out (every 50' or 100') and elevations are established at each grid point.

1. Radial grid method

   a. All horizontal angles are recorded for each shot

   b. All rod readings are recorded for each shot.

   c. Each horizontal distances is measured by taping or by reading stadia hairs.

   d. Elevations are determined at each point

   e. Contours are interpolated

2. Rectangular grid method

   a. A square grid is laid out and marked

   b. All rod readings are recorded at each grid point

   c. Elevations are determined at each grid point

   d. Contours are interpolated from each grid elevation.

   (NOTE: It is assumed that the slope is constant from each grid point to the next.)

INFORMATION SHEET

IX. **Topographic field note keeping techniques** (Transparencies 2 and 3)

A. Keep notes neat and legible.

B. Keep concise records.

C. Clearly label the columns.

D. Topo should be taken in order or in sequence when possible.

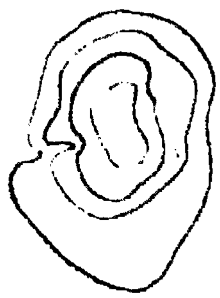
E. Description of topo items should be clear.

F. Points should be numbered for easy reference to sketches.

G. Sketches should be neat and done with a straight edge.

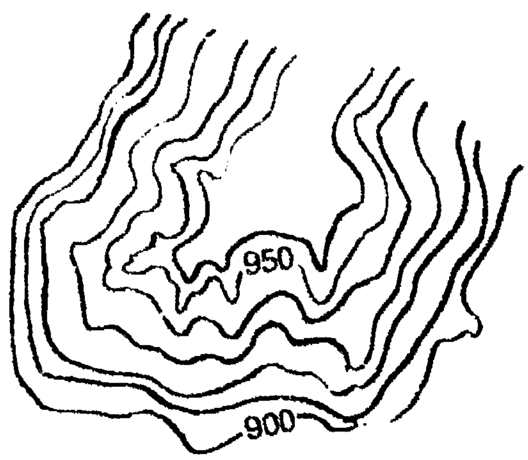
Contour Line Configurations

Summit

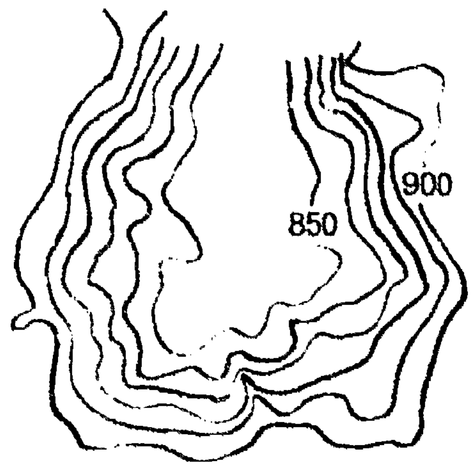


Depression

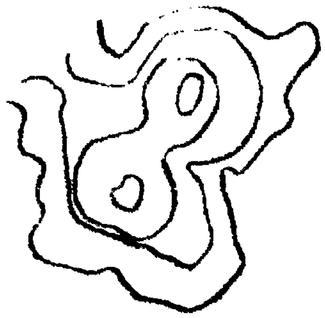
Ridge



Valley



Saddle



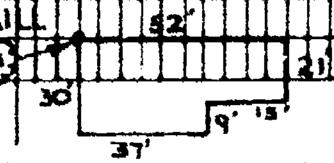
Stream

Standard Offset Topo Notes

Topo of Locust Circle

D. OLSON | 4-2-79
T. CROYMONS | 61° | 20

STA	Offset (LT.)	Offset (RT.)	Description
0-50	On Line		BARB FENCE RUNS DIAG. W/PROP
0-48	On Line		POWER POLE ON ℄ LOCUST
0-04	84^{4}'		℄ 24" DIA. R.C.P. STORM SEWER CULVERT
0+02		28^{5}'	℄ STORM SEWER M.H. (4^{5}' DEEP)
0+20		75^{0}'	BARB FENCE ANGLES W/PROPERTY
0+57	68^{4}'		EAST END 24" R.C.P. STM. SW'R CULVERT
0+60	35^{0}'	53^{0}'	FENCE CORNER (BARBED)
0+60			18" DEC. TREE
0+71	34^{0}'		PWR. POLE (NE. to S.W.)
0+77	34^{0}'		PWR. POLE (E.W. to S.W.)
0+83		21^{3}'	12" DEC TREE
0+92	88^{5}'		10" DEC TREE
1+10		42^{0}'	6" DEC TREE
1+18		42^{5}'	4" DEC TREE
1+30		42^{0}'	6" DEC TREE
1+61		33^{0}'	FENCE CORNER (LOT DIVISION) DIAG. S.W. (SHADY LN.)
*0+41		33^{3}'	FENCE CORNER (DIAG.) BARBED
1+65	33^{5}'	45^{0}'	FENCE CORNER (DUE NORTH) BARBED
1+83		18^{0}'	℄ 55' DIA. WTR. STORE TANK (MEAS. to FACE)
1+88			6" DEC. TREE
1+95	108^{0}'		18" DEC. TREE
2+02	57^{5}'		OLD ABAN. WIND MILL
2+37	88^{3}'		NW △ BARN (SKETCH)



Stadia Topo Notes

Known Point	Topo Point	Angle	Rod Int	Hor. Dist	
South 1/16 Corner					
	1	40°15'	1.5	150	
	2	45°20'	.95	95	
	3	46°10'	1.85	185	
	4	88°15'	4.6	460	
Section Corner					
	5	10°16'	6.2	620	

Stadia Constant 100

B. Jones - Tape
A. King - $\bar{\wedge}$
H. White - Notes
Hot, Clear

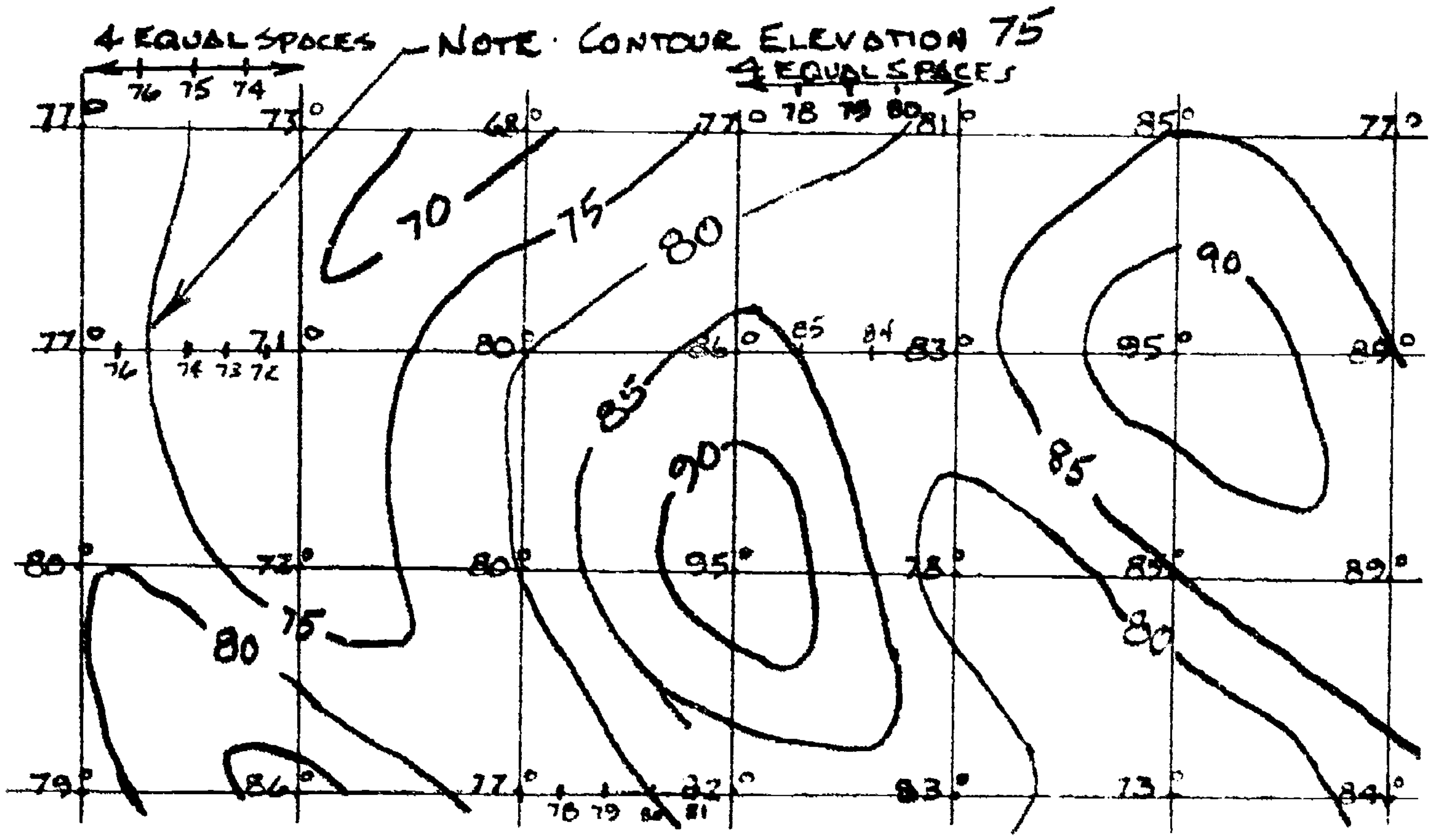
Description	
B.S. at Section Corner	19/20 20/25
S.W. Corner of Barn	
N.W. Corner of Barn	
N.E. Corner of Barn	
Windmill	
B.S. on S. 1/16 Corner	19/20
S.E. Corner of Barn	

TOPOGRAPHIC SURVEYING
UNIT VIII

ASSIGNMENT SHEET #1 — CONSTRUCT AN ACCURATE CONTOUR DRAWING

Directions: Accurately plot each 2 foot contour line starting with elevation 100.00 in the lower right-hand corner of the grid area. Label each contour and neatly draw each contour line after the position has been interpolated.

Example:



(NOTE: Study this example noting that each grid square is broken into a certain number of divisions that coincide with the number of feet difference in elevation.)

ASSIGNMENT SHEET #1

Problem: Interpolate every (even) two foot interval. Plot and sketch in each contour line. Label each contour with its elevation.

103.0	101.0	98.0	95.0	98.0	101.5	102.9
100.0	98.0	95.0	92.0	96.0	99.0	101.0
97.0	95.0	92.0	91.7	94.5	96.0	98.0
94.0	93.0	90.0	90.0	93.0	94.0	95.0
95.3	95.0	92.0	90.0	90.0	92.0	94.0
99.0	97.0	94.0	92.6	93.0	94.0	97.9
98.0	96.0	93.0	94.0	94.6	96.2	98.1
96.4	94.5	93.2	95.6	96.8	98.0	101.1

TOPOGRAPHIC SURVEYING
UNIT VIII

ASSIGNMENT SHEET #2 — LAYOUT AND PLOT CONTOURS FROM RADIAL SURVEY NOTES

Directions: Accurately layout the site topography from the field notes on the following page on a 24" × 36" sheet of drafting vellum. Assume a scale of 1" = 100' unless otherwise instructed by your teacher.

Upon completion of layout of existing topography, pencil in each ground elevation in its proper location on the drawing according to the field notes. Proportionally layout each "even" two-foot contour line on your drawing in light pencil. (Example: 158, 160, 162, etc.) Use all of the standard characteristics for contours discussed in Objective VII of the Information Sheet. Once each contour line has been located, darken in all lines with smooth, dashed lines labeling each contour with the proper elevation.

ASSIGNMENT SHEET #2

TOPOGRAPHIC DETAILS OF TRAVERSE AREA
BY TRANSIT STADIA

POINT	AZIMUTH	ROD INT.	VERT ∢	HOR. DIST.	ROD DIST.
	⊼ @ STA #5; H.I. = 5.2				
STA. #1	46°30′	(MAG.)			
1	1°40′	1.20	−0°26′	120	5.2
2	2°45′	1.20	−1°24′	120	5.2
3	3°20′	1.[illegible]	−2°21′	135	5.2
4	55°30′	2.10	+0°51′	210	6.0
5	85°10′	2.52	+0°12′	252	5.2
6	85°10′	0.50	−7°18′	49	5.2
7	85°10′	0.75	−4°22′	75	5.2
8	115°50′	1.50	−2°05′	150	5.2
9	181°30′	1.75	−1°38′	175	7.0
10	197°20′	1.90	−1°49′	190	5.2
11	220°40′	2.60	−1°42′	260	5.2
12	232°20′	2.14	−1°15′	214	5.2
13	270°10′	1.80	−0°40′	180	5.2
14	284°30′	1.51	+0°18′	151	5.2
15	345°40′	1.92	+0°51′	192	5.2
STA #1	46°30′	CHECK			
			Signature		
	⊼ @ STA #6; H.I. = 5.0				
STA #5	5°12′30″	(MAG.)			
16	--	—	—	–	...
17	...	...	—		...

DATE
WEATHER
EQUIPMENT

DUTIES
"
"

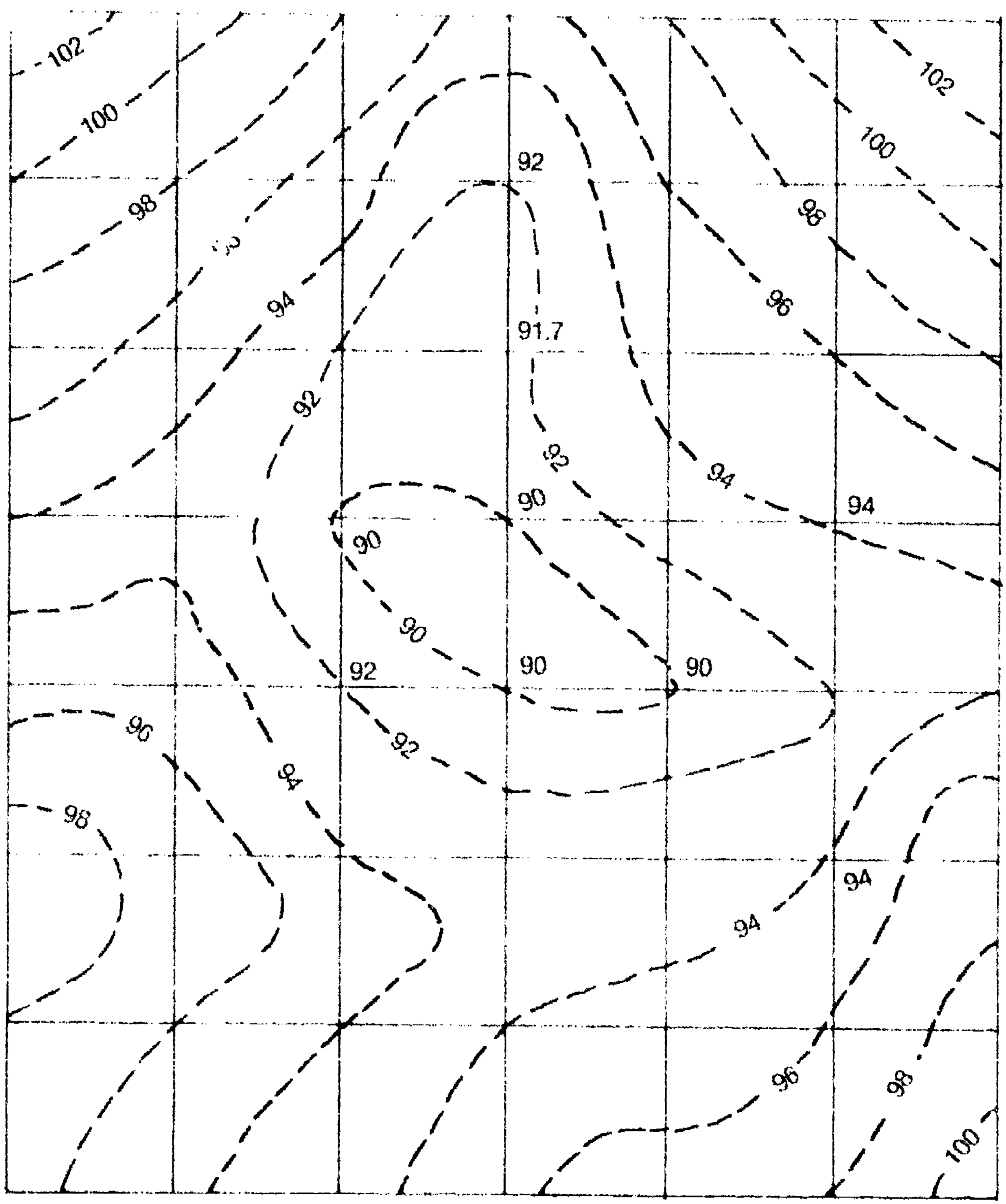
PAGE ___
NAME
NAME
NAME

Δ ELEV	ELEV	DESCRIPTION
	94553	
		TRAVERSE STA. #1
−0.9	944.6	BASE OF FIRE PLUG
−2.9	942.6	N.W. COR. ROAD INTERSECTION
−5.5	940.0	N.E. COR. ROAD INTERSECTION
+2.3	947.8	TOP OF SLOPE
+0.9	946.4	TRAVERSE STA. #2
−6.3	939.2	WEST EDGE ROAD
−5.7	939.8	EAST EDGE ROAD
−5.4	940.1	10" DIA. ELM TREE
−6.8	938.7	TRAVERSE STA. #6
−6.0	939.5	PT. ON UNIFORM SLOPE
−7.7	937.8	FENCE LINE
−4.6	940.9	ANGLE PT. IN FENCE
−2.1	943.4	FENCE LINE
+0.8	946.3	SLOPE CHANGE
+2.8	948.3	NOSE OF SLIGHT RIDGE
	938.7	

TOPOGRAPHIC SURVEYING
UNIT VIII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1



Assignment Sheet #2 — Evaluated to the satisfaction of the instructor

TOPOGRAPHIC SURVEYING
UNIT VIII

JOB SHEET #1 — PERFORM A RADIAL TOPO SURVEY

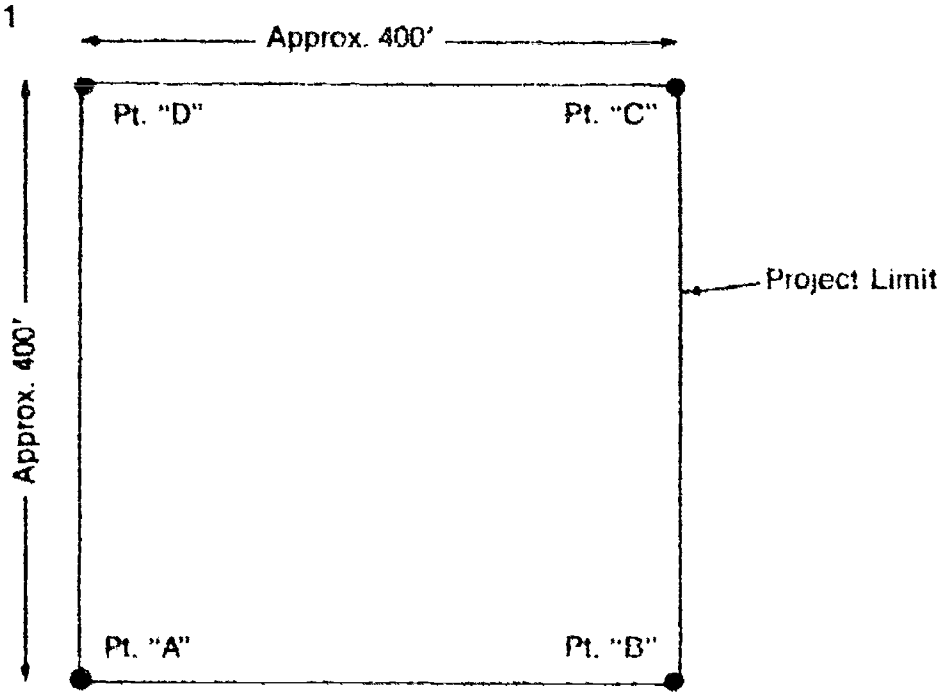
A. Tools and equipment

1. Transit or theodolite
2. Tripod
3. Chain
4. Chaining pins and ring
5. Level rod
6. Field book and pencil

B. Procedure

1. The instructor shall set up a square boundary for the survey crew to serve as a project limit. (Figure 1)

FIGURE 1

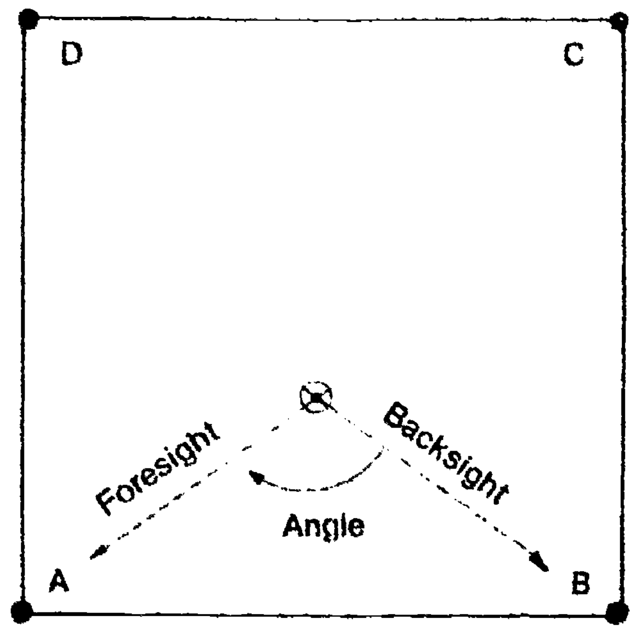


2. The survey crew should set the instrument up in the approximate center or at any point that makes sighting most areas of the project advantageous.

3. After leveling the theodolite and zeroing the vernier, the instrument person should sight a backsight point (one of the boundary corners) and turn an angle to another boundary corner. (Figure 2)

JOB SHEET #1

FIGURE 2



4. Upon reading this angle and recording it in the field book, the distance to the backsight and foresight should be measured and recorded.

   (NOTE: This operation has located the instrument station in respect to the boundary.)

5. After this is documented, the instrument person should rezero the theodolite at Pt. "B" and lock the lower tangent.

6. The rod person can then begin a random series of ground shots preferably in increasing angular sequences while the instrument person is recording:

   a. Horizontal angle

   b. Horizontal distance (either taped or by recording top and bottom stadia hairs)

   c. Description of point (ground shot, building, corner, tree, etc.)

   d. And center hair rod reading (trying to keep the instrument level at all times if possible)

6. Continue this pattern in a clockwise motion, locating all items within the boundary. (Figure 3)

   a. Trees

   b. Buildings

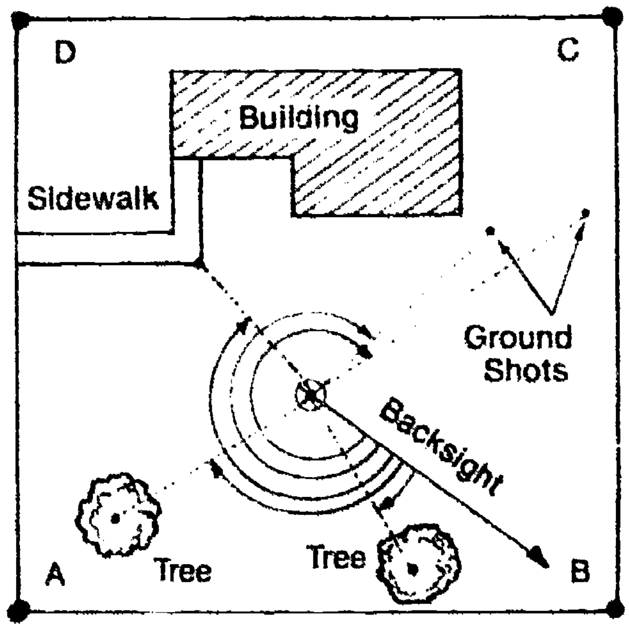
   c. Sidewalks

JOB SHEET #1

d. Any changes in grade

e. Other

FIGURE 3



8. After completing 360° and resighting Pt. B to verify that the instrument was not bumped off of the original backsighted 0°00'00", make one more observation of the site, checking that nothing was missed when collecting the field information.

   (NOTE: If certain items can not be sighted from this point, the instrument may be relocated in a different area of the boundary and the process repeated.)

9. Either prior to starting at each instrument set up or before moving the instrument, a bench mark should be sighted with the telescope level and the center hair reading documented.

10. Upon completion of the survey, the party chief should obtain bench mark elevation, calculate height of instrument, and reduce all rod shots or minus shots to each random point.

TOPOGRAPHIC SURVEYING
UNIT VIII

JOB SHEET #2 — PERFORM A RIGHT-ANGLE OFFSET SURVEY

A. Tools and equipment

1. Transit or theodolite
2. Tripod
3. Chain
4. Chaining pins and ring
5. Nails or wood hubs
6. Hammer
7. Cloth tape
8. Double pentagon prism
9. Field book and pencil

B. Procedure

1. Set up transit over Point "A".

    a. Level instrument.

    b. Sight Pt. "B". (Figure 1)

FIGURE 1

2. Begin measuring 100 feet intervals and placing nails or wood hubs on line. (Figure 2)

    a. Instrument person should use hand signals to give line.

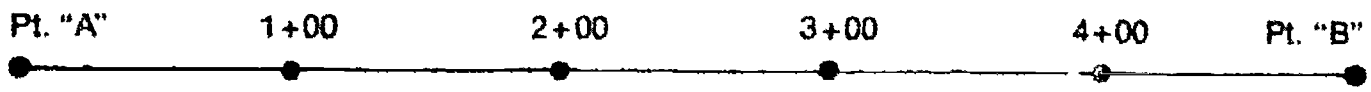
    b. Rear tape person holds zero at Pt. "A".

    c. Head tape person holds 100 foot mark and locates a pt. (Sta. 1+00) on line.

JOB SHEET #2

d. Each point set should be flagged for easy reference.

FIGURE 2

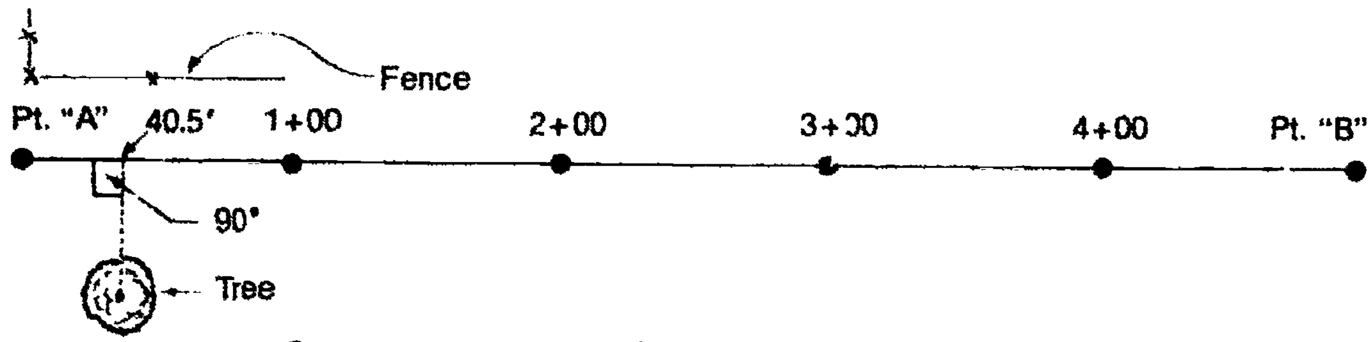


3. After baseline has been established and stationed every 100 ft., offset topo can begin.

   a. Lay tape out from Sta. 0+00 (Pt. "A") to Sta. 1+00. Take care to keep it straight.

   b. Using a cloth tape to measure each offset distance to any existing features, position yourself over the base line at a 90° angle from the object to be located. (Figure 3)

FIGURE 3



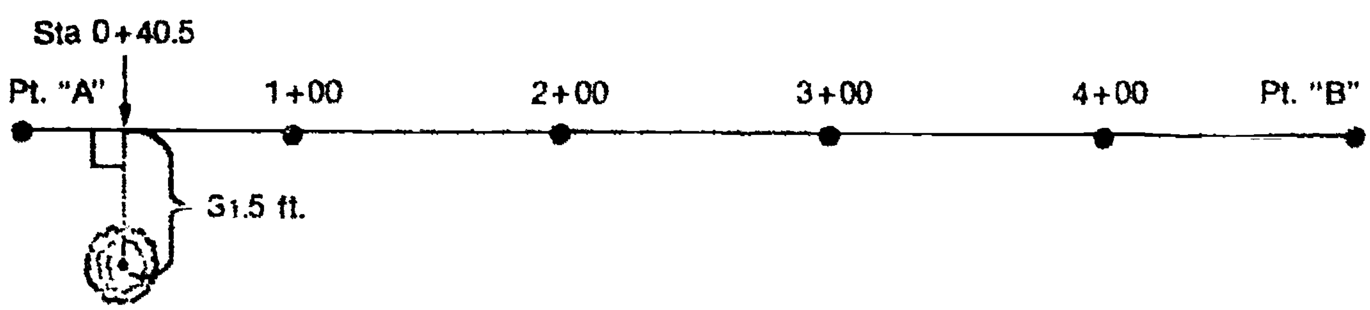
   c. Once you are satisfied that you are at 90° to the baseline (either by estimating or by the use of a pentaprism), the station or distance from the last 100 foot station should be recorded.

      Example: 40.5 ft. would equal Sta. 0+40.5 to the tree

   d. After the station is noted in the field book and the item is described, the tape person should take the zero end of the tape toward the object (Example: tree) and measure the offset distance (horizontal) from the tree to the tape laying at the baseline of the survey. (Figure 4)

      Example: 31.5' (Right) to 6" tree

FIGURE 4



JOB SHEET #2

e. This information should be documented in the field book and if it is left or right of the baseline.

4. This total process is continued throughout the length of the survey base line.

   a. All existing features are located with a station and an offset left or right.

      (NOTE: Left and right are **always** designated when facing in the direction the stationing is progressing.)

   b. Document all descriptions of objects, sketches of buildings, etc. on the right hand page of the field book.

5. After completion of survey,

   a. Pick up all equipment.

   b. Clean up and make a check for missing items.

   c. Store equipment in proper locations.

TOPOGRAPHIC SURVEYING
UNIT VIII

NAME ____________________

TEST

1. Match the term^ on the right wih the correct definitions.

_____a.	The difference in elevation or inequality of a land surface; the type of terrain on a given parcel of land	1. Contour
_____b.	A line that connects points of the same or equal elevation	2. Cultural features
_____c.	The configuration of a surface including its relief and the position of its natural and manmade features	3. Interpolation
_____d.	Artificial features that are products of people such as roads, trails, buildings, bridges, canals, etc.	4. Relief
_____e.	A method of making a horizontal distance measurement by the use of a fixed angle intercept	5. Stadia
_____f.	A method of determining approximate horizontal distances (±1 foot in 300 feet) by the use of two additional cross hairs in most transits and levels, one above and one below the center hair; a form of tacheometry	6. Tacheometry
_____g.	Estimating the position of a point between two known points; commonly used when plotting contour lines	7. Topography

2. List two purposes of topographic surveying.

a. ____

b. ____

____

TEST

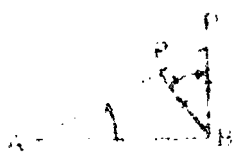
3. Distinguish between the two classifications of topographic surveys by placing an "A" next to the description(s) of aerial surveys and a "G" next to the description(s) of ground surveys

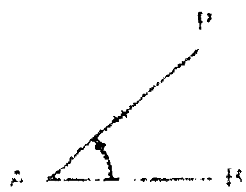
   _____ a. Used frequently for smaller areas to be mapped

   _____ b. Involve the actual survey crew performing on-site control surveys to obtain all topographic features

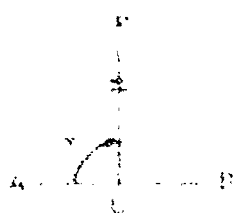
   _____ c. Involve the use of actual photographs taken from airplanes, helicopters, and satellites to determine topographic features on the ground

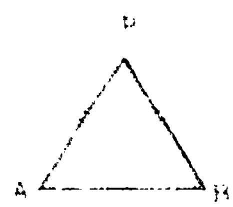
4. Identify the following methods of locating topographic details. Select your answers from the following list (not all are shown here): Two distances — intersecting method; two angles — intersecting method; one angle and the adjacent distance — polar method; one angle and the opposite distance — polar method; one distance and a right angle offset — rectangular method; intersection of lines from straddle points — intersecting method; and two angles at the point to be located — resecting method.





a. ______________________________ b. ______________________________





c. ______________________________ d. ______________________________

TEST

5. Distinguish between the three methods of topographic surveying by placing the following letters next to the correct descriptions:

   - "R" for radial surveys
   - "RA" for right angle offset surveys
   - "G" for grid layout surveys

   _____ a. 1) A baseline is setup with stations laid out (usually every 100 ft.)
   2) Right angles are established at each of the objects that are to be located, either by estimating 90° or by the use of a double-pentagon prism.
   3) The station along the baseline is noted where the right angle is made, and a horizontal distance is measured from this point to the object to be located.

   _____ b. 1) A grid system of points is laid out across the overall area to be surveyed.
   2) Lines and points are identified by using letters and/or numbers.
   3) Measurements are made from grid points to each of the features that must be located.

   _____ c. 1) A traverse point is occupied with a transit or theodolite.
   2) Each topographic feature is observed and an angle and distance to that point is recorded.

6. Complete the following statements concerning stadia principles by circling the correct answers.

   a. Stadia is a form of tacheometry that relies on a (**variable, fixed**) angle intercept for measuring distances.

   b. Is commonly used in topographic surveys where an accuracy of ($^1/_{100}$, $^1/_{400}$) is acceptable.

   c. Involves a transit, theodolite, or sometimes a level that is equipped with a cross-hair reticle that has (**tacheometry, stadia**) hairs.

   d. Stadia methods (**are, are not**) suitable for inclined measurements.

7. Select from the following list characteristics of contours by placing an "X" in the appropriate blanks.

   _____ a. Contours are parallel to the direction of maximum slope.

   _____ b. Contours are perpendicular to the direction of maximum slope.

   _____ c. The slope between contour lines is assumed to be uniform.

   _____ d. Concentric closed contours that increase in elevation represent depressions.

TEST

[illegible] depression contour.

[illegible] a vertical surface [illegible]

[illegible]

[illegible] the following letters [illegible] for indirect method, and "G" [illegible]

[illegible] high and low points and [illegible]

[illegible] elevation points.

[illegible] high points, etc. and deter- [illegible]

[illegible] established elevation point.

[illegible] are established [illegible]

[illegible]

[illegible]

[illegible]

[illegible] elevation

[illegible] position.

[illegible] instrument to deter- [illegible]

[illegible] the ground that indi- [illegible]

[illegible] then recorded to locate [illegible]

[illegible]

TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

10. Construct an accurate contour drawing. (Assignment Sheet #1)

11. Layout and plot contours from radial survey notes. (Assignment Sheet #2)

12. Demonstrate the ability to:

    a. Perform a radial topo survey. (Job Sheet #1)

    b. Perform a right-angle offset survey. (Job Sheet #2)

TOPOGRAPHIC SURVEYING
UNIT VIII

ANSWERS TO TEST

1. a. 4
   b. 1
   c. 7
   d. 2
   e. 6
   f. 5
   g. 3

2. Any two of the following:
   a. To determine the location of all natural and cultural features on the site.
   b. To determine the configuration (relief) of the earth's surface.
   c. To determine the most desirable and economical location of highways, railways, canals, pipelines, buildings, and many other facilities.

3. a. G
   b. G
   c. A

4. a. One angle and the opposite distance — Polar method
   b. One angle and the adjacent distance — Polar method
   c. One distance and a right-angle offset — Rectangular method
   d. Two distances — Intersecting method

5. a. RA
   b. G
   c. R

6. a. Fixed
   b. $^1/_{400}$
   c. Stadia
   d. Are

7. b, c, e, f

8. a. I
   b. G
   c. D

ANSWERS TO TEST

9. Any five of the following:
   a. Keep notes neat and legible.
   b. Keep concise records.
   c. Clearly label the columns.
   d. Topo should be taken in order or in sequence when possible.
   e. Description of topo items should be clear.
   f. Points should be numbered for easy reference to sketches
   g. Sketches should be neat and done with a straight edge.

10.-11. Evaluated to the satisfaction of the instructor.

12. Performance skills evaluated to the satisfaction of the instructor.

CONSTRUCTION SURVEYING
UNIT IX

UNIT OBJECTIVE

After completion of this unit, the student should be able to state the rule for computing grades or slopes, identify primary cases where slope stakes may be used, and calculate and stake both horizontal and vertical curves. Competencies will be demonstrated by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to construction surveying with the correct definitions.
2. State the purpose of construction surveys.
3. Select true statements concerning the responsibilities of a construction surveyor.
4. State the purposes of horizontal and vertical control points
5. Complete statements concerning laying out control points.
6. State the rule or formula for computation of grades or slopes.
7. Complete statements concerning offset stakes.
8. Differentiate between a baseline and an offset stake.
9. Match types of stake markings with their descriptions.
10. Arrange in order the steps in laying out a building location.
11. Identify typical roadway sections.

OBJECTIVE SHEET

12. Complete statements concerning slope staking.

13. State the equations used in locating slope stakes.

14. Distinguish between the types of horizontal curves.

15. Identify the elements of a simple horizontal circular curve.

16. Arrange in order the steps for computing and laying out a simple horizontal curve.

17. Match the elements of a simple vertical curve with their correct locations on a schematic drawing.

18. Arrange in order the steps for computing a vertical curve.

19. Calculate a simple horizontal curve. (Assignment Sheet #1)

20. Calculate a simple vertical curve. (Assignment Sheet #2)

21. Demonstrate the ability to:

    a. Stake a horizontal curve. (Job Sheet #1)

    b. Stake a centerline profile with a vertical curve. (Job Sheet #2)

    c. Stake a sewer profile with offsets. (Job Sheet #3)

CONSTRUCTION SURVEYING
UNIT IX

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Suggest that the students keep daily logs of what they do for a one or two week period. Demonstrate the importance of documenting information frequently.

2. Discuss the different techniques of note keeping for construction staking procedures.

3. Visit current construction sites, monitoring progress, visiting with construction superintendents, field inspectors, and construction surveyors.

4. Visit a building site, study the configuration of the building, note the technique of batter boards used, and possibly set up a batter board for a simple building.

5. Layout one of the various types of spiral curves discussed in this unit.

6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1 — Procedure for Setting Profile Line and Grade
2. TM 2 — Typical Cut and Fill Stakes
3. TM 3 — Typical Building Layout
4. TM 4 — Typical Roadway Sections
5. TM 5 — Slope Stake Locations

D. Assignment sheets

1. Assignment Sheet #1 — Calculate a Simple Horizontal Curve
2. Assignment Sheet #2 — Calculate a Simple Vertical Curve

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1 — Stake a Horizontal Curve
2. Job Sheet #2 — Stake a Vertical Curve
3. Job Sheet #3 — Stake a Sewer Profile With Offsets

G. Test

H. Answers to test

REFERENCES USED IN WRITING THIS UNIT

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B. Brinker, R.C., and P.R. Wolf. *Elementary Surveying*, 7th ed. New York, NY: Harper and Row, 1984.

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A. Davis, R.E., F.S. Foote, and J.H. Kelly. *Surveying*, 5th ed. New York, NY: McGraw Hill Book Company, 1966.

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D. Pafford, F.W. *Handbooks of Survey Notekeeping.* New York: John Wiley and Sons, 1962.

CONSTRUCTION SURVEYING
UNIT IX

INFORMATION SHEET

I. **Terms and definitions**

A. Construction surveying — The process of laying out all types of facilities on proposed engineered sites prior to construction by giving alignment and grade to aid the contractor during installation

B. Equal tangent curve — A vertical curve with tangent lengths that are the same, therefore making the curve symmetrical

C. Flow line — Normally referring to the inside bottom of a pipe or culvert

(NOTE: This is similar to the invert of pipe.)

D. Grade stake — A stake set by a surveyor to give contractors a known elevation to base their construction on, usually noted with a cut or a fill for the vertical distance above or below the stake

E. Grade rod reading — The calculated rod reading that is desired if the rod was placed on design grade

Example: H.I. — Design grade = Grade rod reading

F. Gradient — The decimal form of a percent of slope; indicates the steepness of a sloped surface

G. Invert elevation (I.E.) — The lowest visible surface; the bottom or floor of a manhole, drain, sewer, channel, tunnel, etc.

(NOTE: This is usually a subsurface item.)

H. Slope ratio — The inclination of a surface expressed as one unit of rise or fall for so many horizontal units

Examples: 4:1, 3:1

II. **Purpose of construction surveys** — To provide the horizontal and vertical layout for every key component of a construction project.

(NOTE: Surveyors lay out and position all types of facilities from streets, water and sewer lines, and structures according to the design plan. Over 60% of all hours spent surveying is on location-type work giving line and grade.)

III. **Responsibilities of a construction surveyor**

A. Keeping notes

1. Should be extensive and detailed on every phase of construction.

2. Are often used when developing as-built drawings.

INFORMATION SHEET

3. Are used to document field changes.

4. Could conceivably be used in court as documented evidence.

B. Keeping daily logs or diaries

1. Are used to document in detail the daily progress.

2. Are often used for partial payment of work completed.

3. Are used to record all field changes or change orders.

4. Are used for final quantities and as-built drawings.

C. Communicating at the construction site

1. Instructions must be clear to all contractors about staking procedures, offset distances, cut/fill markings, and traffic control.

2. Good communication must exist with any involved parties such as adjacent owners and the concerned public.

3. Directions must be clear to all survey party members on staking methods, accuracy, safety, and the importance of clear and correct stake markings.

IV. Purposes of horizontal and vertical control points

A. To serve as a good framework of control around the project area.

B. To act as a base for positioning structures, utilities, roads, etc.

V. Laying out control points

A. Should be far enough from the actual construction to ensure working room for the contractor and freedom from possible destruction.

B. Should be clearly marked and understood by the contractor in the absence of a surveyor.

C. Should be supplemented by guard stakes to deter accidental removal.

D. Should be "tied off" or located by tie points outside the actual construction area so that replacement, if necessary, can be performed without difficulty.

(NOTE: Prior to construction work, any existing government control points should be researched and relocated. Any control point that is disturbed by construction should be documented and the proper authorities notified.)

INFORMATION SHEET

VI. **Computation of grades or slopes** (Figure 1)

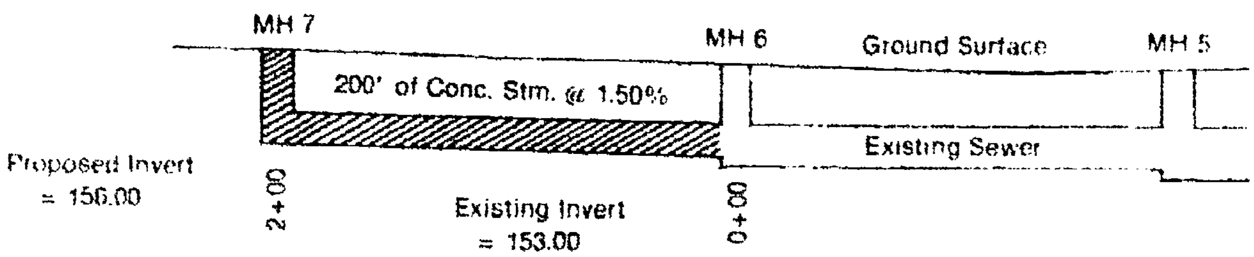
A. Determine the total horizontal distance between the two points that the proposed grade must match.

B. Determine the total vertical difference in elevation of the two points being matched.

C. Apply the following formula to find the percent (%) of slope:

$$\frac{\text{Vertical difference}}{\text{Horizontal distance}} = \%\ \text{slope}$$

FIGURE 1



Profile View

VII. **Offset stakes** (Transparency 1)

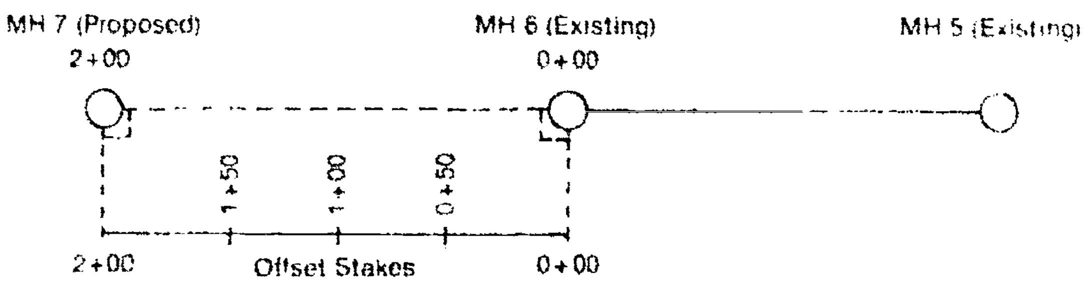
A. Normally located (Figure 2)

1. Away from actual construction
2. Convenient for transferring grade by the contractor

B. Offset distance may vary depending on depth of excavation.

C. Usually designated with a cut or fill from top of offset stake.

FIGURE 2



Plan View

INFORMATION SHEET

D. Are installed parallel to construction alignment.

E. Design elevations are determined at each offset stake.

F. Actual offset stake elevations are determined by leveling procedures.

G. Cuts or fills are calculated by the following relationship:

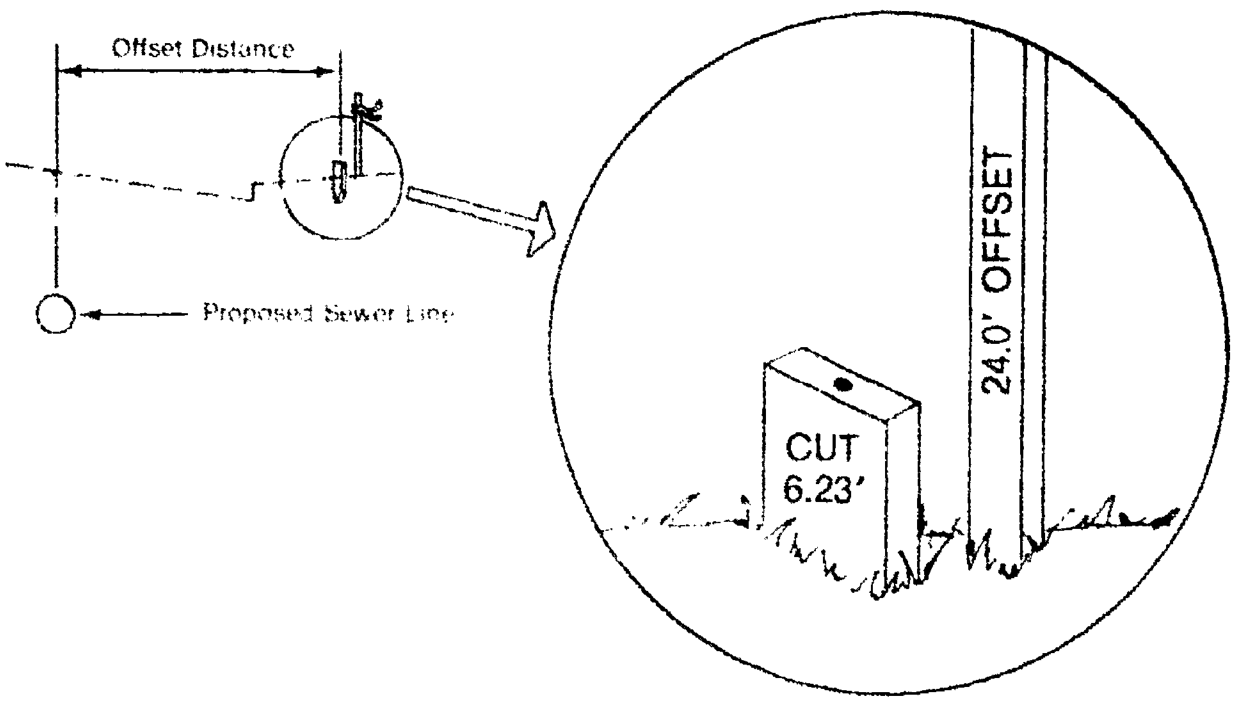
$$\frac{\text{Design elevation}}{\text{Offset stake elevation}} = \text{Cut or fill}$$

(NOTE: The algebraic sign indicates cut (−) or fill (+).)

H. Calculations are checked prior to marking stakes.

I. Offset stakes are marked for construction use. (Figure 3)

FIGURE 3



(NOTE: Stake markings vary from project to project and contractor to contractor. This should be discussed extensively prior to construction.)

VIII. **Baseline stationing and offsets** (Figure 4)

A. Baselines are normally located from control points.

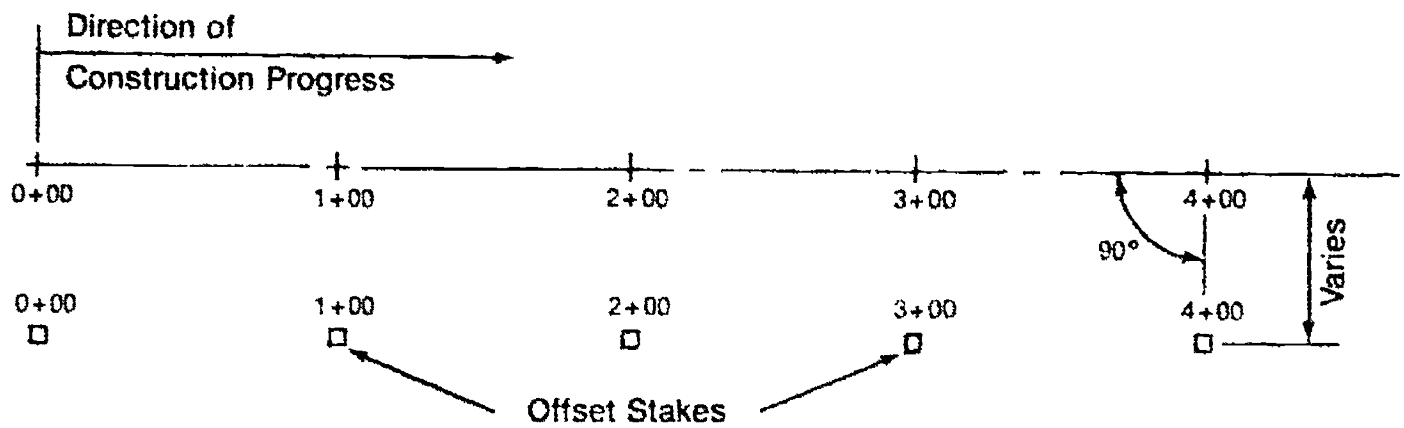
B. Stations are established at regular intervals (usually 100 feet) along the baseline, normally in the direction of construction progress.

INFORMATION SHEET

C. Construction stationing should coincide with design stationing.

D. Offsets are established perpendicular to construction baseline.

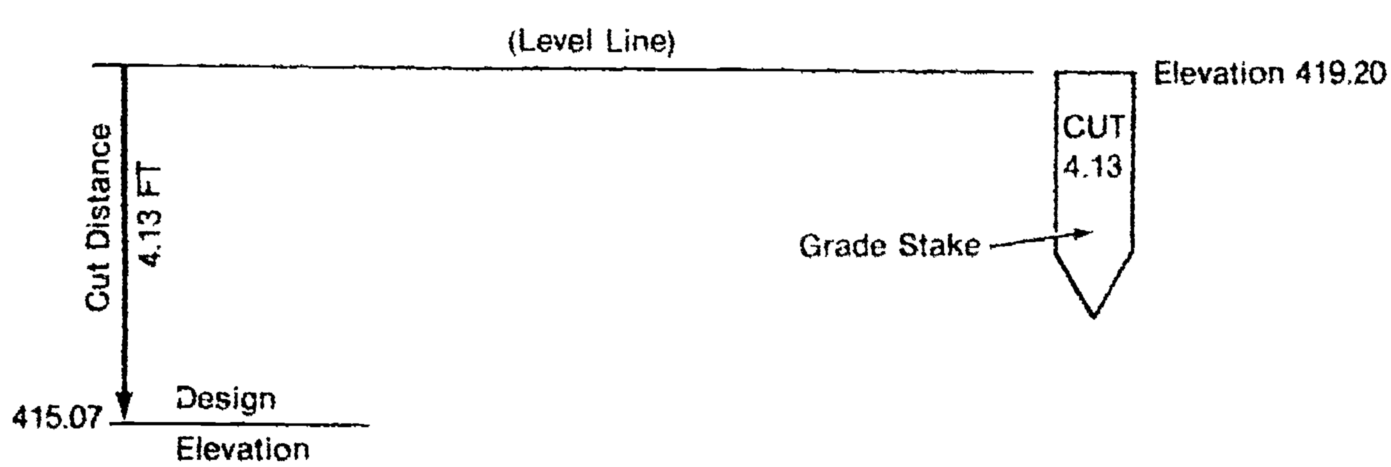
FIGURE 4



IX. **Types of stake markings** (Transparency 2)

A. Cuts — Are determined vertical distances from the proposed design elevation to the actual stake elevation. (Figure 5)

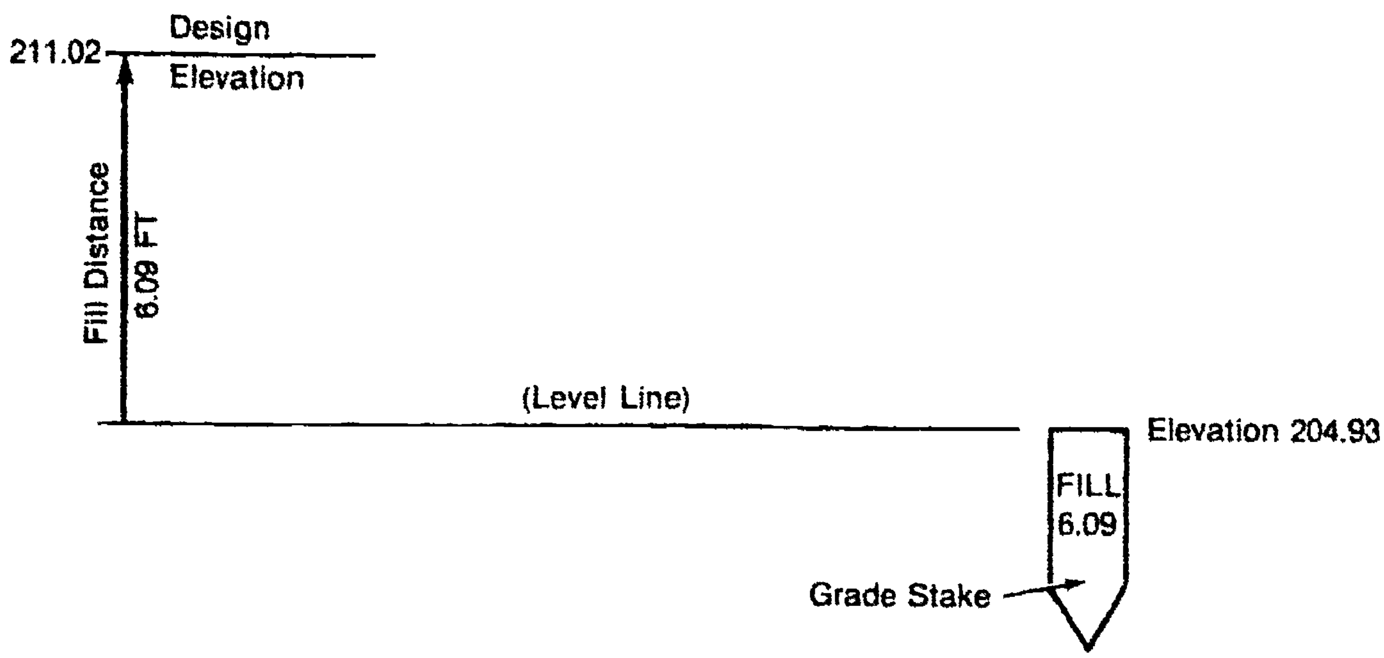
FIGURE 5



INFORMATION SHEET

B. Fills — Are determined vertical distances from the proposed design elevation to the actual stake elevation. (Figure 6)

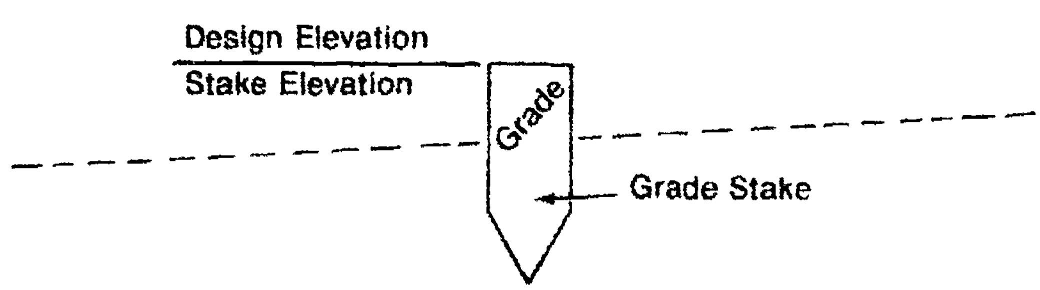
FIGURE 6



(NOTE: Often cut or fill stakes are set at an offset which is commonly marked on the reverse side of the stake. This offset distance should always be discussed with the contractor to assure a convenient distance and to understand exactly what the offset is referenced to, such as back of curb, face of curb, or ℄ manhole.)

C. Blue tops — Construction stakes that are set by the surveyor to the actual design elevation according to the construction plans. (Figure 7)

FIGURE 7



X. **Laying out a building location** (Transparency 3)

A. Locate the building perimeter on the property following the approved layout plans.

(NOTE: This needs to follow the city's setback ordinances and any restrictive covenants.)

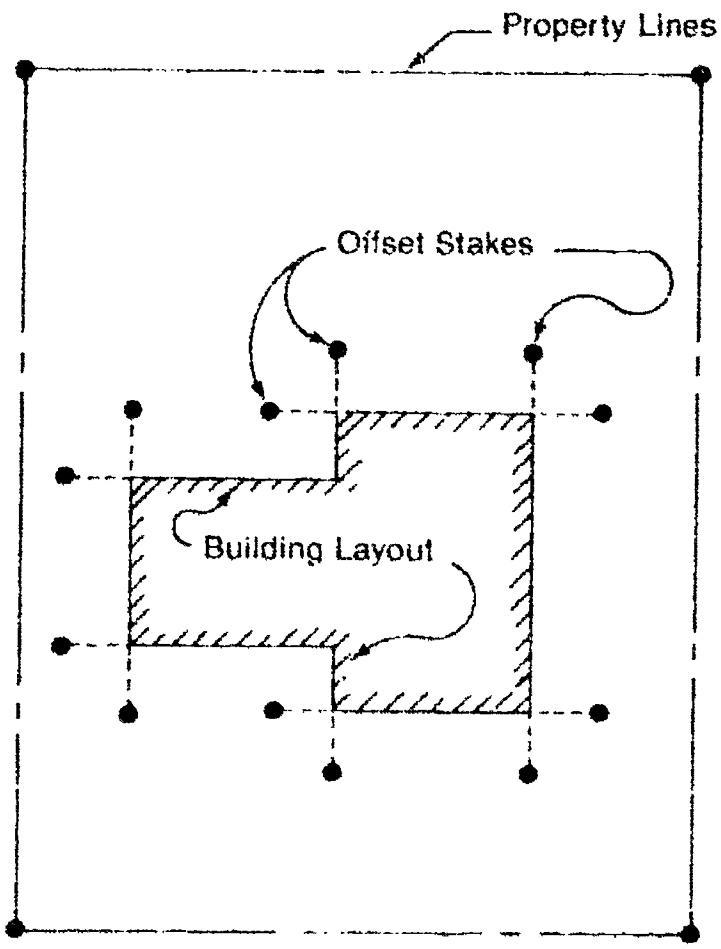
INFORMATION SHEET

B. Lay out actual building corners on the site as a visual check on positioning.

(NOTE: Obviously, these will be lost immediately when construction begins.)

C. Set the offset stakes perpendicular to each building corner at the required distance. (Figure 8)

FIGURE 8

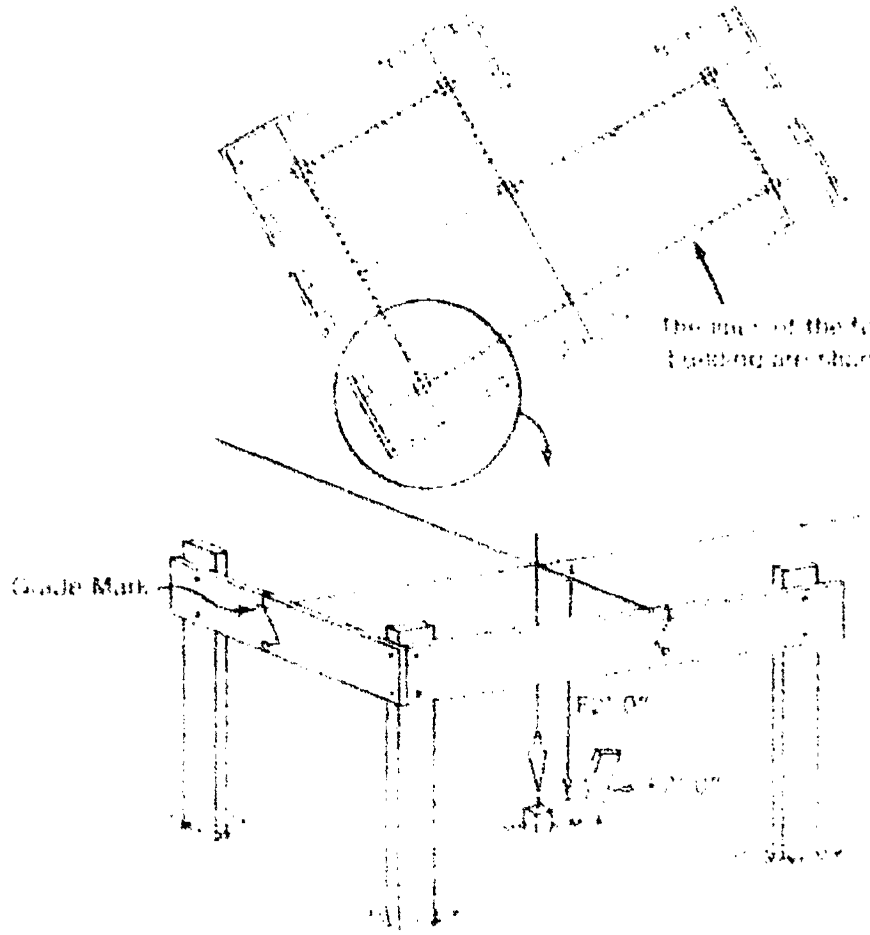


INFORMATION SHEET

D. With a level determine the elevation of each offset stake, and reference the finish floor or top of foundation wall with either a cut or fill distance from the top of each stake.

(NOTE: Batter boards are normally set up at each building corner intersection and referenced to finish floor. See Figure 9.)

FIGURE 9



XI. **Typical roadway sections** (Transparency 4)

A. Fill section

1. Occurs when the future roadway is located above existing grade.

2. Usually the existing topsoil or black dirt will be removed and then an approved fill material is installed and compacted to the proper elevation.

INFORMATION SHEET

B. Cut section

1. Occurs when the future roadway will be located below the existing ground surface.

2. The existing ground is stripped away to a depth that reflects the desired subgrade elevation, then the roadway material is installed.

C. Transition or mixed section

1. Occurs when both cut and fill operations must be performed, such as along the side of a hill.

2. The areas of cut will be stripped away and are often moved into the areas of fill and recompacted.

XII. **Slope staking** (Transparency 5)

A. Slope stakes are set to guide the contractor during excavation.

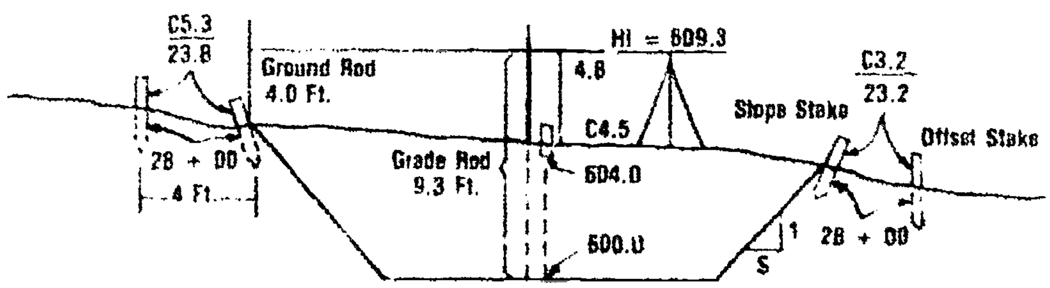
B. These are normally placed at the intersection of the original ground and each side slope, or sometimes offset a short distance 2 to 4 feet.

C. The cut or fill at each location is marked on the slope stake.

1. Actually there is no cut or fill at the slope stake.

2. The markings indicate the vertical distance from the ground elevation at the slope stake to design grade. (Figure 10)

FIGURE 10



D. Normally used for construction of:

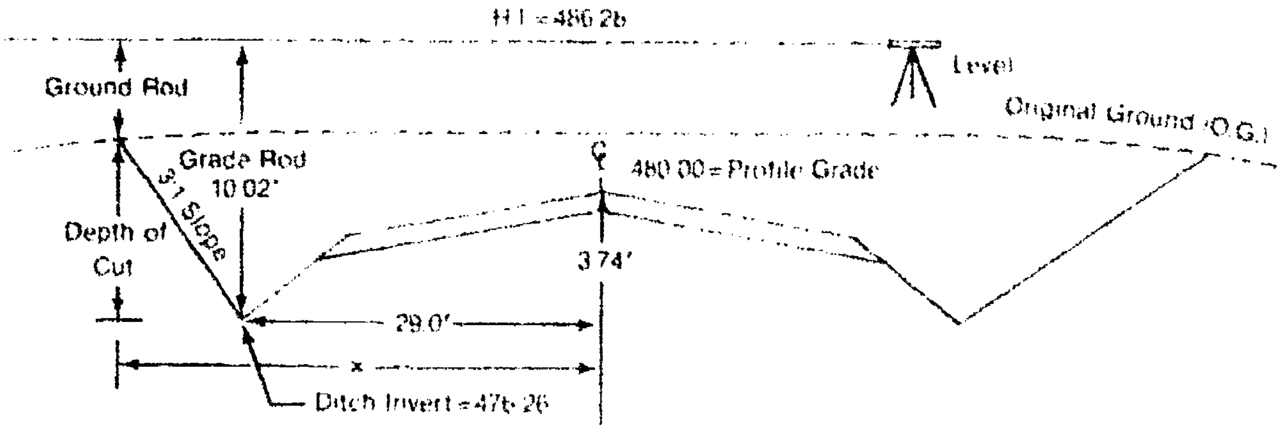
1. Streets or highways
2. Drainage ways or canals
3. Dikes and embankments
4. Bridge approachways
5. Dams or reservoirs
6. Berms along structures

INFORMATION SHEET

XIII. Procedures of slope staking

A. Location of a slope stake in a cut section (Figure 11)

FIGURE 11



Given: Profile grade (top of granular) = Elevation 480.00
Height of instrument setup = Elevation 486.28
Vertical distance to ditch invert = -3.74 feet

Calculate: Ditch invert elevation: 480.00 - 3.74 = 476.26
Grade rod reading: 486.28 - 476.26 = 10.02

1. Using the following eq ation compute the depth of cut at each trial position.

   Depth of cut = Grade rod reading − Ground rod reading

2. Using the following equation compute the horizontal offset distance (X) where the slope stake should be placed.

   X = (Depth of cut × slope) + ½ base distance

   Example: X = (Depth of cut × 3) + 29.0'

3. The rod person holds the rod and cloth tape an estimated distance from centerline and gives a rod reading.

   Example: 6.0 rod reading at a distance of 35.0' from center line

   Compute: Depth of cut: 10.02 - 6.0 = 4.02
   X = (4.02 × 3) + 29 = 41.06 ft.

   Therefore, X = 41.06 ft.

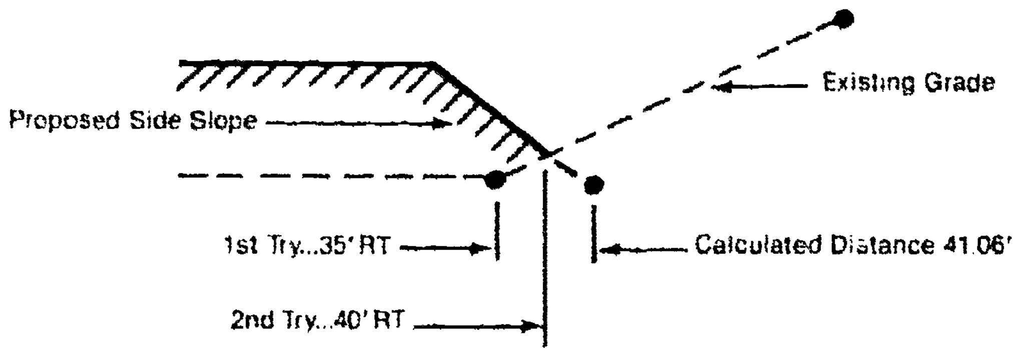
INFORMATION SHEET

4. The rod person was only at 35.0 feet from centerline and it was calculated that he should be at 41.06 ft. Therefore, he should move farther out.

   *An important rule to remember when each attempt is made is:

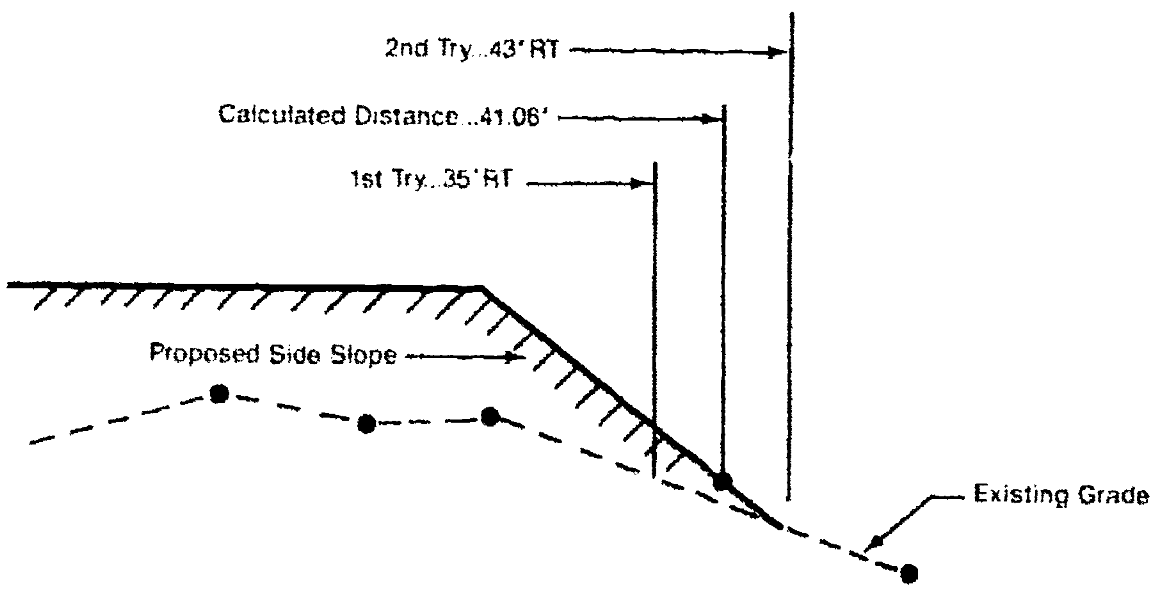
   a. If the existing grade and the proposed side slope are sloping in opposite directions, the rod person should move out less than the previous calculated distance.

      Example: FIGURE 12



   b. If the existing grade and the proposed side slope are sloping in the same direction, the rod person should move out farther than the previous calculated distance.

      Example: FIGURE 13



5. The rod person moves out to the next point for a second try.

INFORMATION SHEET

6. The rod person should then move in closer using the determined distance last computed.

   Example: 6.10 rod reading at a distance of 41.0 feet from centerline.

   Compute: Depth of cut = 10.02 - 6.10 = 3.92
   X = (3.92 × 3) + 29 = 40.80 ft.

   (NOTE: This location is within a few tenths of a foot from the actual point, so the stake is driven at a slight angle and a cut figure of 3.92 ft. would be marked on it, usually rounded to tenths, C = 3.9 ft.)

B. Locations of slope stakes for fill sections would be calculated with the same procedure. (Figures 14 and 15)

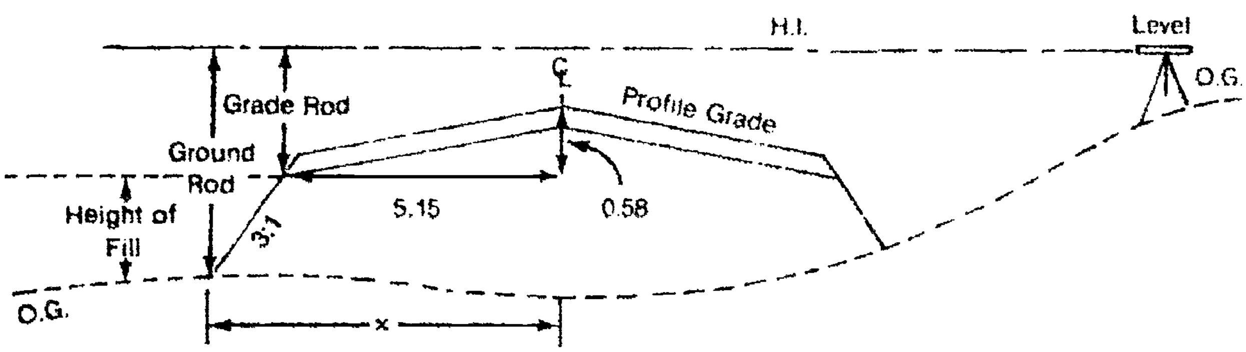
1. In all cases, it is done by trial and error with each attempt being recorded in field notes.

2. Distances from cross-section drawings can be scaled to aid in determining your first initial trial distance.

3. The process seems lengthy, but after work has commenced, the surveyor can proceed more quickly.

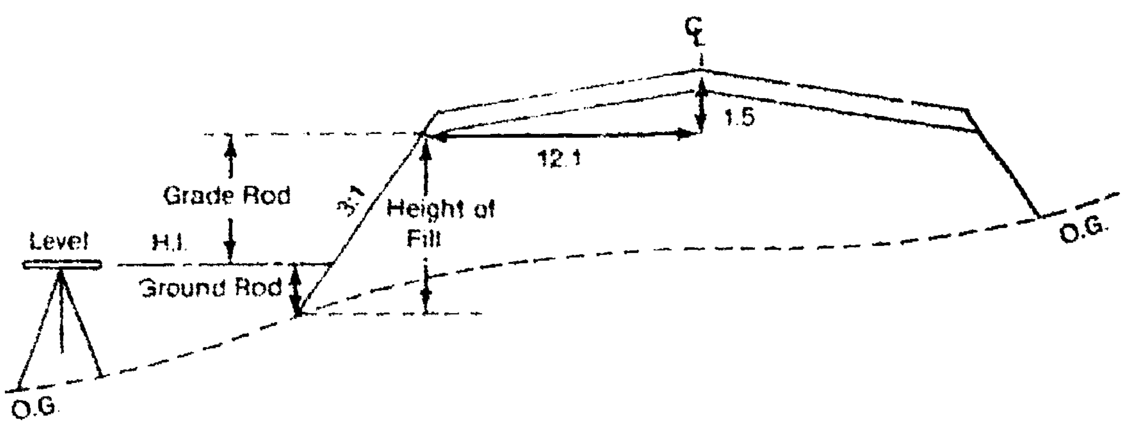
   (NOTE: Various methods of documenting the information are used. After discussing with your instructor, an agreed-upon method can be used.)

FIGURE 14 — Instrument H.I. above subgrade



INFORMATION SHEET

FIGURE 15 — Instrument H.I. below subgrade



XIV. Horizontal curves

A. There are two types of horizontal curves.

1. Circular curves

2. Spiral curves

B. Circular curves consist of (Figure 16)

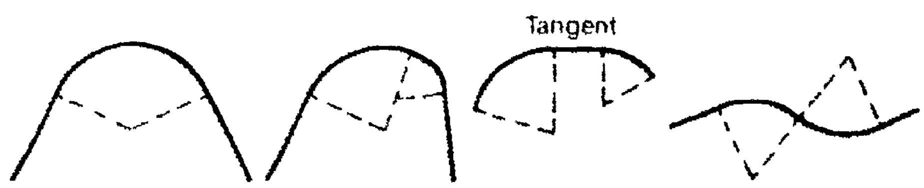
1. Simple curve: A circular arc connecting two tangents

2. Compound curve: Composed of two or more arcs of different radii tangent to each other

3. Broken-back curve: The combination of a short tangent length (usually less than 100') connecting two circular arcs that have centers on the same side.

4. Reverse curve: Consists of two circular arcs tangent to one another with their centers on opposite sides

FIGURE 16



Simple Curve **Compound Curve** **Broken-Back Curve** **Reverse Curve**

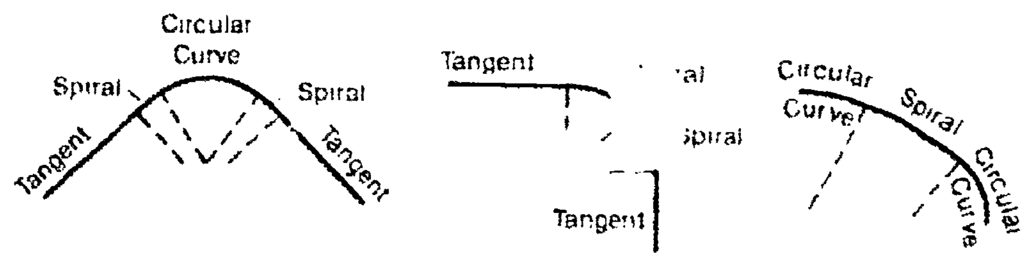
INFORMATION SHEET

C. Spiral curves (Figure 17)

1. Consist of a radius that increases or decreases slowly fr. infinity at the tangent to that of the curve it meets.

2. Can be used to connect a tangent to a circular curve, a tangent with a tangent (double spiral), or a circular curve with a circular curve.

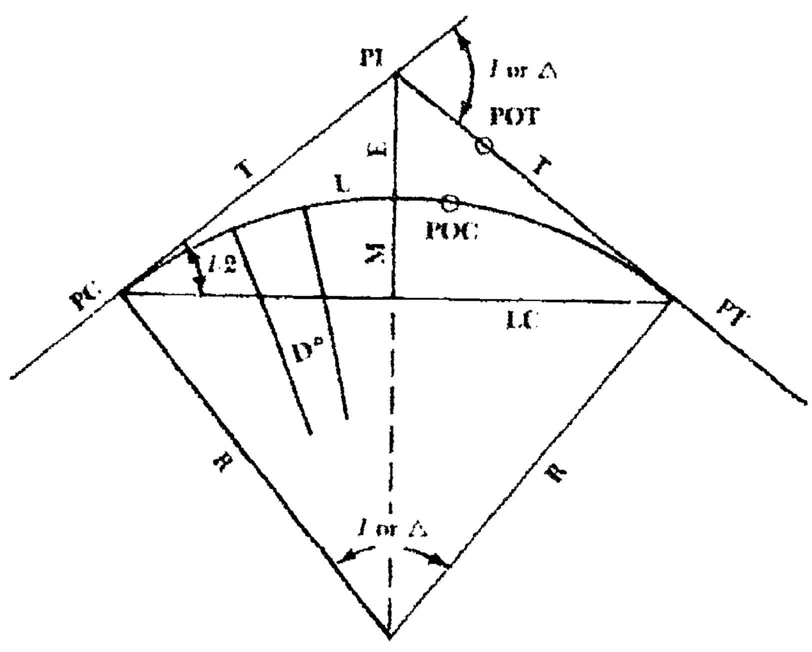
FIGURE 17



Spiral between Tangent and Circular Curve | **Double Spiral** | **Spiral between Circular Curves**

XV. **Elements of a simple horizontal circula. curve** (Figure 18)

FIGURE 18



I or Δ = Angle "I" or (Delta) — The central angle subtended by a curve or the change in direction of two tangents

P.I. = Point of intersection (of the tangents)

P.C. = Point of curvature (beginning of the curve)

INFORMATION SHEET

P.T. = Point of tangent (end of the curve)

T = Tangent distance (distance from P.C. to P.I. or P.I. to P.T.)

R = Radius (horizontal distance from the radius point of the complete circle to any point along the curve)

L.C. = Long chord (straight line distance from P.C. to P.T.)

L = Length of curve (distance along the curve from P.C. to P.T.)

E = External distance (distance from P.I. or vertex to the curve)

M = Middle ordinate (distance from midpoint on long chord to midpoint of the curve)

P.O.C. = Point on curve (any point along the actual curve)

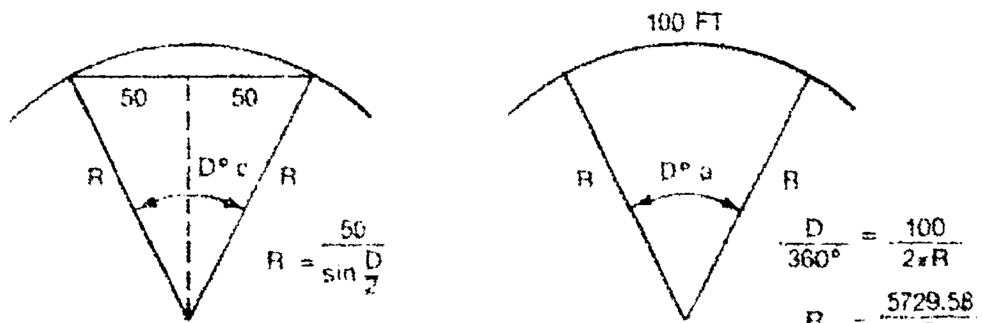
P.O.T. = Point on tangent (any point along the tangent lines)

D°a (Arc definition) = Degree of curvature (See Figure 17)

D°c (Chord definition) = Degree of curvature (See Figure 17)

(NOTE: Degree of curvature is defined as the central angle at the center of a circular arc subtended by a 10 foot arc or chord (depending on the method Da or Dc). The "arc method" is four to be the most common.)

FIGURE 19



Chord Definition

Arc Definition

Formulas for solving curve elements

$$\frac{D°}{360°} = \frac{100}{2\pi R} \text{ and } R = \frac{5729.58}{D} \text{ ft.}$$

$$T = R \cdot \tan \frac{I}{2}$$

INFORMATION SHEET

$L = 100 \frac{I}{D}$ or $L = \frac{I}{360} (\pi \cdot \text{Dia})$

$R = T/\tan \frac{I}{2}$

$LC = 2 \cdot R \sin \frac{I}{2}$

$D°a = \frac{5729.58}{R}$ or $\sin \frac{D°c}{2} = \frac{50}{R}$

$E = R\left(1/\cos \frac{I}{2}\right) - 1$

$M = R \cdot \left(1 - \cos \frac{I}{2}\right)$

XVI. **Steps for computing and laying out a simple horizontal curve** (Follow with Table 1 and Figures 20 and 21.)

A. Set the P.I.: Intersect the two tangent lines

B. Measure the plus station of the P.I. (Note Table 1, measure from station 7 + 00, 47.64 ft. = 7 + 47.64)

C. Measure I angle (also referred to as Δ or Delta.)

(NOTE: Angle X can be measured and Δ can be computed 180° – X = Δ.)

	180°00′00″		
	– 105°13′24″	=	X angle
Δ angle =	74°46′36″		(for this example)

D. Compute "T": T = R tan Δ/2

T = 229.27 ft.

E. Compute "L": L = Δ/360· (π Dia.) or 100· Δ/D° or use Table 1 below.

70°	=	1.22173	
4°	=	0.06981	
40′	=	0.01164	
6′	=	0.00174	
30″	=	0.00015	
6″	=	0.00003	
Sum	=	1.30510	

1.30510
× R = 300
391.53000

L = 391.53ft

INFORMATION SHEET

Table 1 — Length of Curve for Radius 1.00 ft

Given: [illegible]

[illegible]	Length	[illegible]	Length	[illegible]	Length
10°	0.17453	10′	0.00291	10″	0.00005
20°	0.34907	20′	0.00582	20″	0.0[illegible]
30°	0.52360	30′	0 00873	30″	0.0[illegible]
40°	0.69813	40′	0.01164	40″	0.00019
50°	0.87266	50′	0.01454	50″	0.00024
60°	1.04720	60′	0.01745	60″	0.00029
70°	1.22173	70′	0.02036	70″	0.00034
80°	1.39626	80′	0.02327	80″	0.00039
90°	1.57080	90′	0.02618	90″	0.00044
100°	1.74533	100′	0.02910	100″	0.00048

F. Compute the plus stations:

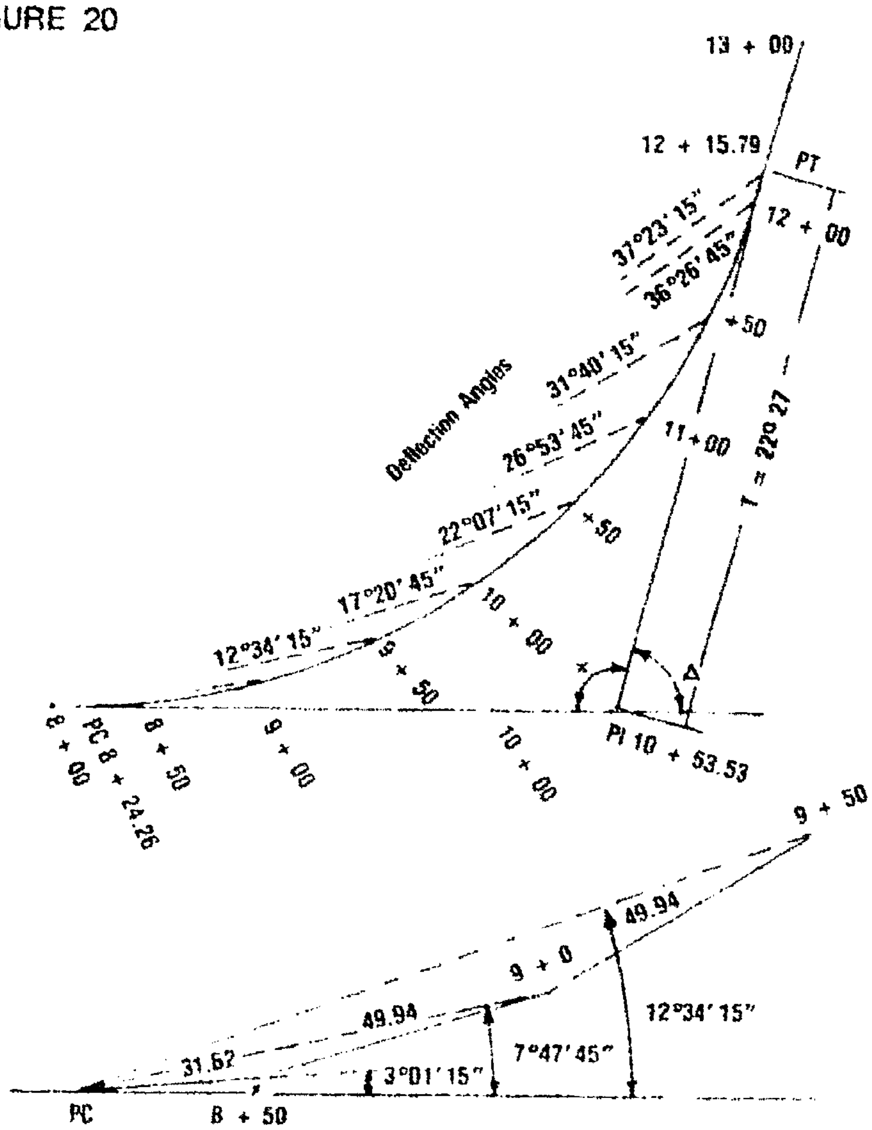
P.I. sta.	=	7 + 47.64
− "T"		− 229.27
P.C. sta.	=	5 + 18.37
+ "L"		+ 391.53
P.T. sta.	=	9 + 09.90

(NOTE: The P.T. station does not equal the P.I. station plus "T" [tangent distance].)

INFORMATION SHEET

G. Compute the deflection angles. (Figure 20)

FIGURE 20



1. First deflection angle:

Station	5 + 50	
P.C. station	5 + 18.37	
Length 1st arc =		31.63

Apply the formula

$$\frac{\text{Arc length}}{\text{radius}} \times 1718.87 = \text{Def. angle in minutes}$$

(NOTE: 1718.87 is often rounded to 1719 except on long curves.)

$$\frac{31.63}{300} \times 1719 = 181.24 \text{ minutes}$$

$$\frac{181.24}{60} = 3°1.24' \text{ or } 3°01'15''$$

INFORMATION SHEET

FIGURE 21

Sta	Chord	Deflec	Curve Data	
+29.80 PT	9.9(	37°23'25"	R = 300L	
12 + 50	49.94	35°53'0"	Δ = 74°46'36"	
+50	49.94	31°46'30"	$\frac{\Delta}{2}$ = 37°23'18"	
11 + 0	49.94	26°20'00"	= 37°23.20'	
+50	49.94	21°33'30"		
+47.64 PI			T = 229.27	
10 + 0	49.94	16°47'00"		
			L = 391.53	
+50	49.94	12°00'30		
9 + 0	49.94	7°14'0"		
+24.26	31.62	2°27'30"		
+18.37 PC		0		
8 + 0				

2. 2nd deflection is equal to the 1st deflection plus the deflection which subtends the 50' arc length.

   thus: $\frac{50}{300} \times 1719 = 286.50$ minutes or 4°46'30"

   (NOTE: This value is added to each previous deflection angle to determine the next angle setting, until the last arc length is encountered.)

3. Last deflection angle:

P.T. sta.	9 + 09.90
Last even sta.	− 9 + 00.00
Last arc length:	09.90

   $\frac{9.90}{300} \times 1719 = 56.73$ minutes or 0°56'44"

   This amount 56'44" is added to the previous total deflection angle to set the last point or P.T.

   (NOTE: A mathematic check of work is that the last deflection should equal $\Delta/2$.)

H. Compute the chord lengths:

1. First chord = Sin of the 1st deflection angle × dia.

   Sin of 3°01'15 (or .052699) × 600 = 31.62 ft.

2. Intermediate chord = Sin of the angle for a 50' arc × dia.

   Sin of 4°46'30" (or .083243) × 600 = 49.94 ft.

INFORMATION SHEET

3. Last chord = sin of the last angle to the P.T. × dia.

   Sin of 0°56′44″ (or .016502) × 600 = 9.90 ft.

   (NOTE: Long chords are sometimes calculated which involve taping distances from the P.C. station directly to each point on the curve. If this is to be performed, the same formula applies but the total deflection angle is used in place of for example, the angle for a 50′ arc. Short chords are frequently used unless an E.D.M. is accessible to measure the long chord distances, due to long taping distances.)

XVII. **Vertical curves**

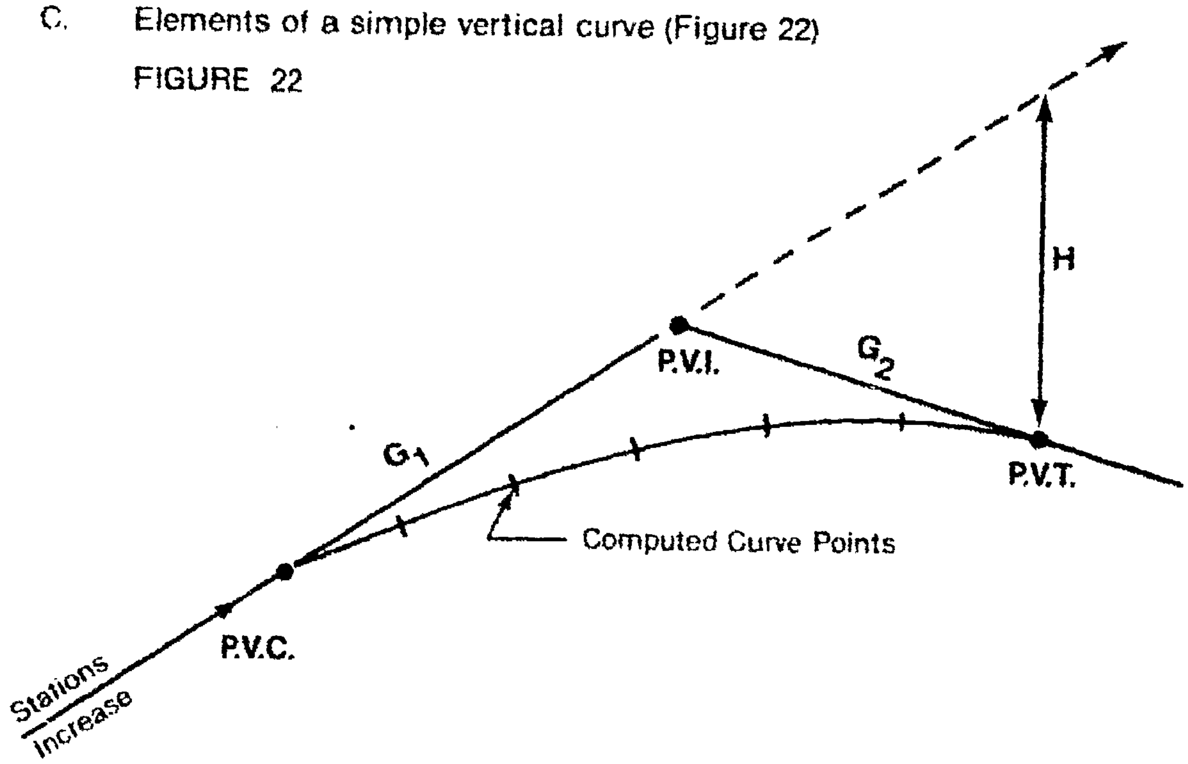
A. Are used in highway and street vertical alignment to provide a gradual change between two adjacent grade lines.

B. Two general types

1. Crests — Changing from a positive gradient to a negative
2. Sags — Changing from a negative gradient to a positive

C. Elements of a simple vertical curve (Figure 22)

FIGURE 22



P.V.C. = Point of vertical curvature
P.V.I. = Point of vertical intersection
P.V.T. = Point of vertical tangent
G_1 = Gradient or slope of back tangent
G_2 = Gradient or slope of fore tangent
H = Vertical distance from back tangent extended to the P.V.T.

INFORMATION SHEET

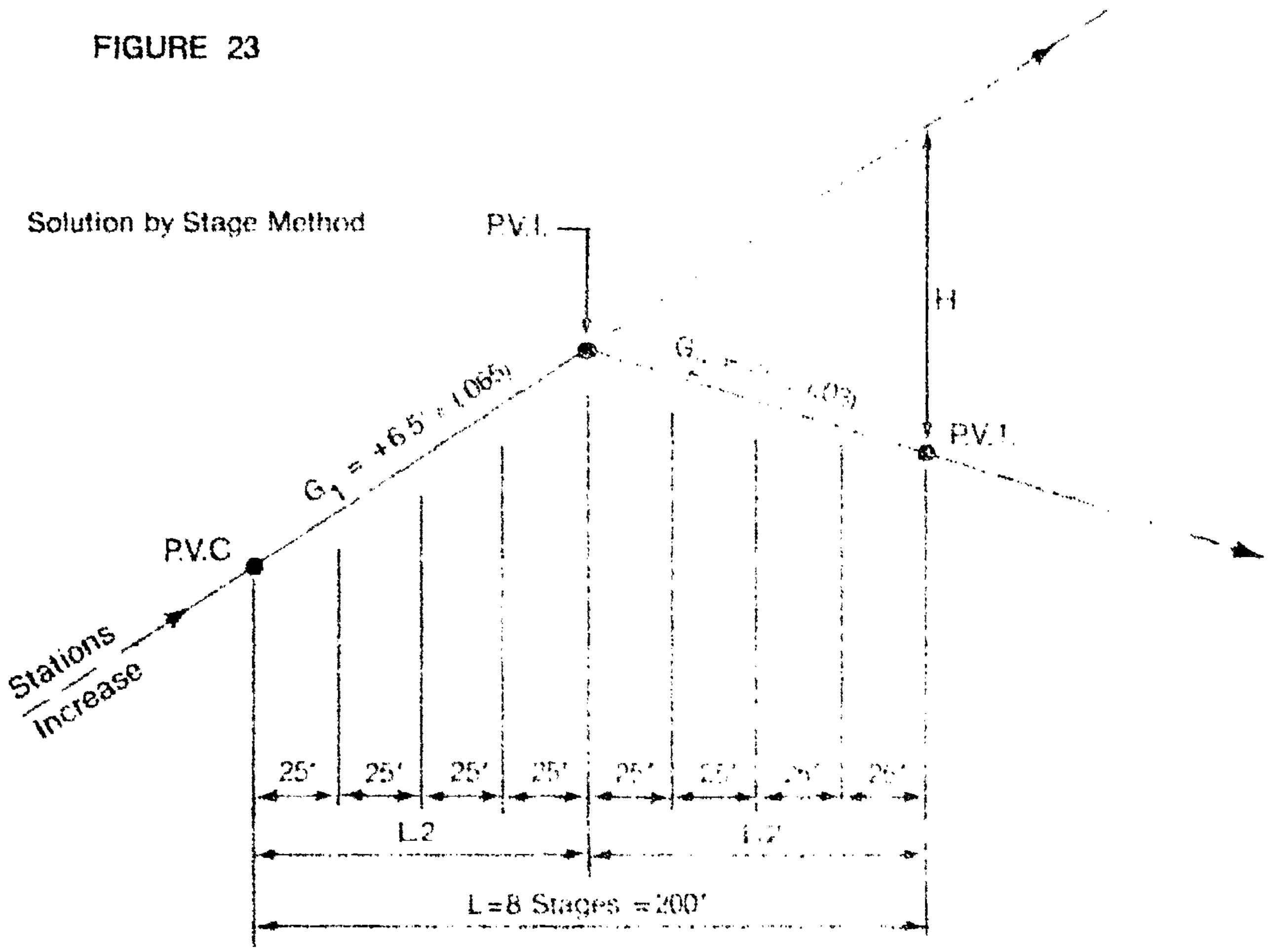
XVIII. Procedure for calculating a vertical curve (equal tangents)

(NOTE: The method used here is the stage method which is a common method of computation. It is easiest to understand when working with an example problem. The known curve data is listed below.)

...Known curve data...

L = 200' (8 stages)
G_1 = + 6.5% (+.065)
G_2 = - 3% (-.03)
P.V.I. = Sta. 14 + 19
P.V.I. = Elev. 1229.41

FIGURE 23



A. Find P.V.C. and P.V.T. stations and elevations

1. P.V.C. sta. formula: P.V.I. sta. − L/2 = P.V.C. sta.

   Example: 14 + 19 − 200/2 = **13 + 19 • P.V.C. sta.**

2. P.V.C. elev. formula: L/2 × G (with sign changed) = Elev. diff.
   Elev. diff. + P.V.I. elev. = P.V.C. elev.

   Example: 200/2 × −.065 = −6.5'

   −6.5' + 1229.41 = **1222.91 • P.V.C. elev.**

INFORMATION SHEET

3. P.V.T. sta. formula: P.V.I. sta. + L/2

   Example: 14 + 19 + 100 = **15 + 19** ← **P.V.T. sta.**

4. P.V.T. elev. formula: L/2 × G_2 = Elev. diff.
   Elev. diff. + P.V.I. elev. = P.V.T. elev.

   Example: 200/2 × −.03 = −3'
   −3' + 1229.41 = **1226.41** ← **P.V.T. elev.**

B. Compute H Formula: G_2 - G_1 × L/2 = H

Example: −.03 − .065 = −.095 × 100 = −9.5' ← "H"

C. Compute C Formula: $\left(\frac{S.L.}{L}\right)^2 \times H = C$

Where: S.L. = Stage length
L = Curve length

$\left(\frac{25}{200}\right)^2 \times -9.5 = -.1484375$ ← "C"

D. Compute "C" for each stage Formula: C × X^2 = Each stage correction

(NOTE: See Table 2.)

TABLE 2

STATION	X	X²	C = −.1484375	TANGENT ELEVATION	CURVE ELEVATION
PVC 13+19	0	0	0	1222.91	1222.91
13 + 44	1	1	−0.15	1224.54	1224.39
13 + 69	2	4	−0.59	1226.16	1225.57
13 + 94	3	9	- 1.34	1227.79	1226.45
PVI 14+19	4	16	−2.38	1229.41	1227.03
14 + 44	5	25	−3.71	1231.04	1227.33
14 + 69	6	36	−5.34	1232.66	1227.32
14 + 94	7	49	−7.27	1234.29	1227.02
PVT 15+19	8	64	−9.50	1235.91	1226.41

E. Compute tangent elevation Formula: G_1 × A (Table 2)

F. Compute curve elevation Formula: Tangent elevation + "C" (Table 2)

G. Compute high or low point

(NOTE: High points are often calculated to find the exact station of the crest of the curve. Low points are often calculated to find the lowest point on the curve for location of drainage structures, etc.)

1. Find "A" A = dist. from P.V.C.

   A = G_1 × (L/G_1-G_2)
   A = .065 × 200/.095 = 136.84'
   A = 136.84 ← Dist. from P.V.C. (13 + 19 + 136.84, Sta. 14 + 55.84)

INFORMATION SHEET

2. Find "C"

   $C = (A/L)^2 \times H$

   $C = (136.84/200)^2 \times -9.5'$

   $C = -4.45 \leftarrow$ Elev. diff.

3. Find tangent elev. = $G_1 \times A$ = T.E. + P.V.C.

   $.065 \times 136.84 = 8.89 + 1222.91 = 1231.80$

4. Find curve elev. = Tangent elev. + "C"

   $1231.80 + -4.45 = 1227.35 \leftarrow$ Elev. high pt.

5. High pt.: sta. 14 + 55.84 Elev.: 1227.35

   (NOTE: All calculated data should be tabulated as shown in Table 2. Field note entries will vary from surveyor to surveyor, but any convenient method is acceptable.)

Procedure for Setting Profile Line and Grade Stakes

BLIP ST. GRDS. FOR N. CURB

Sta	+	HI	−	Rod	Elev
BM#5	6.28	64.53			58.25
TP#1	0.27	57.54	7.26		57.27
0+0				3.35	54.19
1+0				4.42	53.12
TP#2	2.66	50.78	9.42		48.12
2+0				9.75	41.03
BM#6			7.17		43.61
	9.21		23.85		

Sneak X
Clark I
Martin

Clear
71°F
10-1-84

May and Pine Sta. "X" in Curb

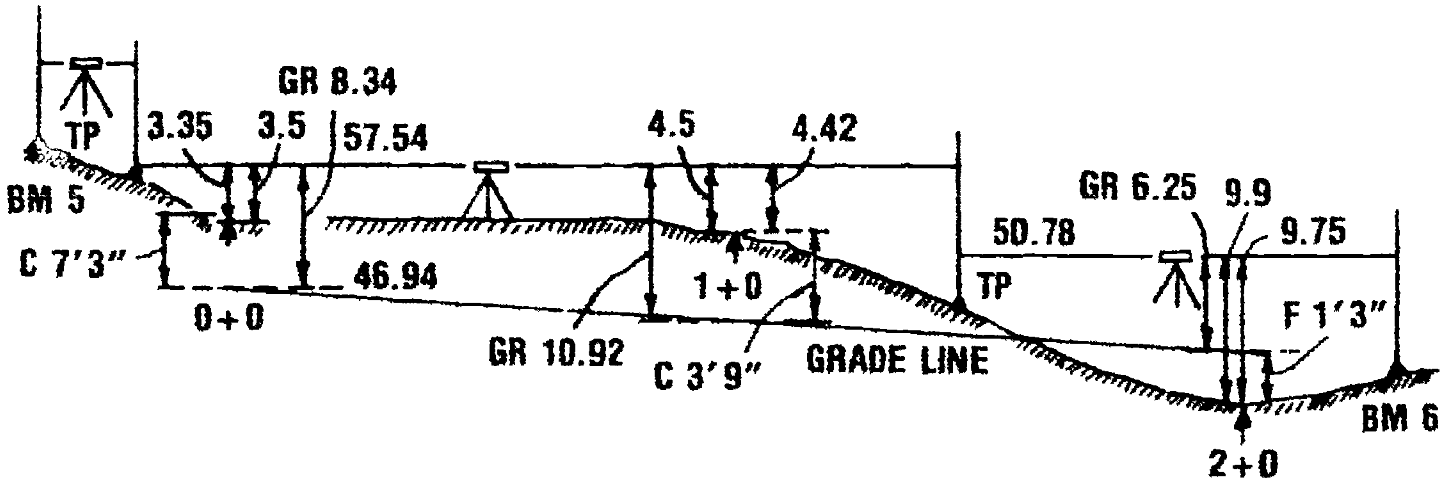
C 7'3" — 57.54 HI − 46.94 Gd = 10.60 Gd Rod

C 3'9" — 57.54 − 44.36 = 13.18

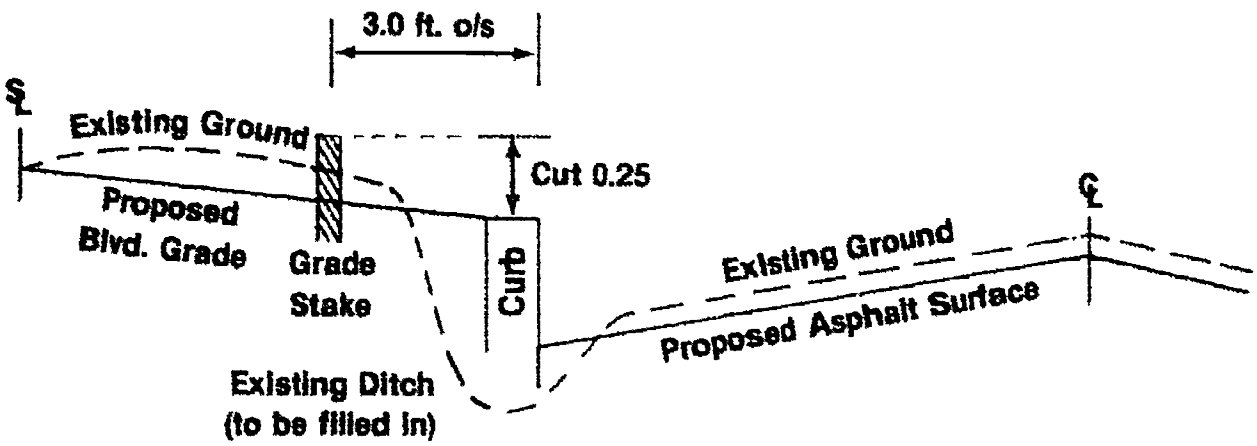
F 1'3" — 50.78 − 42.27 = 8.51

Gnd 3.5, 4.5, 9.9

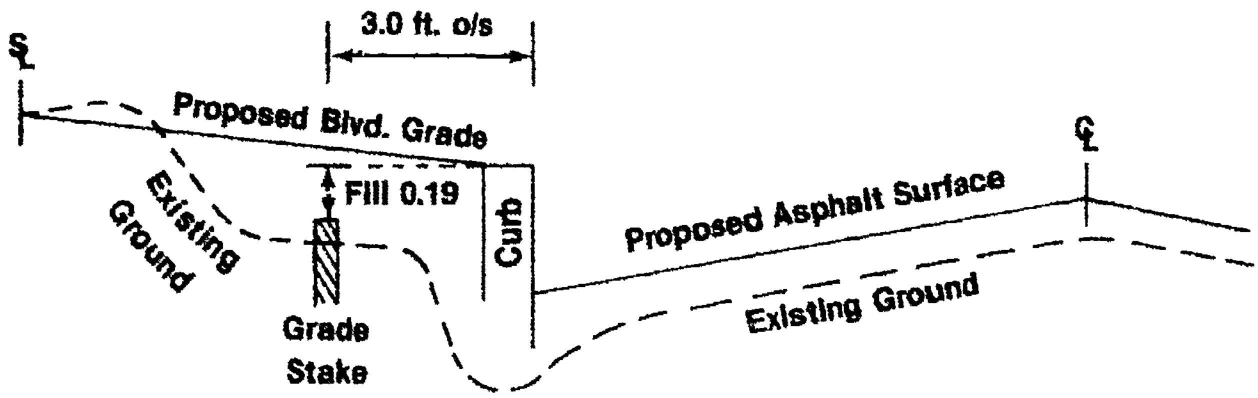
Check
9.21
−23.85
− 14.64
58.25
43.61



Typical Cut and Fill Stakes



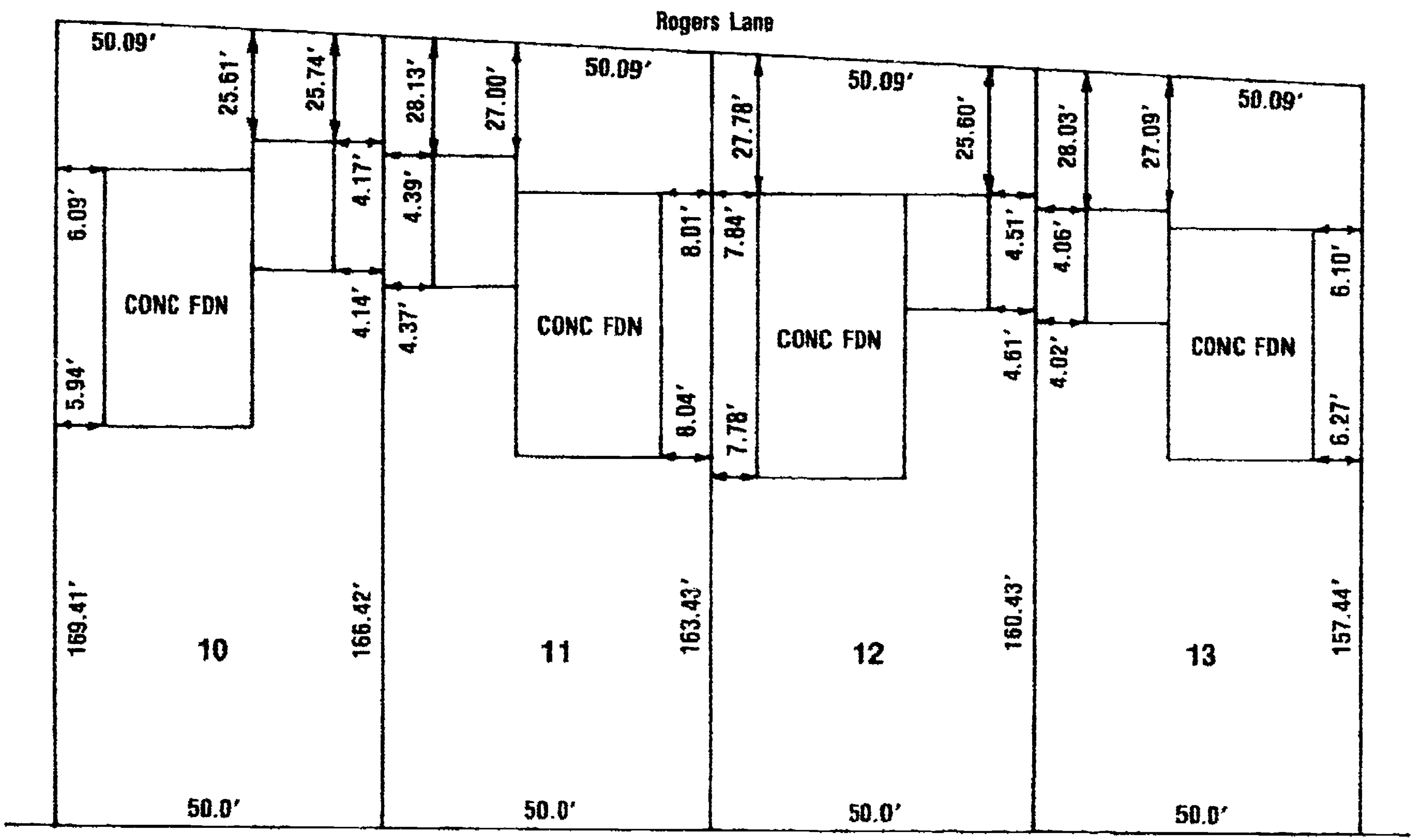
Cut Cross Section



Fill Cross Section

Typical Building Layout

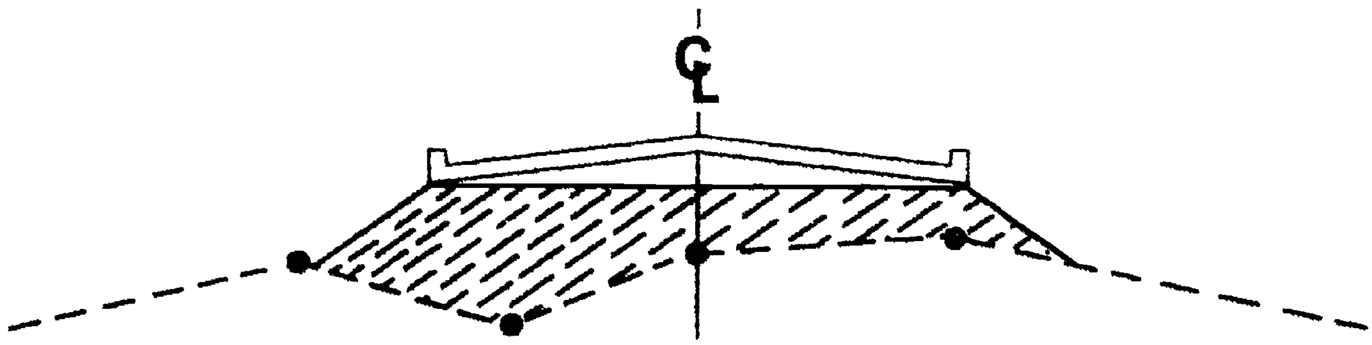
Plan of Survey of
Block 1 Lots 10 to 13 Bob's Addition 1st Section
to City of Chambers, Payne Co.



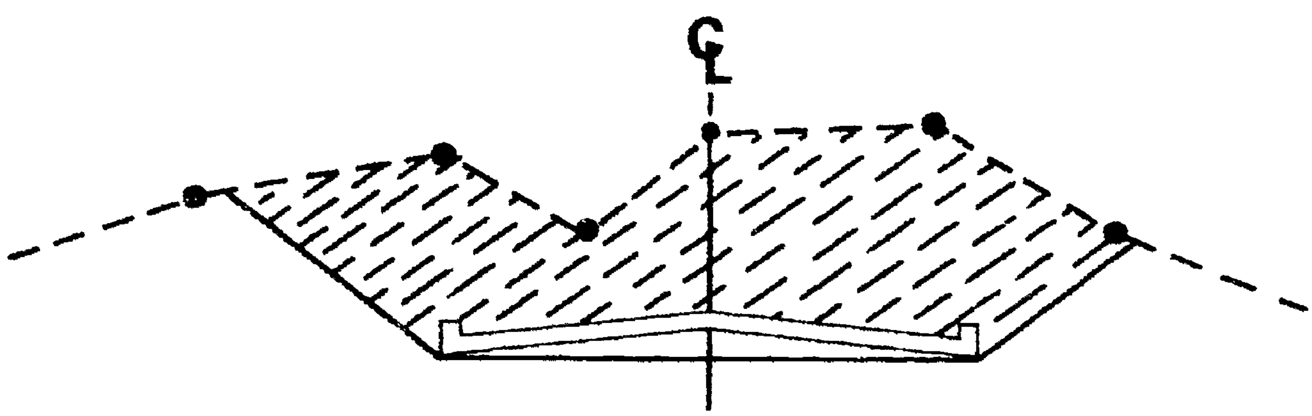
TM 3

S-457

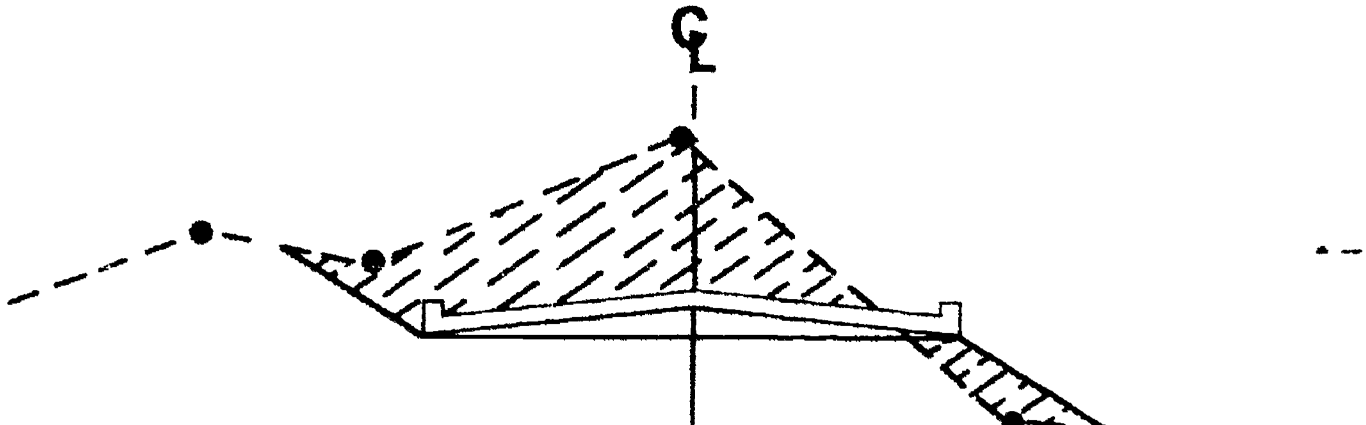
Typical Roadway Sections



Fill Section

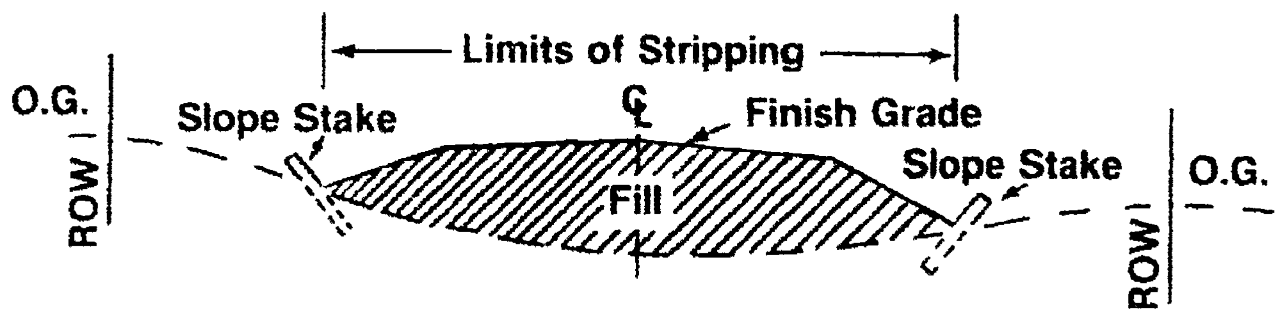


Cut Section

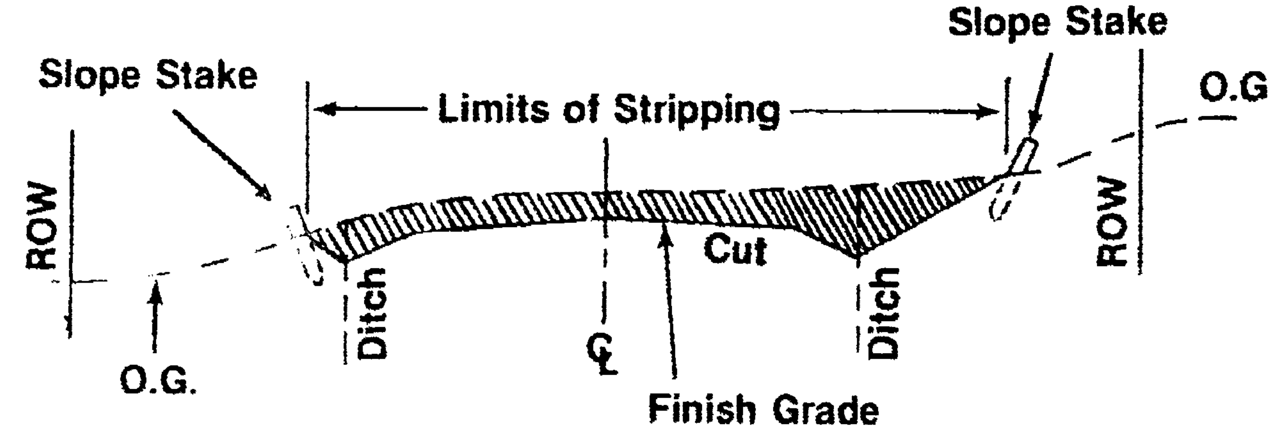


Transition (Mixed) Section

Slope Stake Locations



Fill Section



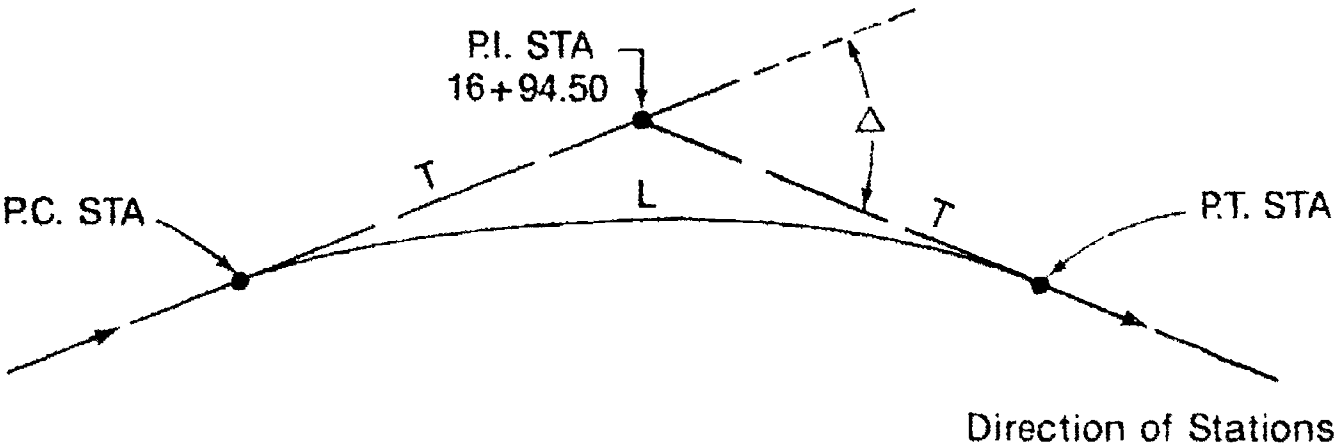
Cut Section

CONSTRUCTION SURVEYING
UNIT IX

ASSIGNMENT SHEET #1 — CALCULATE A SIMPLE HORIZONTAL CURVE

PART I

Directions: Apply each formula below to obtain each of the items listed. Record your answers in the blanks provided.



Given: P.I. sta.: 16 + 94.50
"Δ" angle: 43°24′20″
Radius: 550.00

	— FIND —	— FORMULA —
A.	Δ/2 = ______	Step No. 1 — ("Δ" angle ÷ 2)
B.	"T" = ______	Step No. 2 — (R · tan Δ/2)
C.	"L" = ______	Step No. 3 — (Δ/360° · (π · D)
D.	P.C. sta. = ______	Step No. 4 — (P.I. sta. – "T")
E.	P.T. sta. = ______	Step No. 5 — (P.C. sta. + "L")
F.	1st def. angle = ______	Step No. 6 — (L of Arc/R × 1718.87)
G.	25° def. angle = ______	Step No. 7 — (Arc 25/R × 1718.87)
H.	Last def. angle = ______	Step No. 8 — (L of Arc/R × 1718.87)
I.	Chord length of 25′ arc = ______	Step No. 9 — (Sin of 25′ def × dia.)
J.	Long chord = ______	Step No. 10 — (Sin Δ/2 × dia.)

ASSIGNMENT SHEET #1

PART II

Directions: Calculate each deflection angle, long chord, and short chord for each 25' curve station and place in the field book form below.

STA.	S.C.	L.C.	DEFLECTION ANGLE				CURVE DATA...
							Δ =
							R =
							T =
							L =
							L.C. =
							D° =
							P.C. =
							P.I. =
							P.T. =

CONSTRUCTION SURVEYING
UNIT IX

ASSIGNMENT SHEET #2 — CALCULATE A SIMPLE VERTICAL CURVE

PART I

Direction: Complete all of the required computations prior to computing curve elevations. Record your answers in the blanks provided.

— Known curve data —
Sta. 0 + 00: Elevation 1446.20
Sta. 12 + 50: Elevation 1421.20 (P.V.I. station)
Sta. 20 + 00: Elevation 1428.70
Curve length: 200.0 feet
Stage length: 25.0 feet

A. Compute: G_1 ______________________

G_2 ______________________

NOTE: Formula $\dfrac{\text{Vertical difference}}{\text{Horizontal distance}} = \%\ \text{slope}$

B. Compute station and elevation of P.V.C. and P.V.T.

P.V.C. sta. __________ elev. __________

P.V.T. sta. __________ elev. __________

C. Compute "H": __________

NOTE: Formula $H = G_2 - G_1 \times \dfrac{L}{2}$

D. Compute "C": __________

NOTE: Formula (Stage length/Curve length)^2 × "H"

ASSIGNMENT SHEET #2

PART II

Directions: Complete the following curve data:

Station	X	X^2	C =	Tang. Elev	Curve Elev.
P.V.C. Sta.					
P.V.I. Sta					
P.V.T. Sta.					

E. Compute low point

1. Station ____________________

NOTE: Find "A" A = Dist. from P.V.C.
A = G × (L/G - G)
P.V.C. + A = Station of low pt

2. Elevation of low pt.: ____________________

NOTE: Find "C": $(x/L)^2 \times H$.

Then find tangent elevation: (G × A) + P.V.C elevation

Then find curve elevation: Tangent elevation + "C"

CONSTRUCTION SURVEYING
UNIT IX

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

PART I

A. 21°42′10″
B. 218.902′
C. 416.663′
D. 14 + 75.60
E. 18 + 92.26
F. 1°16′15″
G. 1°18′08″
H. 0°53′57″
I. 24.999
J. 406.771′

PART II

STA.	S.C.	L.C.	DEFLECTION ANGLE		
14 + 75.6					
15 + 00	24.40	24.40	1°	16′	16″
+ 25	25.0	49.39	2°	34′	24″
+ 50	25.0	74.35	3°	52′	31″
+ 75	25.0	99.27	5°	10′	39″
16 + 00	25.0	124.14	6°	28′	47″
+ 25	25.0	148.94	7°	46′	55″
+ 50	25.0	173.67	9°	5′	3″
+ 75	25.0	198.31	10°	23′	11″
17 + 00	25.0	222.85	11°	41′	18″
+ 25	25.0	247.27	12°	59′	26″
+ 50	25.0	271.57	14°	17′	34″
+ 75	25.0	295.72	15°	35′	42″
18 + 00	25.0	319.72	16°	53′	50″
+ 25	25.0	343.56	18°	11′	58″
+ 50	25.0	367.22	19°	30′	6″
+ 75	25.0	390.68	20°	48′	13″
+ 92.26	17.26	406.77	21°	42′	10″

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #2

PART I

A -2% (-.0200)
   +1% (+.0100)

B Sta 11 + 50 1423.20

   Sta 13 + 50 1422.20

C. 3'

D .0469

PART II

Station	X	X	C = +.0469	Tang. Elev.	Curve Elev.
P.V.C. sta.	0	0	0	1423.20	1423.20
11 + 75	1	1	.05	1422.70	1422.75
12 + 00	2	4	.19	1422.20	1422.39
12 + 25	3	9	.42	1421.70	1422.22
P.V.I. sta.	4	16	.75	1421.20	1421.95
12 + 75	5	25	1.17	1420.70	1421.87
13 + 00	6	36	1.69	1420.20	1421.89
13 + 25	7	49	2.30	1419.70	1422.00
P.V.T. sta.	8	64	3.0	1419.20	1422.20

E. 1. 12 + 83.33

   2. 1421.87

CONSTRUCTION SURVEYING
UNIT IX

JOB SHEET #1 — STAKE A HORIZONTAL CURVE

A. Tools and equipment

1. Transit or theodolite
2. Tripod
3. Chain
4. Chaining pins
5. Wood s..kes
6. Range pole
7. Hammer
8. Field book and pencil

B. Procedure

(NOTE: Use the data obtained in Assignment Sheet #1, Part II.)

PART I: Layout the tangent lines using the given delta angle of 43°24'20" and an assumed point called: P.I. station 16+94.50.

1. Locate a stake in the middle of an open area, approximately 500 ft. by 500 ft. (called P.I. sta. 16+94.50).
2. Set the transit or theodolite up over the P.I.
   a. Level up the instrument.
   b. Zero up the vernier or horizontal circle.
3. Rod person should set a stake near a far corner of the work area. Refer to this as the "Back Tangent Line" (decreasing stations).
4. Instrument person should sight this point with the transit scope inverted and lock the instrument on line.
5. The rod person and another chain person should then tape the "T" distance (that was calculated on Assignment Sheet #1, Part I) from the P.I. away ..om and along the back tangent line using the instrument person for alignment.

JOB SHEET #1

6. Upon reaching the appropriate distance, a stake should be placed in the ground. Refer to this as the P.C. station.

7. The telescope should then be plumbed or reinverted and the delta angle of 43°24'20" turned (preferably right or clockwise in this example).

8. The tape person and rod person should then proceed along this line taping the "T" distance again and placing another stake at this distance. Refer to this as the P.T. station.

   (NOTE: Upon finishing this sequence, all of the three horizontal curve points have been accurately set: the P.C. station, P.I. station, and P.T. station.)

PART II — Stake each horizontal 25' station along the curve line.

1. Relocate the transit or theodolite at the P.C. station.

   a. Level up the instrument.

   b. Zero up the vernier or circle.

2. With the upper motion locked at 0°00'00" sight the P.I. station and lock the lower motion.

3. Referring to Assignment Sheet #1, Part II, begin by laying out the first station on the curve: Sta. 15+00.

   a. Set the vernier to the deflection angle of Sta. 15+00 (as noted in the field notes in Part II) by loosening the upper motion of the instrument and slowing rotating the instrument clockwise.

   b. Lock the upper motion and sight through the telescope to give the tape person alignment.

   c. Measuring from the P.C. station to the first station (15+00) on the curve, layout the short chord distance (as indicated on the field note form in Assignment Sheet #1, Part II), and set a stake at this point (Sta. 15+00).

      (NOTE: Make sure to set the point on line with the transit.)

4. Locate t [illegible] n on the curve (15+25).

   a. Loosen the upper motion of the instrument.

   b. Turn clockwise to the next deflection angle for Sta. 15+25.

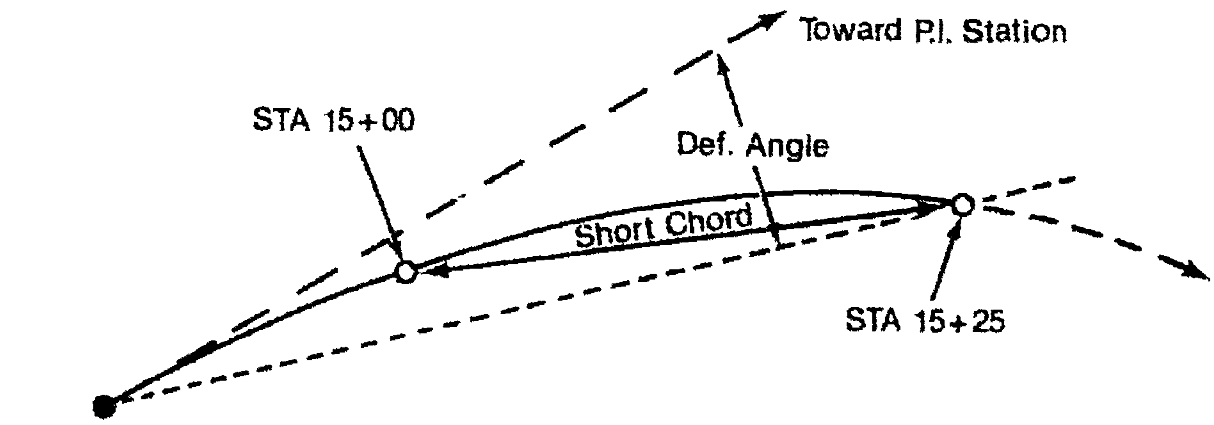
   c. Lock upper motion and give line for taping procedure.

JOB SHEET #1

d. Tape the short chord distance for a 25' deflection angle, measuring from the previously set Sta. 15+00 to the desired point (Sta. 15+25). (Figure 1)

(NOTE: Verify alignment prior to setting stake, then check distance again.)

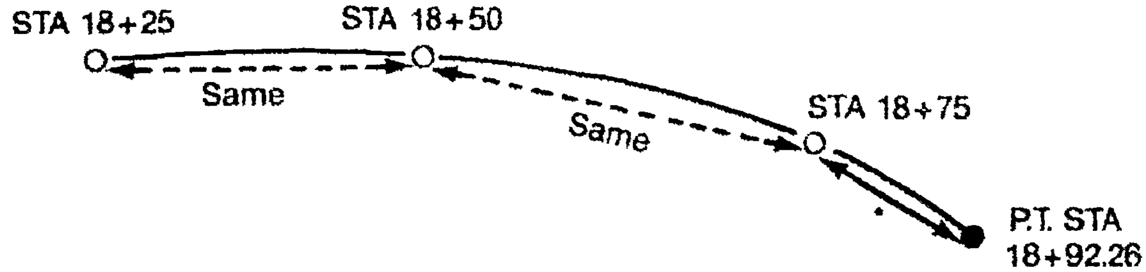
FIGURE 1



5. Locate each point on the curve by repeating step 4 and setting the correct deflection angle into the instrument for the appropriate station.

6. The short chord distance remains the same for each station until reaching the P.T. station. (Figure 2)

FIGURE 2



*Short chord for last deflection

7. After reading the P.T. sta., a check can be made:

   a. The angle in the instrument should be equal to ½ of Delta or Δ.

   b. The distance from P.C. sta. to P.T. sta. (straight line) can be measured and should equal distance L.C.

JOB SHEET #1

8. Have instructor verify the completed work.

9. Pick up all equipment and store in assigned areas.

10. Remove all existing stakes.

CONSTRUCTION SURVEYING
UNIT IX

JOB SHEET #2 — STAKE A CENTERLINE PROFILE WITH A VERTICAL CURVE

A. Tools and equipment

1. Transit/theodolite
2. Tripod
3. Wooden stakes and hammer
4. Chain or tape and chaining pins
5. Range poles
6. Level
7. Level rod
8. Field book and pencil
9. Calculator

B. Procedure

PART I — Establish a baseline

1. Within a narrow strip of land (100' × 500') set up a transit over a point at one end of the site. Refer to as Sta. 0+00.
2. Sight along an arbitrary line and lock motions of the transit to layout a baseline.
3. Begin setting 25' stations from 0+00 using the instrument for alignment and placing stakes at each 25' interval for approximately 400 ft.

PART II — Establish existing centerline profile elevations

(NOTE: Instructor should provide an assumed bench mark elevation for the following procedure.)

1. Set up level near approx. Sta. 2+00, and establish an HI.

   (NOTE: A bench circuit may need to be run into the site depending on the location of the bench mark given.)

2. Read foresights and record in field book all rod shots along the baseline stakes (shooting the ground next to the stake at this time, and recording as shown):

JOB SHEET #2

FIGURE 1

	B.S.	H.I.	F.S.	R.S.	ELEV.
BM	x	H.I.			
0+00				R.S.	
+25				R.S.	
+50				R.S.	
+75				R.S.	
1+00				R.S.	
+25				R.S.	

3. Compute existing ground elevations at each station and record in the field book.

4. After all points have been calculated, check back into the bench mark.

   (NOTE: Prior to Part III, show your instructor the field notes for existing ground shots. Your instructor will give you the required information to compute the vertical curve.)

PART III — Compute 200′ vertical curve.

1. Using the known data: (given by instructor)

   Sta. 0+00: Elevation ____________ (design)
   P.V.I. sta. 2+00: Elevation ____________ (design)
   Sta. 4+00: Elevation ____________ (design)
   Curve length: 200.00 ft.
   Stage length: 25.00 ft.

   Compute: G_1: ____________
   G_2: ____________
   P.V.C. sta.: ____________ Elev. ____________
   P.V.T. sta.: ____________ Elev. ____________
   "H": ____________
   "C": ____________

   (NOTE: Using Assignment Sheet #2 calculate the above information. Set up a table similar to Part II, Assignment Sheet #2 and calculate each curve elevation.)

2. After completion, have instructor verify all calculations before performing Part IV.

JOB SHEET #2

PART IV — Determine stake elevations and calculate cuts or fills.

1. Set up level near approx. Sta. 2+00.

   a. Determine H.I. elevation.

   b. Record in field book.

2. Read and record each rod shot or (foresight) taken on top of each 25 station starting at Sta. 0+00 and progressing to Sta. 4+00.

   FIGURE 2

STA.	B.S.	H.I.	F.S.	R.S.	ELEV.	Design Elev.	C/F
BM	x	H.I.					
0+00				R.S.			
+25				R.S.			
+50				R.S.			
+75				R.S.			
1+00				R.S.			
+25				R.S.			

3. Check back into the bench mark and calculate each stake elevation by subtracting the rod shot from the H.I. Record in the appropriate column.

4. Use the following formula to determine each cut or fill for every station beginning at Sta. 0+00 and ending at Station 4+00.

   Design Elevation
   – Stake Elevation
   Cut or Fill

5. Record this information in the far right-hand column of the field notes. (See Figure 2)

6. Instructor will evaluate work performed.

   (NOTE: Instructor may want the students to actually mark the cut or fill on each stake although it is not necessary in this job sheet.)

CONSTRUCTION SURVEYING
UNIT IX

JOB SHEET #3 — STAKE A SEWER PROFILE WITH OFFSET

A. Tools and equipment

1. Tape
2. Wooden stakes and hammer
3. Level rod
4. Tripod
5. Level instrument
6. Field book and pencil

B. Procedure

(NOTE: Use the baseline previously established in Job Sheet #2 as an assumed center line of a proposed sewer line.)

PART I

1. Establish a 20′ offset line.
   a. Measure 20′ right from existing stake at Sta. 0+00.
   b. Place stake in ground 20′ right at 90 degrees from existing baseline.
   c. Repeat this operation at each of the existing stakes through Sta. 4+00.
2. Using the previous bench mark, set up the level instrument and establish a new H.I.
3. Read and record each rod shot (foresight) at every 25′ station along the 20′ offset line (shooting the top of the stake).
4. Reduce field notes and record each stake elevation.
5. Have instructor evaluate.

JOB SHEET #3

PART II — Determine sewer profile elevations.

1. Instructor should determine a hypothetical percent of slope for the proposed sewer line and an invert elevation of the sewer line starting at Sta. 0+00.

   Known: Sewer line percent of slope:__________%
   Invert elevation at Sta. 0+00:__________

2. Using the known data calculate each proposed sewer elevation for every 25 foot station.

   Formula: Station × % = V.D.
   then
   V.D. + Beginning Elev. = Sewer elevation at that station

Sta.	Elevation		Sta.	Elevation
0+00	__________	(given)	2+00	__________
+25	__________		+25	__________
+50	__________		+50	__________
+75	__________		+75	__________
1+00	__________		3+00	__________
+25	__________		+25	__________
+50	__________		+50	__________
+75	__________		+75	__________
			4+00	__________

3. Instructor should verify proposed elevation at each station before performing Part III.

JOB SHEET #3

PART III — Compute cuts to sewer profile.

1. Insert known data in the following table.

Station	Stake Elev.	Design Elev.	Cuts
0+00			
+25			
+50			
+75			
1+00			
+25			
+50			
+75			
2+00			
+25			
+50			
+75			
3+00			
+25			
+50			
+75			
4+00			

2. Calculate the cut at each stake using the following formula:

   Design Elevation
   – Stake Elevation
   ____
   Cut (to sewer profile)

3. Record this information in the column labeled "Cuts"

4. Instructor may or may not request that you actually mark the stakes with the calculated data.

CONSTRUCTION SURVEYING
UNIT IX

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. A stake set by a surveyor to give contractors a known elevation to base their construction on, usually noted with a cut or a fill

_____b. The decimal form of a percent of a slope; indicates the steepness of a sloped surface

_____c. The process of laying out all types of facilities on proposed engineered sites prior to construction by giving alignment and grade to aid the contractor during installation

_____d. The calculated rod reading that is des red if the rod was placed on design grade

_____e. The inclination of a surface expressed as one unit of rise or fall for so many horizontal units

_____f. A vertical curve with tangent lengths that are the same, therefore making the curve symmetrical

_____g. Normally referring to the inside bottom of a pipe or culvert

_____h. The lowest visible surface; the bottom or floor of a manhole, drain, sewer, channel, tunnel, etc.

1. Construction surveying
2. Equal tangent curve
3. Flow line
4. Grade stakes
5. Grade rod reading
6. Gradient
7. Invert elevation
8. Slope ratio

2. State the purpose of construction surveys.

____

____

3. Select true statements concerning the responsibilities of a construction surveyor by placing an "X" next to the true statements.

a. Keeping notes

_____1) Should be extensive and detailed on every phase of construction.

_____2) Are seldom used when developing as-built drawings.

_____3) Are used to document field changes.

_____4) Cannot be used in court as documented evidence.

TEST

b. Keeping daily logs or diaries

_____1) Are used to briefly describe the daily progress.

_____2) Are often used for partial payment of work completed.

_____3) Are used to record all field changes or change orders.

_____4) Are used for final quantities and as-built drawings.

c. Communicating at the construction site

_____1) Instructions must be clear to all contractors about staking procedures, offset distances, and cut/fill markings.

_____2) The surveyor should not communicate with adjacent owners or the public about the construction going on.

4. State the purposes of horizontal and vertical control points.

a. ____

b. ____

5. Complete the following statements concerning laying out control points by correctly filling in the blanks.

a. Should be far enough from the actual construction to ensure working room for the __________ and freedom from possible destruction.

b. Should be clearly marked and understood by the contractor in the absence of a __________.

c. Should be supplemented by guard stakes to deter __________.

d. Should be "tied off" or located by __________ outside the actual construction area so that replacement, if necessary, can be performed without difficulty.

TEST

6. State the rule or formula for computation of grades and slopes.

7. Complete the following statements concerning offset stakes by circling the correct words.

   a. Normally located (**within, away from**) actual construction area.

   b. Offset distance may vary depending on (**width, depth**) of excavation.

   c. Usually designated with a cut or fill from (**top, bottom**) of offset stake.

   d. Are installed (**perpendicular, parallel**) to construction alignment.

   e. Design elevations are determined at (**every other, each**) offset stake.

   f. Actual offset stake elevations are determined by (**measuring, leveling**) procedures.

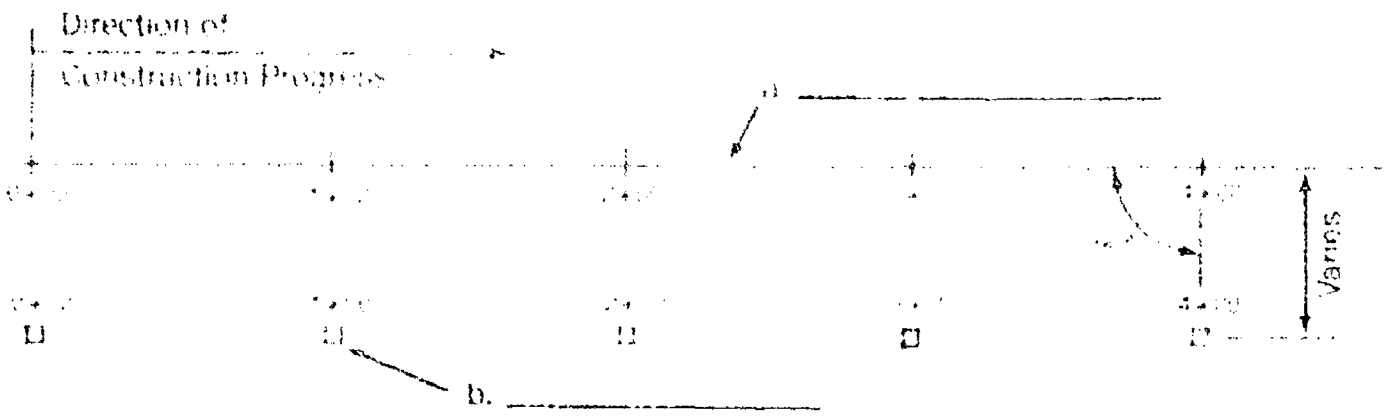
   g. Cuts or fills are calculated by the following relationship:

   $$\frac{\text{1) } (\textbf{Offset stake, Design}) \text{ elevation}}{\text{2) } (\textbf{Offset stake, Design}) \text{ elevation}} = \text{Cut or fill}$$

   h. Calculations are checked (**after, prior to**) marking stakes

TEST

8. Differentiate between a baseline and an offset stake by placing an "X" next to the arrow pointing to the baseline and an "O" next to the offset stake.



9. Match the types of stake markings on the right with their descriptions.

____ a.	Are stakes showing the vertical distance that must be added to the actual elevation to bring it to the proposed design elevation	1. Cuts
____ b.	Are construction stakes that are set to the actual design elevation of the construction item	2. Fills
____ c.	Are stakes showing the vertical distance that must be removed from the actual elevation to bring it to the proposed design elevation	3. Blue tops

10. Arrange in order the steps in laying out a building location by placing the correct sequence numbers (1-4) in the appropriate blanks.

____ a. Set the offset stakes perpendicular to each building corner at the required distance.

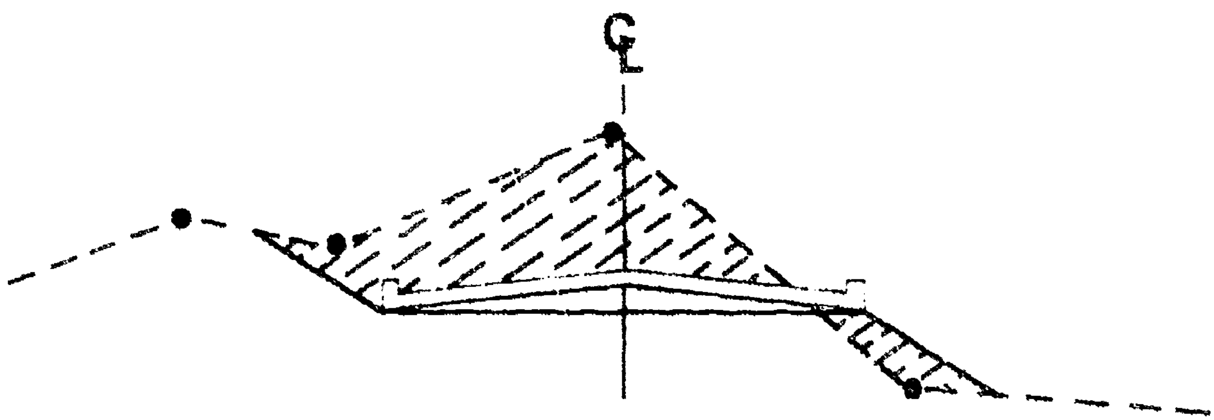
____ b. With a level determine the elevation of each offset stake, and reference the finish floor or top of foundation wall with either a cut or fill distance from the top of each stake.

____ c. Locate the building perimeter on the property following the approved layout plans.

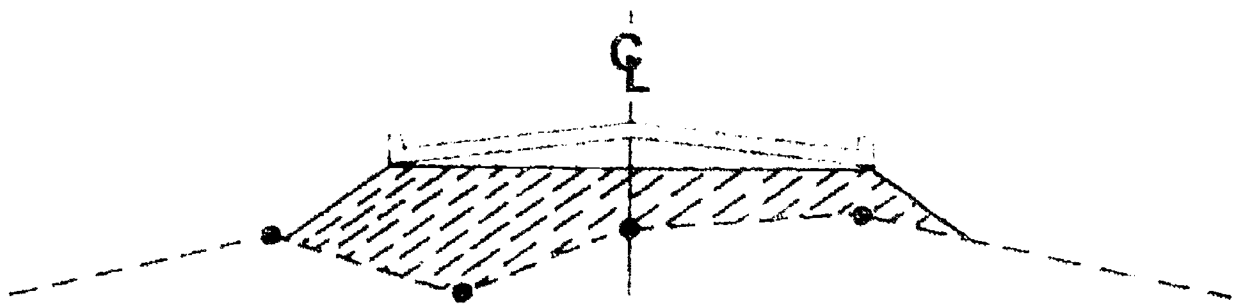
____ d. Lay out actual building corners on the site as a visual check on positioning.

TEST

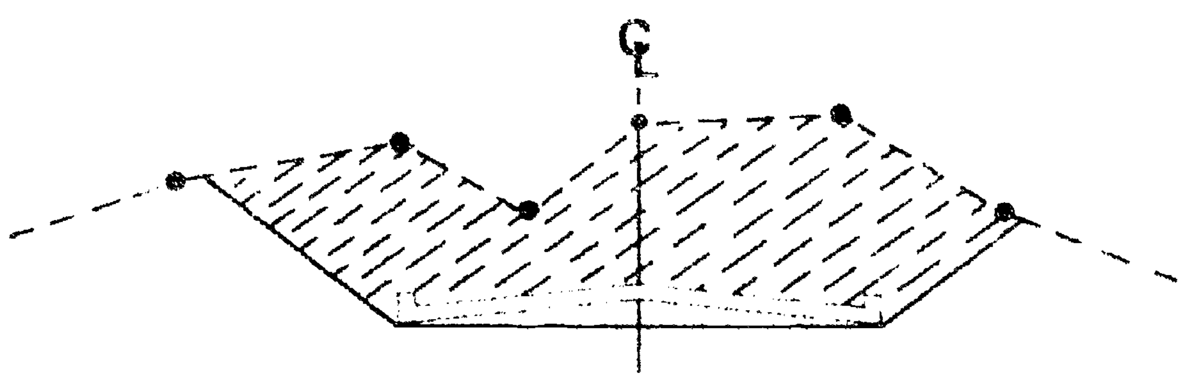
11. Identify the following typical roadway sections.



a. ____



b. ____



c. ____

TEST

12. Complete statements concerning slope staking by correctly filling in the blanks.

 a. Slope stakes are set to guide the contractor during ____________.

 b. Slope stakes are normally placed at the intersection of the ____________ and each side slope.

 c. The cut or fill at each location is marked on the ____________.

 d. Slope staking is normally used for the construction of (list two)

  1) ____

  2) ____

13. State the equations used in locating slope stakes.

 a. Depth of cut or height of fill = ______________________________

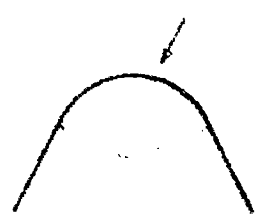
 ____

 b. Distance from centerline where the stake should be placed (x) = ____________

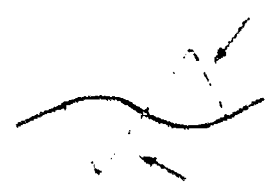
 ____

14. Distinguish between the types of horizontal curves by placing an "X" next to the circular curves and an "O" next to the spiral curves.

a. ____________



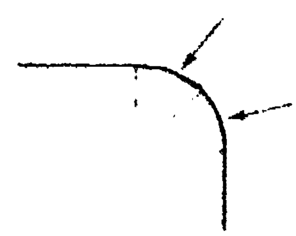
b. ____________



c. ____________

d. ____________

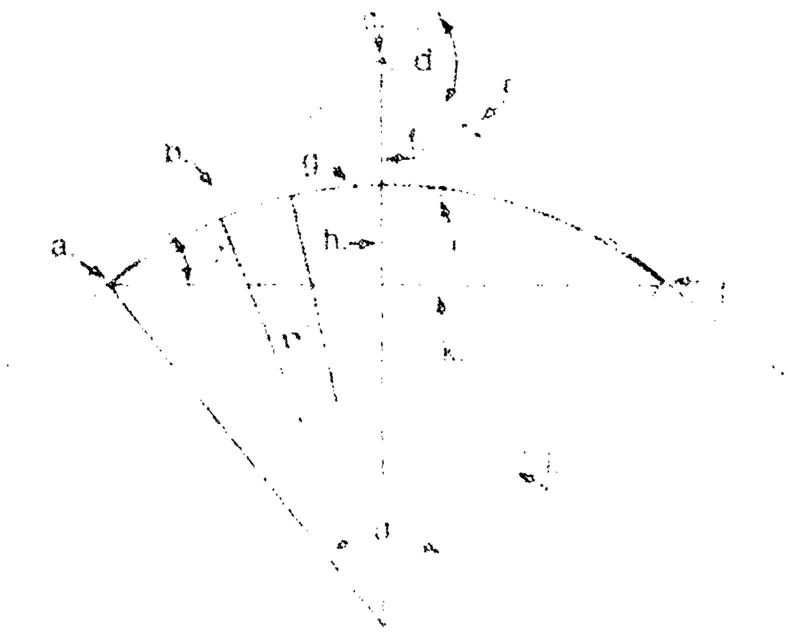
e. ____________



f. ____________

TEST

15. Identify the elements of a simple horizontal circular curve by matching the abbreviations of the elements listed at the right with the correct letters showing their locations on the schematic drawing below.



I or Δ = Angle "I" or Delta

R = Radius

PI = Point of intersection

PC = Point of curvature

PT = Point of tangent

T = Tangent distance

LC = Long chord

L = Length of curve

E = External distance

M = Middle ordinate

POC = Point on curve

POT = Point on tangent

_____ a. _____ g.

_____ b. _____ h.

_____ c. _____ i.

_____ d. _____ j.

_____ e. _____ k.

_____ f. _____ l.

TEST

16. Arrange in order the steps for computing and laying out a horizontal curve by placing the correct sequence numbers (1-8) in the appropriate blanks.

_____a. Measure the plus station of the PI

_____b. Compute "L"

_____c. Compute the chord lengths

_____d. Compute the plus stations

_____e. Measure I angle (Delta or Δ)

_____f. Set the PI

_____g. Compute the deflection angles

_____h. Compute "T"

17. Match the elements of a simple vertical curve listed on the right with their correct locations on the schematic drawing below by placing the corresponding numbers in the appropriate blanks.

_____a.

_____b.

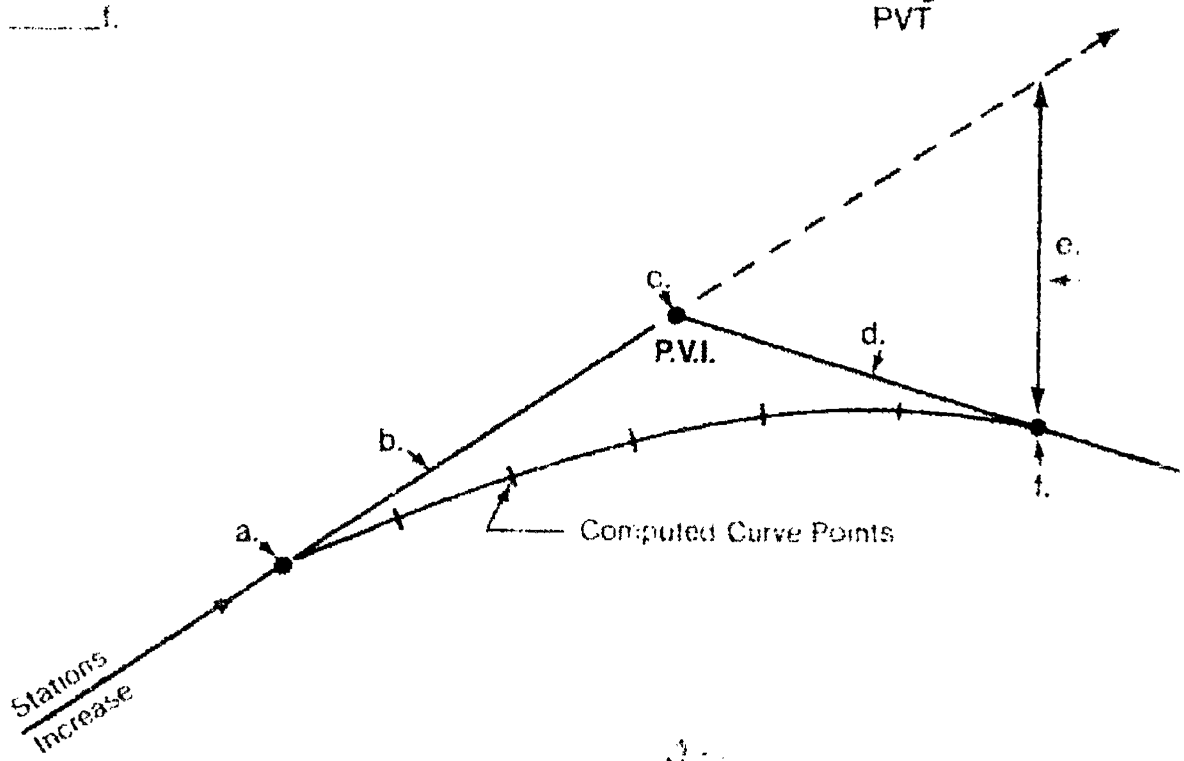
_____c.

_____d.

_____e.

_____f.

1. PVC = Point of vertical curvature
2. PVI = Point of vertical intersection
3. PVT = Point of vertical tangent
4. G_1 = Gradient or slope of back tangent
5. G_2 = Gradient or slope of fore tangent
6. H = Vertical distance from back tangent extended to the PVT



TEST

18. Arrange in order the steps for computing a vertical curve by placing the correct sequence numbers (1-7) in the appropriate blanks.

    _____a. Compute C

    _____b. Compute curve elevation

    _____c. Compute C for each stage

    _____d. Find PVC and PVT stations and elevations

    _____e. Compute H

    _____f. Compute high or low point

    _____g. Compute tangent elevation

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

19. Calculate a simple horizontal curve. (Assignment Sheet #1)

20. Calculate a simple vertical curve. (Assignment Sheet #2)

21. Demonstrate the ability to:

    a. Stake a horizontal curve. (Job Sheet #1)

    b. Stake a centerline profile with a vertical curve. (Job Sheet #2)

    c. Stake a sewer profile with offsets. (Job Sheet #3)

CONSTRUCTION SURVEYING
UNIT IX

ANSWERS TO TEST

1. a. 4 e. 8
   b. 6 f. 2
   c. 1 g. 3
   d. 5 h. 7

2. To provide the horizontal and vertical layout for every key component of a construction project.

3. a. 1,3
   b 2,3,4
   1

4. a. To serve as a good framework of control around the project area
   b. To act as a base for positioning structures, utilities, roads, etc.

5. a. Contractor
   b. Surveyor
   c. Accidental removal
   d. Tie points

6. a. Determine the total horizontal distance between the two points that the proposed grade must match.
   b. Determine the total vertical difference in elevation of the two points being matched.
   c. Apply the following formula to find the percent (%) of slope:

$$\frac{\text{Vertical difference}}{\text{Horizontal distance}} = \%\ \text{slope}$$

7. a. Away from
   b. Depth
   c. Top
   d. Parallel
   e. Each
   f. Leveling
   g. 1) Design
      2) Offset stake
   h. Prior to

8. a. X
   b. O

9. a. 2
   b. 3
   c. 1

ANSWERS TO TEST

10. a. 3
    b. 4
    c. 1
    d. 2

11. a. Transition or mixed
    b. Fill
    c. Cut

12. a. Construction
    b. Original ground
    c. Slope stake
    d. Any two of the following:
       1) Streets or highways
       2) Drainage ways or canals
       3) Dikes and embankments
       4) Bridge approachways
       5) Dams or reservoirs
       6) Berms along structures

13. a. Depth of cut or height of fill = Grade rod reading - ground rod reading
    b. Distance from centerline where the stake should be placed (X) = (Depth of cut × slope) + ½ base distance

14. a. O
    b. X
    c. X
    d. O
    e. X
    f. O

15. a. PC
    b. T
    c. PI
    d. I
    e. POT
    f. E
    g. L
    h. M
    i. POC
    j. PT
    k. LC
    l. R

16. a. 2
    b. 5
    c. 8
    d. 6
    e. 3
    f. 1
    g. 7
    h. 4

17. a. 1
    b. 4
    c. 2
    d. 5
    e. 6
    f. 3

ANSWERS TO TEST

18. a. 3
    b. 6
    c. 4
    d. 1
    e. 2
    f. 7
    g. 5

19.-20. Evaluated to the satisfaction of the instructor.

21. Performance skills evaluated to the satisfaction of the instructor.

LEGAL ASPECTS
UNIT X

UNIT OBJECTIVE

After completion of this unit, the student should be able to match the four common methods of legal land descriptions with the correct descriptions, properly write legal land descriptions, and research and record existing property records. Competencies will be demonstrated by correctly completing assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student shc · able to:

1. Match terms related to legal aspe. · ˈ the correct definitions.
2. State purposes of legal land surveys.
3. Complete statements concerning the two principles affecting laws on boundary positions.
4. Distinguish between the two types of laws regulating land surveying.
5. List methods of transferring property titles.
6. Select true statements concerning properly prepared deeds.
7. List types of information contained in land descriptions.
8. Match legal terms affecting property possession with the correct descriptions.
9. Match types of boundary evidence with the correct descriptions.
10. Select true statements concerning riparian rights.

OBJECTIVE SHEET

11. Distinguish between terms related to riparian rights and changes in water boundaries.
12. Complete statements concerning deed descriptions.
13. Match methods of legal land decriptions with the correct characteristics.
14. Write a metes and bounds description. (Assignment Sheet #1)
15. Plot or layout a legal land description. (Assignment Sheet #2)
16. Write a lot and block description. (Assignment Sheet #3)
17. Research and record existing property records. (Assignment Sheet #4)

LEGAL ASPECTS
UNIT X

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Integrate the following activities throughout the teaching of this unit:

1. Have a legal land surveyor visit the class and discuss procedures used to file a platted document.
2. Visit your local registrar of deeds office and follow the procedure used to research a parcel of land.
3. Visit a land title agency and examine their methods of filing registered plats.
4. Visit a possible legal land dispute case in court.
5. Discuss surveying problems in court.
6. Prepare court documents.
7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

H. Give test.

I. Evaluate test.

J. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1 — U.S. Public Land Survey System
2. TM 2 — Sample Subdivision of a Section
3. TM 3 — Lot and Block Description
4. TM 4 — Typical Metes and Bounds Description

D. Assignment sheets

1. Assignment Sheet #1 — Write a Metes and Bounds Description
2. Assignment Sheet #2 — Plot or Layout a Legal Land Description
3. Assignment Sheet #3 — Write a Lot and Block Description
4. Assignment Sheet #4 — Research and Record Existing Property Records

E. Answers to Assignment

F. Test

G. Answers to test

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C *Definitions of Surveying and Associated Terms.* American Congress on Surveying and Mapping and the American Society of Civil Engineers. 1978.

LEGAL ASPECTS
UNIT X

INFORMATION SHEET

I. **Terms and definitions**

A. Aliquot — A fractional part

B. Boundary — A surveyed line that indicates fixed ownership between properties; a separating line

C. Bearing — The direction of a straight line in respect to a compass, magnetic or true north

(NOTE: Sometimes a bearing may be in respect to another random line.)

D. Corner -- The point in which converging lines meet; the intersection of two boundary or property lines usually marked with a stone, iron bar, pipe, or brass disc or plug

E. Condemnation — The act of judicially or legally condemning ownership of a parcel of land; to acquire ownership or public use by eminent domain

F. Conveyance — The method of transferring ownership of property to another party

G. Deed — A signed and sealed document containing legal language that transfers ownership of property to another party

H. High water mark — A determined land marking that is used sometimes for ownership boundaries, often determined by vegetation or alkaline marks

I. Monument — An identifying marker, normally stone, that indicates ownership; generally used to mark a corner

J. Quit claim deed — A deed used to release one person's right, title, or interest to another without providing a guarantee or warranty of title

K. Senior deed — The deed for the first parcel to be sold off from a tract of land

L. Warranty deed — A deed authorizing that the grantor has a good title free and clear of any liens and encumbrances and will defend the grantee against any claims

II. **Purposes of legal land surveys**

A. To subdivide public lands into townships, sections, and lots

INFORMATION SHEET

B. To attain the necessary information for writing a legal description

C. To determine the exact area of a particular tract of land

D. To reestablish the boundaries of a parcel of land that has been previously surveyed and legally described

E. To subdivide a parcel of land into two or more smaller units

F. To establish the exact position of features such as buildings on a parcel with respect to the boundaries

III. Principles affecting laws on boundary positions

A. Intent

1. The position of boundaries is determined by the "intent" of the parties that establish the new boundary.

2. Their intent is judged by the evidence of their acts, their written instruments, and the circumstances involved.

B. Acceptance of present conditions

1. With the passage of time, evidence of the parties' intent becomes more difficult to secure. Therefore, rules have been developed to eliminate old evidence in favor of "present conditions."

2. The longer the period of acceptance of these conditions, the stronger the evidence becomes.

IV. Types of laws regulating land surveying

A. Common law

1. Is the greater proportion of law relating to land ownership

2. Is the body of rules and principles that have been accepted by continual usage

(NOTE: The written decisions in court down through the years have become clear and definite.)

B. Statutory law

1. Is composed of the body of law enacted by governing bodies, such as city, county, or state ordinances.

2. Many of these relate to land and acceptance of boundary locations.

INFORMATION SHEET

V. **Methods of transferring property titles**

A. Deeds

1. Grant

2. Quit claim

3. Agreement

4. Warranty

5. Senior

B. Inheritance through a will

C. Inheritance without a will

D. Adverse possession

VI. **Properly prepared deeds**

A. Will contain some sort of description of the boundaries of the land conveyed.

B. Must be tied directly or indirectly to physical marks on the ground or monuments and surrounding properties.

C. Is usually recorded in a county court house (register of deed) where it is open to public inspection.

VII. **Information contained in land descriptions**

A. Point Of Beginning (P.O.B.) — Must be permanent, identifiable, and well-referenced; may be one of the property corners

B. Point of Commencement (P.O.C.) — A well-referenced point at which the description of a property begins; usually leads to the point of beginning or first property corner

C. Lengths and directions of the property sides — Dimensions of all sides of property and all directions of property sides listed by angles, true bearings, or azimuths

(NOTE: Dimensions of property sides are usually listed in feet and decimals of a foot, although older deeds or property descriptions may be listed in rods or chains rather than feet.)

D. Names of adjoining property owners — Helpful to show the "intent" of the deed in case an error occurs leaving a gap or creating an overlap of property

E. Area of the parcel described — Normally listed in acres or sq. feet; aids in assessing the valuation of the property conveyed

INFORMATION SHEET

VIII. **Legal terms affecting property possession and their descriptions**

A. Encumbrance — A claim against a property

B. Easement — Right to use the land of another for a specific purpose

(NOTE: Easements can be created by the owner, the public, or by the state. The owner can create an easement by deed or dedication. The public can acquire an easement by being allowed to use the land for a statutory period of time, known as the right by prescription. The state has the right of eminent domain over private property.)

C. Right-of-way — Right to pass across another's land

D. Eminent domain — Right of a government to take private property for public use provided the owner receives just compensation

E. Adverse possession — When land is used by a person other than the owner for an extended period of time, the land may be claimed by the user from the title owner. Strict rules apply as follows:

1. User must have color of title — A legal claim or the appearance that shows the belief that the user has acquired title.

2. User must be in actual, open, notorious, and exclusive possession.

   Examples: Cultivating fields, building a house, renting the property to a tenant, preventing others from using the property

   (NOTE: Actions of this type help to prove user belief in ownership of title.)

3. User must be in continuous possession for a statutory period of years (commonly 20 years).

4. Possession is hostile, without owner's consent.

F. Encroachment — Gradually taking possess[illegible] another's land

Examples: Improper positioning of a fen[illegible] [illegible]lidings [illegible]

1. The owner can remove the encroachment up [illegible] boundary, and collect the cost of removal from the encroacher.

2. Once in position for a statutory period of time, the encroacher can claim the land by adverse possession.

3. Owner must notify the encroacher at once. Failure to do so bars the owner from claiming title of the land being occupied. The legal bar is called an *estoppel*.

INFORMATION SHEET

IX. **Types of boundary evidence**

A. Acquiescence (practical location) -- When two persons owning adjoining land use the land up to a certain line for a reasonable period and show by their actions that they accept it as the boundary

B. Agreement -- When two adjoining land owners agree upon where a boundary is located and either record the agreement in written form or show by their actions where the line is located

C. Records of boundary position (written evidence) -- The position of boundaries is found in the land description in one of these forms:

1. Deeds
2. Wills
3. Dedications
4. Condemnation proceedings
5. Agreements

D. Visual evidence -- Marks on the ground which identify boundaries

Examples: Structures, fences, or surveyor's landmarks, such as monuments, irons, or stakes

X. **Riparian rights**

A. Refer to those rights of a property owner of land that borders on a body of water.

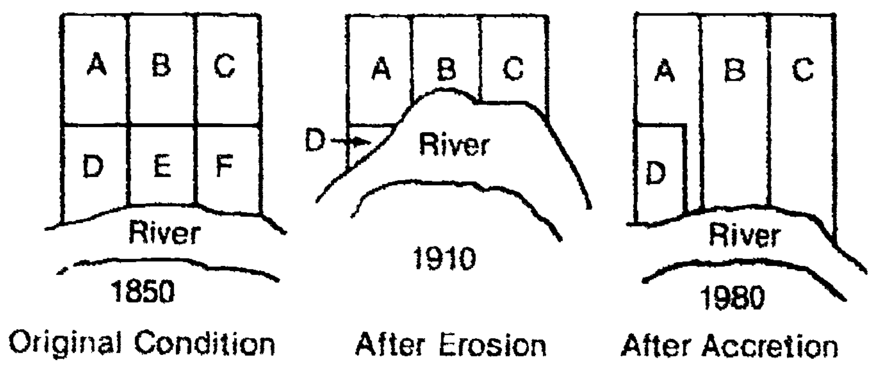
B. Difficulties in surveying these types of properties include

1. The boundaries are irregular in shape.
2. The boundaries are subject to changes incurring with changes in water-levels.
3. The ownership may extend to a high-water mark, low-water mark, or to the center of a stream or river.
4. Certain survey systems include a strip of land (usually 1 chain wide) parallel to the shoreline or high-water mark, termed "shoreline road allowances."

INFORMATION SHEET

C. Changes in positions of water bodies play a direct role in location of boundaries. (Figure 1)

FIGURE 1



XI. Terms related to riparian rights and changes in water boundaries

A. Avulsion (or revulsion) — The sudden change in the position of a body of water usually due to heavy storms or flooding.

(NOTE: The state presumably loses title to the part of the "bed" no longer occupied by the water. The riparian owner, it may be argued, advances to the water over unclaimed land.)

B. Alluvium (accretion) — The increase of land by the gradual addition of matter (clay, sand, silt) that then belongs to the owner of the land to which it is added

C. Erosion — The gradual wearing away of the land by the forces of water and wind

XII. Deed descriptions

A. Include the direction and distances of all lines along the property boundaries of the parcel of land.

B. Are usually in written form, rather than a survey plan, but a drawing is sometimes included.

C. Property is described as starting or commencing from a point of beginning and continues either clockwise or counterclockwise around the property, returning to the point of beginning.

INFORMATION SHEET

D. Bearings of lines may be assumed, magnetic, or true, the last being preferable.

E. Property descriptions are commonly written by surveyors (sometimes by lawyers).

XIII. **Methods of legal land descriptions and their characteristics**

(NOTE: These methods will be discussed in more detail in Units XI and XII.)

A. Public land survey system (Transparencies 1 and 2)

1. Inaugurated by the Continental Congress on May 20, 1785, for the survey of the public lands of the United States.

2. Usually, and in all cases where practical, its units are in rectangular form.

3. A helpful tip in reading a legal description of a section to locate a tract a land is to read it backwards.

   Example Written: N 1/2, NW 1/4, SW 1/4, SEC 6, T 55 N, R 69 W

   Reads: R 69 W, T 55 N, SEC 6, SW 1/4, NW 1/4, N 1/2

4. A complete description always begins with the smallest division and progresses to the largest.

B. Lot and block description (Transparency 3)

1. Describes land by referring to a recorded plat, the lot number, the block number, the subdivision, the city, the county, and the state.

   (NOTE: Under the government survey system, 40 acres is the smallest subdivision of land. To further split up land into smaller parcels or lots is called the subdivision of land [subdivision plat]. This utilizes lot and block descriptions of land.)

2. Describes small units of property in a subdivision.

3. Must be filed with the county as part of a plat.

4. Each block is numbered consecutively.

5. Each lot carries a number shown in consecutive order within the block.

INFORMATION SHEET

6. A plat is captioned with the legal description.

   Example: Typical lot and block description: Lot 9, Block 40, Boulder subdivision, City of Louisville, Boulder County, State of Colorado

   (NOTE: Legal descriptions are commonly referred back to the local register of deeds by listing the proper page and book number of where the original deed description can be found.)

7. Advantage of lot and block description is it shows all lots in relationship to other parcels of land.

C. Metes and bounds descriptions (Transparency 4)

1. Oldest known manner of describing land.

2. Method employed for demarcation of tracts of land in the original 13 states.

3. Ofte.ı used to describe irregularly shaped plats.

4. Description must begin at some known point that can be readily identified.

5. Begins at some point in the boundary of the tract and then recites the courses (directions) and distances from point to point entirely around the tract.

6. All bounds are listed in rational order and referenced to a chart by bearing, distance, and monuments.

7. The description must close — The courses and distances of a description m' ' come back to the place of beginning.

8. A plat is drawn from a metes and bounds description.

   (NOTE: A complete description of real property may include all three types of description in combination — sectional system, metes and bounds, and/or lot and block description.)

D. State plane coordinate system

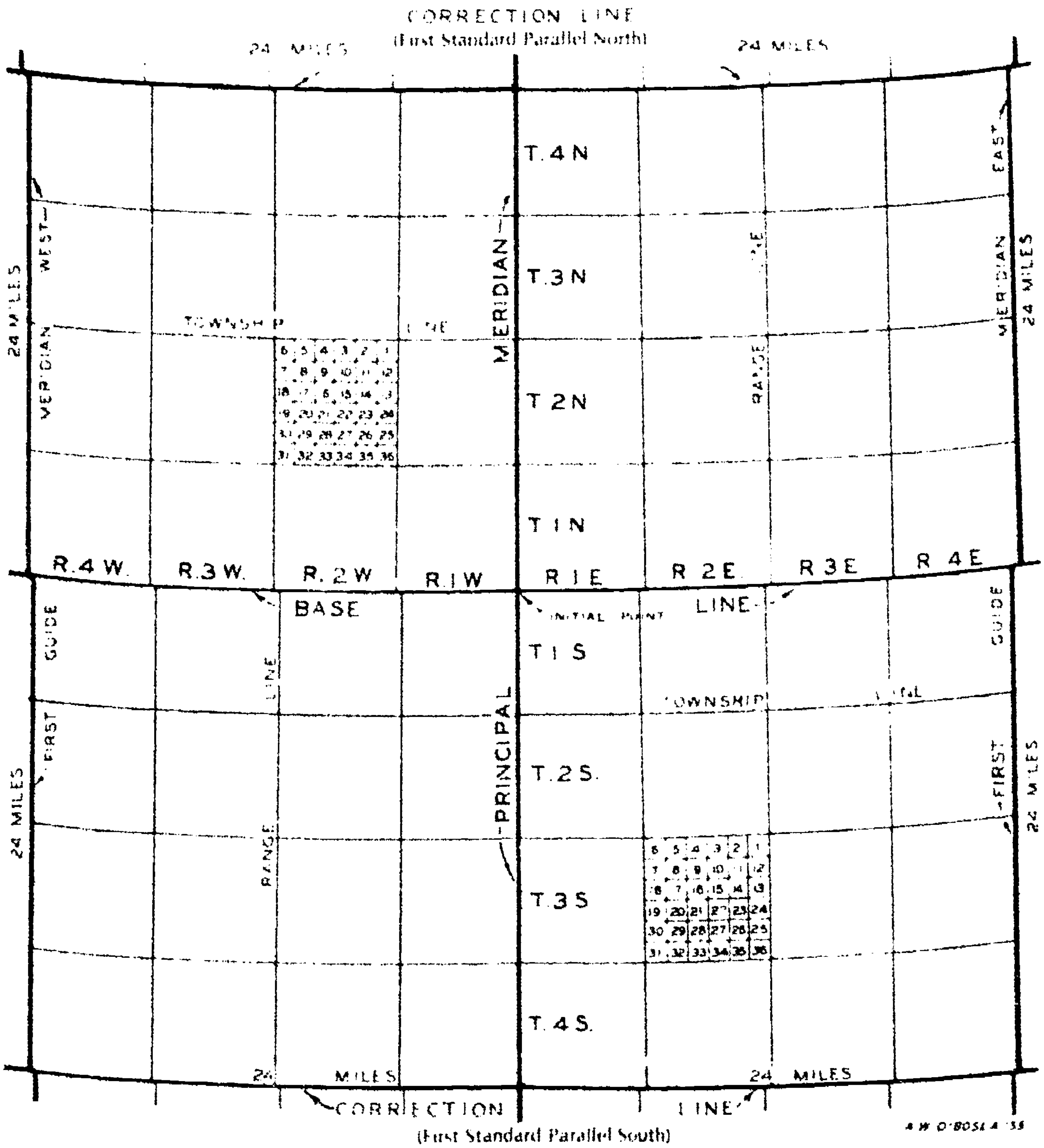
1. Was established in 1933 by the U.S. Coast and Geodetic Survey

2. Uses a rectangular grid designed to fit the curved shape of the earth to a plane surface with as little distortion as possible

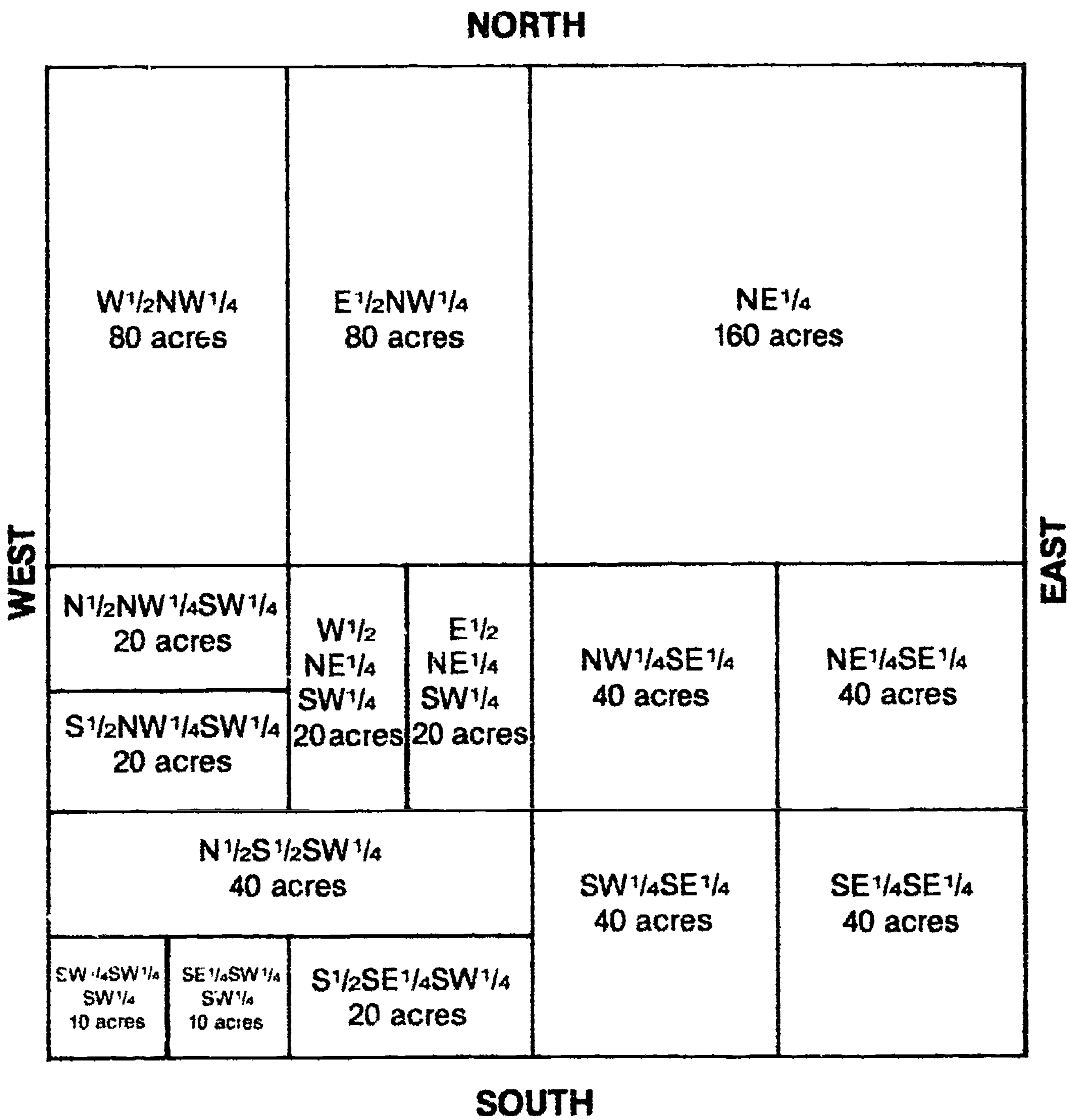
3. Is used for defining positions of geodetic stations in terms of plane rectangular (X and Y) coordinates

4. All states have established by law a state plane coordinate system in either the Lambert projection or the transverse Mercator projection with one or more zones.

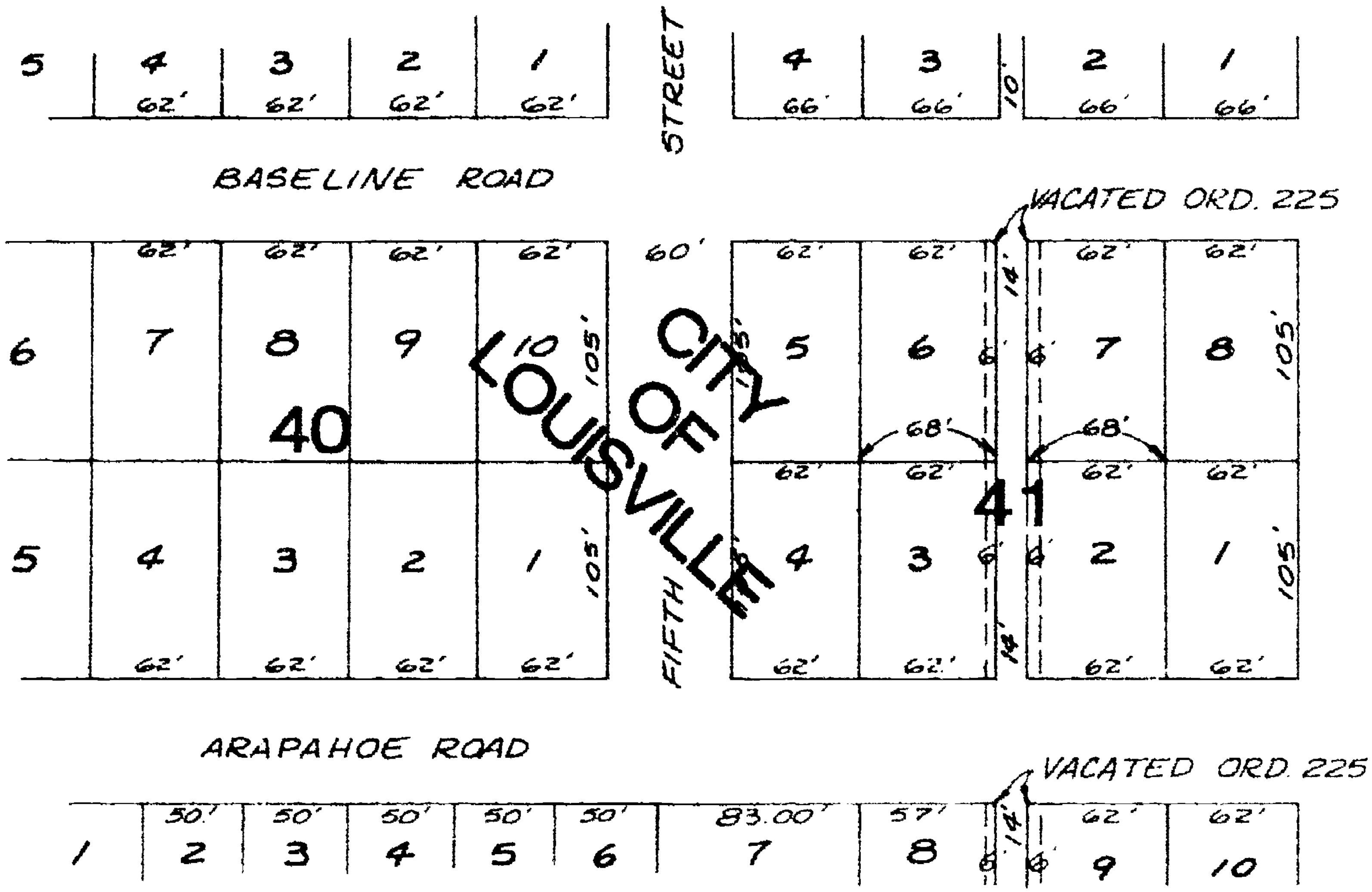
U.S. Public Land Survey System



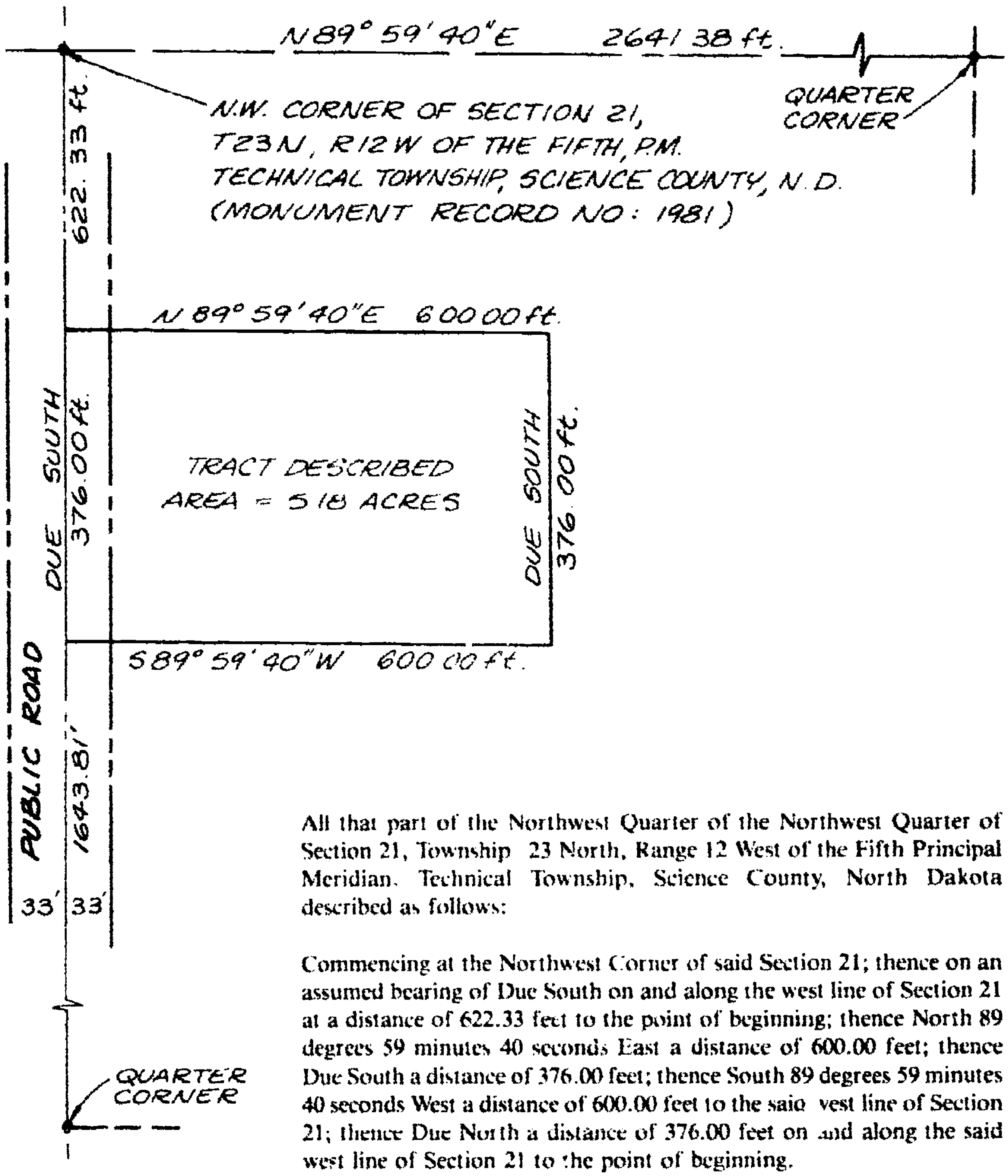
Sample Subdivision of a Section



Lot and Block Description



Typical Metes and Bounds Description



All that part of the Northwest Quarter of the Northwest Quarter of Section 21, Township 23 North, Range 12 West of the Fifth Principal Meridian, Technical Township, Science County, North Dakota described as follows:

Commencing at the Northwest Corner of said Section 21; thence on an assumed bearing of Due South on and along the west line of Section 21 at a distance of 622.33 feet to the point of beginning; thence North 89 degrees 59 minutes 40 seconds East a distance of 600.00 feet; thence Due South a distance of 376.00 feet; thence South 89 degrees 59 minutes 40 seconds West a distance of 600.00 feet to the said west line of Section 21; thence Due North a distance of 376.00 feet on and along the said west line of Section 21 to the point of beginning.

The above described tract contains 5.18 acres more or less and is subject to an existing public road over and across its most westerly 33.00 feet.

LEGAL ASPECTS
UNIT X

ASSIGNMENT SHEET #1 — WRITE A METES AND BOUNDS DESCRIPTION

Directions: Write a metes and bounds description for the house and lot where you live. Assume any necessary data. Sketch a map of the property to coincide with the description. Refer to Transparency 4 if needed.

LEGAL ASPECTS
UNIT X

ASSIGNMENT SHEET #2 — PLOT OR LAYOUT A LEGAL LAND DESCRIPTION

Directions: Plot up the following description of a parcel of land using a scale of 1" = 400'.

(NOTE: The property is located in a standard U.S. public land survey system.)

Legal Description: "Commencing at the southwest corner of Section 35 in Township 10 N., Range 3 W.,

Thence N 0°05'W along the westerly boundary of Section 35, 2053.00 feet to a point therein:

Thence N 89°45'E, 1050.00 feet:

Thence southerly, parallel with the westerly limit of Section 35, 670.32 feet;

Thence N 89°45'E, 950.00 feet:

Thence southerly, parallel with the westerly limit of Section 35, 1381.68 feet, more or less, to the point of intersection with the southerly boundary of Section 35;

Thence westerly along the southerly boundary of Section 35, 2000.00 feet, more or less, to the point of commencement.

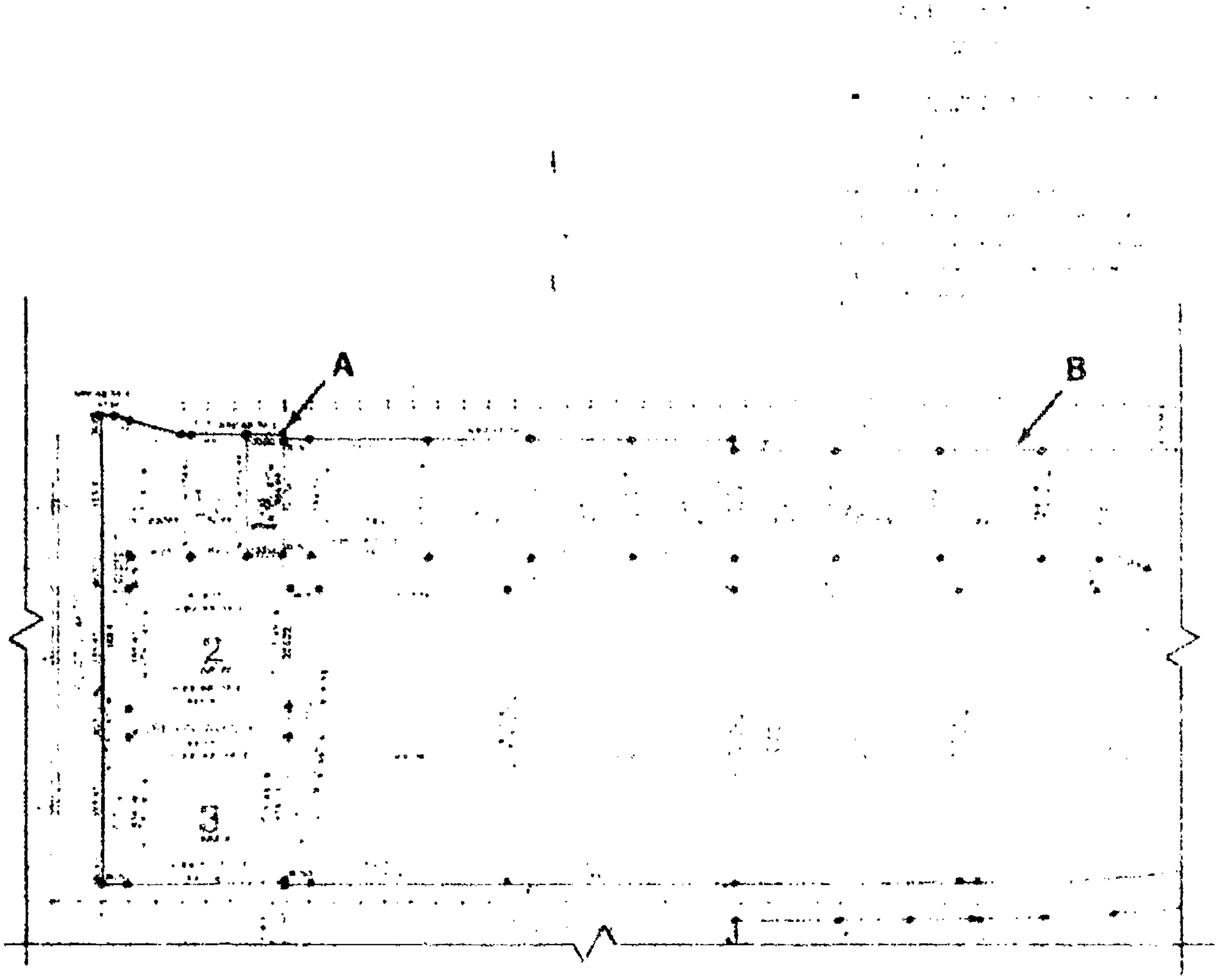
LEGAL ASPECTS
UNIT X

ASSIGNMENT SHEET #3 — WRITE A LOT AND BLOCK DESCRIPTION

Directions: In the space below write lot and block descriptions for the two lots shaded on the partial subdivision shown.

PLAT OF BRECKENRIDGE INDUSTRIAL PARK

A PART OF SECTION 9, TOWNSHIP 132 NORTH, RANGE 47 WEST WITHIN THE CITY OF BRECKENRIDGE, AND A PART OF SECTION 10, TOWNSHIP 132 NORTH, RANGE 47 WEST WITHIN BRECKENRIDGE TOWNSHIP, ALL WITHIN THE FIFTH PRINCIPAL MERIDIAN, WILKIN COUNTY, MINNESOTA



A. ____

____

B. ____

____

LEGAL ASPECTS
UNIT X

ASSIGNMENT SHEET #4 — RESEARCH AND RECORD EXISTING PROPERTY RECORDS

Directions:

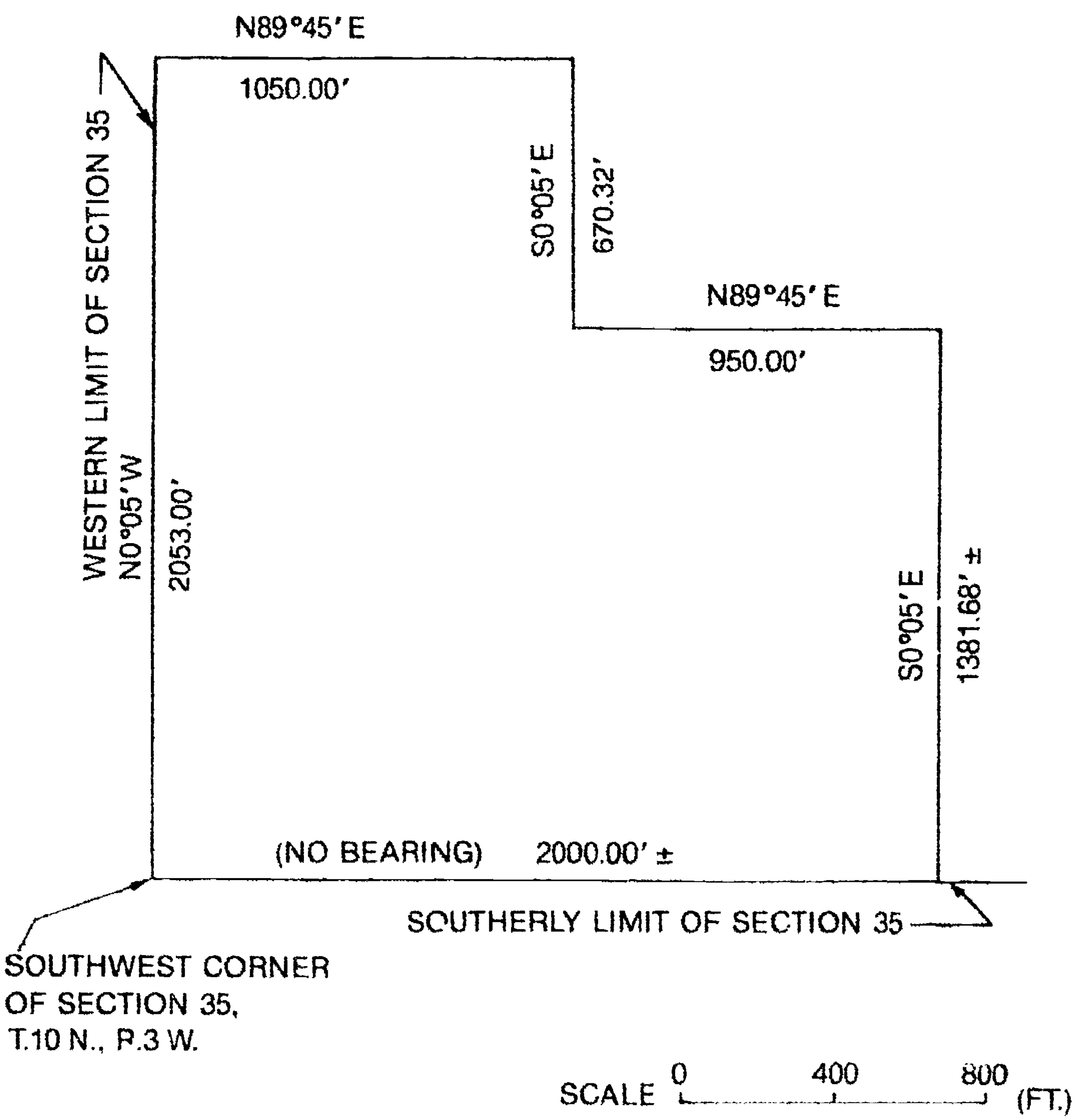
1. Visit your local county court house, register of deeds' office.
2. Have someone help you locate the original plat and description of one of the following parcels of land:
   a. Your residence
   b. Your school
   c. Your neighbors residence
3. Recopy the legal description.
4. Record the original surveyor.
5. Record the date of the original survey.
6. Note any encumbrances.
7. Retrace any sales of property or transfer of ownership.

LEGAL ASPECTS
UNIT X

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1 — Evaluated to the satisfaction of the instructor

Assignment Sheet #2



ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3

A. Lot 3. Block 1, Breckenridge Industrial Park, City of Breckenridge, Wilkin County, State of Minnesota

B. Lot 7. Block 4, Breckenridge Industrial Park, City of Breckenridge, Wilkin County, State of Minnesota

Assignment Sheet #4 — Evaluated to the satisfaction of the instructor

LEGAL ASPECTS
UNIT X

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. A signed and sealed document containing legal language that transfers ownership of property to another party

_____b. A determined land marking that is used sometimes for ownership boundaries, often determined by vegetation or alkaline marks

_____c. A surveyed line that indicates fixed ownership between properties; a separating line

_____d. A fractional part

_____e. The deed for the first parcel to be sold off from a tract of land

_____f. A deed used to release one person's right, title, or interest to another without providing a guarantee or warranty of title

_____g. An identifying marker, normally stone, that indicates ownership; generally used to mark a corner

_____h. The method of transferring ownership of property to another party

_____i. A deed authorizing that the grantor has a good title free and clear of any liens and encumbrances and will defend the grantee against any claims

_____j. The act of judicially or legally condemning ownership of a parcel of land; to acquire ownership or public use by eminent domain

_____k. The direction of a straight line in respect to a compass, magnetic or true north

_____l. The point in which converging lines meet; the intersection of two boundary or property lines usually marked with a stone, iron bar, pipe, or brass disc or plug

1. Aliquot
2. Boundary
3. Bearing
4. Corner
5. Condemnation
6. Conveyance
7. Deed
8. High water mark
9. Monument
10. Quit claim deed
11. Senior deed
12. Warranty deed

TEST

2. State three purposes of legal land surveys.

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. Complete the following statements concerning the two principles affecting laws on boundary positions by placing either the word "intent" or "acceptance" in the appropriate blanks.

   a. The position of boundaries is determined by the ____________ of the parties that establish the new boundary.

   b. With the passage of time, evidence of the parties' ____________ becomes more difficult to secure.

   c. Rules have been developed to eliminate old evidence in favor of "present conditions." The longer the period of ____________ of these conditions, the stronger the evidence becomes.

4. Distinguish between the two types of laws regulating land surveying by placing a "C" next to the description of common law and an "S" next to the description of statutory law.

   _____ a. Is composed of the body of law such as ordinances enacted by governing bodies.

   _____ b. Is the body of rules and principles that have been accepted by continual usage.

5. List three methods of transferring property titles.

   a. ______________________________

   b. ______________________________

   c. ______________________________

6. Select true statements concerning properly prepared deeds by placing an "X" next to the true statements.

   _____ a. Will contain some sort of description of the boundaries of the land conveyed

   _____ b. Must be tied directly or indirectly to physical marks or monuments on the ground and surrounding properties

   _____ c. Is usually recorded in a county court house, and is closed to the public.

TEST

7. List four types of information contained in land descriptions.

   a. ______

   b. ______

   c. ______

   d. ______

8. Match the legal terms affecting property possession on the right with the correct descriptions.

______a. A claim against a property		1. Adverse possession
______b. Right to use the land of another for a specific purpose		2. Easement
		3. Eminent domain
______c. Right to pass across another's land		4. Encroachment
______d. Right of a government to take private property for public use provided the owner receives just compensation		5. Encumbrance
		6. Right-of-way
______e. When land is used by a person other than the owner for an extended period of time, the land may be claimed by the user from the title owner. Strict rules apply.		
______e. Gradually taking possession of another's land		

9. Match types of boundary evidence on the right with the correct descriptions.

______a. The position of boundaries is found in the land description in the form of deeds, wills, dedications, condemnation proceedings, or agreements		1. Acquiescence
		2. Agreement
______b. When two adjoining land owners agree upon where a boundary is located and either record the agreement in written form or show by their actions where the line is located		3. Records of boundary position (written evidence)
		4. Visual evidence
______c. Marks on the ground which identify boundaries		
______d. When two persons owning adjoining land use the land up to a certain line for a reasonable period and show by their actions that they accept it as the boundary		

TEST

10. Select true statements concerning riparian rights by placing an "X" next to the true statements.

_____a. Refer to those rights of a property owner of land that borders another piece of land owned by someone else

_____b. Difficulties in surveying these types of properties include: the boundaries are irregular in shape, and the bounda·´es are subject to changes incurring with changes in water-levels.

_____c. The ownership may extend to a high-water mark, low-water mark, or to the center of a stream or river

_____d. Changes in positions of water bodies play a direct role in location of boundaries

11. Distinguish between terms related to riparian rights and changes in water boundaries by placing the following letters next to the correct descriptions:

- Al — Alluvium (accretion)
- Av — Avulsion (revulsion)
- E — Erosion

_____a. The gradual wearing away of the land by the forces of water and wind

_____b. The increase of land by the gradual addition of matter (clay, sand, silt) that then belongs to the owner of the land to which it is added

_____c. The sudden change in the position of a body of water usually due to heavy storms or flooding

12. Complete the following statements concerning deed descriptions by circling the correct words.

a. Include the direction and distances of (**most, all**) lines along the property boundaries of the parcel of land.

b. Are usually in (**written, illustrative**) form.

c. Property is described as starting or commencing from a point of beginning and continues either clockwise or counterclockwise around the property, (**ending at a monument, returning to the point of beginning**).

d. Bearings of lines may be assumed, magnetic, or true, with (**assumed, magnetic, true**) being preferable.

e. Property descriptions are most commonly written by (**surveyors, lawyers**).

TEST

13. Match the methods of legal land descriptions on the right with the correct characteristics.

_____a.	Oldest known manner of describing land. Employed for demarcation of tracts of land in the original 13 states.	1. Lot and block descriptions
_____b.	Was established in 1933 by the U.S. Coast and Geodetic Survey. Uses a rectangular grid designed to fit the curved shape of the earth to a plane surface with as little distortion as possible.	2. Metes and bounds descriptions
_____c.	Describe land by referring to a recorded plat, the lot number, block number, the subdivision, the city, the county, and the state.	3. Public land survey system
_____d.	Inaugurated by the Continental Congress on May 20, 1785, for the survey of the public lands of the United States.	4. State plane coordinate system

(NOTE: If the following activities have not been accomplished prior to the test, ask you instructor when they should be completed.)

14. Write a metes and bounds description. (Assignment Sheet #1)

15. Plot or layout a legal land description. (Assignment Sheet #2)

16. Write a lot and block description. (Assignment Sheet #3)

17. Research and record existing property records. (Assignment Sheet #4)

LEGAL ASPECTS
UNIT X

ANSWERS TO TEST

1.

a.	7	g.	9
b	8	h.	6
c.	2	i.	12
d.	1	j.	5
e.	11	k.	3
f.	10	l.	4

2. Any three of the following:
   a. To subdivide public lands in townships, sections, and lots
   b. To attain the necessary information for writing a legal description
   c. To determine the exact area of a particular tract of land
   d. To reestablish the boundaries of a parcel of land that has been previously surveyed and legally described
   e. To subdivide a parcel of land into two or more smaller units
   f. To establish the exact position of features such as buildings on a parcel with respect to the boundaries

3. a. Intent
   b. Intent
   c. Acceptance

4. a. S
   b. C

5. Any three of the following:
   a. Deed (several types)
   b. Inheritance through a will
   c. Inheritance without a will
   d. Adverse possession

6. a, b

7. Any four of the following:
   a. Point of beginning
   b. Point of commencement
   c. Lengths and directions of the property sides
   d. Names of adjoining property owners
   e. Area of the parcel described

8.

a.	5	d.	3
b.	2	e.	1
c.	6	f.	4

ANSWERS TO TEST

9. a. 3
   b. 2
   c. 4
   d. 1

10. b, c, d

11. a. E
    b. Al
    c. Av

12. a. All
    b. Written
    c. Returning to the point of beginning
    d. True
    e. Surveyors

13. a. 2
    b. 4
    c. 1
    d. 3

14.-17. Evaluated to the satisfaction of the instructor

BOUNDARY SURVEYING
UNIT XI

UNIT OBJECTIVE

After completion of this unit, the student should be able to list common types of monumentation, discuss the procedures used to establish the U.S. public land survey system, research and obtain deed descriptions, and retrace boundaries from a deed description. Competencies will be demonstrated by correctly performing the procedures outlined in the job and assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to boundary surveying with the correct definitions.
2. List the purposes of a boundary survey.
3. Match the types of boundary surveys with the correct descriptions.
4. Select true statements concerning legal interpretation of evidence.
5. List common types of monumentation found when setting boundary lines.
6. Complete a chart of abbreviations used for marking monuments.
7. Complete statements concerning the establishment of the U.S. public land survey system.
8. Select from a list the states not subdivided under the U.S. public land survey system.
9. Complete statements concerning the subdivision of a section.
10. Arrange in order the procedures used for performing a boundary survey.

OBJECTIVE SHEET

11. Answer questions based on the public land survey system. (Assignment Sheet #1)

12. Write and locate descriptions for the subdivision of a section. (Assignment Sheet #2)

13. Research and obtain deed descriptions of an assigned tract of land. (Assignment Sheet #3)

14. Demonstrate the ability to retrace boundaries from a deed description. (Job Sheet #1)

BOUNDARY SURVEYING
UNIT XI

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheet.

H. Discuss and demonstrate the procedure outlined in the job sheet.

I. Integrate the following activities throughout the teaching of this unit:

1. Visit the local county courthouse and obtain a copy of the plat for the location of the student's home or school.

2. Obtain a copy of the local codes concerning easements, setbacks, and road right-of-ways.

3. Obtain a U.S.G.S. 7.5 minute quadrangle map of your local area and locate by township, range, and section many local landmarks.

4. Provide students with various U.S.G.S. 7.5 minute quadrangle maps for Assignment Sheet #1.

5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1 — U.S. Public Land Survey System
2. TM 2 — Sections
3. TM 3 — Public Land Survey System (Areas Covered and Not Covered)

D. Handouts

1. Handout #1 — Principal Meridians
2. Handout #2 — Subdivision Steps

E. Assignment sheets

1. Assignment Sheet #1 — Answer Questions Based on the Public Land Survey System
2. Assignment Sheet #2 — Write and Locate Descriptions for the Subdivision of a Section
3. Assignment Sheet #3 — Research and Obtain Deed Descriptions of an Assigned Tract of land

F. Answers to assignment sheets

G. Job Sheet #1 — Retrace Boundaries from a Deed Description

H. Test

I. Answers to test

REFERENCES USED IN WRITING THIS UNIT

A. Kavanagh, Barry F., and S. J. Glenn Bird. *Surveying: Principles and Applications.* Reston, Virginia: Reston Publishing Co., Inc., 1984.

B. Brinker, Russell and P.R. Wolf. *Elementary Surveying*, 7th ed. New York: Harper & Row, 1984.

C. Davis, R.E., F.S. Foote, and J.H. Kelly. *Surveying*, 5th ed. New York: McGraw-Hill Book Company, 1966.

D. *Manual of Surveying Instructions.* Technical Bulletin 6. Bureau of Land Management/ U.S. Department of the Interior, 1973.

E. Kissam, Phillip. *Surveying for Civil Engineers.* New York: McGraw-Hill, 1976.

SUGGESTED SUPPLEMENTAL MATERIALS

A. Hoag, John S. *Fundamentals of Land Management*. Chicago, IL: Chicago Title Insurance Company, 1971.

B. *Glossaries of BLM Surveying and Mapping Terms*. 2nd ed. Bureau of Land Management/U.S. Department of the Interior, 1980.

C. *Definitions of Surveying and Associated Terms*. American Congress on Surveying and Mapping and the American Society of Civil Engineers, 1978.

D. Kissam, Phillip. *Surveying Practice*. New York: McGraw-Hill, 1978.

E. Breed, Hosmer (Fang, Barry). *Principles and Practices of Elementary Surveying*, 11th ed. New York: Wiley, 1977.

BOUNDARY SURVEYING
UNIT XI

INFORMATION SHEET

I. **Terms and definitions**

A. Aliquot parts — Smaller, identical parts or parcels of land divided from a large parcel of land; used in subdivisions

B. Base line — A principal parallel line that runs straight east and west that is used in establishing the rectangular system of land description; is run astronomically by surveyors

C. Boundary survey — A survey that is performed usually around a certain parcel of land to determine ownership and the legal location of ownership limits

D. Central meridian — The line of longitude at the center of a projection

E. Deed — Legal document which specifies the ownership of the land

F. Land survey — A survey that locates property corners and boundary lines; usually closed with a traverse

G. Legal description — A written statement recognized by law as a definite location of a tract of land by reference to a survey, recorded map, or adjoining property

H. Longitude — Arc distance measured in degrees east and west from the prime meridian

I. Meander line — A survey line that follows the mean high water marks and is used for plotting and protraction of area only

J. Meridian — Line of longitude that runs straight north and south; is run astronomically by surveyors

K. Monument — Permanent object that marks established points

1. Natural: Created by nature

   Examples: Trees, rivers

2. Artificial: Created by human beings

   Examples: Wooden stake, stone, or other permanent marker properly located and witnessed

L. Parcel number — A method of identifying a specific parcel within a tract of land

INFORMATION SHEET

M. Prime meridian — The meridian of longitude 0°: the meridian of Greenwich, England

N. Principal meridian — A meridian established as a basis for establishing a reference line for the organization of the rectangular system

O. Prorating or proportioning — A method used when locating property corners of effectively distributing an excess or deficiency of error within the distance to the nearest monument found

P. Protracting — The process of plotting the interior, unsurveyed boundaries of an official plat

Q. Public domain (lands) — Any or all of those areas of land ceded to the federal government by the original states and to such other lands as were later acquired by treaty, purchase, or cession and are disposed of only under the authority of Congress

R. Random line — A survey line that is run knowing that it is not exactly in the correct position but once established, calculated right angle offsets can be calculated to determine the true line

S. Reconnaissance — A preliminary survey used to obtain information about a specific site

T. Resection — A method of locating a point by measuring angles between a point of known location from the point in question

U. Subdivision (USPLS) — The division of a township such as into a section, half section, quarter section, quarter-quarter section, or sixteenth section or lotting, section, township, and range numbers and the description of the principal meridian to which referred

V. Subdivision survey — A type of land survey in which the legal boundaries of an area are located and the area is divided into parcels of lots, streets, right-of-ways, etc.

II. **Purposes of a boundary survey**

A. To secure the necessary data for writing a legal description of the tract of land

B. To define the boundaries of the property with visible objects.

C. To determine the area of a designated tract of land.

D. To reestablish the boundaries of a previously surveyed parcel of land.

E. To subdivide a tract of land into two or more parcels of land.

INFORMATION SHEET

III. **Types of boundary surveys**

A. Original surveys

1. Measure unknown lengths and directions of boundaries not previously established.

2. Document a tract of land bound on all sides by adjoining property owners.

3. Usually performed when a tract has not been previously surveyed and is being transferred from one owner to another.

B. Resurveys

1. Reestablish the boundaries of a tract of land for which a survey has previously been made.

2. The surveyor is guided by a description based upon the original survey and by evidence on the ground.

3. The description being followed may be in the form of old original survey notes, an old deed, or a map or plat on which the recorded lengths and bearings have been recorded.

4. Usually performed when land is transferred by deed from one party to another.

C. Subdivision surveys

1. Subdivide land into more or less regular tracts in accordance with a prearranged plan.

2. The division of public lands of the United States into townships, sections, and quarter sections is an example of the subdivision of rural lands.

3. The laying out of blocks and lots in a city addition is an example of subdivision of urban lands.

4. Usually performed when large tracts of land are divided into many parcels for development by several individual owners.

IV. **Legal interpretation of evidence**

A. The description of the boundaries of a tract include

1. Objects that fix the location of all corners

2. Lengths and directions of all lines between corners

3. The area of the tract

INFORMATION SHEET

B. Deed description may contain errors or mistakes in measurement, thus making retracement difficult.

C. The universal principle of law endeavors to make the deed effectual rather than void, and to execute the actual "intent" of the contracting parties.

D. The following rules have been formulated to carry out this principle:

1. Monuments -- Visible objects which mark the corners of the parties concerned are considered the best form of evidence. A corner thus established will prevail against all other forms of evidence, providing there is reason to believe the monument was set in accordance with the original intent and it has not been disturbed.

2. Distance, direction, and area -- In case of conflicts among "calls" in the deed or dimensions on a recorded plat, the following order of importance is observed.

    a. Distances control over bearings

    b. Bearings control over area of a tract

3. Mistakes -- It is a well established principle that deed descriptions indicate all intentions of parties concerned. Therefore, obvious mistakes such as omissions of full tape lengths in a dimension or the transposition of words "northeast" for "northwest" will have no effect on the validity of a description providing it is otherwise complete and consistent.

4. Purchaser favored -- In the case of a description having two or more interpretations, the one favoring the purchaser will prevail over any others.

5. Ownership of highways -- Land described as being bound by highways or streets conveys ownership to the center of the highway or street. Any variation from this must be explicitly stated in the description.

6. Original government surveys -- Errors found in original government surveys do not affect the boundaries established under those surveys, and will remain fixed as originally established.

V. **Types of monumentation found when setting boundary lines**

A. Common types

1. A wrought iron pipe, zinc coated, 2 in. inside diameter, 30 in. long. The lower end is split for 4 or 5 in. and spread. A brass cap is fastened to the top. The pipe is filled with concrete. It is set with three-quarters of its length in the ground.

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2. A durable native stone at least 20 by 6 by 6 in., set with three-quarters of its length in the ground

3. A cross mark on surface rock

4. A tablet set in surface rock

5. A living tree when it occupies the position of the corner

6. A steel rod

7. A wooden post

8. A deposit of charcoal or glass or any durable artificial material (called a memorial)

B. Auxilary types

1. Witness corner — Used when it is impractical to occupy the site of the corner. If possible, it is placed as near to the corner as is practical, on one of the lines running to the corner. It must not be more than 10 chains distant. If this is impossible, it is placed anywhere within 5 chains.

2. Reference monuments — Placed within a short distance of corners. At least two and sometimes four are set. They are used when the corner mark is liable to destruction and no trees are available that can be used.

3. Bearing objects — Any tree or other natural object near the corner (ordinarily within 3 chains). The bearing and distance from the corner to the object is recorded. The distance to a tree is measured to the center of the tree just above the root bole. Bearings only are often recorded to distant landmarks.

4. Pits and mounds — Pits are rectangular and are placed on lines that run to the corner. The excavated material is placed in a mound at the corner or on one of the lines. New and old specifications differ.

C. Marks of identification on monuments and bearing objects

1. Various systems of numbers and letters are used to mark monuments. The meaning of the marks should be decipherable from the list of abbreviations in Objective VI.

2. Grooves or notches are used on stone monuments marking closing corners. Grooves are cut in the face, notches in the corner. They are placed toward each of the three township corners of the township to which the corner belongs. The number of grooves or notches indicate the number of miles to that corner.

INFORMATION SHEET

VI. Abbreviations used for marking monuments

AM	Amended (new corner position when old remains)
AMC	Auxiliary meander corner
AP	Angle point
BO	Bearing object
BR	Bearing rock
BT	Bearing tree
C	Center
CC	Closing corner
E	East
LM	Location monument (for U.S. Survey not connected with Public Land System)
M	Mile
MC	Meander corner
N	North
NE	Northeast
NW	Northwest
PL	Public land (unsurveyed)
R	Range
RM	Reference monument
S	Section
S	South
SC	Standard corner
SE	Southeast
SMC	Special meander corner
SW	Southwest
T	Township
TR	Tract
W	West
WC	Witness corner
WP	Witness point
1/4	Quarter section
1/16	Sixteenth section

INFORMATION SHEET

VII. **Establishment of the U.S. public land survey (USPLS) system** (Transparencies 1, 2 and 3)

A. Thirty-seven *initial points* have been established which serve as the starting points for subdividing the public lands.

B. *Principal meridians* and *base lines* pass through initial points and make up the framework upon which this system is built. (Transparencies 1 and 3)

1. There are 35 principal meridians.

   a. A north-south line is designated the principal meridian for a particular state or area.

   b. The principal meridian is marked and monumented, and is fixed by a longitudinal reading (so many degrees, minutes, and seconds west of the Greenwich Meridian).

   c. Some principal meridians are numbered, some are named. (Handout #1)

   Examples: 5th principal meridian, Louisiana meridian, Black Hills meridian

2. There are 32 base lines.

   a. These are east-west lines run at right angles (90°) to the principal meridian.

   b. Location of each (latitude) is fixed astronomically (so many degrees north of the equatorial line).

C. The first subdivision of public land is into *quadrangles* (tracts) which are approximately 24-mile squares.

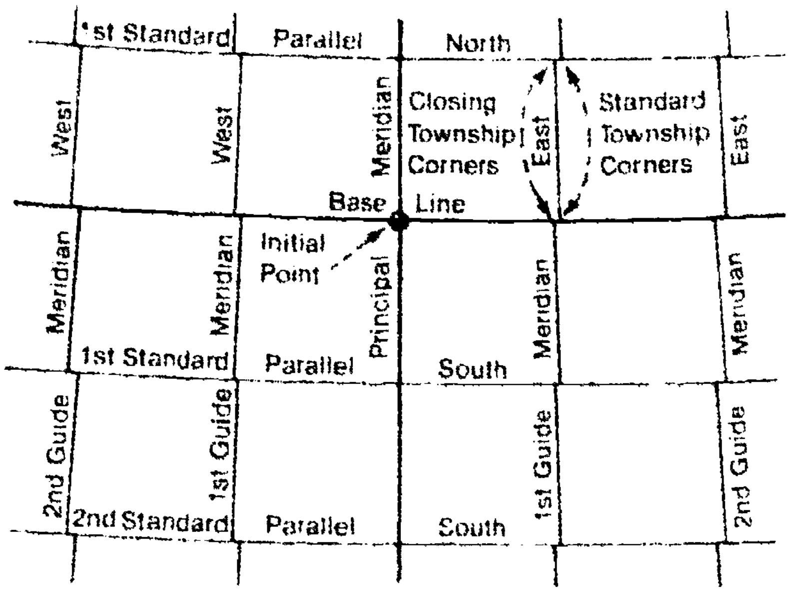
D. To compensate for the convergence of the lines due to curvature of the earth.

1. *Correction lines* (also called *standard parallels*) are run parallel to base lines.

INFORMATION SHEET

2. *Guide meridians* are run parallel to principal meridians.

FIGURE 1



E. Townships

1. The quadrangles (24-mile squares) are divided into smaller tracts of land called townships.

2. *Township lines* are east-west lines at six-mile intervals parallel to the base line.

3. *Range lines* are north-south lines at six-mile intervals parallel to the principal meridian.

4. In order to locate a township, two numbers are assigned — a township number and a range number.

   Example: T2S, R4E; T6N, R2W

F. Sections (Transparency 2)

1. A Congressional act in 1796 directed each township to be subdivided into 36 sections.

2. Each section measures approximately one square mile (640 acres).

3. Each section corner is to be monumented.

INFORMATION SHEET

4. The sections in each township are numbered consecutively from 1 to 36 beginning with #1 in the northeast corner of the township and #36 in the southeast corner. (Figure 2)

FIGURE 2

N

	6	5	4	3	2	1	
	7	8	9	10	11	12	
W	18	17	16	15	14	13	E
	19	20	21	22	23	24	
	30	29	28	27	26	25	
	31	32	33	34	35	36	

S

G. Fractional sections

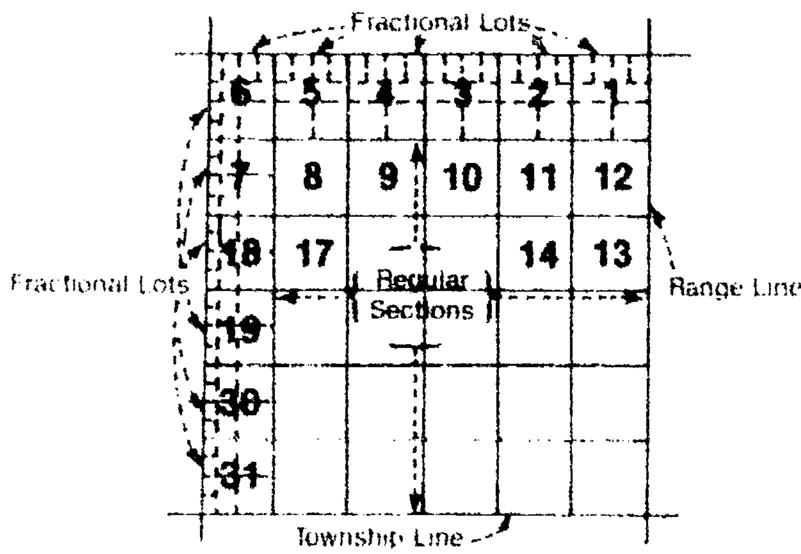
1. Are all sections bordering on the north and west sides of the township

   (NOTE: Each township does not form a perfect square due to the convergence of meridians and other causes.)

2. Are expected in counties bordering oceans, lakes, and streams

3. Should be divided into equal fractional parts (if possible). (Figure 3)

FIGURE 3



INFORMATION SHEET

VIII. **States not subdivided under U.S. public land survey system** (Transparency 3)

A. Original thirteen colonial states

1. New Hampshire
2. New York
3. Massachusetts
4. Connecticut
5. Rhode Island
6. Pennsylvania
7. New Jersey
8. Maryland
9. Delaware
10. Virginia
11. North Carolina
12. South Carolina
13. Georgia

B. Texas

C. Parts of Louisiana

D. Hawaii

E. West Virginia

F. Kentucky

G. Tennessee

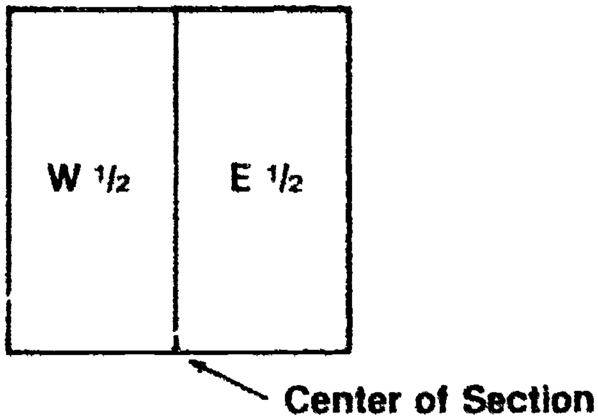
H. Part of Ohio

INFORMATION SHEET

IX. **Subdivision of a section** (Handout #2)

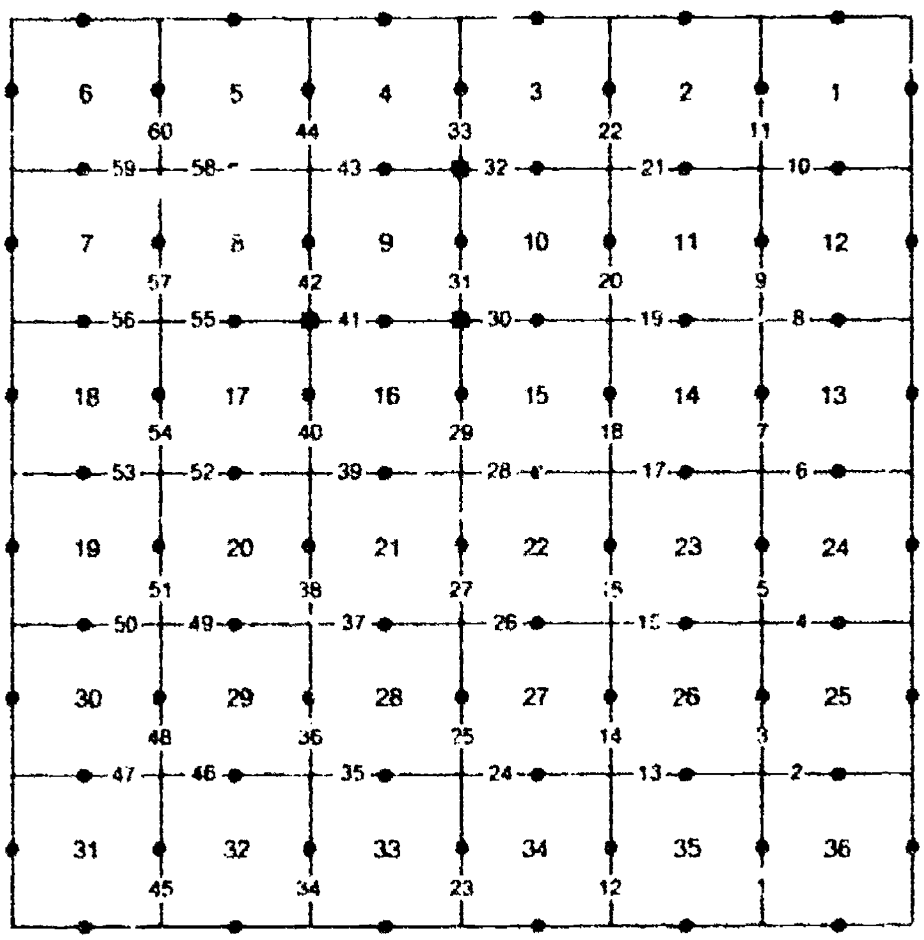
A. In 1800 Congress directed that a section could be subdivided in east and west halves (320 acres each). (Figure 4)

FIGURE 4



B. In 1805 Congress directed further subdivision into quarter sections and the monumenting of all quarter section corners. (Figure 5)

FIGURE 5



(NOTE: Numbers on lines indicate order of points set.)

Quarter Section Corner

Section Corner Established for Resurvey Example

INFORMATION SHEET

C. At later dates Congress directed further subdivision of the section. The quarter-quarter section of 40 acres in the smallest statutory division of regular sections.

D. Legal descriptions of land which follow the regular subdivision of a regular section must include the principal meridian, section, township, and range.

E. A helpful tip in reading a legal description of a section to locate a tract of land is to read it backwards.

Example written: N 1/2, NW 1/4, SW 1/4, SEC 6, T 55 N, R 69 W

Reads: R 69 W, T 55 N, SECT 6, SW 1/4, NW 1/4, N 1/2

F. A complete description always begins with the smallest division and progresses to the largest.

X. **Procedure used for performing boundary surveys**

A. A copy of the offer to purchase or any other document related to the property boundaries should be obtained.

(NOTE: If the description mentions any other registered deed numbers, a copy should be obtained.)

B. A reference monument or corner to the township must be located or reestablished.

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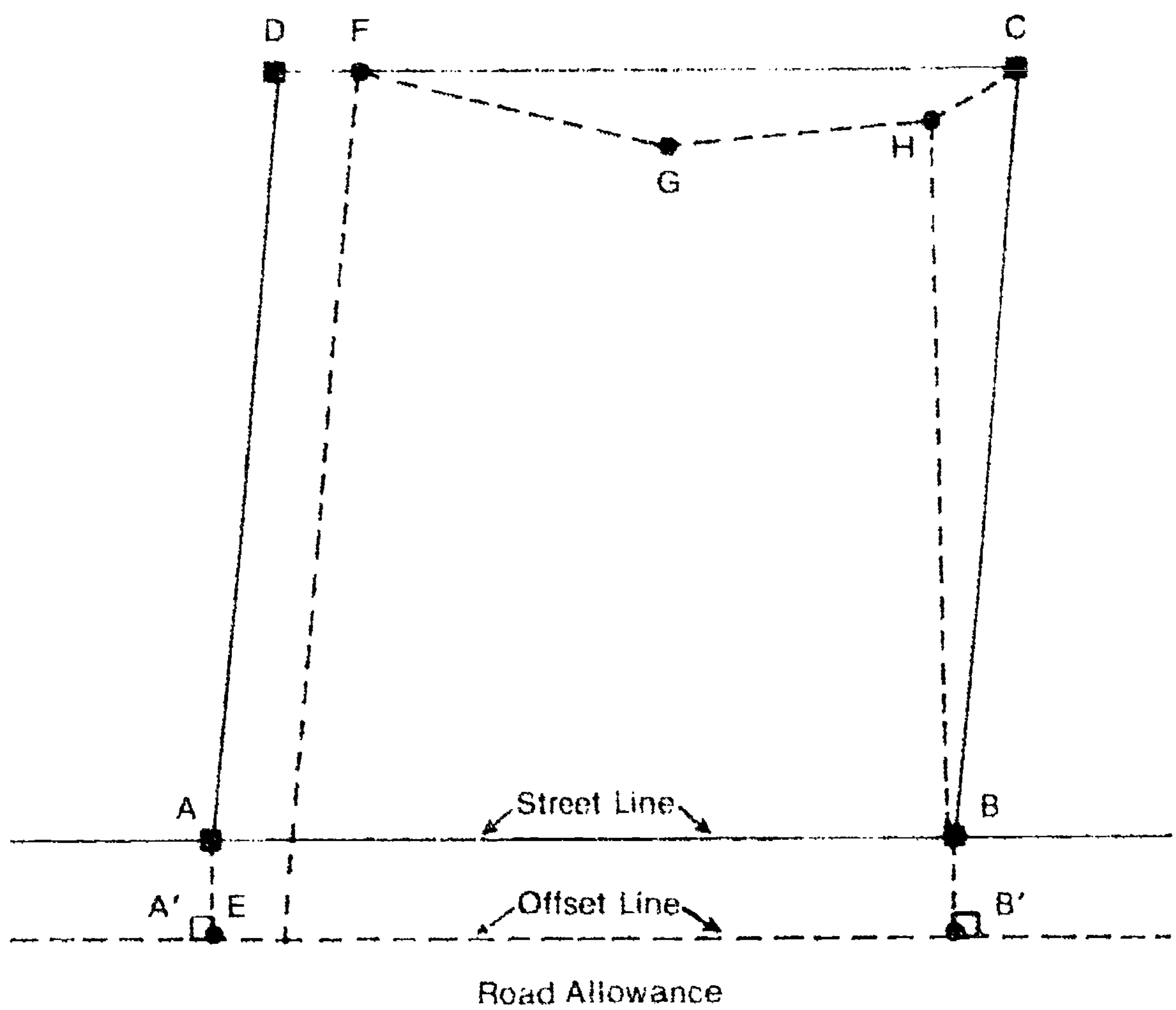
C. The property line adjacent to the street or highway must be determined.

(NOTE: If these points cannot be found, they in turn should be reestablished. Fences or trees sometimes may obstruct the work; therefore, offset lines or random lines are commonly used. See Figure 6.)

FIGURE 6



D. The other corners are established by a variety of field methods.

1. Locating the actual corner

2. Establishing random offset lines and setting offset reference points

   (NOTE: Many methods used can only be discovered through years of field experience by a professional land surveyor.)

E. The distances and angles are measured and carefully recorded in the field notes.

INFORMATION SHEET

F. The rectangular coordinates of each property corner are calculated.

G. A plan of the property boundaries is drawn showing

   1. Bearings of lines
   2. Distances between corners
   3. Monumentation found
   4. Monumentation set
   5. Reference points or ties to corners

H. The area of the parcel is calculated and shown on the plan drawing.

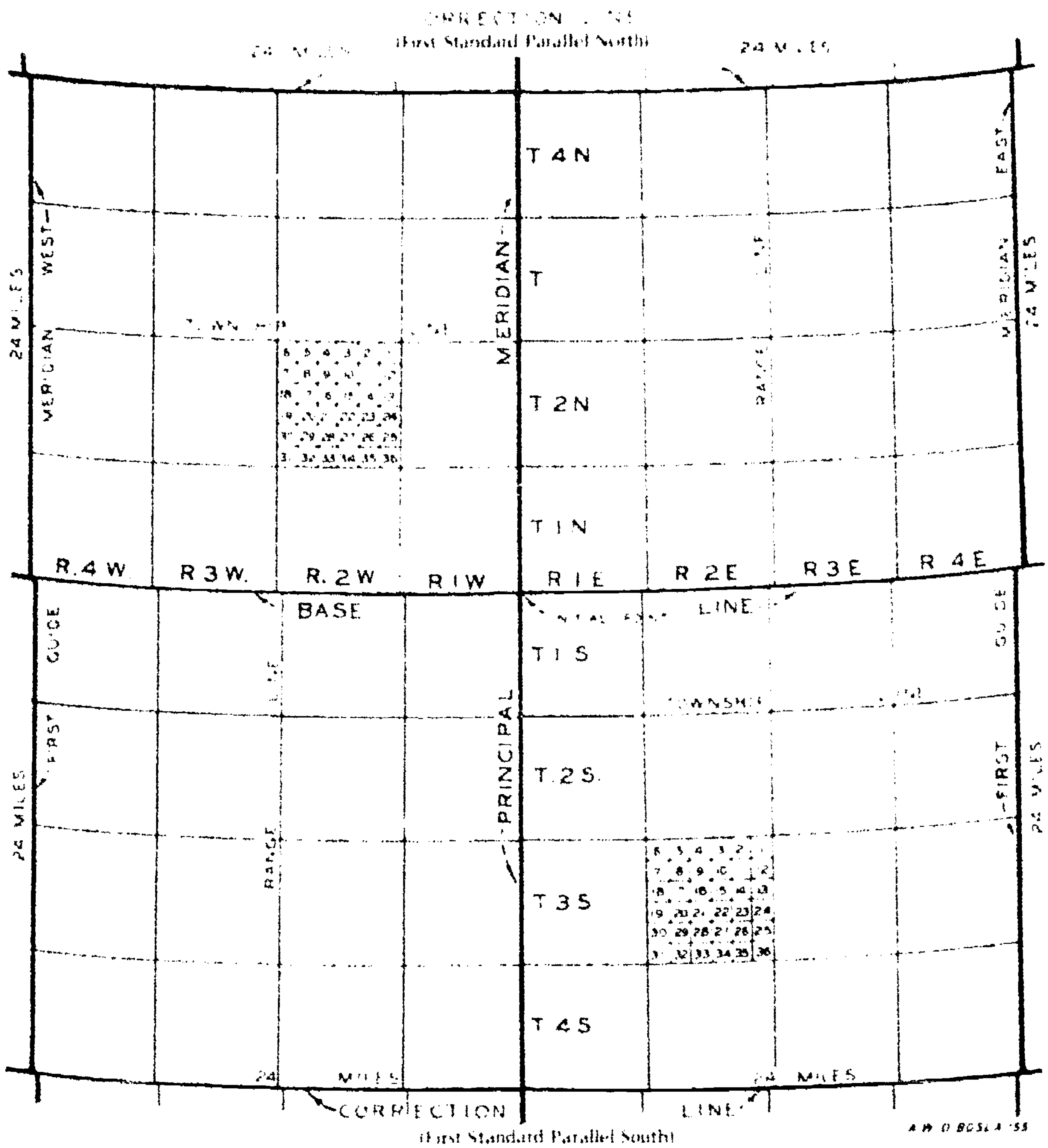
I. A deed description is prepared using one of the standard methods.

   1. Public land survey system method
   2. Metes and bounds method
   3. Lot and block method
   4. State plane coordinate method

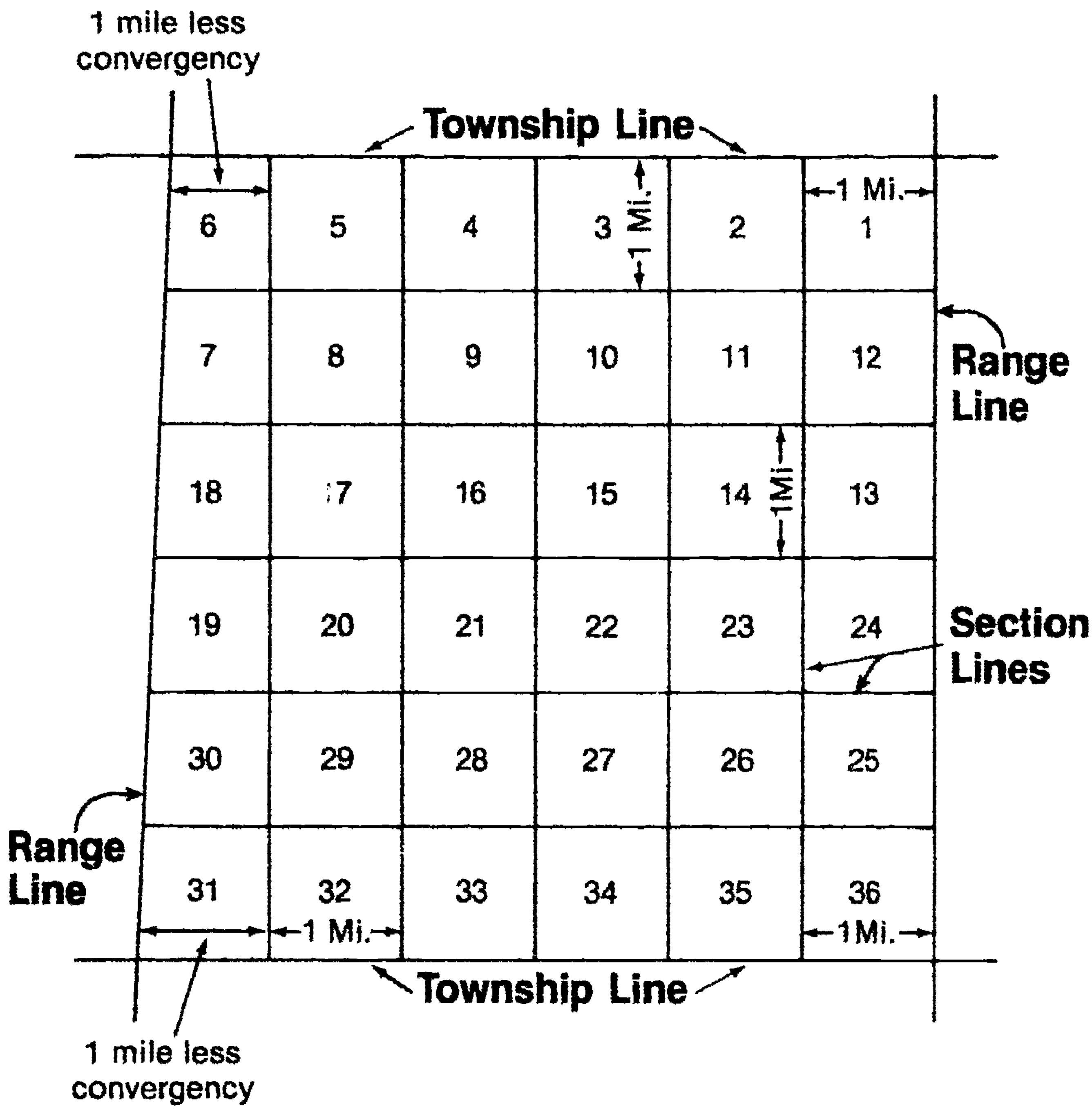
J. A deed description and survey plan is submitted to the client and to the local county registry office.

(NOTE: Rural or urban surveys are very similar in methods of surveying. Urban surveys or mortgage surveys may require verification of possible encroachment of any buildings or structures on the parcel. In either case, structures are normally located in reference to the boundaries of the parcel.)

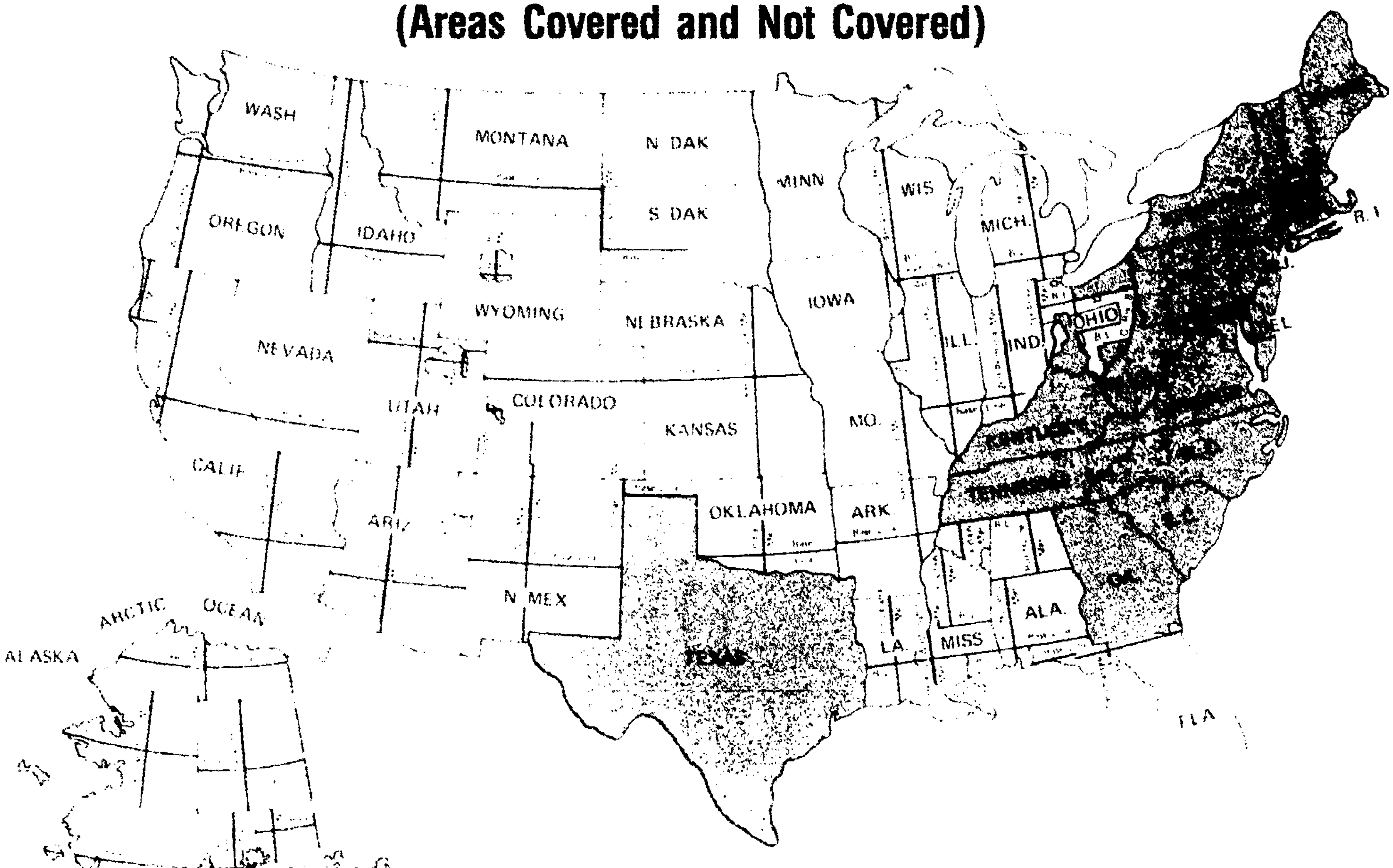
U.S. Public Land Survey System



Sections


1 mile less convergency
Township Line
6
5
4
3
1 Mi.
2
1 Mi.
1
7
8
9
10
11
12
Range Line
18
17
16
15
14
1Mi
13
19
20
21
22
23
24
Section Lines
30
29
28
27
26
25
Range Line
31
32
1 Mi.
33
34
35
36
1Mi.
Township Line
1 mile less convergency

Public Land Survey System
(Areas Covered and Not Covered)



Areas shaded are not subdivided under this sytem. Texas has a rectangular system similar to the public land survey system.

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HANDOUT #1 — PRINCIPAL MERIDIANS

Meridian	Adopted	Governing Surveys (wholly or in part) in States of	Initial Points: Latitude °	′	″	Longitude °	′	″
Black Hills	1878	South Dakota	43	59	44	104	03	16
Boise	1867	Idaho	43	22	21	116	23	35
Chickasaw	1833	Mississippi	35	01	58	89	14	47
Choctaw	1821	...do	31	52	32	90	14	41
Cimarron	1881	Oklahoma	36	30	05	103	00	07
Copper River	1905	Alaska	61	49	04	145	18	37
Fairbanks[1]	1910	...do	64	51	50.048	147	38	25.949
Fifth Principal	1815	Arkansas, Iowa, Minnesota, Missouri, North Dakota, and South Dakota	34	38	45	91	03	07
First Principal	1819	Ohio and Indiana	40	59	22	84	48	11
Fourth Principal	1815	Illinois	40	00	50	90	27	11
do	1831	Minnesota and Wisconsin	42	30	27	90	25	37
Gila and Salt River	1865	Arizona	33	22	38	112	18	19
Humboldt	1853	California	40	25	02	124	07	10
Huntsville	1807	Alabama and Mississippi	34	59	27	86	34	16
Indian	1870	Oklahoma	34	29	32	97	14	49
Kateel River[2]	1956	Alaska	65	26	16.374	158	45	31.014
Louisiana	1807	Louisiana	31	00	31	92	24	55
Michigan	1815	Michigan and Ohio	42	25	28	84	21	53
Mount Diablo	1851	California and Nevada	37	52	54	121	54	47
Navajo	1869	Arizona	35	44	56	108	31	59
New Mexico Principal	1855	Colorado and New Mexico	34	15	35	106	53	12
Principal	1867	Montana	45	47	13	111	39	33
Salt Lake	1855	Utah	40	46	11	111	53	27
San Bernardino	1852	California	34	07	13	116	55	48
Second Principal	1805	Illinois and Indiana	38	28	14	86	27	21
Seward	1911	Alaska	60	07	37	149	21	26
Sixth Principal	1855	Colorado, Kansas, Nebraska, South Dakota, and Wyoming	40	00	07	97	22	08
St. Helena	1819	Louisiana	30	59	56	91	09	36
St. Stephens	1805	Alabama and Mississippi	30	59	51.463	88	01	21.076
Tallahassee	1824	Florida and Alabama	30	26	03	84	16	38
Third Principal	1805	Illinois	38	28	27	89	08	54
Uintah	1875	Utah	40	25	59	109	56	06
Umiat[3]	1956	Alaska	69	23	29.654	152	00	04.551
Ute	1880	Colorado	39	06	23	108	31	59
Washington	1803	Mississippi	30	59	56	91	09	36
Willamette	1851	Oregon and Washington	45	31	11	122	44	34
Wind River	1875	Wyoming	43	00	41	108	48	49

[1] U.S.C. & G.S. station "Initial 1941" is located S. 66° 44′ E. 2.85 feet distant from the initial point of the Fairbanks Meridian. The geodetic station (latitude 64° 51′ 50.037″ N., longitude 147° 38′ 25.883″ W.) was inadvertently used as the origin from which to compute positions on the Fairbanks Meridian protraction diagrams.

[2] The Kateel River initial point is identical with U.S.C. & G.S. station "Jay, 1953".

[3] The Umiat initial point is identical with U.S.C. & G.S. station "Umiat, 1953." Positions are as published by the United States Coast and Geodetic Survey.

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HANDOUT #2 — SUBDIVISION STEPS

ITEM	SUBDIVISION OF A TRACT	SUBDIVISION OF A TOWNSHIP
Starting point	SE corner of SW township	SW corner of SE section (36)
Meridional lines		
Name	Range line	Section line
Direction	True north	North, parallel with east range line
Length	6 mi = 480 ch	1 mi = 80 ch
Corners set	Quarter-section and section corners at 40 and 80 ch alternately	Quarter-section corner at 40 ch; section corner at 80 ch
Latitudinal lines		
Name	Township line	Section line
Direction of random	True east-west parallel	East, parallel with south side of section
Length	6 mi less convergence	1 mi
Permissable error	3 ch, length or falling	50 lk, length or falling
Distribution of error		
Falling	Corners moved proportionately from random to true line	Corners moved proportionately from random to true line
Distance	All error thrown into west quarter-section	Error divided equally between quarter-sections

[Work repeated until north side of area is reached. Subdivision of last area on the north of the range of townships and sections follows.]

CASE I. WHEN LINE ON THE NORTH IS A STANDARD PARALLEL

ITEM	SUBDIVISION OF A TRACT	SUBDIVISION OF A TOWNSHIP
Direction of line	True north	North, parallel with east range line
Distribution of error in length	Placed in north quarter-section	Placed in north quarter-section
Corner placed at end	Closing corner	Closing corner
Permissable errors	Specified in *Manual of Surveying Instructions*	Specified in *Manual of Surveying Instructions*

CASE II. WHEN LINE ON THE NORTH IS NOT A STANDARD PARALLEL

ITEM	SUBDIVISION OF A TRACT	SUBDIVISION OF A TOWNSHIP
Direction of line	No case	Random north and correct back to section corner already established
Distribution of error in length		Same as case I

[Other ranges of townships and sections continued until all but two are laid out.]

ITEM	SUBDIVISION OF A TRACT	SUBDIVISION OF A TOWNSHIP
Location of last two ranges	On east side of tract	On west side of township
Next-to last range subdivided	As before	As before
Last range		
Direction of random	True east	Westerly, parallel with south side of section
Nominal length	6 mi less convergence	1 mi less convergence
Correction for temporary corners	Corners moved proportionately from random to true line	Corners moved proportionately from random to true line
Distribution of error of closure	Corners moved westerly (or easterly) to place error in west quarter-section	Corner placed on the true line so that total error falls in west quarter-section

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ASSIGNMENT SHEET #1 — ANSWER QUESTIONS BASED ON THE PUBLIC LAND SURVEY SYSTEM

Directions: Using the U.S.G.S. 7.5 minute quadrangle map provided by your instructor, answer the following questions:

Questions

1. The scale of this maps is________________________________

2. The map series is________________________________

3. The contour interval is________________________________

4. Date of issue________________________________

5. Magnetic declination at date of issue________________________________

6. Year(s) of original survey________________________________

7. Year of revised (updated) survey________________________________

8. What would be the next map to the

   south:________________________________

   west:________________________________

   north:________________________________

   east:________________________________

   SE:________________________________

   SW:________________________________

   NW:________________________________

   NE:________________________________

9. In parts, what range(s) is covered by the map?________________

10. In parts, what township(s) is covered by the map?________________

11. Approximately how many square miles are covered by this map?________________

12. Choose three cultural locations such as church, water tank, etc., and give the legal description of each location.

    ____

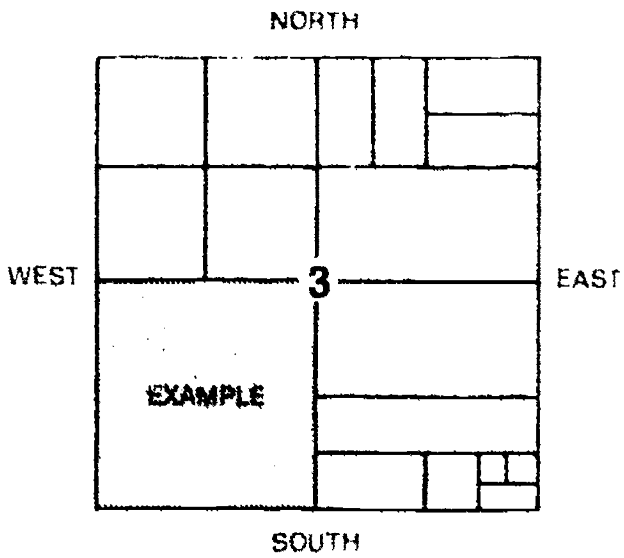
BOUNDARY SURVEYING
UNIT XI

ASSIGNMENT SHEET #2 — WRITE AND LOCATE DESCRIPTIONS FOR THE SUBDIVISION OF A SECTION

PART I — WRITE DESCRIPTIONS FOR THE SUBDIVISION OF A SECTION

Directions: Write the legal description and acreage of the shaded area of each section given.

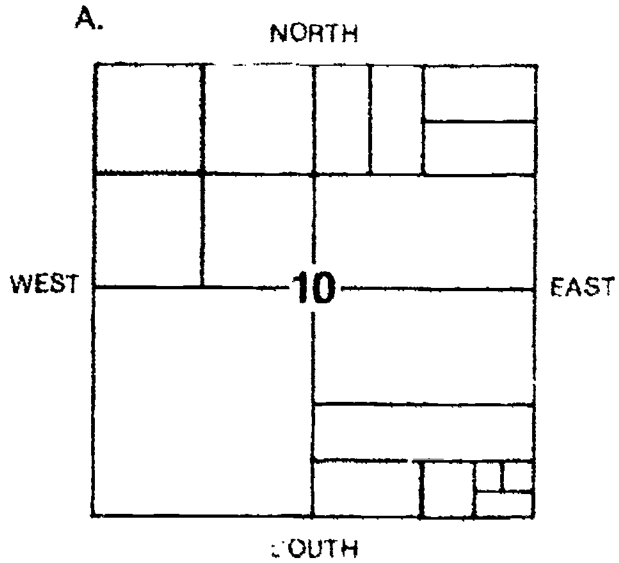
Example:



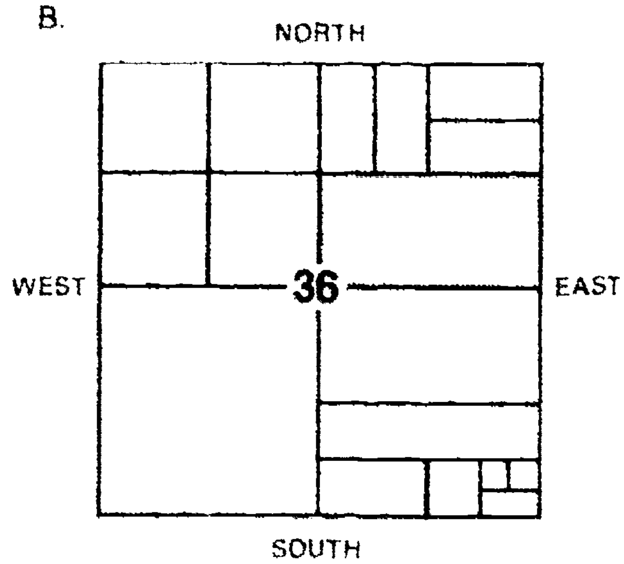
SW ¼, SECTION 3

ACRES: 160

A.



B.



A. ______________________

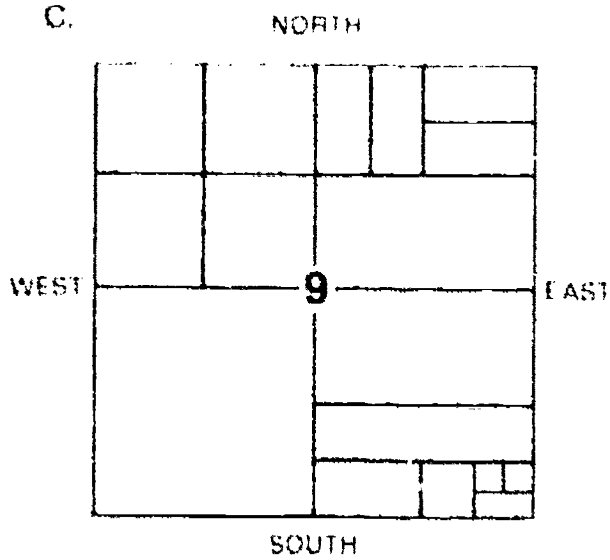
ACRES: ______________

B. ______________________

ACRES: ______________

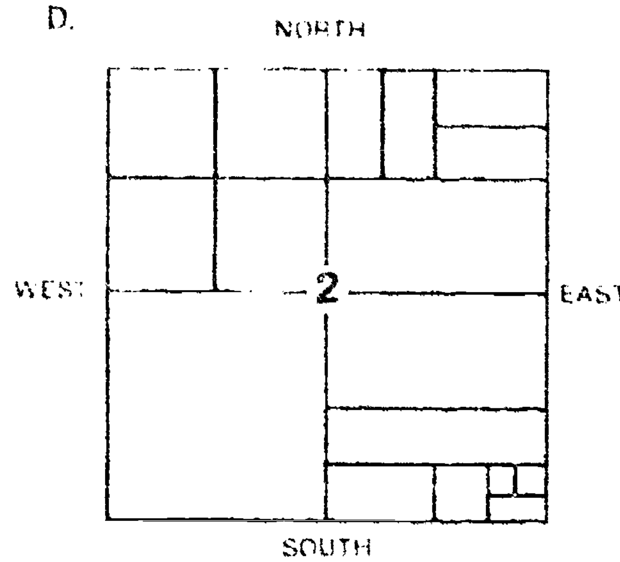
ASSIGNMENT SHEET #2

C.



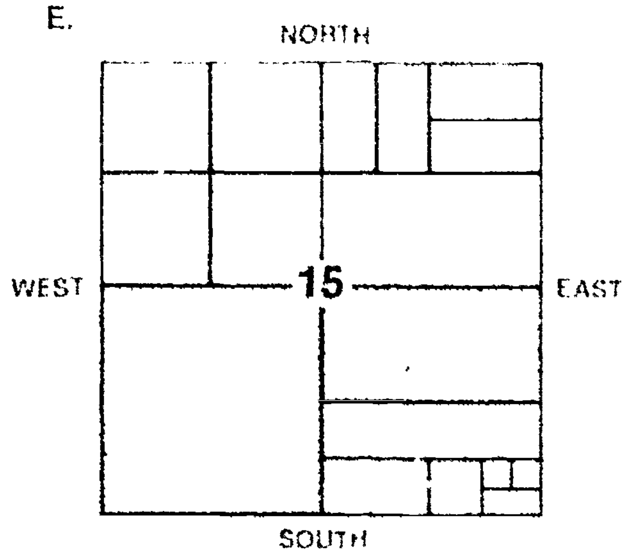
ACRES:

D.



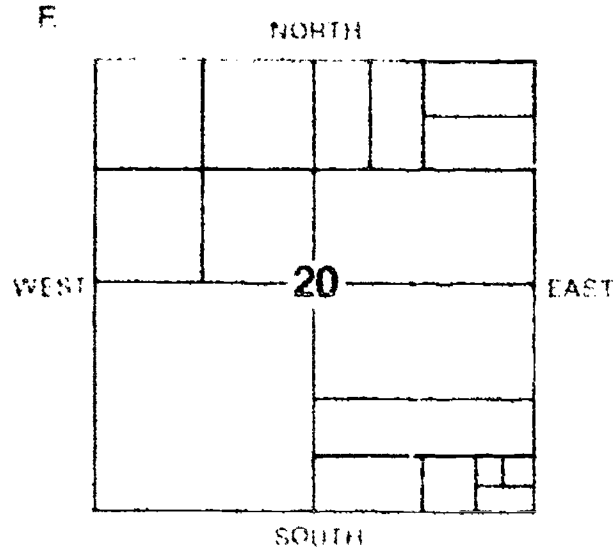
ACRES:

E.



ACRES:

F.



ACRES:

ASSIGNMENT SHEET #2

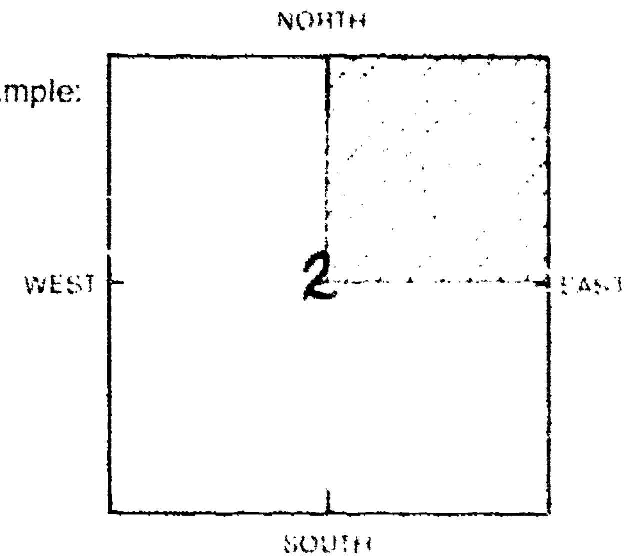
PART II — LOCATE SUBDIVISION OF A SECTION

Directions: The illustrations given are blocks that represent sections and legal descriptions. Using the descriptions given, do the following:

1. Label the section number in the center of section.
2. Subdivide each section according to the legal description. Shade this area in.
3. Give acreage of the shaded area in space provided.

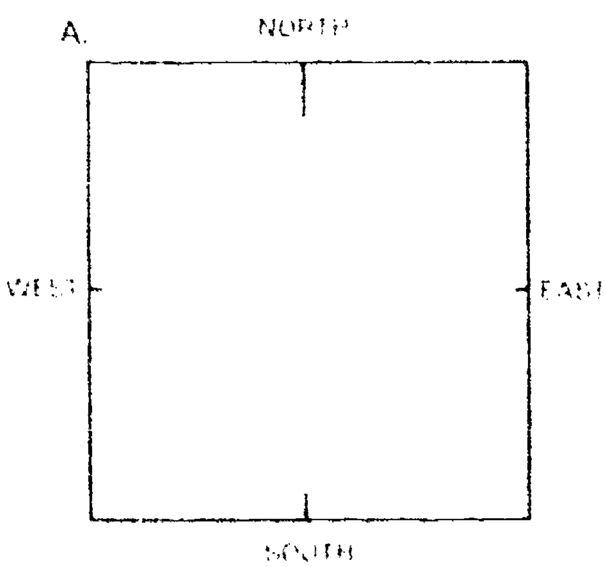
Given Descriptions
Example: NE ¼, SECT 2
A. SE ¼, SE ¼, SECT 10
B. N ½, NE ¼, SECT 31
C. SW ¼, NW ¼, SW ¼, SECT 7
D. SE ¼ & S ½, NE ¼, SECT 23
E. N ½, SECT 5
F. S ½, NE ¼, SW ¼, SECT 16

Example:



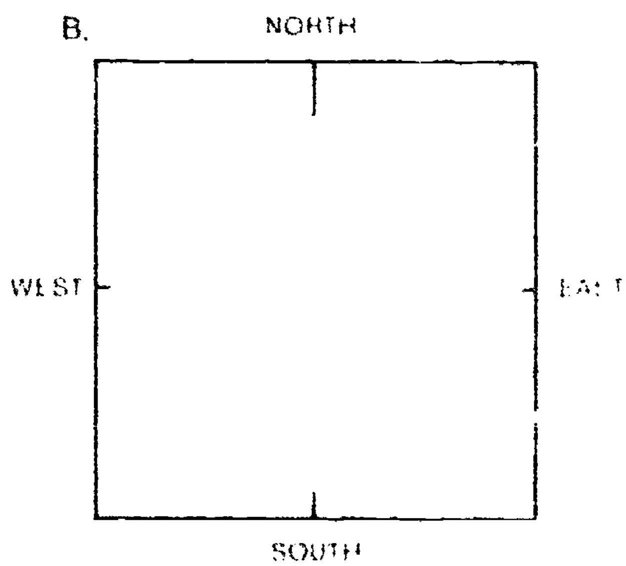
ACRES: 160

A.



ACRES:__________

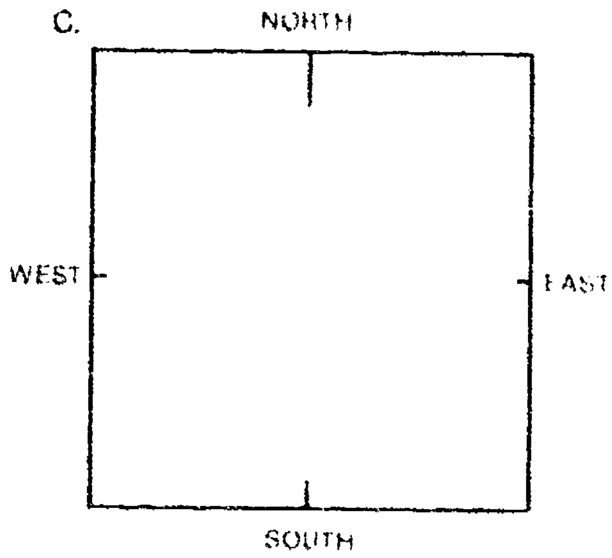
B.



ACRES:__________

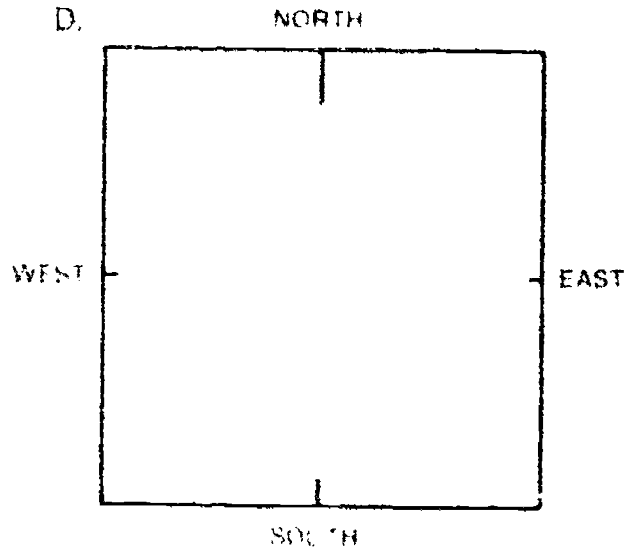
ASSIGNMENT SHEET #2

C.



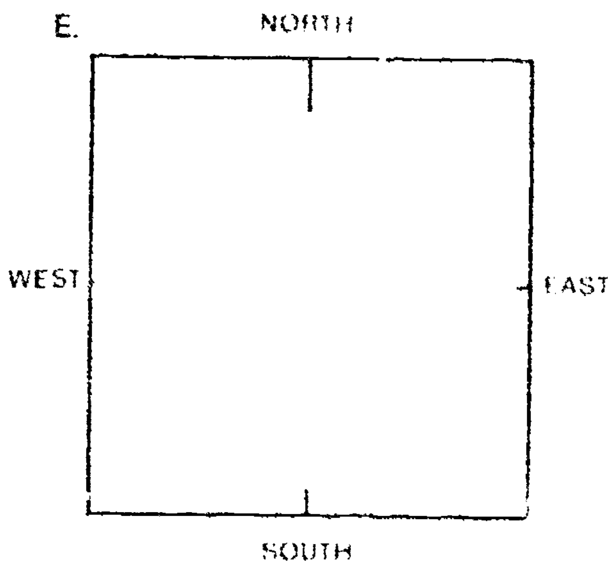
ACRES:____________________

D.



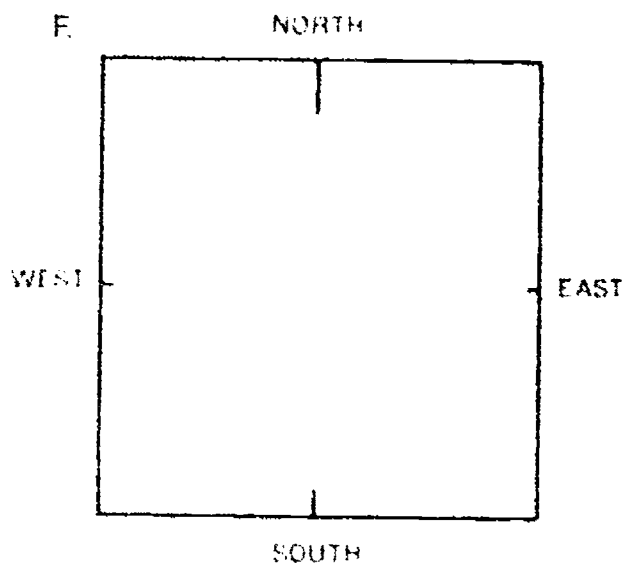
ACRES:____________________

E.



ACRES:____________________

F.



ACRES:____________________

BOUNDARY SURVEYING
UNIT XI

ASSIGNMENT SHEET #3 — RESEARCH AND OBTAIN DEED DESCRIPTIONS OF AN ASSIGNED TRACT OF LAND

Directions:

1. Visit your local county courthouse, register of deed office.

2. Have someone help you locate the original plat and description of the parcel assigned by your instructor using one of the following:

   a. Legal descripton

   b. Sectional description

   c. Parcel number

3. Recopy the legal description.

4. Record the original surveyor.

5. Record the date of the original survey.

6. Note any encumbrances.

7. Retrace any sales of property or transfer of ownership.

BOUNDARY SURVEYING
UNIT XI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1 -- Answers will vary depending on which U.S.G.S. 7.5 minute quadrangle map is used. Evaluate accordingly.

Assignment Sheet #2

PART I

A. NW 1/4, NW 1/4, SECT 10 (40 acres)

B. S 1/2, NE 1/4, SECT 36 (80 acres)

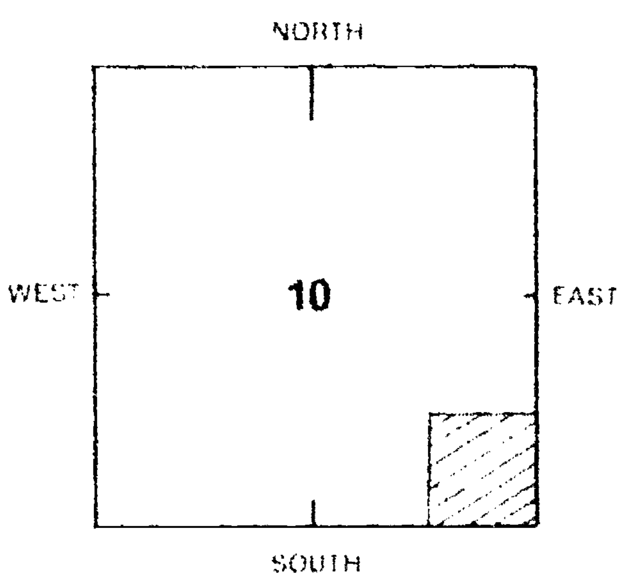
C. N 1/2, S 1/2, SE 1/4, SECT 9 (40 acres)

D. E 1/2, NW 1/4, NE 1/4, SECT 2 (20 acres)

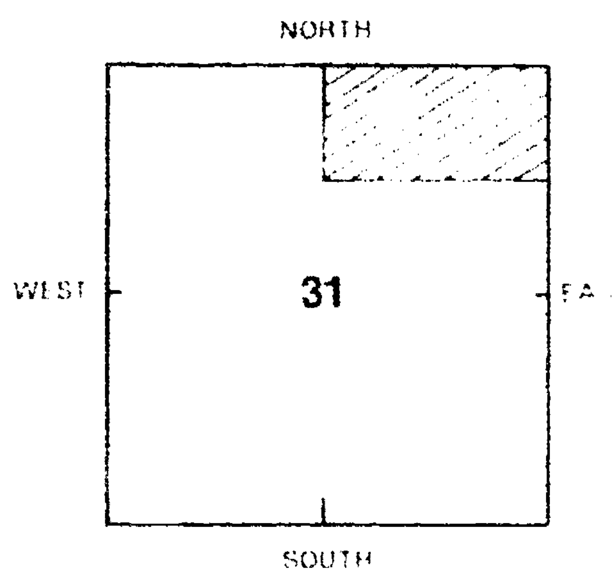
E. SW 1/4 and N 1/2, SE 1/4, SECT 15 (240 acres)

F. N 1/2, NE 1/4, NE 1/4, SECT 20 (20 acres)

PART II

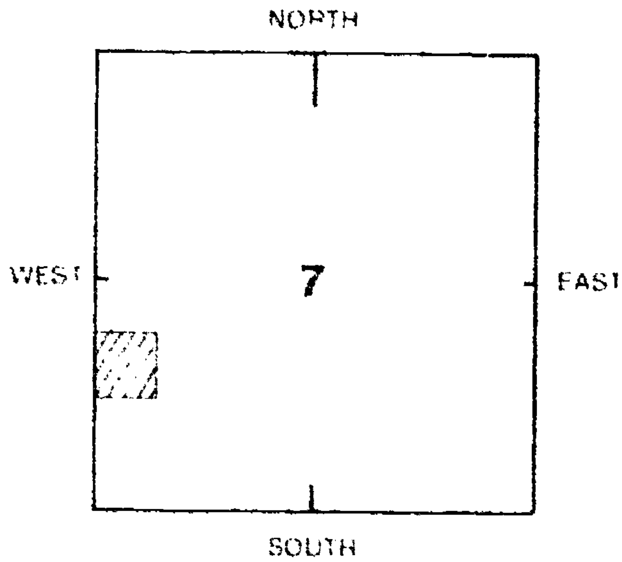


A. 40 acres

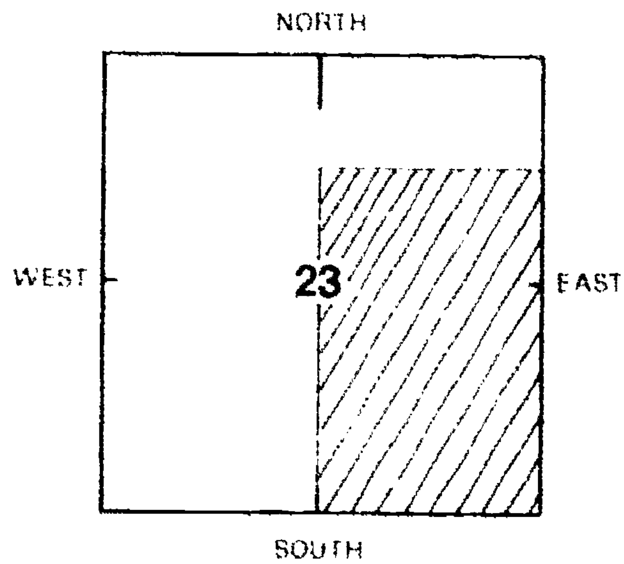


B. 80 acres

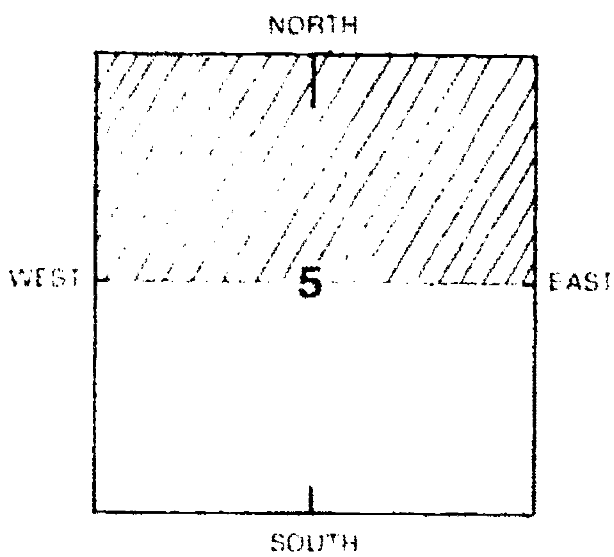
ANSWERS TO ASSIGNMENT SHEETS



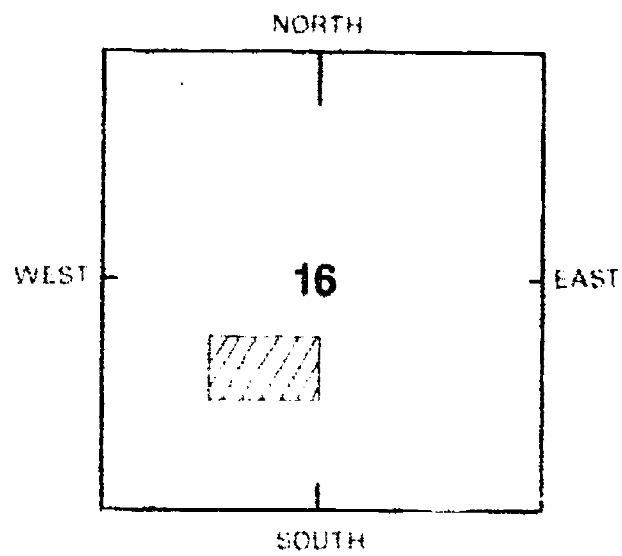
C. 10 acres



D. 240 acres



E. 320 acres



F. 20 acres

Assignment Sheet #3 — Evaluated to the satisfaction of the instructor.

BOUNDARY SURVEYING
UNIT XI

JOB SHEET #1 — RETRACE BOUNDARIES FROM A DEED DESCRIPTION

A. Tools and materials

1. Theodolite — transit (tripod)
2. Chain
3. Chaining pins
4. Range pole
5. Plumb bob
6. Metal locator
7. Shovel
8. Field book
9. Copy of deed description

B. Procedure

1. Obtain copy of deed from local county courthouse or register of deeds.

   a. Research parcel and adjacent properties for any recorded easements or encumbrances.

   b. Research adjacent property for any recorded monuments or ties to them.

2. Locate the parcel of land and briefly note any fences, agricultural markings, hedges, etc. that can sometimes indicate ownership.

3. Begin to retrace the property by locating one of the property corners and verifying its position.

   (NOTE: The corner could be below grade. A metal locator may be needed to find buried metal corner markers.)

4. Once this corner is found and marked, use the copy of the deed to retrace the distance and angle or bearing recorded on it to try to establish its adjacent corner.

JOB SHEET #1

5. Repeat this process from corner to corner around the perimeter of the tract.

   (NOTE: Many times, all corners cannot be found or some may be destroyed. Resetting of any corners should *only* be done by registered land surveyors or strictly under their direction.)

6. Once complete, check with your instructor to see if you should reference the tract to the nearest section or quarter corner with a horizontal distance.

BOUNDARY SURVEY [illegible]
UNIT X[illegible]

[illegible]

TEST

1. Match the terms on the right with the correct definitions.

_____a.	A survey line that follows the mean high water marks and is used for plotting and protraction of area only	1. Aliquot parts
_____b.	Smaller, identical parts or parcels of land divided from a large parcel of land used in subdivisions	2. Base line
_____c.	The meridian of longitude 0°, the meridian of Greenwich, England	3. Boundary survey
_____d.	A survey that is performed usually around a certain parcel of land to determine ownership and the legal location of ownership limits	4. Central meridian
_____e.	A principal parallel line that runs straight east and west that is used in establishing the rectangular public land system of land descriptions; is run astronomically by surveyors	5. Deed
_____f.	Legal document which specifies the ownership of the land	6. Land survey
_____g.	A survey that locates property corners and boundary lines; usually closed with a traverse	7. Legal description
_____h.	A method used when locating property corners of effectively distributing an excess or deficiency of error within the distance to the nearest monument found	8. Longitude
_____i.	Permanent object that marks established points	9. Meander line
_____j.	A survey line that is run knowing that it is not exactly in the correct position but once established, calculated right angle offsets can be calculated to determine the true line	10. Meridian
_____k.	A meridian established as a basis for establishing a reference line for the origination of the rectangular system	11. Monument

TEST

_____l.	Line of longitude that runs straight north and south; is run astronomically by surveyors	12. Parcel number
_____m.	A written statement recognized by law as a definite location of a tract of land by reference to a survey, recorded map, or adjoining property	13. Prime meridian
_____n.	The line of longitude at the center of a projection	14. Principal meridian
_____o.	A preliminary survey used to obtain information about a specific site	15. Prorating or proportioning
_____p.	A method of identifying a specific parcel within a tract of land	16. Protracting
_____q.	A type of land survey in which the legal boundaries of an area are located and the area is divided into parcels of lots, streets, right-of-ways, etc.	17. Public domain (lands)
_____r.	The division of a township such as into a section, half section, quarter section, quarter-quarter section, or sixteenth section or lotting, section, township, and range numbers and the description of the principal meridian to which referred	18. Random line
_____s.	Any or all of those areas of land ceded to the federal government by the original states and to such other lands as were later acquired by treaty, purchase, or cession and are disposed of only under the authority of Congress	19. Reconnaissance
_____t.	Arc distance measured in degrees east and west from the prime meridian	20. Resection
_____u.	The process of plotting the interior, unsurveyed boundaries of an official plat	21. Subdivision (USPLS)
_____v.	A method of locating a point by measuring angles between a point of known location from the point in question	22. Subdivision survey

2. List three purposes of a boundary survey.

a. ____

b. ____

c. ____

TEST

3. Match the types of boundary surveys on the right with the correct definitions.

_____a. Subdivide land into more or less regular tracts in accordance with a prearranged plan

_____b. Usually performed when a tract has not been previously surveyed and is being transferred from one owner to another

_____c. Reestablish the boundaries of a tract of land for which a survey has previously been made

_____d. The surveyor is guided by a description based upon the original survey and by evidence on the ground

_____e. Usually performed when large tracts of land are divided into many parcels for development by several individual owners

_____f. Measure unknown lengths and directions of boundaries not previously established

1. Original surveys
2. Resurveys
3. Subdivision surveys

4. Select the following true statements concerning legal interpretation of evidence by placing an "X" next to the true statements.

_____a. The universal principle of law endeavors to make the deed effectual rather than void, and to execute the actual "intent" of the contracting parties.

_____b. Monuments which mark the corners of the parties concerned are considered inadequate forms of evidence.

_____c. A corner established with a monument will prevail against all other forms of evidence, providing there is reason to believe the monument was set in accordance with the original intent and it has not been disturbed.

_____d. In case of conflicts among "calls" in the deed or dimensions on a recorded plat, bearings control over both distances and the area of the tract.

_____e. Obvious mistakes such as omissions of full tape lengths in a dimension or the transposition of words "northeast" for "northwest" will destroy the validity of a description even if it is otherwise complete and consistent.

_____f. In the case of a description having two or more interpretations, the one favoring the purchaser will prevail over any others

_____g. Land described as being bound by highways or streets conveys ownership up to 5 feet from the edge of the highway or street. Any variation from this must be explicitly stated in the description

_____h. Errors found in original government surveys do not affect the boundaries established under those surveys, and will remain fixed as originally established.

TEST

5. List four common types of monumentation found when setting boundary lines.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

6. Complete the following chart of abbreviations used for marking monuments.

a.	______	Amended (new corner position when old remains)	i.	R	______
b.	AP	______	j.	RM	______
c.	BO	______	k.	______	Standard corner
d.	______	Bearing tree	l.	______	Township
e.	CC	______	m.	______	Tract
f.	______	Mile	n.	WC	______
g.	______	Meander corner	o.	WP	______
h.	______	Public land (unsurveyed)			

7. Complete statements concerning the establishment of the U.S. public land survey system by circling the correct words.

a. There are (**25, 35**) principal meridians.

b. There are (**32, 35**) base lines.

c. Point of intersection of principal meridian and base is the beginning for the laying out of (**townships, sections**).

d. 24 miles squares are then established with (**correction lines, guide meridians**) to the north and south of the base line.

TEST

e. Township lines are (**north-south, east-west**) lines at six mile intervals parallel to the base line.

f. Range lines are (**north-south, east-west**) lines at six mile intervals parallel to the principal meridian.

g. A Congressional act in 1796 directed each township to be subdivided into (**24, 36**) sections.

h. Each section measures approximately (**one, six**) square mile(s).

i. The sections in each township are numbered consecutively with #1 in the (**north-west, northeast**) corner of the township.

j. Fractional sections border on the north and (**east, west**) of the township.

8. Select from the following list the states **not** subdivided under the U.S. public land survey system by placing an "X" in the appropriate blanks.

_____a. Tennessee

_____b. Texas

_____c. Mississippi

_____d. Georgia

_____e. Alabama

_____f. Virginia

_____g. Michigan

_____h. Pennsylvania

_____i. New York

_____j. Florida

_____k. Kansas

_____l. California

9. Complete statements concerning the subdivision of a section by circling the correct words.

a. In 1800 Congress directed that a section could be subdivided in (**north and south, east and west**) halves (320 acres each).

b. In 1805 Congress directed further subdivision into (**fractional, quarter**) sections and the monumenting of all those corners.

TEST

c. At later dates Congress directed further subdivision of the section. The quarter-quarter section of (**40, 80, 160**) acres is the smallest statutory division of regular sections.

d. Legal descriptions of land which follow the regular subdivision of a regular section must include the (**principal meridian, base line**), section, township, and range.

e. A helpful tip in reading a legal description of a section to locate a tract of land is to (**read it backwards, locate the township**).

f. A complete description always begins with the (**smallest, largest**) division.

10. Arrange in order the steps used for performing a boundary survey by placing the correct sequence numbers (1-10) in the appropriate blanks.

_____a. A plan of the property boundaries is drawn.

_____b. The distances and angles are measured and carefully recorded in the field notes.

_____c. A deed description and survey plan is submitted to the client and to the local county registry office.

_____d. A copy of the offer to purchase or any other document related to the property boundaries should be obtained.

__8__e. The area of the parcel is calculated and shown on the plan drawing.

_____f. The rectangular coordinates of each property corner are calculated.

_____g. The other corners are established by a variety of field methods.

_____h. A reference monument or corner to the township must be located or reestablished.

_____i. A deed description is prepared using one of the standard methods.

_____j. The property line adjacent to the street or highway must be determined.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

11. Answer questions based on the public land survey system. (Assignment Sheet #1)

12. Write and locate descriptions for the subdivision of a section. (Assignment Sheet #2)

13. Research and obtain deed descriptions of an assigned tract of land. (Assignment Sheet #3)

14. Demonstrate the ability to retrace boundaries from a deed description. (Job Sheet #1)

BOUNDARY SURVEYING
UNIT XI

ANSWERS TO TEST

1.
a.	9	i.	11	q.	22
b.	1	j.	18	r.	21
c.	13	k.	14	s.	17
d.	3	l.	10	t.	8
e.	2	m.	7	u.	16
f.	5	n.	4	v.	20
g.	6	o.	19		
h.	15	p.	12		

2. Any three of the following:
   a. To secure the necessary data for writing a legal description of the tract of land
   b. To define the boundaries of the property with visible objects
   c. To determine the area of a designated tract of land
   d. To reestablish the boundaries of a previously surveyed parcel of land
   e. To subdivide a tract of land into two or more parcels of land

3. a. 3
   b. 1
   c. 2
   d. 2
   e. 3
   f. 1

4. a, c, f, h

5. Any four of the following:
   a. A wrought-iron pipe, zinc coated, 2 in. inside diameter, 30 in. long. (The lower end is split for 4 or 5 in. and spread. A brass cap is fastened to the top. The pipe is filled with concrete. It is set with three-quarters of its length in the ground.)
   b. A durable native stone at least 20 by 6 by 6 in., set with three-quarters of its length in the ground
   c. A cross mark on surface rock
   d. A tablet set in surface rock
   e. A living tree when it occupies the position of the corner
   f. A steel rod
   g. A wooden post
   h. A deposit of charcoal or glass or any durable artificial material (called a memorial)

6.
a.	AM	i.	Range
b.	Angle point	j.	Reference monument
c.	Bearing object	k.	SC
d.	BT	l.	T
e.	Closing corner	m.	TR
f.	M	n.	Witness corner
g.	MC	o.	Witness point
h.	PL		

ANSWERS TO TEST

7. a. 35
   b. 32
   c. Townships
   d. Correction lines
   e. East-west
   f. North-south
   g. 36
   h. One
   i. Northeast
   j. West

8. a, b, d, f, h, i

9. a. East and west
   b. Quarter
   c. 40
   d. Principal meridian
   e. Read it backwards
   f. Smallest

10.

a.	7	f.	6
b.	5	g.	4
c.	10	h.	2
d.	1	i.	9
e.	8	j.	3

11.-13. Evaluated to the satisfaction of the instructor

14. Performance skills evaluated to the satisfaction of the instructor

CONTROL SURVEYS
UNIT XII

UNIT OBJECTIVE

After completion of this unit, the student should be able to distinguish between types of control surveys and reference datums, complete statements concerning FGCC accuracy standards, global positioning systems, and celestial observations, and determine the direction of a line by polar observation. Competencies will be demonstrated by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to control surveys with the correct definitions.
2. State the purpose of control surveys.
3. List items provided by established horizontal and vertical reference monuments.
4. Distinguish between the types of control surveys.
5. Distinguish between the types of reference datums.
6. Complete statements concerning the FGCC accuracy standards used in control surveys.
7. Select true statements concerning global positioning systems.
8. Distinguish between the techniques used in making d. pler observations.
9. Complete statements concerning inertial surveying systems.
10. Complete statements concerning state plane coordinates.

OBJECTIVE SHEET

11. Complete statements concerning celestial observations.

12. Calculate the azimuth of a line. (Assignment Sheet #1)

13. Demonstrate the ability to determine direction of a line by polar observation. (Job Sheet #1)

CONTROL SURVEYS
UNIT XII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheet.

H. Discuss and demonstrate the procedure outlined in the job sheet.

I. Integrate the following activities throughout the teaching of this unit:

1. Invite a land surveyor to discuss with the class the fundamentals and properties of state plane coordinates.
2. Have students make solar observations to determine direction of a line.
3. Have students write a research paper on "global positioning systems."
4. Obtain a copy of your state's information on state plane coordinates.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

H. Give test.

I. Evaluate test.

J. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1 — Lambert and Transverse Mercator Projections

2. TM 2 — Celestial Sphere

D. Handout #1 — State Mapping Grid Systems

E. Assignment Sheet #1 — Calculate the Azimuth of a Line

F. Answers to Assignment Sheet #1

G. Job Sheet #1 — Determine Direction of a Line By Polar Observation

H. Test

I. Answers to test

REFERENCES USED IN WRITING THIS UNIT

A. Kavanagh, Barry F., and S. J. Glenn Bird. *Surveying: Principles and Applications.* Reston, Virginia: Reston Publishing Co., Inc., 1984.

B. Brinker, Russell and P.R. Wolf. *Elementary Surveying.* 7th ed. New York: Harper & Row, 1984.

C. Davis, R.E., F.S. Foote, and J.H. Kelly. *Surveying.* 5th ed. New York: McGraw-Hill Book Company, 1966.

D. Kissam, Phillip. *Surveying for Civil Engineers.* New York: McGraw-Hill, 1976.

SUGGESTED SUPPLEMENTAL MATERIALS

A. Kissam, Phillip. *Surveying Practice.* 3rd ed. New York: McGraw-Hill, 1978.

B. Hoag, John S. *Fundamentals of Land Measurement.* Chicago, IL: Chicago Title Insurance Company, 1971.

CONTROL SURVEYS
UNIT XII

INFORMATION SHEET

I. **Terms and definitions**

A. Control fabric — A network of relatively permanent points that have been established with a higher level of accuracy and are used to reference various smaller surveys performed

B. Datum — Any level surface to which elevations are referred (for example, mean sea level)

C. Distortion — The measurable amount something has for an actual shape versus its true shape

D. Frequency -- The number of complete oscillations of an electromagnetic wave

E. Geodetic surveying — Surveying areas of the earth which are large that their curvature must be allowed for in cal ulations

F. Magnetic declination — The horizontal angle between the direction taken by a compass needle and geographic north

G. Satellite — A data collection device or a reflecting station that is placed in a specific orbit around the earth

H. eroid — A shape which is derived by mathematically revolving an el about the earth's polar axis

I. Triangulation -- A surveying technique that involves:

1. Precisely measuring a baseline as a starting side of a series of triangles

2. Determining each angle of the triangle using a precise theodolite

3. Measuring a subsequent side of one of the triangles as a check for all calculated distances performed

J. Trilateration -- Involves the solution of triangles by using only measured side lengths rather than measuring angles

II. **Purpose of control surveys** — To establish precise horizontal and vertical positions of reference monuments.

INFORMATION SHEET

III. **Items provided by established horizontal and vertical reference monuments**

A. Basis for originating subordinate surveys

B. Method of orienting topographic or hydrographic mapping

C. Basis for determining property boundary delineation

D. Control for route and construction planning, design, and layout

IV. **Types of control surveys**

A. Horizontal control

1. Used to establish geodetic latitudes and longitudes of stations

2. Field procedures include:

a. Triangulation

b. Precise traversing

c. Trilateration

d. Inertial and satellite doppler systems

e. Astronomical observations

B. Vertical control

1. Used to establish elevations for a network of monuments called bench marks

2. Field procedures include:

a. Barometric leveling

b. Trigonometric leveling

c. Differential leveling

d. Inertial and satellite doppler systems

V. **Types of reference datums**

A. Horizontal datums used in the United States

1. Use an initial point, Meades Ranch in Kansas, having known geodetic latitude and longitude.

2. Use a fixed azimuth from Meades Ranch to an intervisible point "Waldo."

INFORMATION SHEET

3. Use a spheroid of known dimensions referred to as the Clarke Spheroid of 1866.

   a. This datum as a framework was adjusted in 1927 and is referred to as the North American Datum of 1927 (NAD27).

   b. A readjustment of NAD27 is being presently done referred to as the North American Datum of 1983, utilizing a new spheroid called the Geodetic Reference System 1980 (GRS80).

   (NOTE: All horizontal observations used to establish more than 260,000 stations in the United States, Canada, and Central America will be simultaneously adjusted by the least squares method.)

B. Vertical datums for referencing bench marks

1. Are based on mean sea level

2. Datum used in the United States is the National Geodetic Vertical Datum of 1929 (NGVD29).

3. NGVD29 was obtained from a best fit of mean sea level observations taken at 26 gauging stations in the United States and Canada.

4. Since 1929, more than 625,000 km of additional control leveling have been run.

5. A current adjustment of all vertical datum bench marks is being performed and should be completed in 1988 and will be referred to as the North American Vertical Datum of 1988 (NAVD88).

VI. FGCC accuracy standards used in control surveys

A. Federal geodetic control committee (FGCC) has prepared a set of detailed classifications, standards of accuracy, and specifications.

1. To provide a uniform set of standards specifying minimum acceptable accuracies of control surveys, and

2. To establish specifications for instruments, field procedures, and misclosure checks to ensure that the intended order of accuracy is achieved

B. FGCC specified orders of accuracy (given in descending accuracy) are

1. First order

2. Second order

3. Third order

INFORMATION SHEET

C. Horizontal control accuracy standards

Order and Class	Relative Accuracy Required Between Directly Connected Adjacent Points
First order	1 part in 100,000
Second order	
Class I	1 part in 50,000
Class II	1 part in 20,000
Third order	
Class I	1 part in 10,000
Class II	1 part in 5,000

D. Vertical control accuracy standards

Order and Class	Relative Accuracy (Standard Error) Required Between Directly Connected Bench Marks
First order	
Class I	0.5 mm $\times \sqrt{K}$
Class II	0.7 mm $\times \sqrt{K}$
Second order	
Class I	1.0 mm $\times \sqrt{K}$
Class II	1.3 mm $\times \sqrt{K}$
Third order	2.0 mm $\times \sqrt{K}$
where K is the distance between bench marks in kilometers.	

(NOTE: Thus a total of 5 classifications are defined in the specifications for **both** horizontal and vertical control surveys.)

VII. Global positioning systems

A. The U.S. Navy Navigation Satellite System encircling the globe is called the transit system.

1. Five transit satellites are in polar orbit at an altitude of 1000 km.

2. System was originally designed for military guidance purposes. It has now been adopted by civil authorities for positioning applications.

   (NOTE: This system is rapidly changing with technical advances and increasing numbers of satellites in orbit.)

INFORMATION SHEET

3. Presently being replaced with the "Navstar" (Navigation Satellite Timing and Ranging) System.

    a. Comprised of 18 satellites

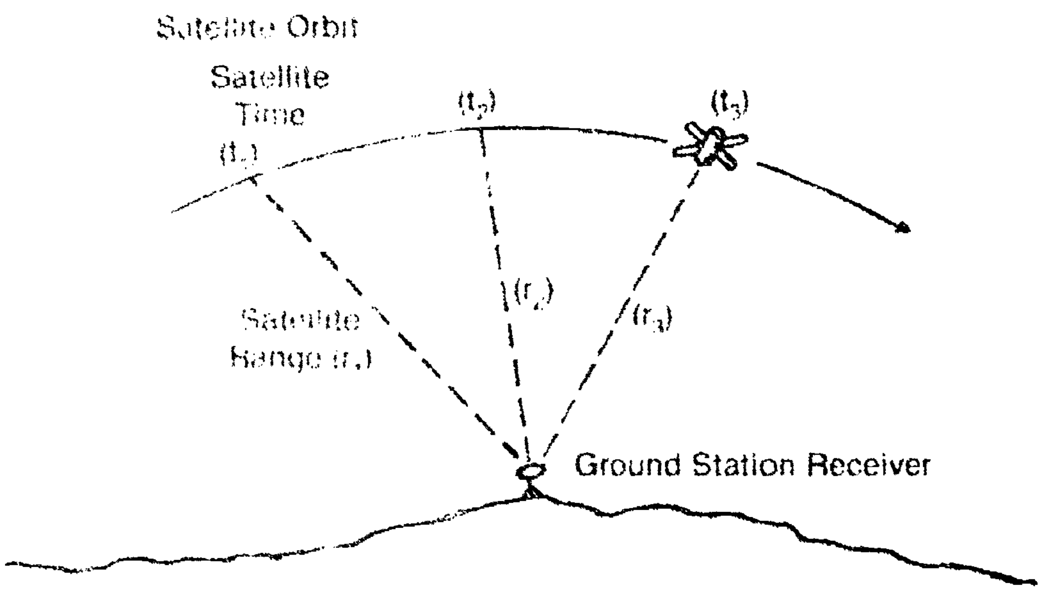
    b. Placed at an altitude of 2,000 km.

    c. Should be in full operation by 1987.

B. Satellite doppler systems

1. Receivers are located on the ground to measure the frequencies of radio signals transmitted from satellites operating in a polar orbit. (Figure 1)

FIGURE 1



2. The satellites circle the earth every 105 minutes sending out a steady transmitting frequency.

    (NOTE: A controlled frequency is transmitted from the satellite as it passes above the observer's station. As the frequency decreases from the satellite passing over, the position of the ground station can be calculated.)

3. Doppler systems are presently being used to augment and strengthen the national geodetic network

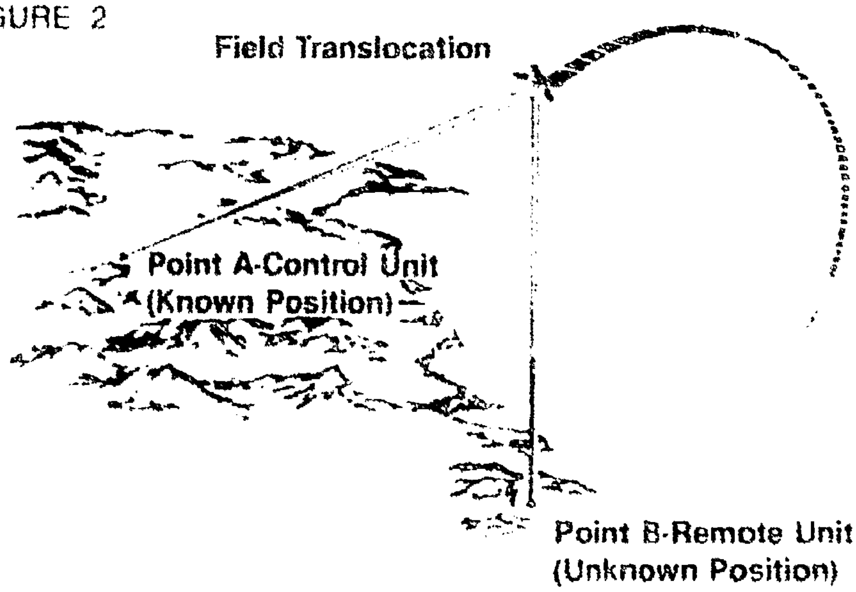
INFORMATION SHEET

VIII. **Techniques used in making doppler observations**

A. Point positioning -- A receiver at an unknown position collects data from a satellite making several passes.

B. Translocation -- Receivers at two or more stations simultaneously track the satellite. The position of one receiver must be known (Figure 2)

FIGURE 2



C. Short-arc -- Fundamentally the same as translocation, except corrections are made for the satellites orbital parameters.

IX. **Inertial surveying systems (ISS)**

A. Have revolutionized current control surveying practices.

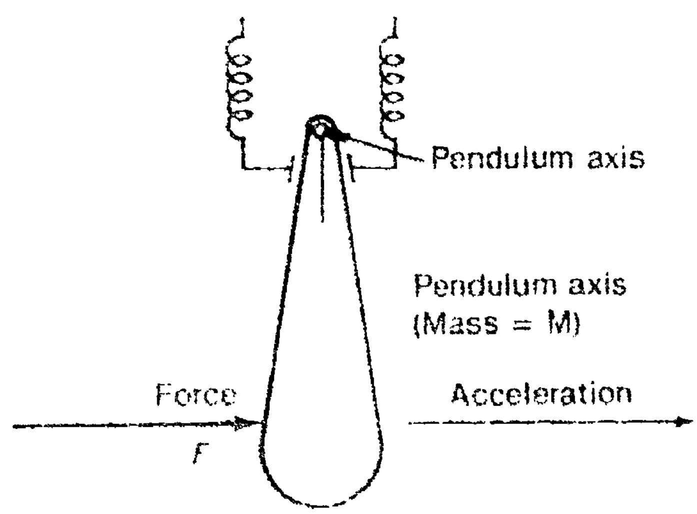
B. Are carried in helicopters or land vehicles.

C. Are oriented by a computer-controlled process called gyrocompassing. Gyros sense the earth's rotation and orient themselves facing north-south and east-west.

INFORMATION SHEET

D. Accelerometers (three are required) measure components of movement in the cardinal directions and in elevations as they are moved from point to point. (Figure 3)

FIGURE 3



E. Advantages and disadvantages of an inertial system

1. Advantages

   a. Equipment is refined and accuracies are improving.

   b. Do not require direct angle or distance measurements.

   c. Clear lines of sight are not necessary.

   d. Can operate day or night, rain or shine.

2. Disadvantages

   a. Initial costs are high

   b. Serviceability can be difficult.

   c. Operational costs are high

   d. High technological training is necessary.

   e. Will not presently meet high accuracy requirements for first order work.

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X. State plane coordinates

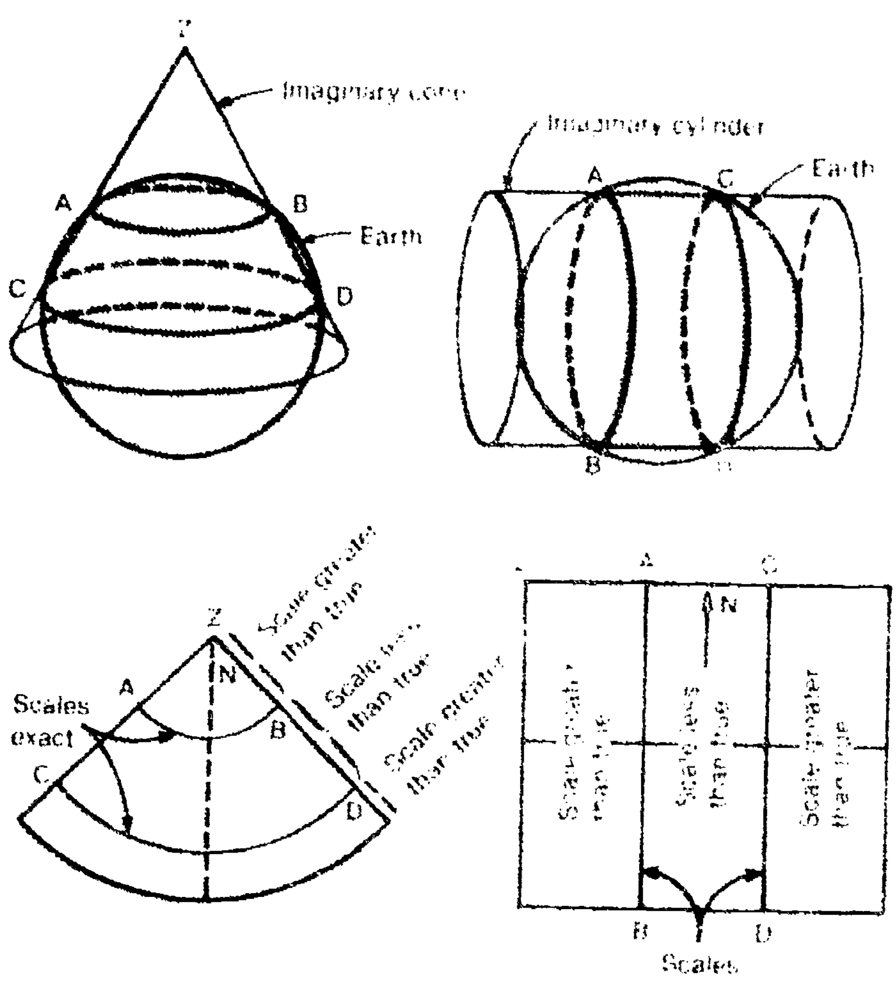
A. Were established in 1933 by the U.S. Coast and Geodetic Survey.

B. Use a rectangular grid designed to fit the curved shape of the earth to a plane surface with as little distortion as possible.

C. Are used for defining positions of geodetic stations in terms of plane rectangular (X and Y) coordinates.

D. All states have established by law a state plane coordinate system in either the Lambert projection or the transverse Mercator projection with one or more zones. (Figure 4, Transparency 1, and Handout #1)

FIGURE 4



Lambert Projection

Transverse Mercator Projection

E. Lambert and Mercator grid systems each select one true meridian (known as the central meridian).

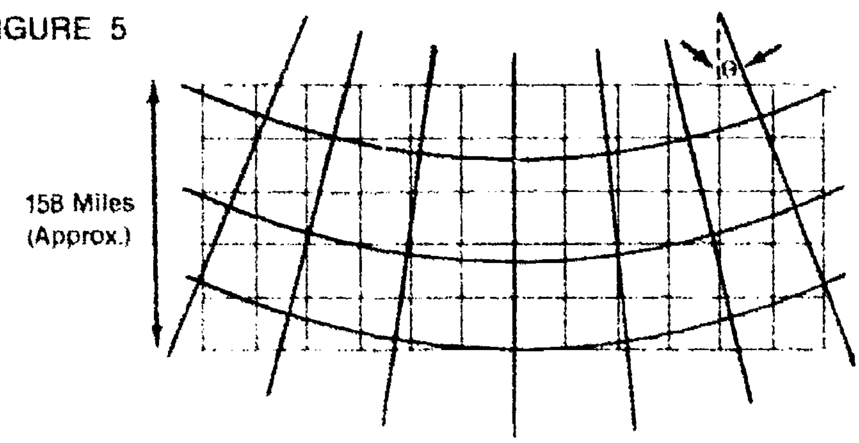
INFORMATION SHEET

F. All north-south lines of the grids are drawn parallel to the central meridian.

G. The Lambert projection grid assigns an X value at the central meridian (Y axis) of 2,000,000 ft and a Y value at the X axis of "0" ft.

H. The Lambert projection was limited to 158 miles (approx.) in the north-south direction to minimize distortion. (Figure 5)

FIGURE 5



Lines of latitude (parallels) and lines of longitude (meridians) on the Lambert projection grid.

I. The Mercator projection grid assigns an X value to the central meridian (Y axis) of 500,000 ft and a Y value to the X axis of "0" ft.

J. The transverse Mercator projection was limited to 158 miles (approx.) in the east-west width to minimize distortion.

K. Coordinates are based on sea level.

(NOTE: If the local survey is tied into coordinate grid points and is not at sea level, it is necessary to convert the geodetic lengths to ground level distances.)

L. Are used extensively for photogrammetric plotting and electronic surveying.

M. Scale error varies from zero up to about one part in 10,000.

N. Use of the state plane coordinate system depends on the availability of a sufficient number of geodetic control monuments to permit the determination of the grid position of points in the survey by plane surveying.

(NOTE: Consult N.G.S. state codes to determine the extent to which coordinates have been established, the form of designation assigned to them, and their legal connotation.)

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XI. **Celestial observations** (Transparency 2)

A. Polaris, commonly called the North Star

1. Has been used for centuries by sailors for navigation.

2. Is used by surveyors to establish astronomic directions on survey control lines.

3. Is useful because its apparent path of rotation keeps the stars very close to the extension of the earth's polar axis through the north pole.

B. Observations of the sun

1. Are usually more convenient than those of other stars because the sun can be observed during normal working hours.

2. Due to the size and speed at which the sun appears to move, directions that are based on solar observations are generally less precise than those taken on the stars.

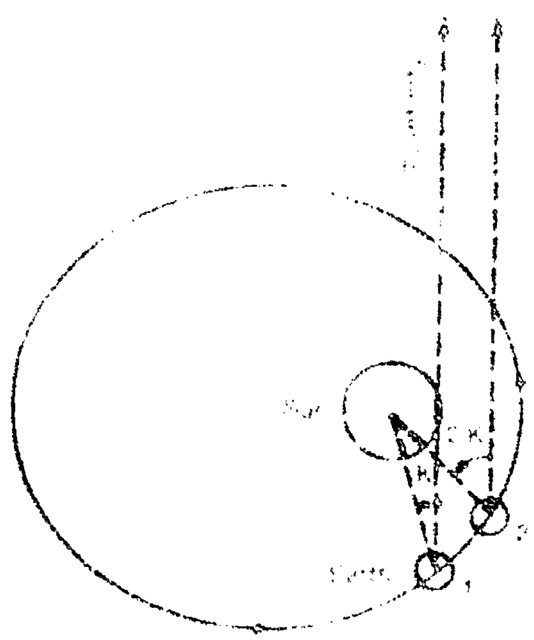
C. Time

1. One day is a complete revolution of the earth on its axis.

2. One solar day is 360° plus the partial revolution of angle K. (Figure 6)

(NOTE: Angle K is the partial revolution that the earth makes. For example, the earth makes 366.2422 revolutions on its axis while completing its annual orbit of the sun. The sum of all partial revolutions is equal to one day. Therefore, there are 365.2422 solar days in a year.)

FIGURE 6



Elliptical path of the earth around the sun

INFORMATION SHEET

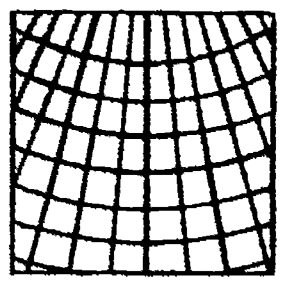
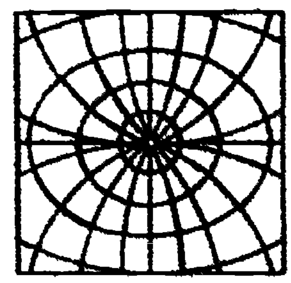
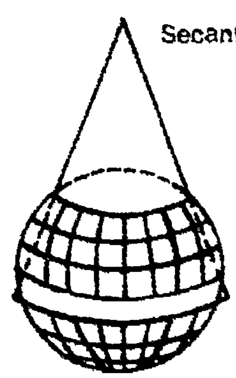
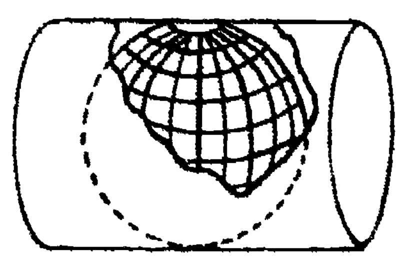
3. The earth makes 366.2422 revolutions on its axis while completing the annual solar orbit.

4. In 24 hours the earth revolves 360 degrees of longitudes and in 1 hour the earth revolves through 15° of longitude.

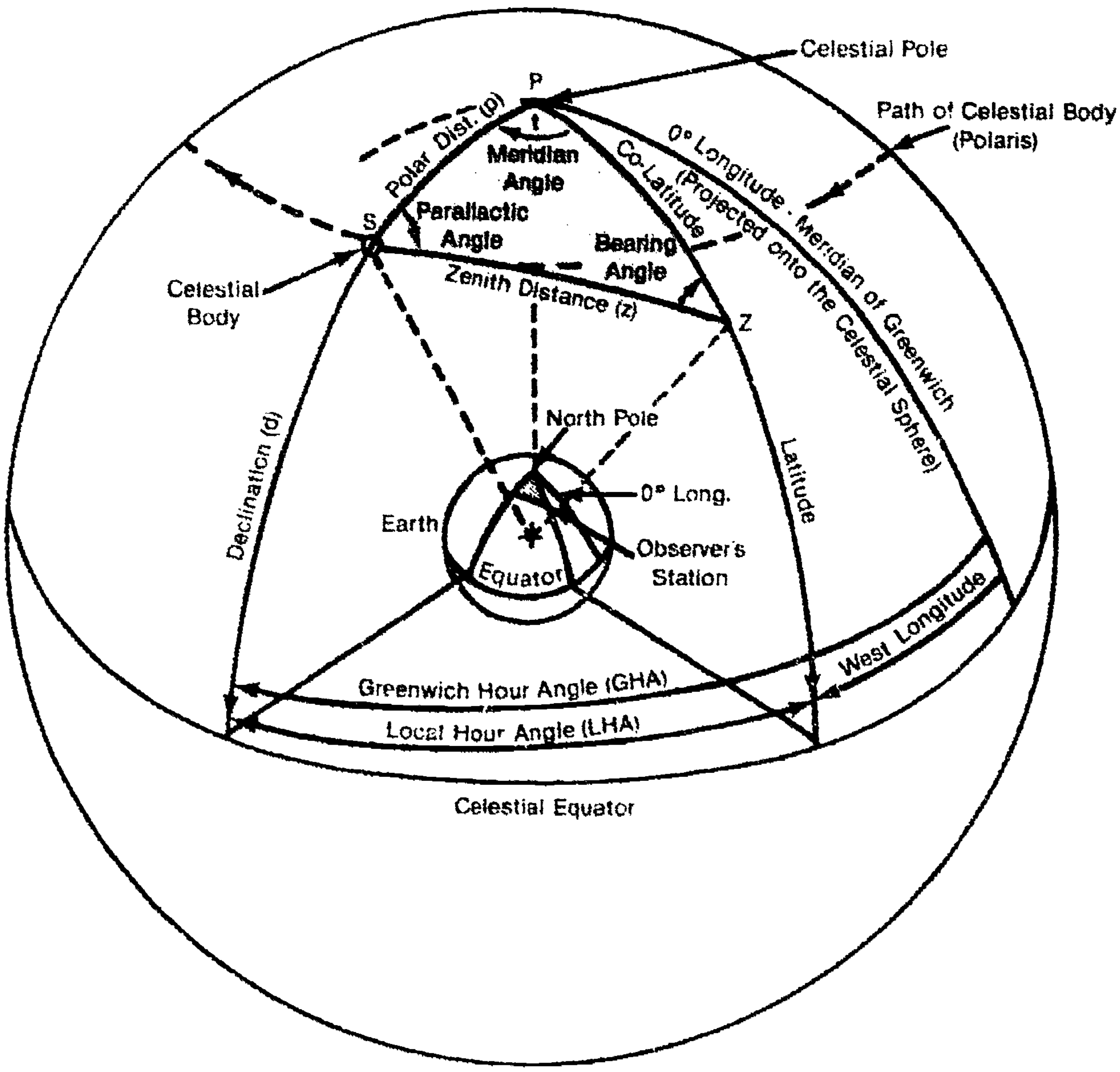
5. The relationship between time and longitude is summarized as follows:

24 hours = 360°	360° = 24 hours
1 hour = 15°	1° = 4 minutes
1 minute = 15′	1′ = 4 seconds
1 second = 15″	1″ = 0.067 seconds

Lambert and Transverse Mercator Projections

Characteristics	Lambert Conformal	Transverse Mercator
Parallels	Arcs of Concentric Circles Nearly Equally Spaced	Curves Concave Toward Nearest Pole
Meridians	Straight Lines Converging at the Pole	Complex Curves Concave Toward Central Meridian
Appearance of Grid		
Great Circle	Approximated by Straight Line	Curved Line
Rhumb Line	Curved Line	Curved Line
Distance Scale	Nearly Constant	Nearly Constant
Graphic Illustration	Secant Cone 	Cylinder Tangent Across Poles 
Origin of Projectors	Center of Sphere	Center of Sphere
Distortion of Shapes and Areas	Very Little	Increases Away from Meridian of True Scale

Celestial Sphere



Z = Observer's Zenith

t = LHA or (360°-LHA) whichever is Smaller

CONTROL SURVEYS
UNIT XII

HANDOUT #1 — STATE MAPPING GRID SYSTEMS

The mapping grid systems used in the United States vary from state to state, and in some cases, from state zone to state zone. The following is a listing of the states, their zones, and the grid system used per zone. It will be observed that there are two grid systems used in the United States: the Lambert conformal projection, and the transverse Mercator projection.

State and Zone	Mapping Grid System
Alabama	
eastern	transverse Mercator projection
western	transverse Mercator projection
Alaska	
zone 1	oblique transverse Mercator projection
zones 2-9	transverse Mercator projection
zone 10	Lambert conformal projection
Arizona	
eastern	transverse Mercator projection
central	transverse Mercator projection
western	transverse Mercator projection
Arkansas	
northern	Lambert conformal projection
southern	Lambert conformal projection
California	
zones 1-7	Lambert conformal projection
Colorado	
northern	Lambert conformal projection
central	Lambert conformal projection
southern	Lambert conformal projection
Connecticut	Lambert conformal projection
Delaware	transverse Mercator projection
Florida	
eastern	transverse Mercator projection
western	transverse Mercator projection
northern	Lambert conformal projection
Georgia	
eastern	transverse Mercator projection
western	transverse Mercator projection
Hawaii	
zones 1-5	transverse Mercator projection
Idaho	
eastern	transverse Mercator projection
central	transverse Mercator projection
western	transverse Mercator projection
Illinois	
eastern	transverse Mercator projection
western	transverse Mercator projection
Indiana	
eastern	transverse Mercator projection
western	transverse Mercator projection
Iowa	
northern	Lambert conformal projection
southern	Lambert conformal projection

State and Zone	Mapping Grid System
Kansas	
northern	Lambert conformal projection
southern	Lambert conformal projection
Kentucky	
northern	Lambert conformal projection
southern	Lambert conformal projection
Louisiana	
northern	Lambert conformal projection
southern	Lambert conformal projection
Maine	
eastern	transverse Mercator projection
western	transverse Mercator projection
Maryland	Lambert conformal projection
Massachusetts	
mainland	Lambert conformal projection
island	Lambert conformal projection
Michigan	
eastern	transverse Mercator projection
central	transverse Mercator projection
western	transverse Mercator projection
Minnesota	
northern	Lambert conformal projection
central	Lambert conformal projection
southern	Lambert conformal projection
Mississippi	
eastern	transverse Mercator projection
western	transverse Mercator projection
Missouri	
eastern	transverse Mercator projection
central	transverse Mercator projection
western	transverse Mercator projection
Montana	
northern	Lambert conformal projection
central	Lambert conformal projection
southern	Lambert conformal projection
Nebraska	
northern	Lambert conformal projection
southern	Lambert conformal projection
Nevada	
eastern	transverse Mercator projection
central	transverse Mercator projection
western	transverse Mercator projection
New Hampshire	transverse Mercator projection
New Jersey	transverse Mercator projection

HANDOUT #1

State and Zone	Mapping Grid System
New Mexico	
eastern	transverse Mercator projection
central	transverse Mercator projection
western	transverse Mercator projection
New York	
Long Island	Lambert conformal projection
eastern	transverse Mercator projection
central	transverse Mercator projection
western	transverse Mercator projection
North Carolina	Lambert conformal projection
North Dakota	
northern	Lambert conformal projection
southern	Lambert conformal projection
Ohio	
northern	Lambert conformal projection
southern	Lambert conformal projection
Oklahoma	
northern	Lambert conformal projection
southern	Lambert conformal projection
Oregon	
northern	Lambert conformal projection
southern	Lambert conformal projection
Pennsylvania	
northern	Lambert conformal projection
southern	Lambert conformal projection
Rhode Island	transverse Mercator projection
South Carolina	
northern	Lambert conformal projection
southern	Lambert conformal projection
South Dakota	
northern	Lambert conformal projection
southern	Lambert conformal projection

State and Zone	Mapping Grid System
Tennessee	Lambert conformal projection
Texas	
northern	Lambert conformal projection
north-central	Lambert conformal projection
central	Lambert conformal projection
south-central	Lambert conformal projection
southern	Lambert conformal projection
Utah	
northern	Lambert conformal projection
central	Lambert conformal projection
southern	Lambert conformal projection
Vermont	transverse Mercator projection
Virginia	
northern	Lambert conformal projection
southern	Lambert conformal projection
Washington	
northern	Lambert conformal projection
southern	Lambert conformal projection
West Virginia	
northern	Lambert conformal projection
southern	Lambert conformal projection
Wisconsin	
northern	Lambert conformal projection
central	Lambert conformal projection
southern	Lambert conformal projection
Wyoming	
zones 1-4	transverse Mercator projection

CONTROL SURVEYS
UNIT XII

ASSIGNMENT SHEET #1 — CALCULATE THE AZIMUTH OF A LINE

(Survey Data)

Rover, Latitude 42°45′ N, Longitude 73°56′ W
30 July 1983, Temp. 80°F, Pressure 28.7 in Hg.

Point Sighted	Watch Time (P.M.)	Vert. Angle	Horizon Angle (Clockwise)
Ridge			0°00′00″
Sun (direct)	$3^h\ 33^m\ 10^s$	49°44′	214°08′
Sun (direct)	$3^h\ 34^m\ 20^s$	49°32′	214°28′
Sun (plunged)	$3^h\ 35^m\ 37^s$	49°52′	215°19′
Sun (plunged)	$3^h\ 36^m\ 49^s$	49°40′	215°37′
Ridge			0°00′00″
Mean =	$3^h\ 34^m\ 59^s$	49°42.0′	214°53.0′

Solution:

Mean vertical angle =	49°42.0′
Index correction =	00.0′
Correction for refraction and parallax =	− 00.6′
(taken from pp. 65 and 66 *K&E Ephemeris*)	

1. Find true altitude: ______________

Mean watch time (EST) =	$3^h\ 34^m\ 59^s$
Correction 0^h G.C.T. to noon =	$+\ 12^h$
Correction for E.D.T. =	$+\ 4^h$

2. Find Greenwich Civil time of observation: ______________

Declination 0^h G.C.T., 31 July 19[illegible] = N 18°27.8′
(pg. 59, *K&E Ephemeris*)
Correction for 4.42^h earlier (0.61×4.42^h) = + 02.7′

3. Find declination at the time of observation: ______________

ASSIGNMENT SHEET #1

Equation: Cos. Z =

$$\frac{\text{sin of declination at time of observation}}{\text{cos. latitude of Pt. (Rover)} \times \text{cos of true altitude}} \quad \text{minus}$$

tan of the latitude of Pt. (Rover) × tan of the true altitude

4. Find Z (where Z is the horizontal angle measured from the sun's position to the point of the line whose azimuth is desired) using the above equation.

____

Since the observation was made in the afternoon, angle Z is counterclockwise from north, and the minus sign indicates an angle greater than 90°; thus, the sun's azimuth at the time of observation is: 360°00'00" – 114°55.4' = 245°04.6'

Azimuth of the sun = 245°04.6'

Horizontal ridge to sun = 214°53.0'

5. Find the azimuth of line Rover – Ridge = ____________________

CONTROL SURVEYS
UNIT XII

ANSWERS TO ASSIGNMENT SHEET #1

1. 49°41.[illegible]'

2. 19° 34' 59" = 19.58°

3. N 18°30.5'

4. Cos Z = −0.421387 or 114°55.4'

5. 30°11.6'

CONTROL SURVEYS
UNIT XII

JOB SHEET #1 — DETERMINE DIRECTION OF A LINE BY POLAR OBSERVATION

A. Tools and materials

1. Transit or theodolite
2. Tripod
3. Level rod
4. Field book and pencil
5. Flashlight and batteries

B. Procedure

1. Prepare note forms in advance.
2. Check to see that equipment is working properly and that a good supply of flashlight batteries and spares are available.
3. Predetermine the necessary correction to the latitude to give the altitude of Polaris.
4. After carefully setting u **orecisely** leveling the instrument (STA 100), approximately determine the d. ı of north and establish a target.

   (NOTE: Figures in parentheses correspond to sample field notes in Figure 2.)

5. With the horizontal scales zeroed, sight at the reference station (STA 422).
6. Sight an object about 250 m (800 ft) away and focus carefully. This is the instrument's infinite focus which must be set when sighting the star. Some surveyors mark this point on the focus ring so that the infinite focus can be reestablished after dark when there may be no suitable long-range sight available.

   (NOTE: Proper identification of the infinite focus position on the focusing ring is emphasized because if the telescope is only slightly off focus, the star will not even appear in the telescopic field of view and much time will be wasted.)

7. If the telescope has been properly directed toward north, and if the correct altitude has been set on the vertical circle, and if the focus adjustment has been properly set (infinite focus), Polaris should appear in the telescope at least 15 minutes prior to nightfall. It may be necessary to move the telescope through slight horizontal and vertical arcs to find the star.

JOB SHEET #1

8. At the instant the star has been carefully centered on the cross hairs, record the time in the field notes. (Figure 2)

9. Transit (plunge) the telescope and with the upper motion free (lower motion still clamped), resight the star. Record the second time. (Figure 2)

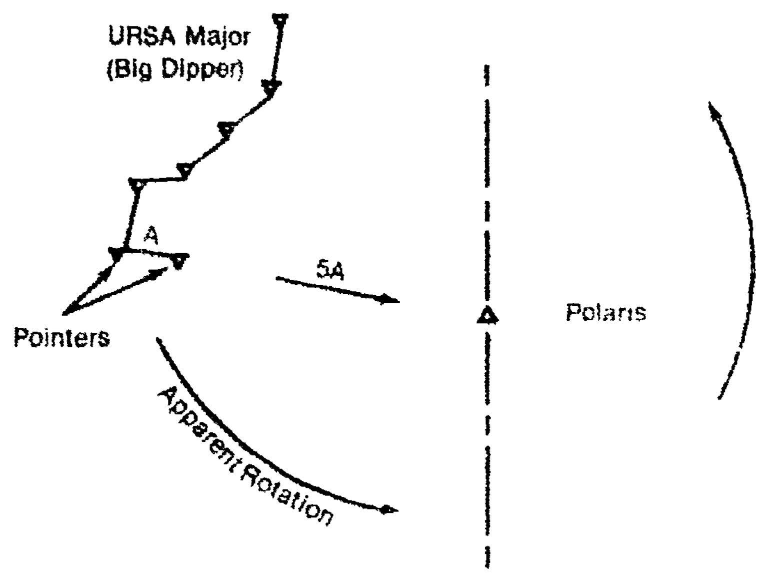
10. Sight the telescope back on the original reference station (422) and note the angle. (It should be 180°00'.)

11. Repeat this procedure if higher accuracies are required.

12. Use the average time for the bearing calculation for Polaris, and use the average angle to determine the bearing of the line (100-422). Record. (Figure 2)

(NOTE: When Polaris is to be observed during darkness, Polaris can be located by using the two Big Dipper (Ursa Major) stars as pointers. See Figure 1.)

FIGURE 1



JOB SHEET #1

FIGURE 2

Garby Park Control Survey

Observation on Polaris

STA	TIME		HCR	VCR
⊼	@ STA #100			
	LAT 41°42'17" N		} Scaled from	
	LONG 75°20'50" W		} Topographic Map	
#110			0°0'0"	
Polaris	8:10:00		52°13'20"	
Polaris	8:10:40		232°13'20"	
#110			180°0'0"	
	8:10:120		52°13'20"	
Watch time - OK				
Bearing of Polaris			0°42.8' West (Computed)	
Field Angle			52°13.2'	
Bearing =			N 52°56' W	

T. Owens - Notes G May - ⊼
June 16, 1979

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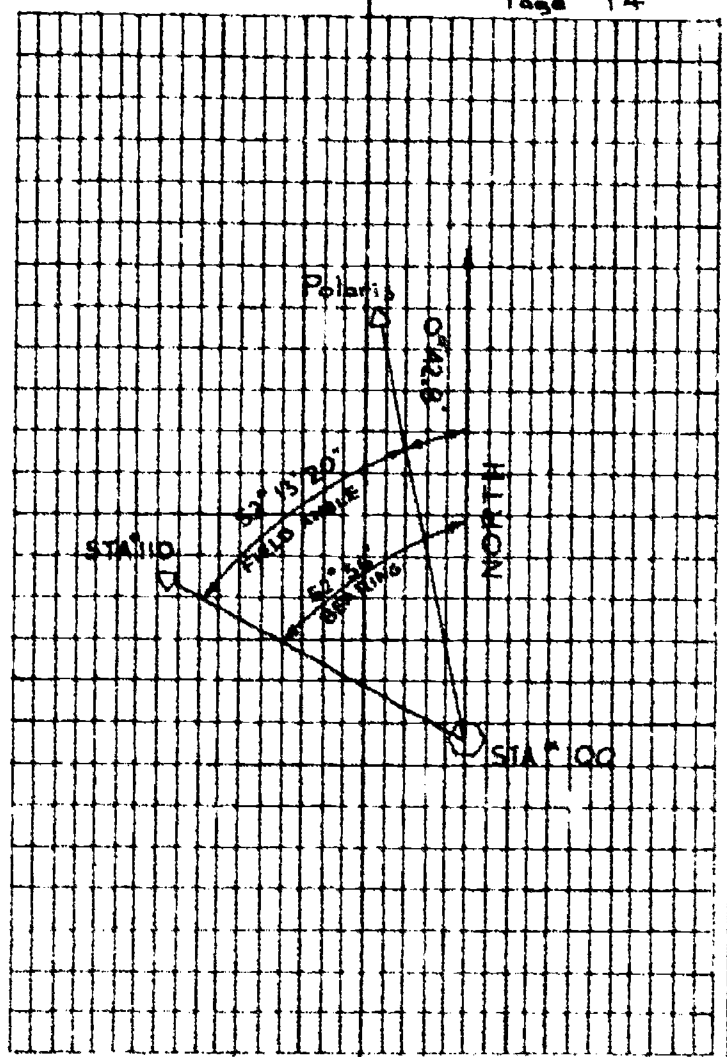


CONTROL SURVEYS
UNIT XII

NAME ____________________

TEST

Match the terms on the right with the correct definitions.

_____a.	The horizontal angle between the direction taken by a compass needle and geographic north	1.	Control fabric
_____b.	A data collection device or a reflecting station that is placed in a specific orbit around the earth	2.	Datum
_____c.	Surveying areas of the earth which are so large that their curvature must be allowed for in calculations	3.	Distortion
_____d.	The number of complete oscillations of an electromagnetic wave	4.	Frequency
_____e.	Involves the solution of triangles by using only measured side lengths rather than measuring angles	5.	Geodetic surveying
_____f.	A shape which is derived by mathematically revolving an ellipse about the earth's polar axis	6.	Magnetic declination
_____g.	The measurable amount something has for an actual shape versus its true shape	7.	Satellite
_____h.	A network of relatively permanent points that have been established with a higher level of accuracy and are used to reference various smaller surveys performed	8.	Spheroid
_____i.	A surveying technique that involves: 1)precisely measuring a baseline as a starting side of a series of triangles, 2) determining each angle of the triangle using a precise theodolite, 3) measuring a subsequent side of one of the triangles as a check for all calculated distances performed	9.	Triangulation
_____j.	Any level surface to which elevations are referred (for example, mean sea level)	10.	Trilateration

TEST

2. State the purpose of control surveys.

____

____

3. List two items provided by established horizontal and vertical reference monuments.

   a. ____

   b. ____

4. Distinguish between the types of control surveys by placing an "H" for horizontal control and a "V" for vertical control next to their characteristics.

   _____a. Field procedures include barometric leveling, trigonometric leveling, differential leveling, and inertial and satellite do[illegible]er systems

   _____b. Used to establish geodetic latitudes and longitudes of stations

   _____c. Field procedures include triangulation, precise traversing, trilateration, inertial and satellite doppler systems, and astronomical observations

   _____d. Used to establish elevations for a network of monuments called bench marks

5. Distinguish between the types of reference datums by placing an "H" for horizontal datums and a "V" for vertical datums next to their characteristics.

   _____a. Are based on mean sea level

   _____b. A current adjustment is being performed and should be completed in 1988

   _____c. Use an initial point, Meades Ranch in Kansas, having known geodetic latitude and longitude

   _____d. Use a spheroid of known dimensions referred to as the Clarke Spheroid of 1866

   _____e. Since 1929, more than 625,000 km of additional control leveling have been run

TEST

6. Complete the following statements concerning the FGCC accuracy standards used in control surveys by correctly filling in the blanks.

   a. Federal geodetic control committee (FGCC) has prepared a set of detailed classifications, standards of accuracy, and specifications.

      1) To provide a uniform set of standards specifying minimum acceptable accuracies of ________________, and

      2) To establish specifications for ________________ field procedures, and misclosure checks to ensure that the intended order of accuracy is achieved.

   b The highest order of accuracy specified by the FGCC is ________________ order.

   c. Horizontal control accuracy standards

Order and Class	Relative Accuracy Required Between Directly Connected Adjacent Points
First order	1 part in ________________
Second order	
Class I	1 part in 50,000
Class II	1 part in 20,000
Third order	
Class I	1 part in ________________
Class II	1 part in 5,000

   d. Vertical control accuracy standards

Order and Class	Relative Accuracy (Standard Error) Required Between Directly Connected Bench Marks
First order	
Class I	0.5 mm × $\sqrt{K}$
Class II	0.7 mm × $\sqrt{K}$
Second order	
Class I	1.0 mm × $\sqrt{K}$
Class II	1.3 mm × $\sqrt{K}$
Third order	________________ mm × $\sqrt{K}$

where K is the distance between bench marks in kilometers.

TEST

7. Select true statements concerning global positioning systems by placing an "X" in the appropriate blanks.

_____a. The U.S. Navy Navigation Satellite System encircling the globe is called the transit system.

_____b. Three transit satellites are in polar orbit at an altitude of 1200 km.

_____c. The U.S. Navy Navigation Satellite System was originally designed for positioning applications by civil authorities.

_____d. The "Navstar" System is comprised of 18 satellites and should be in full operation by 1987.

_____e. Satellite doppler systems have receivers located on the ground to measure the frequencies of radio signals transmitted from satellites operating in a polar orbit.

_____f. Satellites circle the earth every 55 minutes sending out a steady transmitting frequency.

_____g. Doppler systems are presently being used to augment and strengthen the national geodetic network.

8. Distinguish between the techniques used in making doppler observations by placing a "P" for point positioning, a "T" for translocation, and an "S" for short-arc next to their descriptions.

_____a. Receivers at two or more stations simultaneously track the satellite. The position of one receiver must be known

_____b. A receiver at an unknown position collects data from a satellite making several passes.

_____c. Fundamentally the same as translocation, except corrections are made for the satellite's orbital parameters.

9. Complete the following statements concerning inertial surveying systems by correctly filling in the blanks.

a. Have revolutionized current _______ _______ surveying practices

b. Are carried in ______________ or land vehicles.

c. Are oriented by a computer-controlled process called ______________. Gyros sense the earth's rotation and orient themselves facing north-south and east-west.

d. ______________ (three are required) measure components of movement in the cardinal directions and in elevations as they are moved from point to point.

TEST

e. An advantage of an inertial system is ____________

____

f. A disadvantage of an inertial system is ____________

____

10. Complete the following statements concerning state plane coordinates by circling the correct words.

    a. Were established in **(1963, 1933)** by the U.S. Coast and Geodetic Survey.

    b. Use a/an **(rectangular, oval)** grid designed to fit the curved shape of the earth to a plane surface with as little distortion as possible.

    c. **(All, Most)** states have established by law a state plane coordinate system in either the Lambert projection or the transverse Mercator projection with one or more zones.

    d. Lambert and Mercator grid systems each select **(several, one)** true meridian(s).

    e. All **(east-west, north-south)** lines of the grids are drawn parallel to the central meridian.

    f. The Lambert projection was limited to **(138, 158)** miles (approx.) to minimize distortion.

    g. The **(Lambert, Mercator)** projection grid assigns an "X" value to the central meridian (Y axis) of 500,000 ft and a Y value to the X axis of "0" ft

    h. Coordinates are based on **(the central meridian, sea level)**

    i. Scale error varies from zero up to about one part in **(10,000, 1,000)**.

11. Complete the following statements concerning celestial observations by correctly filling in the blanks.

    a. Polaris, commonly called the Nor[illegible]

        1) Has been used for centuries by ____________.

        2) Is used by surveyors to establish astronomic directions on survey ____________.

        3) Is useful because its apparent path of rotation keeps the stars very close to the extension of the earth's polar axis through the ____________.

TEST

b. Observations of the sun

1) Are usually more convenient than those of other stars because the sun can be observed during ____________.

2) Due to the ____________ and ____________ at which the sun appears to move, directions that are based on solar observations are generally less precise than those taken on the stars.

c. Time

1) One day is a complete revolution of the earth on its ____________.

2) One solar day is 360° plus the partial revolution of ____________.

3) The earth makes 366.2422 revolutions on its axis while completing the annual ____________.

4) In ____________ hours the earth revolves 360° of longitude and in 1 hour the earth revolves through 15° of longitude.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

12. Calculate the azimuth of a line. (Assignment Sheet #1)

13. Demonstrate the ability to determine direction of a line by polar observation. (Job Sheet #1)

CONTROL SURVEYS
UNIT XII

ANSWERS TO TEST

1. a. 6 e. 10 i. 9
   b. 7 f. 8 j. 2
   c. 5 g. 3
   d. 4 h. 1

2. To establish precise horizontal and vertical positions of reference monuments.

3. Any two of the following:
   a. Basis for originating subordinate surveys
   b. Method of orienting topographic or hydrographic mapping
   c. Basis for determining property boundary delineation
   d. Control for route and construction planning, design, and layout

4. a. V
   b. H
   c. H
   d. V

5. a. V
   b. V
   c. H
   d. H
   e. V

6. a. 1) Control surveys
      2) Instruments
   b. First
   c. First order — 1 part in 100,000
      Third order (Class I) — 1 part in 10,000
   d. Third order — 2.0 mm $\sqrt{K}$

7. a,d,e,g

8. a. T
   b. P
   c. S

9. a. Control
   b. Helicopters
   c. Gyrocompassing
   d. Acceleration
   e. Any one of the following:
      1) Equipment is refined and accuracies are improving.
      2) Do not require direct angle or distance measurements.
      3) Clear lines of sight are not necessary.
      4) Can operate day or night, rain or shine.

ANSWERS TO TEST

f. Any one of the following:
   1) Initial costs are high.
   2) Serviceability can be difficult.
   3) Operational costs are high.
   4) High technological training is necessary.
   5) Will not presently meet high accuracy requirements for first order work.

10. a. 1933
    b. Rectangular
    c. All
    d. One
    e. North-south
    f. 158
    g. Mercator
    h. Sea level
    i. 10,000

11. a. 1) Navigation
       2) Control lines
       3) North Pole
    b. 1) Normal working hours
       2) Size, speed
    c. 1) Axis
       2) Angle K
       3) Solar orbit
       4) 24

12. Evaluated to the satisfaction of the instructor

13. Performance skills evaluated to the satisfaction of the instructor

ELECTRO-OPTICAL INSTRUMENTS AND COMPUTER INTEGRATION
UNIT XIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to describe the major classifications of E.D.M. instruments, discuss the principles of E.D.M. measurements, list various types of hardware and software that are available for engineering design systems, and make accurate E.D.M. measurements. Competencies will be demonstrated by correctly performing the procedure outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electro-optical instruments and computer integration with the correct definitions.
2. Complete statements concerning early electronic surveying instruments.
3. Distinguish between the major classifications of E.D.M. instruments.
4. Complete statements concerning the principles of E.D.M. measurement.
5. List environmental conditions that affect E.D.M. wavelengths.
6. Complete statements concerning the types of E.D.M.s.
7. Complete statements concerning the use of laser energy for leveling and alignment.
8. Complete statements concerning data collection.
9. List types of computer hardware that make up a complete system.
10. List various types of software programs that are available for engineering design systems.
11. Demonstrate the ability to make E.D.M. measurements. (Job Sheet #1)

ELECTRO-OPTICAL INSTRUMENTS AND COMPUTER INTEGRATION UNIT XIII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheet.

H. Discuss and demonstrate the procedure outlined in the job sheet.

I. Integrate the following activities throughout the teaching of this unit:

1. Have the students research various types of E.D.M. manufacturers listing pros and cons for each.
2. Arrange for a field representative to demonstrate modern E.D.M. equipment and its usage.
3. Have the students familiarize themselves with their own hand-held calculators by reviewing their manuals and all its functions.
4. Visit a local firm that is currently using a computer design system, preferably with electronic surveying instruments and data collection.
5. Have the students obtain manufacturers' information on modern electro-optical instruments and computers from local distributors.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1 — Electromagnetic Spectrum

2. TM 2 — Computer Hardware — Office Computer Setup

3. TM 3 — Computer Hardware — Peripheral Output Devices

D. Job Sheet #1 — Make E.D.M. Measurements

E. Test

F. Answers to test

REFERENCES USED IN WRITING THIS UNIT

A. Kavanagh, Barry F., and S. J. Glenn Bird. *Surveying: Principles and Applications.* Reston, Virginia: Reston Publishing Co., Inc., 1984.

B. Brinker, Russell and P.R. Wolf. *Elementary Surveying.* 7th ed. New York: Harper & Row, 1984.

SUGGESTED SUPPLEMENTAL MATERIALS

A. Davis, R.E., F.S. Foote, and J.H. Kelly. *Surveying.* 5th ed. New York: McGraw-Hill, 1976.

B. Kissam, Phillip. *Surveying for Civil Engineers.* New York: McGraw-Hill, 1976.

C. Anderson, James and Edward Mikhail. *Introduction to Surveying.* New York: McGraw-Hill.

ELECTRO-OPTICAL INSTRUMENTS AND COMPUTER INTEGRATION UNIT XIII

INFORMATION SHEET

I. Terms and definitions

A. E.D.M. (Electronic Distance Measurement) instruments — Function by sending a light wave or microwave along a path to be measured either by measuring the time it takes for traveling the distance or by measuring the wavelengths being sent

B. Infrared — A light beam that is outside the visible spectrum of light due to its long wavelength

C. Laser — A device that generates electromagnetic radiation in the ultraviolet, visible, or infrared regions of the spectrum

D. Microwave — A very short electromagnetic wave that falls between 1 centimeter and 100 centimeters in wavelength

E. Transmitter — The sending unit or actual E.D.M. unit that produces the signal or beam used to determine the measurement of a distance

F. Frequency — The number of complete oscillations per second of an electromagnetic wave

G. Velocity — The [illegible] in which a beam of light will travel a determined distance

H. Prisms or reflectors — Specially shaped surfaces used to reflect transmitted signals back to the sending unit

(NOTE: The quality of the prism is determined by the flatness of the surfaces and by the perpendicularity of the 90° surfaces.)

II. Early electronic surveying instruments

A. Electronic distance measurement or E.D.M. instruments

1. Earliest type, referred to as a geodimeter, was introduced in 1948 by Erik Bergstrand

a. Resulted from attempts to improve methods of measuring the velocity of light.

b. Transmitted visible light and could measure distances up to 25 miles at night

INFORMATION SHEET

2. Second type of E.D.M. called the tellurometer was introduced in 1957 by Dr. T.L. Wadley.

   a. Transmitted invisible microwaves.

   b. Was capable of measurement up to 50 miles or more day or night.

3. Advantages and disadvantages of early E.D.M.s

   a. Advantages

      1) Were noted for their high precision

      2) Had excellent long-range capabilities

   b. Disadvantages

      1) Quite bulky

      2) Very cumbersome to use

B. Digital theodolites

1. First introduced in the late 1960's

2. Set the stage for electronic data collection

3. The fundamental difference between an electronic theodolite and a standard theodolite is

   a. Electronic instruments can resolve angles without interpolation.

   b. Electronic instruments are displayed in digital form using (LED's) light-emitting diodes or (LCD's) liquid-crystal diodes rather than optical-mechanical methods.

   (NOTE: LCD's require less power but require illumination for making night readings.)

III. Classifications of E.D.M. Instruments

A. Electro-optical instruments — Transmit modulated laser or infrared light having wavelengths within or slightly beyond the visible region of the spectrum. (Transparency 1)

B. Microwave equipment — Transmit microwaves with frequencies in the range of 3 to 35 GHz corresponding to wavelengths of about 1.0 to 8.6 mm.

C. Classification by operational range

1. Short range equipment — Are classified as having measuring capabilities of up to 5 km. Normally are considered to be electro-optical equipment.

INFORMATION SHEET

2. Medium range equipment — Have measurement capabilities of up to 100 km. Some may be electro-optical but most are microwave type.

3. Long range equipment — Are instruments used to measure distances over 100 km. Most operate on long radio waves but some employ microwaves.

IV. Principles of E.D.M. measurement

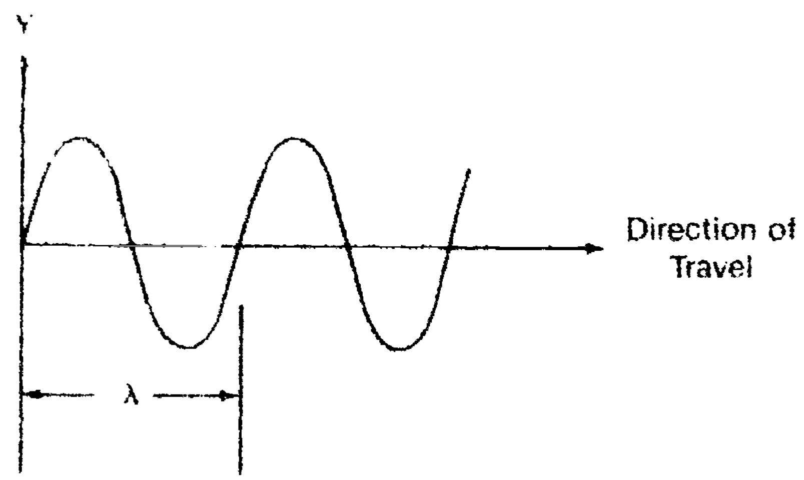
A. E.D.M.s measure distances by comparing a line of unknown length to the known wavelength of modulated electromagnetic energy.

1. Electromagnetic energy propogates through the atmosphere in accordance with the following equation: $V = f\lambda$

   Where: V — is the velocity of electromagnetic energy
   f — is the modulated frequency in hertz
   λ — is the wavelength in meters

2. Electromagnetic energy travels along an x axis with a velocity of 299,792.5 km/sec in vacuum. The frequency of wave is the time taken to complete one wavelength. (Figure 1)

FIGURE 1

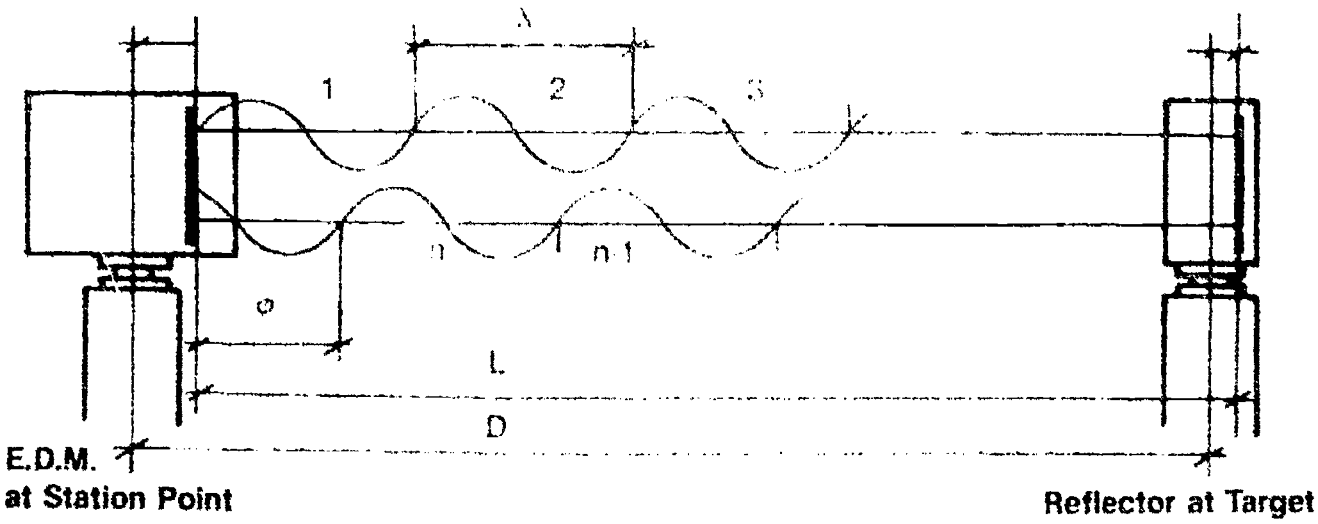


Lightwave

INFORMATION SHEET

B. Actual measurements are made by sending out a modulated electromagnetic wavelength and being reflected (light waves) or retransmitted (microwaves) back to the E.D.M. (Figure 2)

FIGURE 2



1. Double distance (2L) is equal to a whole number of wavelengths (nλ) plus the partial wavelength (φ) occurring at the E.D.M.

2. The partial wavelength (φ) is determined in the instrument by noting the phase delay required to precisely match up the transmitted and reflected or retransmitted waves.

V. Environmental conditions that affect E.D.M. wavelengths

A. Temperature

B. Pressure

C. Water vapor content

D. Atmospheric dust

(NOTE: The refractive index for standard air conditions (0°C, 760mm Hg., and 0.03 CO_2) for the group velocity of light waves is given by the Barrel and Sears formula:

$$N_g = 1 + \left(287.604 + \frac{4.8864}{\lambda^2} + \frac{0.068}{\lambda^4}\right) 10^{-6}$$

Where: λ is the wavelength of the carrier lightwave being used in micrometers (μ)

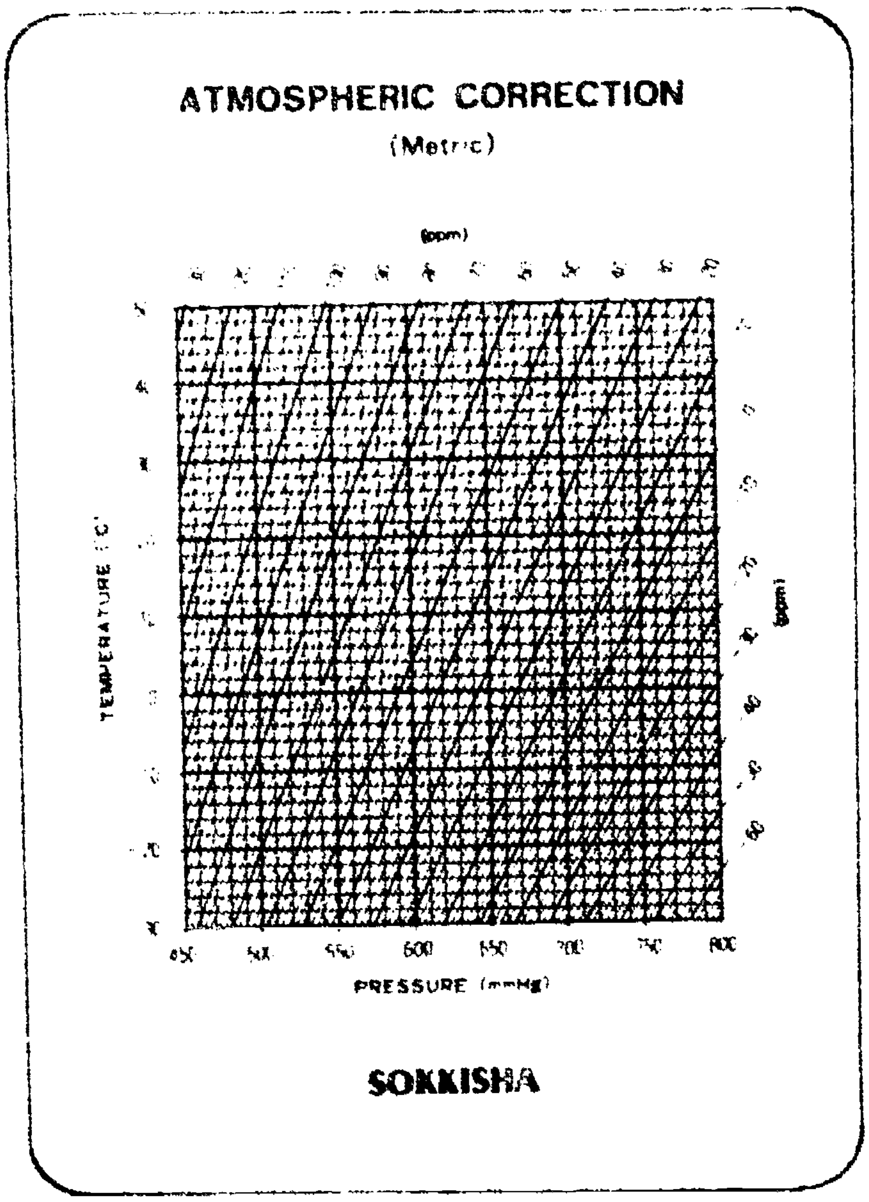
INFORMATION SHEET

Some typical values for λ are given:

Carrier	λ (μ m)
Mercury vapor	0.5500
Incandescent	0.5650
Red laser	0.6328
Infrared	0.8600 to 0.9300

(NOTE: Normally an atmospheric correction graph is used to determine the parts per million [p.p m.] of correction to adjust the instrument. See Figure 3.)

FIGURE 3

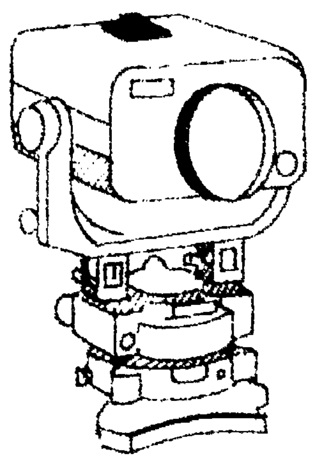


INFORMATION SHEET

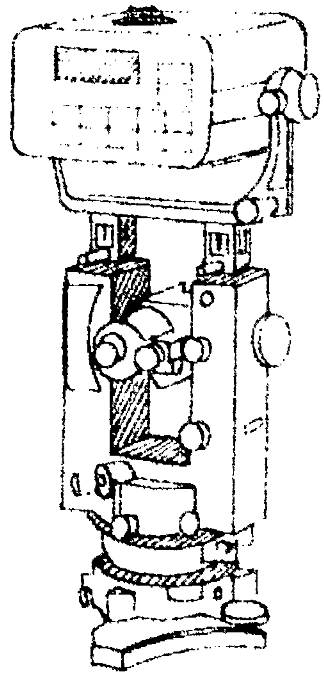
VI. Types of E.D.M.s

A E.D.M.s are designed for tribrach mount, instrument mount, or built into the theodolite. (Figure 4)

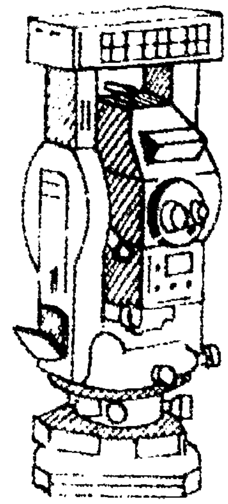
FIGURE 4



Tribrach Mount



Instrument Mount



Total Station

B. Essentially, there are two types of E.D.M.s

1. Measures slope distance only -- If the instrument is mounted on a theodolite, a vertical angle can be recorded and a horizontal distance computed externally.

2. Measures and/or calculates all types of distances and angles -- known as the total station.

a. Can measure horizontal distance, vertical distance, and slope distance.

b. Can measure horizontal and vertical angles

c. Can also measure information such as station coordinates. Stake out distances can be quickly calculated internally.

d. Data can be temporarily stored and then electronically transferred to an interface computer at the office.

INFORMATION SHEET

VII. Use of laser energy for leveling and alignment

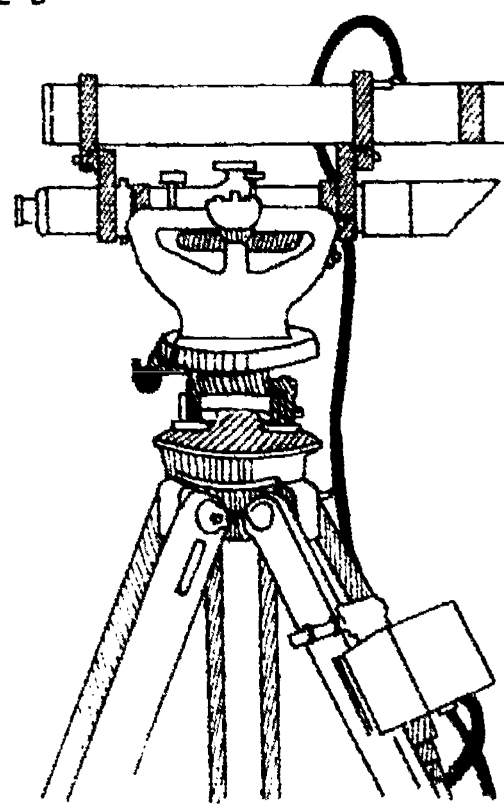
A. Laser devices were first generated around 1960.

B. The beam from a laser is intense, more sharply defined than ordinary light, and can be maintained over long distances.

(CAUTION: Great care must be used when working with lasers because the light at close range can destroy human tissue through burning, especially eyes.)

C. A laser can be attached to a level and the spot it creates can then be used for determining the rod reading. (Figure 5)

FIGURE 5



Laser on a Level

D. Laser alignment and leveling devices are now used in most forms of construction work.

Examples: Sewer pipe installation, site grading applications, trenching methods

E. Lasers are normally used in two modes.

1. Fixed-direction and slope mode
2. Revolving-horizontal pattern mode

INFORMATION SHEET

VIII. Data collection

A. Computers [illegible]

B. Stores field data [illegible] interfaced to an in-office computer

C. Modern data [illegible] and can accurately store

1. Actual time [illegible]

2. [illegible]

3. Temperature [illegible]

4. Backsight [illegible]

5. Coordinates

6. Ground [illegible]

D. Data collected [illegible], to a printer and plotter in the office [illegible] to a computer terminal.

E. Information [illegible] by means of:

1. Storage [illegible]

2. Magnetic [illegible]

F. Information [illegible] of:

1. Manual [illegible]

2. [illegible]

3. Transmitting [illegible]

(NOTE: [illegible] system to the office computer [illegible] and purchasing a total [illegible])

[illegible]

INFORMATION SHEET

IX. Types of computer hardware

A. Office computer setup (Transparency 2)

1. Processing unit terminal (including single or dual disc drives for software programs and storage)
2. Keyboard
3. Monitor (screen)
4. Menu board

B. Peripheral output devices (Transparency 3)

1. Line printer
2. Laser printer
3. Flat bed plotter
4. Drum plotter

X. Types of software programs

A. Business operations

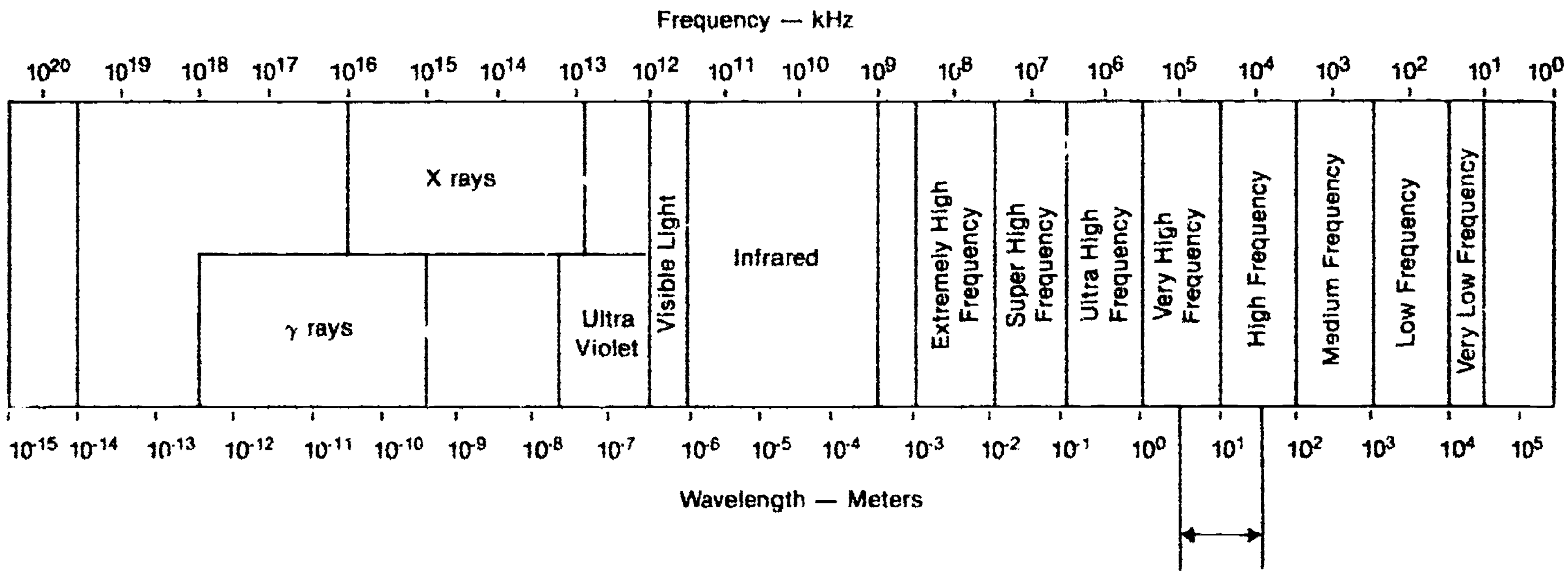
1. Word processing
2. Business financing
3. Business management

B. Engineering operations

1. Structural engineering
2. Sanitary and storm collection
3. Earthwork and quantities
4. Hydrology and drainage engineering
5. Land surveying
6. Coordinate geometry (traversing, triangulation, resection, etc.)

(NOTE: Compatibility of software to the present computer system being used is of utmost importance when purchasing software programs.)

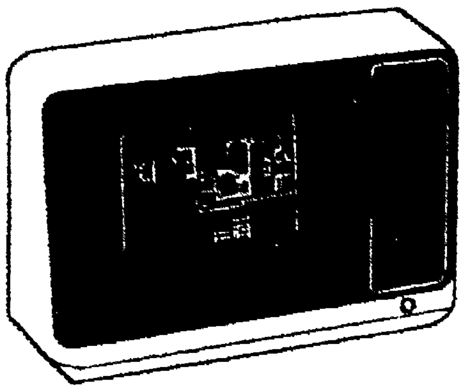
Electromagnetic Spectrum



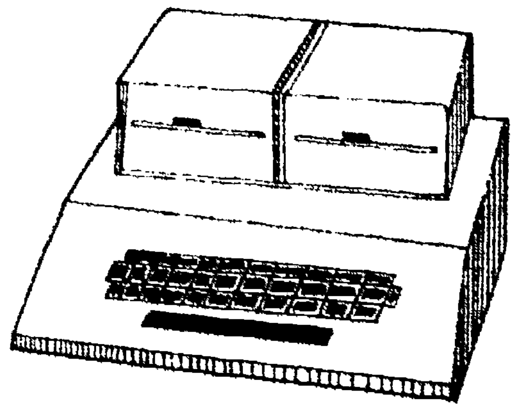
kHz = 10^6 Hertz
MHz = 10^6 Hertz
Hz = 1 cycle per second

Normal Range for Modulation Frequencies for Infrared and Laser Instruments (i.e. 7.5 to 75 MHz)

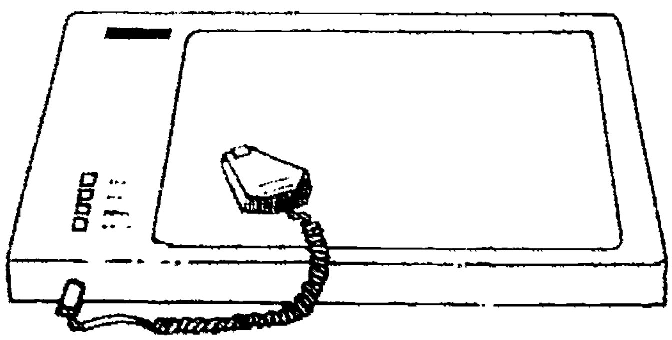
Computer Hardware
Office Computer Setup



Monitor
(CRT display)

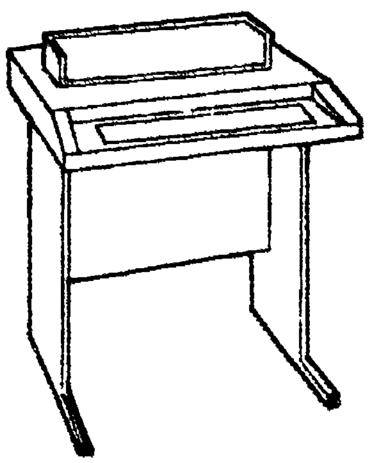


Terminal and
Keyboard

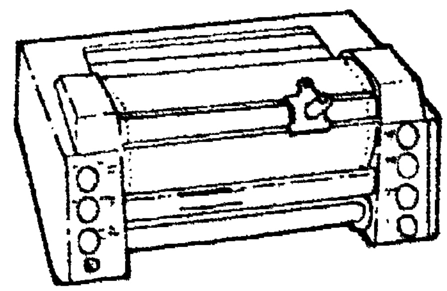


Graphics Tablet
and Menu Board

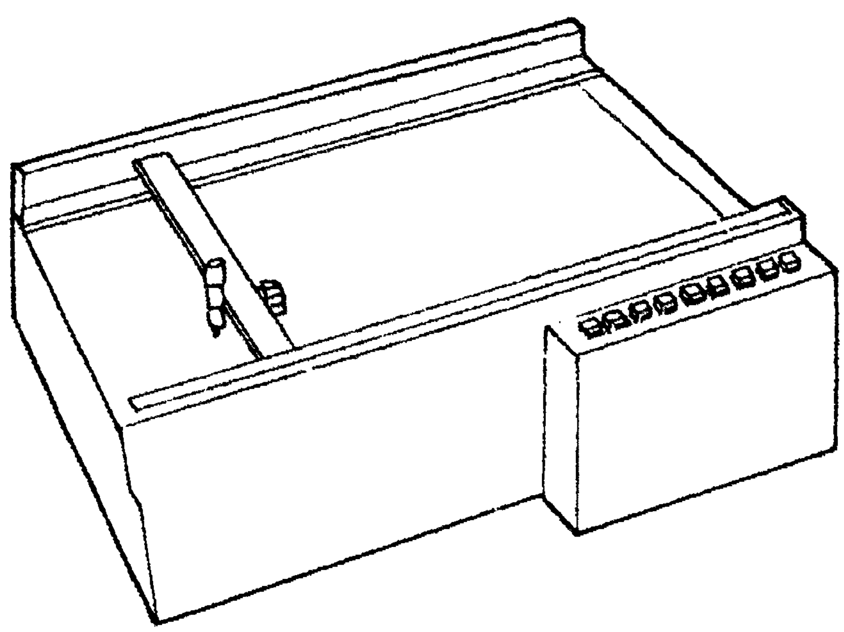
Computer Hardware
Peripheral Output Devices



Printer



Drum Plotter



Flat Bed Plotter

ELECTRO-OPTICAL INSTRUMENTS AND COMPUTER INTEGRATION UNIT XIII

JOB SHEET #1 — MAKE E.D.M. MEASUREMENTS

A. Tools and materials

1. E.D.M. equipment (tripod-instrument, prisms or reflector, etc.)
2. Field book or data collector

B. Procedure

1. Set up

   a. For tribrach-mounted EDMs — After the tribrach has been set over the point (by means of optical plummet) and leveled, insert EDM into the tribrach (forced centering).

   b. For telescope or theodolite yoke-mounted EDMs — Attach EDM to the theodolite after the theodolite has been set over the point and leveled.

   c. Set up the prism either by inserting it into an already set up tribrach (forced centering), or by using a prism pole.

   d. Turn EDM on, and make a quick check to ensure that the EDM is in working condition (battery, display, etc.)

   (CAUTION: Do not look directly into the EDM signal light at close range. Although the light sent out of the instrument is out of the visible spectrum, it can cause damage to the eyes.)

2. Aim

   a. Aim the EDM at the prism by utilizing either built-in sighting devices on the EDM or the theodolite telescope.

   (NOTE: Telescope or yoke-mounted EDMs will have the optical line of sight a bit lower than the electronic signal; however, if the theodolite telescope is clamped when positioned on the prism, the electronic fine adjusting can be easily accomplished using either the theodolite tangent screws or the EDM tangent screws. Vertical movement on yoke-mounted EDMs must be accomplished using the EDM vertical fine adjustment screw.)

   b. Set the electronic signal precisely on the prism by adjusting vertical and horizontal fine adjustment screws until a maximum intensity return signal is displayed on a signal scale. Some EDMs also have an audible prism locator whose variable-tone indicator helps to properly align the electronic signal to the prism. Some EDMs have a signal attentuator that must be used to adjust the strength of the signal to the distance being measured and the atmospheric conditions encountered.

   (NOTE: Newer EDMs have automatic attenuation.)

JOB SHEET #1

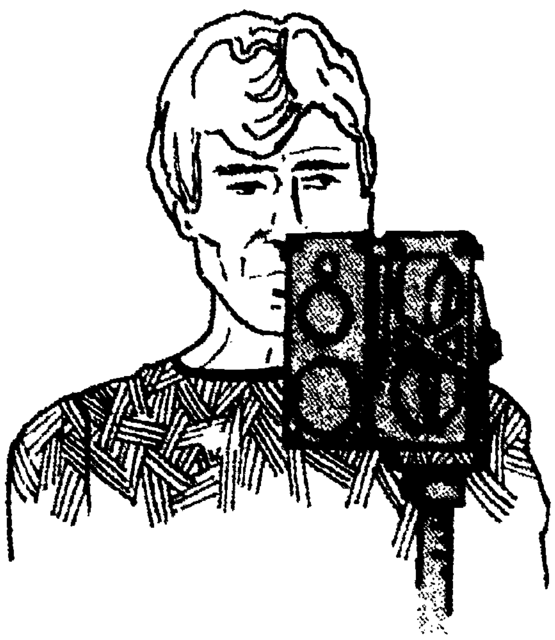
3. Measure the distance

   a. Press the "measure" button and wait a few seconds for the result to appear in the display. The displays are either liquid crystal (LCD) or light-emitting diodes (LED). The measurement is shown to two decimals of a foot, or three decimals of a meter; a foot/meter switch is used to switch from one system to the other.

   b. Some EDMs have a tracking mode that continuously updates and displays the distances as the prism is moved closer to its final layout position. Usually, the tracking mode display is shown to one decimal less than the normal measurement display. The more precise measurement mode can be used when the tracked prism is very close to its final layout position.

   c. All microwave EDMs provide two-way communication on the measuring wave itself; some electro-optical EDMs (e.g. Geodimeter) provide one-way communication from the EDM; obviously, voice communications are a great help when long distances are being measured or when points are being laid out. Two-way field radios are also used for these purposes. Figure 1 shows a remote EDM display device that is particularly useful in layout surveys and in high-noise data gathering surveys.

FIGURE 1



JOB SHEET #1

d. Some EDM instruments have the internal capability of providing corrections to measured distances, whereas other EDMs (older versions usually) require manual corrections to the displayed measurement. Modern EDMs automatically correct for curvature and refraction (c & r) and instrument/prism constants, and can internally correct for atmospheric factors when temperature and pressure are entered. Instrument/prism constants other than that for which the EDM has been calibrated can be entered, and vertical angles can be entered to reduce the slope distance to its horizontal equivalent. Sea level and scale factors can be similarly treated.

4. Record

   a. Record the displayed data conventionally in field notes or manually enter in an electronic data collector.

   b. Total station instruments have the capability of automatically recording all the data collected by the electronic tacheometer.

   c. For older EDMs, in addition to the displayed distance, all other correction-related data (e.g., temperature, prism constants) must be booked for each measurement.

ELECTRO-OPTICAL INSTRUMENTS AND COMPUTER INTEGRATION UNIT XIII

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions

_____a.	A device that generates electromagnetic radiation in the ultraviolet, visible, or infrared regions of the spectrum	1. E.D.M. instruments
_____b.	The number of complete oscillations per second of an electromagnetic wave	2. Frequency
_____c.	The sending unit or actual E.D.M. unit that produces the signal or beam used to determine the measurement of a distance	3. Infrared
_____d.	Function by sending a light wave or microwave along a path to be measured either by measuring the time involved in traversing the distance or by measuring the wave lengths being sent	4. Laser
_____e.	A very short electromagnetic wave that falls between 1 centimeter and 100 centimeters in wave length	5. Microwave
_____f.	The speed or time in which a beam of light will travel a determined distance	6. Prisms or reflections
_____g.	A light beam that is outside the visible spectrum of light due to its long wave length	7. Transmitter
_____h.	Specially-shaped surfaces used to reflect transmitted signals back to the sending unit	8. Velocity

2. Complete the following statements concerning early electronic surveying instruments by circling the correct words.

   a. The earliest type of E.D.M. is referred to as a (**geodimeter, tellurometer**)

   b. The tellurometer transmitted (**visible light, invisible microwaves**).

   c. The early E.D.M.s were noted for their high (**precision, inaccuracies.**)

   d. (**Standard, Electronic**) theodolites are displayed in digital form.

TEST

3. Distinguish between the major classifications of E.D.M. instruments by placing an "X" next to the description of electro-optical instruments.

   _____ a. Transmit microwaves with frequencies in the range of 3 to 35 GHz corresponding to wavelengths of about 1.0 to 8.6 mm.

   _____ b. Transmit modulated laser or infrared light having wavelengths within or slightly beyond the visible region of the spectrum.

4. Complete the following statements concerning the principles of E.D.M. measurement by circling the correct words.

   a. E.D.M.s measure distances by comparing a line of unknown length to the known wavelength of modulated (**radiant, electromagnetic**) energy.

   b. This energy propogates through the atmosphere in accordance with the following equation: (**$V = f\lambda$, $V = \frac{f}{\lambda}$**)

   Where: V -- is the velocity
   f -- is the modulated frequency in hertz
   λ -- is the wavelength in meters

5. List two environmental conditions that affect E.D.M. wavelengths.

   a. ____

   b. ____

6. Complete the following statements concerning the types of E.D.M.s by correctly filling in the blanks.

   a. E.D.M.s are designed for tribrach mount, ______________ mount, or built into the theodolite

   b. One basic type of E.D.M. measures slope distances only, and the other basic type of E.D.M. measures and/or calculates all types of distances and angles. This second type is known as a ______________________.

7. Select the following true statements concerning the use of laser energy for leveling and alignment by placing an "X" next to the true statements.

   _____ a. Laser devices were first generated around 1935.

   _____ b. The beam from a laser is intense and more sharply defined than ordinary light, but it can only be maintained over short distances.

   _____ c. A laser can be attached to a level and the spot it creates can then be used for determining the rod reading.

   _____ d. Laser alignment and leveling devices are now used in most forms of construction work.

TEST

8. Complete the following statements concerning data collection by correctly filling in the blanks.

   a. Data collection comprises an electronic ______________ book.

   b. Stores field data into a compact (hand-held) unit that in turn is interfaced to ______________.

   c. Modern data collectors can reduce values calculated and can accurately store several types of information. List three types below.

      1) ______________________________

      2) ______________________________

      3) ______________________________

   d. Data collection recordings can be transported directly to a printer and plotter in the office or can be transmitted by ______________ lines to a computer terminal.

   e. Information can be stored in a hand-held collector by means of ______________
      ______________________________.

   f. Information can be transmitted to the computer by means of ______________
      ______________________________.

9. List computer hardware components of the office computer setup and peripheral output devices that make up a complete system.

   a. Office computer setup

      1) ______________________________

      2) ______________________________

   b. Peripheral output devices

      1) ______________________________

      2) ______________________________

10. List types of software programs for business operations and engineering operations that are available for engineering design systems.

    a. Business operations

       1) ______________________________

       2) ______________________________

TEST

b. Engineering operations

1) ______________________________

2) ______________________________

3) ______________________________

(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

11. Demonstrate the ability to make E.D.M. measurements. (Job Sheet #1)

ELECTRO-OPTICAL INSTRUMENTS AND COMPUTER INTEGRATION
UNIT XIII

ANSWERS TO TEST

1. a. 4 e. 5
   b. 2 f. 8
   c. 7 g. 3
   d. 1 h. 6

2. a. Geodimeter
   b. Invisible microwaves
   c. Precision
   d. Electronic

3. b

4. a. Electromagnetic
   b. $V = f\lambda$

5. Any two of the following:
   a. Temperature
   b. Pressure
   c. Water vapor content
   d. Atmospheric dust

6. a. Instrument
   b. Total station

7. c, d

8. a. Field
   b. An in-office computer
   c. Any three of the following:
      1) Actual time of survey
      2) Project or job numbers
      3) Temperature, barometric pressure
      4) Backsights and foresights
      5) Coordinates
      6) Ground elevations
   d. Telephone
   e. Either one of the following:
      1) Storage registers within the unit
      2) Magnetic tapes (cassettes)
   f. Any one of the following:
      1) Manual input (keying in data)
      2) Direct input (interface cord)
      3) Transmitting through telephone lines

ANSWERS TO TEST

9. a. Any two of the following:
    1) Processing unit terminal (including single or dual disk drives)
    2) Keyboard
    3) Monitor (screen)
    4) Menu board

   b. Any two of the following:
    1) Line printer
    2) Laser printer
    3) Flat bed plotter
    4) Drum plotter

10. a. Any two of the following:
    1) Word processing
    2) Business financing
    3) Business management

    b. Any three of the following:
    1) Structural engineering
    2) Sanitary and storm collection
    3) Earthwork and quantities
    4) Hydrology and drainage engineering
    5) Land surveying
    6) Coordinate geometry (traversing, triangulation, resection, etc.)

11. Performance skills evaluated to the satisfaction of the instructor.